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Running Head: Flat-Rate Taxes and Leisure

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Abstract

This paper explores the implications that the specification of the leisure activity has on the effects of alternative forms of taxation in a two-sector endogenous growth model of the U.S. economy. Growth and welfare effects of tax reforms are shown to depend markedly on the leisure specification. We also compute the optimal tax structure of factor incomes and consumption taxation. The optimal tax rate on capital income is rather robust to the leisure specification. However, the balance between consumption and labor income taxation and the effects of shifting to the optimal tax structure vary considerably across leisure specifications.

Keywords: Tax structure; Endogenous growth; Welfare

JEL classification: H21; O41
1. INTRODUCTION

Many studies have assessed the growth and welfare effects of alternative forms of taxation in endogenous growth models with human capital accumulation. A partial list includes: Lucas (1990), Jones et al. (1993), Pecorino (1994), Stokey and Rebelo (1995), Ortigueira (1998), Glomm and Ravikumar (1998), Hendricks (1999) and Einarsson and Marquis (2001). The bulk of this literature has considered leisure as a nonmarket activity that requires the use of “raw time” only. Earlier works (Becker, 1965, Heckman, 1976) considered instead leisure as a nonmarket activity requiring “quality time,” a combination of time and human capital. A recent body of literature, starting from Greenwood and Hercowitz (1991) and Benhabib et al. (1991), has modeled leisure as a form of “home production” that uses both human and physical capital inputs, in addition to nonmarket time.

The choice of the particular specification of the leisure activity has been shown to play a crucial role in the theory of endogenous growth. Stokey and Rebelo (1995) and Milesi-Ferretti and Roubini (1998a, 1998b) show that the effects of taxation on growth depend significantly on the specification of the leisure activity. Ladrón-de-Guevara et al. (1999) study the equilibrium dynamics of a two-sector model of endogenous growth in the Uzawa-Lucas framework, in which leisure enters the utility function as raw time. Ortigueira (2000) analyzes, instead, the equilibrium dynamics of this model when leisure enters the utility function as quality time. He shows that the consequences of including leisure as quality time in the model may differ drastically from those of modelling leisure as raw time and concludes that the choice of the leisure specification is an important issue in growth models. However, no attempt has been made to measure how the effects of tax reforms depend on this issue.

The purpose of this present paper is to analyze the quantitative implications that the choice of the leisure activity has on the welfare and growth effects of alternative tax structures in a two-sector endogenous growth model of the U.S. economy. Here, tax structure refers to the mix of flat-rate taxes on physical capital income, labor income and consumption that keep
the present value of government revenues equal to the present value of government expenditures. Thus, we shall consider deficit-neutral tax reforms. As noted by Jorgenson and Wilcoxen (1997), this is an effective device for separating the discussion of tax reform from the budget debate. The analysis in this paper is based on an endogenous growth model where human capital is a non-market good that is produced with effective labor and a flow of market goods and services. As suggested by Engen et al. (1997), the model is recalibrated so as to reflect the original long-run data when testing for the consequences that the specification of the leisure activity has on the effects of tax reforms. It is worth emphasizing that we do not attempt to assess which formulation of the leisure activity is more appropriate. Our concern is limited to studying the consequences that the particular specification of the leisure function has.

Ortigueira (1998) addresses a related question. He studies the welfare cost of taxation and how it is affected by parameters and several model specifications in a framework similar to the one used in this paper. However, as the long-run ratios of the economy are not maintained across the calibrations, he is indeed comparing the effects that tax reforms have on different economies rather than on different specifications of the same economy. Milesi-Ferretti and Roubini (1998a, 1998b) analyze the effects of taxation on growth depending on the leisure specification, comparing the same leisure specifications used in this paper. However, their analysis is mostly theoretical and not quantitative and focuses on growth rather than on welfare effects of tax reforms. Moreover, the changes in tax policy considered are not deficit-neutral, as they assume that the additional tax revenue arising from the tax reform is rebated to consumers in a lump-sum fashion.

In a series of papers, Milesi-Ferretti and Roubini (1995, 1996, 1998b) have extended previous work by Judd (1985), Chamley (1986), Bull (1993) and Jones et al. (1993, 1997) to show that the optimal tax rates on human as well as physical capital income and on consumption are zero in the long-run under alternative specifications of the leisure activity.
The government expenditure would be financed by the interest earned on the assets raised by accumulating budget surpluses during an initial phase of relatively high taxation. To some authors (e.g., Jones et al., 1993, Milesi-Ferretti and Roubini, 1995, Coleman, 2000) this feature might cast some doubt on the practical relevance of the optimal tax policy. Perhaps as a consequence, much of the public finance literature has focused on the long-run properties of such a tax policy. However, as Coleman (2000) points out, the tail end of the optimal dynamic tax policy need not be optimal by itself and welfare may even fall if initial high tax rates are not implemented. Thus, more restrictions need to be placed on the tax codes to obtain an optimal policy plan that seems reasonable.

In this paper, we also estimate the welfare gain that the U.S. could attain by switching from its current tax policy to an optimal tax structure and assess the effect that the specification of the leisure activity has on the optimal tax mix. The restriction that tax rates are constant over time will be placed on the tax code. Limiting the analysis to time-invariant tax rates has been relatively common in the literature (e.g., Lucas, 1990; Cooley and Hansen, 1992; Pecorino, 1994; Stokey and Rebelo, 1995; Glomm and Ravikumar, 1998; Ortigueira, 1998; İmrohoroğlu, 1998; Mendoza and Tesar, 1998; Hendricks, 1999). As pointed out by Coleman (2000), such a tax policy would naturally avoid confiscatory levels of tax rates and would not attain a welfare gain by the promise of significant tax reductions far in the future. Due to its simplicity, this policy seems to be among the most realistic in practice. Furthermore, Cooley and Hansen (1992) and Coleman (2000) provide evidence suggesting that the extra gains made with time-variant taxes relative to time-invariant taxes can be relatively small.

The effect of the leisure specification has not been examined in recent appraisals of the optimal tax structure of the U.S. economy either. İmrohoroğlu (1998) determined the optimal tax mix of labor and capital income taxation in a general equilibrium model with overlapping generations. His analysis is restricted however to steady-state welfare, consumption taxation
is not considered and labor supply is exogenous. Coleman (2000) calculated the optimal time-
invariant tax rates on capital income, labor income and consumption in a neoclassical
exogenous growth model in which leisure enters the utility function as raw time. Grüner and
Heer (2000) computed the optimal constant tax rate on physical capital income in a Lucas’
(1990) supply side model. Consumption taxation is disregarded in their analysis and agents
derive utility from consumption and pure leisure time. Gómez (2000) calculated the optimal
constant tax rates on capital income, labor income and consumption in a two-sector
endogenous growth model with physical and human capital in which leisure is specified as
raw time. In addition, we shall assess the optimal structure of income taxation, keeping the
consumption tax rate constant. This issue is important because the composition of the income
tax as well as the use of income versus consumption taxes lies in the focus of discussion on
tax policy.

The remainder of the paper is organized as follows. Section 2 presents the model. Section
3 solves for the competitive equilibrium. Section 4 discusses the calibration of the model to
U.S. data. Section 5 assesses the implications that the specification of the leisure activity has
on the effects of tax reforms. Finally, Section 6 concludes.

2. THE MODEL

The analysis is based on a three-sector endogenous growth closed-economy. The first sector
produces goods that can be consumed, accumulated as physical capital or devoted to human
capital accumulation, using physical capital and effective labor as inputs. The second sector
produces human capital using goods and effective time as inputs. The third sector produces a
nonmarket good, “leisure,” which can take the form of “raw time” (time not spent working
and learning), “quality time” (time combined with human capital) and “home production”
(time combined with physical and human capital).
2.1. The household sector

The economy is inhabited by a large but fixed number of identical infinitely-lived households. The representative household derives utility from the consumption of both a private consumption good, $c$, and from leisure, $L$. Its preferences are described by the intertemporal utility function

$$ W = \int_0^\infty e^{-\rho t} \frac{(cL^\eta)^{1-\eta} - 1}{1-\sigma} dt. \quad (1) $$

The time argument has been suppressed in this and all subsequent equations. Here, $\rho$ is the rate of time preference, $\sigma$ is the inverse of the elasticity of intertemporal substitution, and $\eta$ reflects preferences for leisure.

The household is endowed with one unit of time per period which can be allocated to work, $u$, learning, $z$, or leisure, $l$. The time constraint is then

$$ 1 = u + z + l. \quad (2) $$

We specify leisure in three alternative ways: “raw time”, “home production” and “quality time”. In the first, utility depends on pure leisure time:

$$ L = l. \quad (3a) $$

In the second, leisure is produced with a Cobb-Douglas technology that uses physical capital, $k$, and human capital, $h$, as inputs:

$$ L = ((1-v)k)^{\xi} (lh)^{1-\xi}, \quad (3b) $$

where $1-v$ is the fraction of physical capital used in the leisure activity. In the third, leisure depends on effective time:

$$ L = lh. \quad (3c) $$

Notice that the home production and quality time specifications coincide when $\xi = 0$.

The household supplies effective labor, $uh$, and rent the fraction $v$ of their physical capital, $vk$, to firms producing goods. The rate of return on physical capital is denoted $r$, and the wage rate, $w$. Income is spent on consumption and investment in physical and human
capital, \( i_k \) and \( e \), respectively. Following Trostel (1993), we shall assume that expenses incurred by firms in on-the-job training are deducted from labor earnings, and a constant fraction \( \kappa \) of goods invested in human capital represents goods used in on-the-job training that are paid for by lower wages. The government imposes flat-rate taxes on physical capital income, labor income and consumption, \( \tau_k \), \( \tau_h \) and \( \tau_c \), respectively, and provides lump-sum transfers, \( s \). Thus, the household’s budget constraint is

\[
(1 - \tau_k)rvk + (1 - \tau_h)(wu_h - \kappa e) + s = i_k + (1 + \tau_c)e + (1 - \kappa)e .
\]

(4)

Notice that the fraction of physical capital devoted to the production of goods, \( v \), is equal to one in the raw time and quality time models.

The stock of physical capital evolves according to the dynamic equation

\[
\dot{k} = i_k - \delta_kk ,
\]

where \( \delta_k \) denotes the depreciation rate of physical capital.

Human capital is produced with effective time, \( zh \), and a flow of market goods and services, \( e \), as inputs according to

\[
\dot{h} = Be^\beta (zh)^{1-\beta} - \delta_hh ,
\]

(6)

where \( B \) is a productivity parameter, \( \beta \) the share parameter that measures the importance of physical inputs relative to effective units of time inputs, and \( \delta_h \) the rate of depreciation of human capital. The learning time, \( z \), includes both time devoted to formal training (schooling) and on-the-job training. This specification of human capital accumulation was suggested by Ben-Porath (1967), and used among others by Heckman (1976), Jones et al. (1993, 1997), Trostel (1993) and Hendricks (1999).

Given the initial endowments of physical capital, \( k_0 \), and human capital, \( h_0 \), the household’s problem is to choose \( c, k, h, i_k, e, v, u, z \) and \( l \) to maximize (1) subject to constraints (2), (4), (5) and (6), taking as given the path of factor returns and fiscal policy parameters.
2.2. The firm sector

The representative firm rents market physical capital, \( vk \), at the rate of interest \( r \) and hires effective labor, \( uh \), at the wage rate \( w \). It uses these factors to produce final output, \( y \), with a constant returns-to-scale Cobb-Douglas technology:

\[
y = (vk)^\alpha (uh)^{1-\alpha}, \quad 0 < \alpha < 1,
\]

where \( \alpha \) is the physical capital income’s share of output.

Measured output in national accounts does not count on-the-job training investments in human capital that are paid for by lower earnings. Hence, measured output will differ from true output. Henceforth, we will use the term GDP for measured output,

\[
GDP = y - \kappa e.
\]

The firm operates in competitive markets and, at each time, chooses \( vk \) and \( uh \) to maximize profits,

\[
y - r vk - wuh,
\]

taking as given the interest rate, \( r \), and the wage rate, \( w \). This is a static problem since investment decisions are made by the representative household.

2.3. The government

The government levies taxes on factor incomes and consumption. Physical capital income is taxed at a rate \( \tau_k \), human capital income at a rate \( \tau_h \), and consumption at a rate \( \tau_c \). Tax revenues are used to finance public expenditure on consumption and lump-sum transfers to households. We shall assume that the government claims a fraction, \( g_c \), of GDP for expenditure on consumption:

\[
g = g_c \, GDP,
\]

and a fraction, \( g_s \), of GDP for lump-sum transfers to households representing welfare programs. Adjustment in lump-sum transfers to households balances the government budget each period, so that
\[ s = g_s \text{ GDP} - d, \]

and the government’s budget constraint can be expressed as

\[ d = (g_s + g_c) \text{ GDP} - \tau_k \alpha v + \tau_h (wuh - ke) - \tau_c c. \quad (9) \]

Thus, \( d \) is the amount of lump-sum taxation (or transfers) needed to keep a balanced budget and, therefore, expresses the primary budget deficit. For simplicity, we do not explicitly consider financing by debt issue since, because of Ricardian Equivalence, the lump-sum tax is equivalent to debt when the sequence of fiscal parameters is held fixed.

3. THE COMPETITIVE EQUILIBRIUM

A competitive equilibrium for this economy is defined as a set of market-clearing prices and quantities such that i) the household’s choice of \( c, k, h, i_k, e, v, u, z \) and \( l \) maximizes (1) subject to constraints (2), (4), (5) and (6), given the initial endowments of physical capital, \( k_0 \), and human capital, \( h_0 \), and taking as given the path of factor returns and fiscal policy variables; ii) the firm’s choice of physical capital, \( vk \), and effective labor, \( uh \), maximizes profits, and iii) the government obeys its budget constraint (9).

Note that in the raw time and quality time models, the fraction of physical capital devoted to the production of goods is \( v = 1 \), so this is not a choice variable in the household’s problem.

3.1. Leisure as “home production”

Profit maximization by firms implies that labor and capital are used up to the point at which marginal product equates marginal cost:

\[ r = \alpha (vk)^{\alpha-1} (uh)^{1-\alpha}, \quad (10a) \]

\[ w = (1 - \alpha) (vk)^{\alpha} (uh)^{-\alpha}. \quad (10b) \]

Constraint (2) will be used to express \( u \) as a function of \( z \) and \( l \), and thus to eliminate it from the problem. Equations (4), (9) and (10) yield the market-clearing condition in the goods market:
\( y = i_k + c + g + e \). \hspace{1cm} (11)

Let \( J \) be the current value Hamiltonian and \( \lambda, \mu \) and \( \theta \) be the multipliers for constraints (4), (5) and (6) in the household’s problem:

\[
J = \frac{(eL)^{1-\sigma} - 1}{1-\sigma} + \lambda \left[ (1-\tau_k)rv + (1-\tau_h)(wu - \kappa e) + s - i_k - (1+\tau_k)c - (1-\kappa)e \right] \\
+ \mu \left[ i_k - \delta_k k \right] + \theta \left[ Be^\theta (zh)^{1-\beta} - \delta_k h \right].
\]

The first order conditions of the household’s problem are

\[
\partial J/\partial c = c^{-\sigma} L^{\eta(1-\sigma)} - (1 + \tau_k)\lambda \lambda = 0, \hspace{1cm} (12a)
\]

\[
\partial J/\partial l = \frac{\eta(1-\xi)c^{1-\sigma} L^{\eta(1-\sigma)}}{l} - \lambda(1-\tau_h)wh = 0, \hspace{1cm} (12b)
\]

\[
\partial J/\partial v = -\frac{\eta\xi c^{1-\sigma} L^{\eta(1-\sigma)}}{1-\nu} + \lambda(1-\tau_k)rk = 0, \hspace{1cm} (12c)
\]

\[
\partial J/\partial z = -\lambda(1-\tau_k)wh + \theta(1-\beta)Be^\theta (zh)^{1-\beta} h = 0, \hspace{1cm} (12d)
\]

\[
\partial J/\partial i_k = -\lambda + \mu = 0, \hspace{1cm} (12e)
\]

\[
\partial J/\partial e = -\lambda(1-\kappa \tau_h) + \theta \beta Be^{\beta-1} (zh)^{1-\beta} = 0, \hspace{1cm} (12f)
\]

\[
\mu = (\rho + \delta_k)\mu - \lambda(1-\tau_k)rv - \frac{\eta\xi c^{1-\sigma} L^{\eta(1-\sigma)}}{k}, \hspace{1cm} (12g)
\]

\[
\theta = (\rho + \delta_h - (1-\beta)Be^\theta (zh)^{1-\beta} z)\theta - \lambda(1-\tau_h)wv - \frac{\eta(1-\xi)c^{1-\sigma} L^{\eta(1-\sigma)}}{h}, \hspace{1cm} (12h)
\]

plus the usual transversality conditions. Using (12a), (12b) and (10), we obtain

\[
\eta(1-\xi)(1+\tau_e)c/h = (1-\tau_h)(1-\alpha)\delta u^{-\alpha} \nu^\alpha (k/h)^\alpha, \hspace{1cm} (13)
\]

which reflects the equality between the marginal rate of substitution between consumption and leisure and the real return rate on human capital. From (12b), (12c) and (10), we get

\[
\alpha(1-\xi)(1-\tau_k)u(1-\nu) = (1-\alpha)\xi(1-\tau_h)lv, \hspace{1cm} (14)
\]

and combining equations (12d) and (12f) yields

\[
(1-\tau_k)(1-\alpha)\beta z u^{-\alpha} \nu^\alpha (k/h)^\alpha = (1-\beta)(1-\kappa \tau_h)(e/h). \hspace{1cm} (15)
\]
From equations (12c) and (12g) and using (12e), it follows that

$$\mu = (\rho + \delta_k - (1 - \tau_k) r) \mu. \quad (16)$$

Combining equations (12d) and (12f) and using (12d), we obtain

$$\dot{\theta} = (\rho + \delta_h - (1 - \beta) Be^\theta (zh)^{\theta}) \theta. \quad (17)$$

Hereafter, let $\gamma_x = \dot{x}/x$ denote the growth rate of the variable $x$. Log-differentiating (12a), and using (12e) and (16), we obtain the law of motion of consumption as

$$\gamma_c = \frac{(1 - \tau_k) r - \delta_k - \rho + \eta(1 - \sigma)(\xi(\gamma_k - v\gamma_y/(1 - v)) + (1 - \xi)(\gamma_i + \gamma_h))}{\sigma}. \quad (18)$$

Denoting $\zeta = \mu/\theta$, (16) and (17) imply that

$$\gamma_{\zeta} = \gamma_{\mu} - \gamma_{\theta} = ((1 - \beta) Be^\theta (zh)^{\theta} - \delta_h) - ((1 - \tau_k) r - \delta_k). \quad (19)$$

From (12f), we get

$$\zeta = \frac{\beta B \varepsilon^{1-\beta} (e/h)^{\beta-1}}{1 - \kappa \tau_h},$$

which, after log-differentiation, yields

$$\gamma_{\zeta} = (\beta - 1)(\gamma_{e/h} - \gamma_{z}). \quad (20)$$

The evolution of the stocks of physical and human capital can be expressed as

$$(\gamma_k + \delta_k)(k/h) = v^\sigma u^{1-\sigma} (k/h)^{\alpha} - g_c (v^\sigma u^{1-\sigma} (k/h)^{\alpha} - \kappa e/h) - e/h - e/h, \quad (21)$$

$$\gamma_h = B \varepsilon^{1-\beta} (e/h)^{\beta} - \delta_h. \quad (22)$$

Along the balanced growth path, consumption, investment in physical and human capital, and the stocks of physical and human capital grow at the same constant rate $\gamma$, and factor allocations remain constant. Imposing these conditions in (18)-(22), and recalling (10), provides

$$\gamma = \frac{1}{\sigma + \eta(\sigma - 1)} (i - \rho). \quad (23a)$$

$$i = (1 - \tau_k) \alpha v^{\alpha-1} u^{1-\alpha} (k/h)^{\alpha-1} - \delta_h. \quad (23b)$$
which, together with (2), (13), (14) and (15), form the system that characterizes the balanced growth path. Equation (23a) relates the long-run growth rate with the net return on physical capital. Equations (23b) and (23c) equal the real return rates of each factor, net of taxes and depreciation, with the interest rate. Equation (23d) establishes that in the long-run human capital grows at the same rate as consumption and physical capital. Equation (23e) is the resource constraint for the economy.

The dynamics of the economy can be characterized in terms of variables that are constant in the steady state. Let $\chi$ denote $c/h$, $\psi$ denote $k/h$ and $\phi$ denote $e/h$. Solving the system (13)-(14) for $u$ and $v$, we obtain

$$u(\chi, \psi, l) = \left[ \frac{(1-\alpha)l}{\eta(1-\xi)(1+\tau_h)\chi} \right]^{1/\alpha} \psi - \frac{(1-\alpha)\xi(1-\tau_h)}{\alpha(1-\xi)(1-\tau_k)},$$  \hspace{1cm} (24)

$$v(\chi, \psi, l) = 1 - \left[ \frac{\eta(1-\xi)(1+\tau_e)\chi}{(1-\alpha)(1-\tau_k)l} \right]^{1/\alpha} \frac{(1-\alpha)\xi(1-\tau_h)}{\alpha(1-\xi)(1-\tau_k)\psi}. \hspace{1cm} (25)$$

Now, equations (2) and (15) yield, respectively,

$$z(\chi, \psi, l) = 1 - u(\chi, \psi, l),$$  \hspace{1cm} (26)

$$\phi(\chi, \psi, l) = \frac{(1-\alpha)\beta(1-\tau_h)z(\chi, \psi, l)v(\chi, \psi, l)^{\alpha}}{(1-\beta)(1-\kappa\tau_h)u(\chi, \psi, l)^{\alpha}}. \hspace{1cm} (27)$$

The laws of motion of $\chi$ and $\psi$ as functions of $\chi$, $\psi$ and $l$ are given by

$$\gamma_\chi(\chi, \psi, l) = \gamma_c(\chi, \psi, l) - \gamma_h(\chi, \psi, l),$$  \hspace{1cm} (28)

$$\gamma_\psi(\chi, \psi, l) = \gamma_k(\chi, \psi, l) - \gamma_h(\chi, \psi, l).$$  \hspace{1cm} (29)
\[ \gamma_k(\chi, \psi, l) = (1 - g_c)v(\chi, \psi, l)^\alpha u(\chi, \psi, l)^{1-\alpha} \psi^{a-1} - (1 - \kappa g_c) \frac{\phi(\chi, \psi, l)}{\psi} - \frac{\chi}{\psi} - \delta_k, \quad (30) \]

\[ \gamma_h(\chi, \psi, l) = Bz(\chi, \psi, l)^{-\beta} \varphi(\chi, \psi, l)^{\beta} - \delta_h. \quad (31) \]

Using (19), the law of motion of \( \zeta \) can be expressed as

\[ \gamma_\zeta(\chi, \psi, l) = (1 - \beta)Bz(\chi, \psi, l)^{-\beta} \varphi(\chi, \psi, l)^{\beta} - \delta_h \]

\[ + \delta_z - (1 - \tau_z)\alpha v(\chi, \psi, l)^{a-1} u(\chi, \psi, l)^{1-a} \psi^{a-1}. \quad (32) \]

Equation (18) can be expressed as

\[ \gamma_\zeta(\chi, \psi, l) = (1/\sigma) \left[ (1 - \tau_z)\alpha v(\chi, \psi, l)^{a-1} u(\chi, \psi, l)^{1-a} \psi^{a-1} - \delta_k - \rho \right. \]

\[ + \eta(1 - \sigma) \left[ \xi \left( \frac{v(\chi, \psi, l)}{1 - v(\chi, \psi, l)} \right) + \gamma_\zeta(\chi, \psi, l) \right] + (1 - \xi)(\gamma_\zeta(\chi, \psi, l) + \gamma_h(\chi, \psi, l)) \right], \quad (33) \]

Log-differentiating the expressions for \( u, v, z \) and \( \varphi \) as functions of \( \chi, \psi \) and \( l \) in (24)-(27) and combining the results with (20),

\[ \gamma_\zeta = (\beta - 1)(\gamma_\varphi(\chi, \psi, l) - \gamma_\zeta(\chi, \psi, l)), \]

provide a system of five equations. Solving this system for \( \gamma_u, \gamma_\nu, \gamma_z, \gamma_\varphi \) and \( \gamma_l \), we get in particular

\[ \gamma_\zeta(\chi, \psi, l) = \gamma_\zeta(\chi, \psi, l) + \gamma_\zeta(\chi, \psi, l)/(1 - \beta), \]

which, using (24), is equivalent to

\[ \gamma_\zeta(\chi, \psi, l) = \gamma_\zeta(\chi, \psi, l) - \gamma_\zeta(\chi, \psi, l) + \gamma_\zeta(\chi, \psi, l)/(1 - \beta), \quad (34) \]

and

\[ \gamma_l(\chi, \psi, l) = \Omega(\chi, \psi, l) \left[ \gamma_\zeta(\chi, \psi, l) - \gamma_k(\chi, \psi, l) - \frac{1 - \alpha}{\alpha(1 - \beta)} \gamma_\zeta(\chi, \psi, l) \right], \quad (35) \]

where

\[ \Omega(\chi, \psi, l) = \frac{(1 - \alpha)\xi(1 - \tau_\zeta)(\eta(1 - \xi)(1 + \tau_\zeta)\chi)^{1/\alpha}}{(1 - \alpha)\xi(1 - \tau_\zeta)(\eta(1 - \xi)(1 + \tau_\zeta)\chi)^{1/\alpha} l - \alpha(1 - \xi)l(1 - \tau_\zeta)((1 - \alpha)(1 - \tau_\zeta) l)^{1/\alpha \psi}. \]

Solving the system (33)-(35) for \( \gamma_\zeta, \gamma_\nu \) and \( \gamma_l \) yields in particular.
\[ \gamma_e(\chi, \psi, l) = \frac{(1 - \nu(\chi, \psi, l))}{(\sigma + \eta(\sigma - 1)(1 - \xi))(1 - \nu(\chi, \psi, l)) - \eta(\sigma - 1)\xi\Omega(\chi, \psi, l)\nu(\chi, \psi, l)} \]

\[ \times \left\{ (1 - \tau_k)\alpha \nu(\chi, \psi, l)^{a - 1}u(\chi, \psi, l)^{1 - a} - a^{a - 1} - \delta - \rho - (\sigma + \eta(\sigma - 1))\gamma_k(\chi, \psi, l) \right\} + \frac{(1 - \alpha)}{\alpha(1 - \beta)} \gamma_e(\chi, \psi, l) \]  

Equations (28), (29) and (34) form the system that characterizes the dynamics of the economy, and allow us to express \( \gamma_\nu, \gamma_\psi \) and \( \gamma_l \) as functions of \( \chi, \psi \) and \( l \) through (30), (31), (32) and (36), recalling (24)-(27).

### 3.2. Leisure as “quality time”

The home production and quality time specifications of leisure coincide when \( \xi = 0 \). The first order conditions of the household’s problem in the quality time model are similar to those of the home production specification simply by taking \( \xi = 0, \nu = 1 \) and eliminating (12c).

Proceeding in the same manner as in the home production case, noticing that equation (18) should be replaced now by

\[ \gamma_e = \frac{(1 - \tau_k)\nu - a^{a - 1} - \delta - \rho + \eta(1 - \sigma)(\gamma_i + \gamma_h)}{\sigma}, \]  

shows that the system (23a)-(23e) together with (2), (13) and (15) form the system that characterizes the balanced growth path.

Let \( \chi \) denote \( c/h \), \( \psi \) denote \( k/h \) and \( \varphi \) denote \( e/h \). Equation (18’) can be expressed as

\[ \gamma_e(\chi, \psi, l) = \frac{(1 - \tau_k)\alpha u(\chi, \psi, l)^{1 - a} - a^{a - 1} - \delta - \rho + \eta(1 - \sigma)(\gamma_i(\chi, \psi, l) + \gamma_h(\chi, \psi, l))}{\sigma}. \]  

Log-differentiating the expressions for \( u, z \) and \( \varphi \) as functions of \( \chi, \psi \) and \( l \) in (24), (26) and (27), and combining the results with (20) provide a system of four equations. Solving this system for \( \gamma_u, \gamma_z, \gamma_\varphi \) and \( \gamma_l \), we get in particular expression (34) for \( \gamma_l \). Solving the system (33’)-(34) for \( \gamma_c \) and \( \gamma_l \) yields in particular
\[
\gamma_c(\chi, \psi, l) = \frac{(1-\tau_k)\alpha u(\chi, \psi, l)^{1-a} \psi^{a-1} - \delta_k - \rho - \eta(\sigma - 1) \gamma_c(\chi, \psi, l)/(1-\beta)}{\sigma + \eta(\sigma - 1)}. \tag{36'}
\]

Equations (28), (29) and (34) form the system that characterizes the dynamics of the economy, and allow us to express \(\gamma_c\), \(\gamma\) and \(\gamma_l\) as functions of \(\chi\), \(\psi\) and \(l\) through (30), (31), (32) and (36'), recalling (24), (26) and (27).

3.3. Leisure as “raw time”

The first order conditions of the household’s problem (12a), (12d), (12e) and (12f) stay the same, substituting \(L = l\), and (12c) does not apply. Conditions (12b), (12g) and (12h) should now be replaced by

\[
\frac{\partial J}{\partial l} = \eta e^{1-\sigma} l^{\sigma(1-\sigma)-1} - \lambda(1-\tau_k)wh = 0, \tag{12b''}
\]

\[
\dot{\mu} = (\rho + \delta_k)\mu - \lambda(1-\tau_k)r, \tag{12g''}
\]

\[
\dot{\theta} = (\rho + \delta_k - (1-\beta)Be^\theta (zh)^{-\beta} (1-l))\theta - \lambda(1-\tau_k)w. \tag{12h''}
\]

Equations (17), (18) and (19) should be replaced now by

\[
\dot{\theta} = (\rho + \delta_k - (1-\beta)Be^\theta (zh)^{-\beta} (1-l))\theta, \tag{17''}
\]

\[
\gamma_c = \frac{(1-\tau_k)r - \delta_k - \rho + \eta(1-\sigma)\gamma_l}{\sigma}, \tag{18''}
\]

and

\[
\gamma_c = \gamma_\mu - \gamma_\theta = \frac{(1-\beta)Be^\theta (zh)^{-\beta} (1-l) - \delta_k}{\sigma}. \tag{19''}
\]

Taking into account that now \(v = 1\), and proceeding in the same manner as in the home production case, we obtain that

\[
\gamma = \frac{1}{\sigma} (i - \rho), \tag{23a''}
\]

\[
i = (1-\beta)Be^{-\beta} (e/h)^{\theta} (1-l) - \delta_k, \tag{23c''}
\]

together with (23b), (23d), (23e), (2), (13) and (15) form the system that characterizes the balanced growth path of the economy.
Let \( \chi \) denote \( c/h \), \( \psi \) denote \( k/h \) and \( \varphi \) denote \( e/h \). Equations (18'') and (19'') can be expressed as

\[
\gamma_\varepsilon(\chi, \psi, l) = (1 - \beta)Bz(\chi, \psi, l)^{-\beta} \varphi(\chi, \psi, l)^{\beta} (1 - l) - \delta_h
\]

\[
+ \delta_k - (1 - \tau_k) \alpha u(\chi, \psi, l)^{1-\alpha} \psi^{a-1}, \tag{32''}
\]

and

\[
\gamma_c(\chi, \psi, l) = \frac{(1 - \tau_k) \alpha u(\chi, \psi, l)^{1-\alpha} \psi^{a-1} - \delta_k - \rho + \eta(1 - \sigma) \gamma_1(\chi, \psi, l)^1}{\sigma}. \tag{33''}
\]

Log-differentiating the expressions for \( u, z \) and \( \varphi \) as functions of \( \chi, \psi \) and \( l \) in (24), (26) and (27), and combining the results with (20) provide a system of four equations. Solving this system for \( \gamma_u, \gamma_z, \gamma_\varphi \) and \( \gamma_l \), we get in particular expression (34) for \( \gamma_l \). Solving the system (33'')-(34) for \( \gamma_c \) and \( \gamma_l \) yields in particular

\[
\gamma_c(\chi, \psi, l) = \frac{1}{\sigma + \eta(\sigma - 1)} \left\{ (1 - \tau_k) \alpha u(\chi, \psi, l)^{1-\alpha} \psi^{a-1} - \delta_k - \rho + \eta(\sigma - 1) \left[ \gamma_h(\chi, \psi, l) - \frac{1}{1 - \beta} \gamma_\varepsilon(\chi, \psi, l) \right] \right\}. \tag{36''}
\]

Equations (28), (29) and (34) form the system that characterizes the dynamics of the economy, and allow us to express \( \gamma_\varphi, \gamma_\psi \) and \( \gamma_l \) as functions of \( \chi, \psi \) and \( l \) through (30), (31), (32'') and (36''), recalling (24), (26) and (27).

4. CALIBRATION OF THE MODEL

To calibrate the model, we shall view the postwar U.S. economy as if it were a closed economy on a balanced growth path. Predetermined parameters and data to be matched are summarized in Table 1. The fraction of investment in human capital that corresponds to on-the-job training, \( \kappa \), is chosen to be 0.25, as in Trostel (1993). Following Lucas (1990) and Pecorino (1994), the elasticity of intertemporal substitution for consumption is chosen to be 0.5. The elasticity of physical capital in the production of leisure in the home production
specification, $\xi$, is set equal to 0.08 following Benhabib et al. (1991) and Campbell and Ludvigson (2001). This value lies in the middle of the range from 0.05 to 0.13, which were the values considered in Parente et al. (2000) and Greenwood and Hercowitz (1991), respectively.

[INSERT TABLE 1 HERE]

Long-run GDP ratios are based on data of the 1998 *Economic Report of the President* (Table B-2) over the period 1965-1991. Neglecting imports and exports, GDP was divided into the fractions 0.645 for private consumption, 0.137 for gross investment in physical capital and 0.218 for government spending. Pre-tax-reform tax rate estimates are set equal to 1990 values, which are taken from Mendoza et al. (1994).

Data of expenditure on education are based on the *Digest of Education Statistics* 1996 (Table 30) and 1997 (Table 409). The expenditure on education amounted to 7.2 percent of GDP in 1990; the share of public expenditure on education to GDP, $g_e$, was 5.6 percent and the share of private expenditure on education to GDP was 1.6 percent. Expenditure on education constitutes investment in human capital in this model. Hence, public expenditure on education is subtracted from government consumption in the national income accounts to obtain a 16.2 percent government’s consumption share of GDP, and private expenditure on education is subtracted from private consumption to obtain a 62.9 percent consumption’s share of GDP. As we have noted above, in this model expenditure on education represents the fraction $1-\kappa$ of total investment in human capital.

Using King and Levine’s (1994) estimates, the stock of (market) physical capital to GDP ratio averaged 1.69 over the period 1965-1988. The long-run growth rate, $\gamma$, is set equal to 1.5 percent (as in Lucas, 1990, and Pecorino, 1994). The fraction of time spent on market production is 0.25 (see, e.g., Greenwood and Hercowitz, 1991, Einarsson and Marquis, 1997, and Knoop, 1999), and the ratio of working to learning time, which includes on-the-job learning time, is approximately 1.25 (see Glomm and Ravikumar, 1998), which entails that
the fraction of time spent learning is around 0.20. This figure lies in the middle of the range from 0.12 to 0.35, which were the values considered by Jones et al. (1997) and Knoop (1999), respectively.

The physical capital income’s share of GDP, $\alpha_E$, is chosen as 0.4. This is a relatively standard choice (e.g., Kydland and Prescott, 1996, İmrohoğlu, 1998, and Coleman, 2000). This value must not coincide with the physical capital income’s share of output, $\alpha$, as there is an unmeasured component of output, $\kappa e$. Using (8), the ratio of output to GDP can be obtained as

$$\frac{y}{GDP} = \frac{GDP + \kappa e}{GDP} = 1 + \frac{\kappa (1 - \kappa) e}{1 - \kappa} \frac{e}{GDP} = 1.024,$$  

substituting the values of $\kappa$ and $(1-\kappa)e/GDP$ reported in Table 1. Thus, the capital’s share of output is calculated as $\alpha = 0.391$ from the condition $\alpha y = 0.4 GDP$.

Parameter values found in the calibration are reported in Table 2. Engen et al. (1997) point out that when testing for the sensitivity of the results, the recalibrated model should reflect the original long-run data. Thus, instead of simply changing the leisure specification, keeping the remaining parameters unchanged, for each specification of the leisure activity the model is recalibrated to match the U.S. data shown in Table 1.

[INSERT TABLE 2 HERE]

Now, we shall briefly explain how the parameter values reported in Table 2 are obtained. Given the predetermined parameter values and data reported in Table 1, the fraction of physical capital devoted to the production of goods, $v$, is obtained from (14) as 0.735 in the home production model. Note that $v=1$ in the raw time and quality time models. Equation (5) (or (23e)) yields the calibrated value of the rate of depreciation of physical capital, $\delta_k$, as 0.066 in the raw time and quality time specifications, and 0.045 in the home production model. These values are in line with those commonly used in the literature. For instance, Coleman (2000) uses a value of 0.048 for the depreciation rate of physical capital, whereas
Stokey and Rebelo (1995) estimate a value of 0.062, close to the value of 0.07 used in Pecorino (1994).

Equation (23b), \( i = (1 - \tau_k)\alpha(y/(vk)) - \delta_k \), allows us to compute the interest rate, \( i \). Then, using (37), the value of the rate of time preference \( \rho \) is obtained from the expression for the growth rate (23a) in the home production and quality time models, and (23a’’) in the raw time model. From \( y/(vk) = \nu^{a-1}u^{1-a}(k/h)^{a-1} \), recalling (37) and using the estimated value of the work time, \( u \), we can compute the ratio of physical to human capital, \( k/h \). Noting that \( e/h = (e/y)(y/k)(k/h) \), we can obtain the value of \( e/h \). Now, Eqs. (23c) and (23d) yield the values of \( B \) and \( \delta_h \) in the home production and quality time models after substituting the value of the learning time, \( z \). In the raw time model, (23c) must be replaced by (23c’’).

Depreciation rates of human capital have been calculated in several studies (e.g., Carliner, 1982, Johnson, 1974, Johnson and Hebein, 1974, Haley, 1976, Heckman, 1976, Rosen, 1974). Estimates of \( \delta_h \) vary markedly in these studies, ranging from 0.2 to 13.3 percent. The calibrated value of the depreciation rate of human capital ranges from 0.4 percent in the quality time model, to 1.1 percent in the home production specification, and to 5.7 percent in the raw time model and, therefore, lies within the wide range noted above.

The reported values of \( \eta \) and \( \beta \) and are obtained from (13) and (15), respectively. Note that \( \xi = 0 \) in the raw time and the quality time models. From the government budget constraint (9), we obtain that the government claims a fraction of 20.7 percent of GDP for lump-sum transfers to households representing welfare programs. Since the economy is on its balanced growth path in its pre-tax-reform equilibrium, the requirement that the present value of government revenues equal that of government expenses entails that the government budget is balanced in the pre-tax-reform equilibrium; i.e., \( d = 0 \).
5. SIMULATION RESULTS

This section assesses the effects of alternative forms of taxation and the consequences that the choice of the leisure function has. We also determine the optimal tax structure and analyze how it is affected by the specification of the leisure activity. We consider tax reforms in which the government undertakes a permanent, unanticipated change in time-invariant capital income, labor income and consumption taxes at $t=0$. Government expenditure and exogenous welfare transfers as a percentage of GDP, $g_e$ and $g_s$, respectively, remain fixed at their pre-tax-reform levels displayed in Tables 1 and 2. The consumption tax rate is also kept fixed at its pre-reform level when the optimal structure of capital and labor income is computed. Taxes are set so that the present value of tax revenue equal that of government expenses. The government adjusts lump-sum taxes $d$ (or equivalently issues debt) as needed to make up for any shortfall or excess of tax revenue over expenses. The welfare gain of a reform is measured as the constant permanent percentage increase in consumption, keeping leisure unchanged, that leaves the household indifferent between remaining in the pre-tax-reform equilibrium or undertaking the tax reform. We explicitly solve for the non-linear transitional dynamics by using the time elimination method (Mulligan and Sala-i-Martín, 1993).

5.1. Effects of tax reforms

Table 3 reports the implications that the choice of the leisure specification has on the effects of alternative forms of taxation. The first experiment considered is to replace the tax on capital income with consumption taxation. As is clearly noted, the choice of the leisure function is crucial when the effects of this tax reform are assessed. The elimination of the capital income tax entails an increase in the consumption tax rate to about 39 percent to keep the present value of tax revenue equal to that of government expenses. As a consequence of the tax reform, in the home production model welfare increases by 1.04 percent and growth by 0.19 percentage points. When leisure is specified as quality time, the welfare increase is
higher and amounts to 1.45 percent but the growth increase is lower and adds up to 0.15 percentage points. The main difference arises when utility depends on pure leisure time. In the raw time model, a replacement of capital income taxation with consumption taxation reduces welfare by 1.85 percent whereas long-run growth rises by only 0.02 percentage points. The long-run allocation of time between work, learning and leisure is also affected by the choice of the leisure function. Work time decreases and learning time increases slightly in the home production and the quality time models. In contrast, both work and learning time diminish in the raw time model. Leisure time rises instead, irrespective of the leisure specification, but the largest increase takes place in the raw time model and the smallest one in the quality time model. The long-run consumption’s share of GDP falls by around 8 to 10 percentage points. The long-run investment in human capital to GDP remains unchanged in the raw time specification and increases by about 1 percentage point (an increase of approximately 11 percent) in the home production and the quality time models.

[INSERT TABLE 3 HERE]

Figure 1 illustrates the dynamic effects of an immediate permanent tax reform that replaces the tax on capital income with consumption taxation. It represents the deviations in percent of output, consumption, physical and human capital stocks, investment in human capital and the allocation of time between leisure, work and learning from their pre-tax-reform equilibrium values. The elimination of the tax on capital income encourages investing in physical capital rather than in human capital. Consequently, learning time and investment in human capital fall sharply whereas work time increases noticeably at the outset. The increment in the consumption tax rate, along with the increase in savings brought on by a lower taxation of interest income, causes consumption to fall by about 25 percent at the outset, while leisure increases by about 16 percent. This behavior is similar in the three leisure specifications.

[INSERT FIGURE 1 HERE]
The increment in the ratio of physical to human capital over time leads to a rise in the wage rate, which affects positively human capital investment. It also entails a decrease in the interest rate over time, which gradually reverses the negative influence from its initial rise. Therefore, time spent on human capital accumulation and investment in human capital grow rapidly over the transition to the new balanced growth path, while labor supply declines towards its long-run equilibrium value. The fall in the interest rate over time also causes a reduction in savings and a subsequent increase in the consumption to GDP ratio. As Milesi-Ferretti and Roubini (1998a) point out, when leisure is modelled as raw time the fraction of human capital corresponding to the fraction of time devoted to leisure is unemployed, and the more human capital is unemployed the lower are the incentives to accumulate human capital. Thus, learning time and investment in human capital in the raw time model are the lowest among the three leisure specifications, both along the transition and in the long run.

The evolution of the growing variables in Figure 1 clearly reveals the long-run effects of a higher growth rate. The deviation of output and the stock of physical capital from the pre-tax-reform equilibrium increases quickly over time, and the economy recovers rapidly from the initial decrease in consumption and the stock of human capital in the home production and quality time models. However, in the raw time specification, the long-run growth rate only increases by 0.02 percentage points after the tax reform. As a consequence, pre-tax-reform consumption and investment in human capital levels are achieved only in the very long run.

The distinct effect of the tax reform on the long-run growth rate in the different leisure specifications can be explained as follows. Milesi-Ferretti and Roubini (1998a, 1998b) show that a tax on capital income negatively affects the long-run growth rate as it reduces the net-of-tax real interest rate in the home production and quality time models, whereas a consumption tax has no growth effect since all human capital is employed. Thus, replacing capital income taxation with consumption taxation causes a large increase in the long-run growth rate in the home production and quality time models. However, when leisure is
modelled as raw time the fraction of human capital corresponding to leisure time is unemployed, and the more human capital is unemployed the lower are the incentives to accumulate human capital. Thus, both capital income and consumption taxation have an indirect effect on the growth rate through their impact on the labor/education-leisure choice. The overall effect of the capital income tax on the growth rate is negative, as is the effect of the consumption tax. Hence, lowering the tax rate on capital income to zero positively affects the growth rate, but increasing the consumption tax has a negative effect on the growth rate. The net effect is a slight increase in the growth rate but much lower than that attained in the quality time and home production models.

Figure 1 also shows that the welfare loss in the raw time model can be explained by the reduction in consumption with respect to the pre-tax-reform equilibrium during the transition to the new balanced growth path, which cannot be compensated by the leisure increase that occurs both along the transition and in the long-run. The welfare gain arising from eliminating the tax on capital income in the quality time model is higher than that in the home production model. The intuition for this result is that, in the home production model, a tax on capital income can be partially avoided by devoting a higher fraction of physical capital to the leisure activity, which is untaxed. This margin of choice is absent in the quality time model as all physical capital is devoted to the production of goods. Thus, capital income taxation is likely to be more distortionary in the quality time model than in the home production model.

The second tax reform illustrated in Table 3 is to replace the tax on capital income with labor income taxation. The elimination of the capital income tax entails an increase in the labor income tax rate to about 57 percent to keep the present value of tax revenue equal to that of government expenses. Now, long-run growth and welfare fall as a consequence of the tax reform regardless of the choice of the leisure specification. However, whereas welfare and growth effects are quite similar in the home production and quality time models, the decrease in welfare and growth is specially pronounced in the raw time model. The long-run
implications of this reform on the time allocation and the shares of consumption and investment in human capital to GDP are similar in the home production and quality time models. Again, the main differences arise when utility depends on pure leisure time. These results are in accordance with those reported by Ortigueira (1998), who finds that the inclusion of leisure as raw time in a Uzawa-Lucas framework increases the welfare taxation cost, specially of labor income taxation which can become even more costly than taxation of capital income.

The dynamic effects of replacing the tax on capital income with labor income taxation are displayed in Figure 2. The elimination of the tax on capital income and the increase in the tax on labor income encourage investing in physical capital rather than in human capital. As a result, learning time and investment in human capital fall sharply whereas work and leisure time increase noticeably at the outset. The increase in savings caused by a lower taxation of interest income causes consumption to fall noticeably at the outset. This behavior is similar in the three leisure specifications.

The increment in the ratio of physical to human capital over time leads to a rise in the wage rate, which encourages human capital investment. It also entails a decrease in the interest rate over time, which gradually reverses the negative influence from its initial rise. Therefore, time spent on human capital accumulation and investment in human capital grow rapidly over the transition to the new balanced growth path, while labor supply declines towards its long-run equilibrium value, which is below its pre-tax-reform value. The fall in the interest rate over time also causes a reduction in savings and a subsequent increase in the consumption to GDP ratio. However, consumption does not attain its pre-tax-reform equilibrium path as growth decreases as a consequence of the tax reform. In the raw time model, the higher the fraction of time devoted to leisure, the more human capital is unemployed and, therefore, the lower are the incentives to accumulate human capital. Thus,
learning time and investment in human capital along the transition in the raw time model are the lowest among the three leisure specifications. As a result, the decrease in the long-run growth rate, and also welfare loss, in the raw time model are considerably higher than those in the quality time and home production models.

The long-run effects of a lower growth rate are clearly revealed in the evolution of the growing variables in Figure 2. Although the stock of physical capital and output increase at the initial time, they eventually fall below their pre-tax-reform equilibrium paths since the long-run growth rate decreases relative to its pre-tax-reform value. This effect is much more noticeable in the raw time model, in which the growth rate falls to only 0.3 percent. Figure 2 also shows that welfare loss can be explained by the severe reduction in consumption relative to its pre-tax-reform equilibrium, which cannot be compensated by the increase in leisure time (in the home production and quality time models, leisure $L$ eventually falls below its pre-tax-reform equilibrium path as a result of the lower long-run growth rate). The welfare loss arising from replacing capital income with labor income taxation in the home production model is higher than that in the quality time model. The intuition for this result is again that when leisure is modelled as home production a tax on capital income can be partially avoided by devoting a higher fraction of physical capital to the leisure activity which is untaxed. Thus, the distortion induced by the capital income tax is likely to be lower in the home production model than that in the quality time model, in which all physical capital is devoted to the production of goods.

The third tax reform shown in Table 3 is to replace the tax on labor income with consumption taxation. The elimination of the labor income tax entails an increase in the consumption tax rate to approximately 33 percent. The long-run implications of this reform on the time allocation between work, learning and leisure, and the shares of consumption and investment in human capital to GDP are similar in the three formulations. Only slightly larger effects on learning time and investment in human capital are noticed in the raw time model.
Both the long-run growth rate and welfare increase as a result of the replacement of labor income taxation with consumption taxation regardless of the leisure specification. However, the extent of the effect varies noticeably across the different specifications. The long-run growth rate increases by 0.11 and 0.15 percentage points, respectively, in the quality time and home production models. In contrast, it augments 0.76 percentage points when utility depends on pure leisure time. The distinct extent of the welfare gains is even more significant. The welfare gain amounts to 0.74 percent in the home production model, 1.50 percent in the quality time model and 2.62 percent in the raw time model. Again, the welfare effect of the tax reform is more pronounced in the quality time model than in the home production model, but the highest growth rate and welfare gain are attained in the raw time model.

The elimination of the tax on labor income encourages investing in human capital. It also induces agents to substitute work/learning for leisure, whereas increasing the consumption tax rate has the opposite effect. The net effect is however to reduce leisure time. The lower leisure value relative to its pre-tax-reform value in the raw time model entails a reduction in the unemployed human capital which, in turn, encourages investment in human capital. As a result, the growth rate increase is higher in the raw time model than in the home production and quality time models. Moreover, the learning time and investment in human capital in the raw time model are the highest and leisure time is the lowest among the three leisure specifications.

The last tax reform illustrated in Table 3 is to replace capital and labor income taxation with consumption taxation. Now the long-run implications of this reform on the allocation of time and the shares of consumption and investment in human capital to GDP are quite similar in the three formulations. However, the extent of the growth and welfare gains are rather different. The increase in the long-run growth rate ranges from 0.27 percentage points in the quality time model, to 0.35 in the home production specification, and to 0.83 percentage points when utility depends on pure leisure time. Welfare effects also diverge considerably
across leisure specifications. Welfare augments 1.78 percent in the home production model, 2.56 percent in the raw time model, and the largest welfare gain is achieved in the quality time model, 3.05 percent. It is worth noting that the largest welfare gain is associated to the smallest increase in the long-run growth rate.

5.2. Optimal tax structure

Table 4 reports the optimal structure of factor incomes and consumption taxation. Two main findings emerge from Table 4. First, simulation results strongly suggest that a higher reliance upon consumption taxation would increase welfare. The optimal constant tax rate on consumption ranges from 45.3 percent in the home production model, to 50.7 percent in the raw time specification, and to 54.5 percent in the quality time model. Second, the optimal tax rate on physical capital income is considerably robust to the choice of the leisure specification, ranging from 18.6 to 22.0 percent, and is considerably lower than its 1990 estimate of 41.5 percent reported in Mendoza et al. (1994). However, the balance between labor income and consumption taxation varies somewhat depending on the leisure specification. The optimal tax rate on labor income is zero in the raw time and quality time models, but adds up to 7.6 percent in the home production specification. These results are in agreement with those of the tax experiments conducted in the previous subsection, which showed that the labor income tax is the most costly tax, specially in the raw time model.

[INSERT TABLE 4 HERE]

The effects of shifting to the optimal tax structure on the long-run growth rate are similar in the home production and quality time models: it increases by 0.23 and 0.21 percentage points, respectively. A considerable difference arises, however, when comparing the welfare effects of the tax reform. The attainable welfare gain is about 1 percent higher in the quality time model than in the home production model (4.87 versus 3.82 percent). Nevertheless, the greatest increase in the long-run growth rate and the largest welfare gain are achieved in the
raw time model, in which the long-run growth rate rises by 0.83 percentage points and welfare by 5.23 percent.

[INSERT FIGURE 3 HERE]

Figure 3 illustrates the dynamic effects of an immediate permanent tax reform that institutes the optimal tax structure. The reduction of the physical capital income tax rate after the tax reform encourages investing in physical capital rather than in human capital. The reduction of the labor income tax rate instead stimulates to invest in human capital. However, the principal cost of investing in human capital is foregone earnings, which is effectively tax-deductible. Only a fraction of the cost of goods and services used in producing human capital is not reduced by taxation. Hence, the effects of reducing the tax on physical capital income outweigh those of reducing the tax on labor income, and the net effect is to encourage investment in physical capital rather than in human capital. Consequently, learning time and investment in human capital fall whereas investment in physical capital and work time rise at the outset regardless of the leisure specification. The higher consumption tax rate and the increase in savings caused by a lower taxation of interest income cause consumption to fall at the outset. As the economy evolves the ratio of physical to human capital increases, which leads to a fall in the interest rate and a rise in the wage rate over time. As a consequence, learning time and investment in human capital grow over the transition to the new balanced growth path, while work time declines towards its long-run equilibrium value.

Although this behavior is similar in the three leisure specifications, the extent of these effects, specially regarding the allocation of time, depends on the choice of the leisure function. In the raw time model, the fraction of human capital corresponding to leisure time is unemployed, and the more human capital is unemployed the lower are the incentives to accumulation. Thus, the representative household has to weigh the positive effect on welfare of a higher fraction of time devoted to leisure and the negative effect of a slower growth due to the lower incentives to human capital accumulation. As a result, in the raw time model the
time devoted to leisure is the lowest and the learning time is the highest among the three leisure specifications considered at each point in time.

The effects of a higher long-run growth rate in the raw time model become apparent in the evolution of the growing variables in Figure 3. The deviation of output and of the stock of physical capital from the pre-tax-reform equilibrium increases quickly over time, and the economy recovers rapidly from the initial decrease in consumption, human capital stock and expenditure on education in all leisure specifications. However, this behavior is more patent in the raw time model in which the long-run growth rate is approximately 0.65 percentage points greater than those achievable in the home production and quality time models.

[INSERT TABLE 5 HERE]

Table 5 illustrates the optimal structure of capital and labor income taxation, keeping constant the consumption tax rate. The optimal tax structure of factor incomes and the effects of instituting this tax structure are rather similar in the home production and quality time models, but differ to some extent from those in the raw time model. The optimal tax rate on capital income ranges from 28.6 percent in the quality time specification, to 29.4 percent in the home production model and to 36.7 percent when utility depends on pure leisure time. This higher reliance upon capital income taxation in the raw time model is accompanied by a appreciably smaller welfare gain: only 0.27 percent versus 1.32 and 1.48 percent attainable in the home production and quality time models, respectively. Furthermore, the long-run growth rate decreases 0.09 percentage points in the raw time model whereas it increases slightly in the other cases.

The ability to manage the consumption tax leads to welfare gains that are considerably larger than those attainable when the consumption tax is kept constant. However, one significant difference between the home production and quality time models, on the one hand, and the raw time specification, on the other, can be noticed. Even if the consumption tax rate cannot be changed substantial welfare gains can be achieved in the home production and
quality time models. However, in the raw time model, the welfare gain attainable is fairly small when the consumption tax is kept constant, whereas the welfare gain attainable when consumption can be set in an optimal manner is the largest one within the three leisure specifications considered. These results are in accordance with those reported in Coleman (2000), who finds that the welfare gains attainable when consumption can be taxed are quite large but they are rather small if consumption cannot be taxed in a neoclassical model in which utility depends on pure leisure time.

The results reported in Tables 4 and 5 differ to a great extent from those obtained in the optimal taxation literature. Milesi-Ferretti and Roubini (1995, 1996, 1998b) found that the optimal long-run rates on physical and human capital income and consumption are zero under the three specifications of the leisure activity considered in this paper. The result of nonzero tax rates in the optimal tax mix can be intuitively explained as follows. When taxes can vary over time, the optimal long-run tax rates are zero. The government expenditure would be financed by the interest earned on the assets raised by accumulating budget surpluses during an initial phase of relatively high taxation. When taxes are constrained to be constant, the optimal tax rate would be a compromise between these two opposite forces, which could result in imposing nonzero constant tax rates throughout. Moreover, government expenditure is exogenously given in the aforementioned papers, whereas here it is a constant fraction of output, and the tax reforms considered are deficit neutral. The magnitude of the tax rate would then be given by the distortion that it induces along with the requirements of the government’s budget constraint.

6. CONCLUSIONS

This paper has assessed the implications that the choice of the leisure function has on the effects of alternative forms of taxation. To address this issue we have considered the three main leisure specifications that have been proposed in the literature: leisure as raw time,
quality time and home production. We have analyzed tax reforms in which the government undertakes a permanent, unanticipated change in time-invariant tax rates, which are set to keep the present value of tax revenue equal to that of government expenses.

The main conclusion is that the specification of the leisure activity really matters when assessing the effects of tax reforms. Substituting the capital income tax with consumption taxation entails a moderate increase in the growth rate and a significant welfare gain in the home production and quality time models. However, in the raw time model, welfare reduces notably whereas the increase in the long-run growth rate is insignificant. The comparison of the dynamic paths of the main economic variables also reflects the importance that the choice of the leisure function has. If capital income taxation is replaced with labor income taxation, long-run growth and welfare fall regardless of the choice of the leisure specification. However, whereas welfare and growth effects are quite similar in the home production and quality time models, the decrease in welfare and growth is specially pronounced in the raw time model. This divergence in growth and welfare effects across leisure specifications can also be noticed when taxation on capital and labor income is replaced with consumption taxation.

This paper has also assessed the optimal structure of factor incomes and consumption taxation. When income and consumption taxes are set in an optimal manner, simulation results strongly suggest that a higher reliance upon consumption taxation would increase welfare. The optimal tax rate on physical capital income is significantly nonzero and ranges from about 19 to 22 percent. These results are robust to changes in the specification of the leisure activity. However, the balance between consumption and wage taxation depends moderately on the leisure specification. The optimal labor income tax rate is zero in the quality time and raw time models, while it adds up to 7.6 percent in the home production model. The largest growth and welfare gains are achieved in the raw time model.
The ability to manage the consumption tax leads to welfare gains that are considerably larger than those attainable when the consumption tax is kept constant. However, in the home production and quality time models, substantial welfare gains can be achieved even if the consumption tax cannot be changed. The capacity to manipulate the consumption tax is instead fundamental to achieve significant welfare gains in the raw time model. Here, the welfare gain achievable without adjusting the consumption tax rate is fairly small, whereas the welfare gain attainable when the consumption tax can be set in an optimal manner is the largest one within the leisure specifications considered. This reinforces our conclusion that the answer to the question posed in this paper is affirmative.
REFERENCES


Table 1. Parameter benchmark values

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| $g_e$                     | 0.056 |   |   |   |
Table 2. Results of the calibration

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<th>$\eta$</th>
<th>$\beta$</th>
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<td>0.201</td>
<td>0.066</td>
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<td>0.201</td>
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Table 3. Effects of tax reforms (in percent)

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<th>Growth rate</th>
<th>Welfare gain</th>
<th>u</th>
<th>z</th>
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<td>1.04</td>
<td>22.6</td>
<td>20.1</td>
<td>57.3</td>
<td>54.7</td>
<td>10.7</td>
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<td>-1.85</td>
<td>23.4</td>
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Table 4. Optimal structure of factor incomes and consumption taxation (in percent)

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<th>( \tau_k )</th>
<th>( \tau_h )</th>
<th>( \tau_c )</th>
<th>Growth rate</th>
<th>Welfare gain</th>
<th>( c ) GDP</th>
<th>( e ) GDP</th>
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<tr>
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<td>7.6</td>
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Table 5. Optimal structure of capital and labor income taxation (in percent)

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<th>$\tau_k$</th>
<th>$\tau_h$</th>
<th>Growth rate</th>
<th>Welfare gain</th>
<th>$u$</th>
<th>$z$</th>
<th>$l$</th>
<th>$c_{GDP}$</th>
<th>$e_{GDP}$</th>
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<td>20.0</td>
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<tr>
<td>Quality Time</td>
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<td>1.51</td>
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<td>20.0</td>
<td>56.5</td>
<td>60.2</td>
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</table>
Figure 1

Dynamic effects of replacing capital income taxation with consumption taxation

![Graphs showing various economic metrics over time](image)

- **Output**
- **Consumption**
- **Physical Capital Stock**
- **Human Capital Stock**
- **Investment in Human Capital**
- **Leisure Time**
- **Work Time**
- **Learning Time**

Legend:
- Home Production
- Raw Time
- Quality Time

Note: Data plotted are deviations in percent of pre-tax-reform equilibrium
Figure 2
Dynamic effects of replacing capital income taxation with labor income taxation

输出

消费

物理资本库存

人力资本库存

人力资本投资

休闲时间

工作时间

学习时间

--- Home Production，--- Raw Time，--- Quality Time

Note: Data plotted are deviations in percent of pre-tax-reform equilibrium

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Figure 3
Dynamic effects of shifting to the optimal tax structure

Home Production, Raw Time, Quality Time

Note: Data plotted are deviations in percent of pre-tax-reform equilibrium