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Fiscal Reform, Long-run Growth and Welfare in a Monetary Model: The Case of Mexico

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Abstract

A neoclassical endogenous growth model is presented where a representative household deriving utility from consumption and leisure must use money in order to purchase consumption goods. Taxes on money holdings, capital and labor income may be used to finance an exogenous stream of wasteful government expenditures. The model is especially calibrated for the Mexican economy and used to analyze the effect of alternative tax reforms and higher government expenditure levels on both growth and welfare.

Resumen

Se presenta un modelo neoclásico de crecimiento endógeno donde una familia representativa que obtiene utilidad por consumo y ocio debe usar dinero para comprar bienes. Impuestos sobre tenencias de dinero y sobre ingresos al capital y al trabajo pueden usarse para financiar una secuencia exógena de gasto de gobierno sin ningún uso en particular. El modelo es calibrado especialmente para la economía mexicana y se utiliza para analizar el efecto de diversas reformas impositivas y de mayores niveles de gasto de gobierno sobre el crecimiento y el bienestar.

Introduction

During the last years, there has been a hotly debated discussion about the desirability to implement a fiscal reform in Mexico. The reasons argued in favor of such a reform are basically to improve the efficiency of the tax system as well as to increase the revenue capacity of the government in order to have additional resources to satisfy basic social needs such as education, health and infrastructure that may allow the economy to grow at faster rates (OECD (2004), Foro Consultivo Científico y Tecnológico (2004), Webb (2001), Dalsgaard (2000)).[1] Remarkably, these discussions typically focuses on static, short-run issues while leaving aside the effect such a reform may have on long-run growth and social welfare (see, for example, Foro Consultivo Científico y Tecnológico (2004) and Trigueros and Fernández (2001)).

   The goal of this paper is thus to give a quantitative answer to the effects of a fiscal reform on growth and welfare in Mexico from a general equilibrium perspective. In particular, two questions are addressed. First, what is the effect of alternative tax reforms on long-run growth and welfare if they are designed to keep government expenditure share in total output constant? And second, if government expenditures in terms of output are now allowed to increase, which among the available taxes necessary to finance this extra expenditure is the least distorting?

   To answer these questions, a neoclassical monetary model with endogenous growth is proposed where the infinitively-lived representative household derives utility from consumption and leisure. Money is introduced in this model via a standard cash-in-advance constraint, whereas endogenous growth is explained by a process of human capital accumulation as in Lucas (1988, 1990). The model considers four alternative tax instruments: seigniorage, capital and labor income taxes, and lump-sum taxes, necessary to finance wasteful government expenditures.[2] For the model purposes, a tax reform is defined as the change in two tax instruments relative to the original tax policy (including seigniorage revenue) so that the budget constraint of the government is balanced in a present-value sense. This implies that a change in a distorting tax may be financed by a change in either a lump-sum tax or an alternative distorting tax.

   The evaluation of growth and welfare effects of tax reforms under the four tax instruments mentioned above is not common in the representative

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[1] For a review of tax reforms implemented in Mexico since 1970, see Gil-Díaz and Thirsk (1997) and Gil-Díaz (1990). Dalsgaard (2000) includes a summary of tax reform measures for the period 1987 – 1998 in Mexico.

[2] The motivation to include seigniorage as a revenue instrument is that sometimes it is argued that a monetary expansion is beneficial for capital accumulation and thus growth (Romero (2000)). This argument is usually reflected in the public perception that the fighting process of the monetary authority against inflation during the last years in Mexico has been too costly in terms of growth. Therefore, it seems interesting to find what the model has to say about this concern.

agent literature.[3] For example, growth and welfare effects of income taxation usually abstract from the use of money (see, among others, Chamley (1981), King and Rebelo (1990), Lucas (1990), Jones et al. (1993), and Ortigueira (1998)). Similarly, the distorting effects of inflation are usually estimated assuming lump-sum taxes in place (see, for example, Cooley and Hansen (1989), Gomme (1993), Dotsey and Ireland (1996), and Wu and Zhang (2000)). However, as pointed out by Cooley and Hansen (1991, 1992), the relationship between alternative sources of revenue (for example, the fiscal implications of lower taxation on money holdings) may have important consequences for the appropriate estimation of growth and welfare.

The present paper has several differences with respect to those in the literature that explicitly study the interaction between seigniorage and income taxes in representative agent models. For example, the estimation of tax reforms in the monetary model of Cooley and Hansen (1991, 1992) takes place in an exogenous growth context. Nevertheless, it is well known that the effect of income taxes on the allocation of time and thus on long-run growth may not be ignored (see, for example, Milesi-Ferretti and Roubini (1998)). Jones and Manuelli (1995) find that the welfare cost of inflation is similar under endogenous and exogenous growth models alike, even under income taxation. The problem with their estimates is that welfare comparisons are made across steady-states only, a problem also present in the AK models of Palivos and Yip (1995) and Smith (1996). As is well known (cf. Lucas (1990), Ortigueira (1998)), ignoring transitional dynamic effects on welfare analysis may be misleading. As described later, the results presented here take fully into account these short-run effects on welfare. Finally, the closest paper in spirit to the present work is found in Wen and Love (1998). They consider a human capital-type endogenous growth model where money enters via a shopping-time technology. Unfortunately, tax reform calculations presented by these authors are inaccurate in the sense that the intertemporal budget constraint of the government is not satisfied, a problem appropriately addressed here.

To provide a numeric answer to the questions originally posed above, the model is carefully calibrated to match the features of the Mexican economy. Next, tax reform exercises are performed where only one of the three distorting taxes is eliminated and replaced either by higher lump-sum or distorting taxes, while keeping government expenditures fixed.[4] An important feature of this work is that the net welfare effect of a fiscal reform is conveniently disentangled into three components: a long-run growth effect, a long-run level effect, and a short-run, transitional effect as in Cassou and Lansing (2003). This division turns out to be important because, as shown

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[3] Notable exceptions are Cooley and Hansen (1991, 1992), Jones and Manuelli (1995), Palivos and Yip (1995), Smith (1996) and Wen and Love (1998).
[4] In the case of seigniorage, the exercise involves driving the inflation rate down to zero.

later, a fiscal reform that yields the highest long-run growth rate is not necessarily the policy that yields the highest welfare because of possible countervailing level and short-run effects.

All the simulations show that the long-run growth rate is not significantly affected by a tax reform designed to keep public expenditures constant: the annual growth rate increases from 1.54 to at most 1.65 percent. This result is consistent with those previously found for the U. S. economy (see Stokey and Rebelo (1995), and Mendoza et al. (1997)).[5] Welfare may either increase or decrease depending on the tax policy in place, but such a change is well below 1.1 percent in absolute value, a result also consistent with the conjecture by Lucas (1990).

The results are slightly different if government's share in total output is increased. In such a case, the long-run growth rate increases modestly unless taxes on labor income are used to balance the government's budget (cf. Devereux and Love (1995), Mendoza et al. (1997), Baier and Glomm (2001). The intuition is that the implied lower share of consumption in total output leads the household to reallocate her time from leisure towards working and schooling time, thus increasing the long-run growth rate of the economy. It turns out that neither seigniorage nor capital income taxes have a substantial effect on the household's allocation of time, so the growth rate remains high. However, labor income taxes do affect working and schooling negatively. This negative effect dominates the effect from higher government expenditures so the output growth rate in fact decreases. Even though the increase in long-run growth under seigniorage and capital income taxes is not particularly large (the highest value is 1.63 percent for a government's share of 20 percent), the corresponding fall in welfare is substantial (slightly less than 11 percent). From the discussion above, the results imply that an appropriate tax reform keeping government expenditures constant may yield the same effect on long-run growth as the policy with increasing government expenditures but with a fraction of the cost in terms of welfare. Putting differently, according to the model a fiscal reform that increases *wasteful* government expenditures to promote long-run growth is highly inefficient.

In relation to the consequences of a lower inflation rate, the model finds that there exists a negligible positive effect of such a policy on both long-run growth and welfare. In particular, moving from the historical inflation rate in Mexico to a zero inflation rate brings about an increase of 0.01 percentage points in the growth rate and a 0.05 percent increase in net welfare if lump-sum taxes are available. The small positive effect of lower inflation on growth

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[5] Of course, this finding does not necessarily mean that a tax reform is unattractive from a policy point of view. First, it may be the case that the growth rate of the economy is substantially higher along the transition to a new balanced growth path with a low speed of convergence towards such a new path. In other words, the transitional growth rate may well be above its long-run estimate for a relative long period. Second, an appropriate tax reform may move the economy to a higher *level* of per capita output and consumption over time even though the long-run growth rate remains about the same.

is roughly consistent with similar theoretical models (cf. Chari et al. (1995)) and empirical evidence (see, for example, Levine and Renelt (1992), Fischer (1991, 1993) and Barro (1995, 1997)).

The final lesson from the numeric simulations is that the policymaker might be faced with conflicting goals at the time of evaluating a fiscal reform. In some cases, the fiscal reform that yields the highest growth rate is simultaneously the policy that yields the lowest welfare, and vice versa (cf. Cassou and Lansing (2003)). The reason is that the positive effect of higher growth on welfare may be easily compensated by negative welfare effects caused by short-run and long-run level distortions. Thus the decision about which fiscal policy reform to implement might well end up depending on the policymaker's goals.

The rest of the paper is divided as follows. The next section presents the basic model. The third section discusses the calibration of the model for Mexico under particular utility and production functions, and evaluates the effect of alternative fiscal policy exercises on both long-run growth and welfare. Section four concludes by including some ways in which the model may be extended.

1. The Model

The framework considered is a standard, deterministic endogenous growth model with infinite horizon where a representative agent is endowed with perfect foresight and a single unit of time that may be devoted to leisure, working or "schooling" activities. The household derives utility from consumption $c(t)$ and raw (non-qualified) leisure $x(t)$ where $0 \le x(t) \le 1$. The instantaneous utility function $U(c(t), x(t))$ is bounded, continuously differentiable, strictly increasing, strictly concave and non-separable in its arguments. The household maximizes the discounted sum of utilities over time at the rate $\rho > 0$ according to:

$$\int_0^\infty e^{-\rho t} U[c(t),\ x(t)] dt \tag{1}$$

The household keeps assets in the form of money holdings $m(t)$ and ownership claims on physical capital $k(t)$. The representative agent in addition is endowed with a stock of human capital $h(t)$. Accordingly, her flow budget constraint is given by:

$$c(t) + \dot{k}(t) + q(t) = \tilde{r}(t)k(t) + \tilde{w}(t)u(t)h(t) + T(t) \tag{2}$$

where $q(t) \equiv \dot{m}(t) + \pi(t)m(t)$ represents gross investment in real money balances, $\pi(t)$ is the inflation rate, and $\tilde{r}(t) \equiv [1 - \tau_k(t)]r(t)$ and $\tilde{w}(t) \equiv [1 - \tau_n(t)]w(t)$ are the real rate of return on physical capital and the real wage respectively, both expressed net of taxes. Here, $\tau_k(t)$, $\tau_n(t)$ and $T(t)$ denote taxes on capital and labor income, as well as lump-sum transfers (taxes if $T(t)$ is negative), respectively, and $u(t)$ is the fraction of time that the household devotes to the production of the single good with $0 \leq u(t) \leq 1$. For simplicity, no depreciation of physical capital is assumed, so gross investment $i(t)$ equals net investment:

$$\dot{k}(t) = i(t) \tag{3}$$

Money is valued in this economy since it is required to purchase consumption goods. An otherwise standard cash-in-advance constraint is generalized by introducing the degree of liquidity constraint faced by the household, namely the fraction of consumption goods that must be purchased with money. Such exogenous fraction is denoted as ϕ, where $0 < \phi \leq 1$. Therefore,

$$\phi c(t) \leq m(t) \tag{4}$$

In order to allow for endogenous growth, it is assumed that human capital accumulation may be affected by the way households allocate their time. Accordingly, if $v(t)$ denotes the fraction of time devoted to schooling activities, the law of motion for human capital is given by:

$$\dot{h}(t) = h(t)H[v(t)] \tag{5}$$

where $H(\cdot)$ is a continuously differentiable, increasing and concave function, and $0 \leq v(t) \leq 1$.

Finally, it must hold:

$$u(t) + v(t) + x(t) = 1 \tag{6}$$

There is perfect competition in the firms sector. Technology is represented by a production function $F[k(t), u(t)h(t)]$ with constant returns to scale in the stock of physical capital $k(t)$ and the effective amount of labor

$u(t)h(t)$. The function $F\big[k(t),u(t)h(t)\big]$ is continuously differentiable, concave, increasingly monotone and satisfies well-known Inada conditions.

Profit maximization implies that both factors of production are paid their marginal products, i.e.,

$$w(t) = F_n\big[k(t),u(t)h(t)\big] \tag{7}$$

$$r(t) = F_k\big[k(t),u(t)h(t)\big] \tag{8}$$

where $F_i(t)$ denotes the marginal product of factor of production $i = k, n$.

The single good produced in this economy may be devoted either to consumption, investment $i(t)$ or government purchases of goods and services $g(t)$. The role of government is to provide currency and to impose taxes on capital income, labor income and money holdings in order to finance the exogenous stream of government expenditures $g(t)$. Any difference between revenue taxation and expenditures may be covered with lump sum transfers $T(t)$.

Money is issued at the rate $\mu(t) \equiv \dot{M}(t)/M(t)$, where $M(t)$ is the (nominal) money supply. Equilibrium in the money market is thus reached when the nominal price level $P(t)$ adjusts so that real money demand equals real money supply, $m(t) = M(t)/P(t)$. Thus,

$$\dot{m}(t)/m(t) = \mu(t) - \pi(t) \tag{9}$$

The amount of revenue raised by the government through money creation at time t is just $\dot{M}(t)/P(t) = \mu(t)m(t)$. Therefore, the government's budget constraint must satisfy:

$$g(t) + T(t) = \mu(t)m(t) + \tau_k(t)r(t)k(t) + \tau_n(t)w(t)u(t)h(t) \tag{10}$$

DEFINITION: Given $k(0) = k_0$, $h(0) = h_0$, and $M(0) = M_0$, a *competitive equilibrium* is defined as the set of infinite sequences for allocations {$c(t)$, $i(t)$, $k(t)$, $h(t)$, $m(t)$, $u(t)$, $x(t)$, $v(t)$}, factor prices $\{r(t), w(t)\}$, and government policy {$\tau_k(t)$, $\tau_n(t)$, $\mu(t)$, $g(t)$, $T(t)$} such that:

(i) Given factor prices and government policy, the allocations {$c(t)$, $i(t)$, $k(t)$, $h(t)$, $m(t)$, $u(t)$, $x(t)$, $v(t)$} maximize (1) subject to (2) – (6);

(ii)   The sequence $\{k(t),\ h(t),\ m(t),\ u(t),\ r(t),\ w(t),\ \tau_k(t),\ \tau_n(t),\ \mu(t),$ $g(t),\ T(t)\}$ satisfies equations (7), (8) and (10); and

(iii)   The goods market clears:[6]

$$c(t)+i(t)+g(t)=F\big[k(t),u(t)h(t)\big]$$

It may be readily verified that the solution to the representative agent's program is defined by the following first-order conditions:

$$U_c(t)=\lambda_1(t)+\phi\lambda_2(t) \tag{11a}$$

$$U_x(t)=\lambda_3(t)H'\big[v(t)\big]h(t) \tag{11b}$$

$$\lambda_1(t)=\lambda_4(t) \tag{11c}$$

$$\dot{\lambda}_1(t)=\lambda_1(t)\big[\rho-\tilde{r}(t)\big] \tag{11d}$$

$$\dot{\lambda}_3(t)=\lambda_3(t)\big\{\rho-H\big[v(t)\big]\big\}-\lambda_1(t)\tilde{w}(t)u(t) \tag{11e}$$

$$\dot{\lambda}_4(t)=\rho\lambda_4(t)+\lambda_1(t)\pi(t)-\lambda_2(t) \tag{11f}$$

$$\lambda_2(t)\big[m(t)-\phi c_1(t)\big]=0\ ,\ \ \lambda_2(t)\geq 0 \tag{11g}$$

plus some well-known transversality conditions. In the above expressions, $U_i(t)$ denotes the derivative with respect to the ith argument, $i = (c, x)$, and $\lambda_1(t)$, $\lambda_2(t)$, $\lambda_3(t)$, and $\lambda_4(t)$ represent the shadow prices of physical capital, the cash-in-advance constraint, human capital and money holdings, respectively.

Expression (11a) above represents the marginal utility of consumption, including the cost of holding money. Equation (11b) simply states that the marginal utility of leisure must be equal to the marginal utility of schooling time. The equality between the price of an extra unit of the consumption good and money holdings is represented by (11c). Finally, expressions (11d) – (11f) are the laws of motion for shadow prices.

Manipulation of (11c), (11d) and (11f) lead to the following expression:

$$\lambda_2(t)=\lambda_1(t)R(t) \tag{12}$$

where $R(t)\equiv\pi(t)+\tilde{r}(t)$ denotes the nominal interest rate (net of taxes). From (12), if $R(t)>0$ then $\lambda_2(t) > 0$ since the shadow price $\lambda_1(t)$ is strictly positive. Therefore, (11g) implies $m(t) = \phi c(t)$ so that the cash-in-advance constraint is strictly binding. On the other hand, if $R(t) = 0$ then $\lambda_2(t) = 0$ and

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[6] Walras' law guarantees that equilibrium in the money market, $m(t) = M(t)/P(t)$, is satisfied if conditions (i), (ii) and (iii) are simultaneously satisfied.

the cash-in-advance constraint is just binding. In other words, it is always the case that $m(t) = \phi c(t)$ (cf. Rebelo and Xie (1999)).

The following step is to define particular utility and technology functions. In the first case, the following CES functional form consistent with the existence of a balanced growth path is proposed (see Ladrón-de-Guevara et al. (1997)):

$$U\big[c(t),\, x(t)\big] = \frac{\big[c(t)^{\psi}\, x(t)^{1-\psi}\big]^{1-\sigma}}{1-\sigma} \tag{13}$$

for $\sigma > 0$, $\sigma \neq 1$ and $0 < \psi \leq 1$, and $U\big[c(t), x(t)\big] = \psi \log c(t) + (1-\psi)\log x(t)$ for $\sigma = 1$.[7]

The production function $F(t)$ is given by a standard Cobb-Douglas specification $F(t) = Ak(t)^{\alpha}\,(u(t)h(t))^{1-\alpha}$ where $0 < \alpha < 1$ and $A > 0$. Following Lucas (1990), human capital technology $H(\cdot)$ is expressed as $H\big[v(t)\big] = Bv(t)^{\eta}$ where $0 \leq \eta \leq 1$ represents the constant elasticity of the learning function with respect to time devoted to human capital accumulation, and $B > 0$ is the constant marginal productivity of schooling time. The value of B is restricted so that the transversality condition $\psi(1 - \sigma)B < \rho$ is satisfied.

Along a balanced growth path, consumption, money holdings, physical and human capital are growing at the constant rate γ. Namely,

$$\dot{c}(t)\big/c(t) = \dot{m}(t)\big/m(t) = \dot{k}(t)\big/k(t) = \dot{h}(t)\big/h(t) = \gamma$$

with $\dot{u}(t)\big/u(t) = \dot{x}(t)\big/x(t) = \dot{v}(t)\big/v(t) = 0$. As usual in this type of models, it is convenient to express the equilibrium in terms of new variables. In particular, variables are defined relative to the human capital stock so that $z(t) \equiv k(t)/h(t)$ and $c(t)/h(t)$. Using the system in (11), it may be shown that a balanced growth path is described by the values of z^{*}, $(c/h)^{*}$, u^{*}, x^{*}, v^{*} and γ that satisfy

$$\frac{(1-\psi)(c/h)^{*}}{\psi x^{*}} = \frac{\tilde{w}^{*}}{1+\phi R^{*}} \tag{14a}$$

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[7] Ladrón-de-Guevara et al. (1999) show that the introduction of non-qualified leisure into an endogenous growth model (like the one considered here) may lead to a multiplicity of steady states for a relatively broad parameter space in a framework with no money and non-distorting taxes. As discussed later in this paper, this potential problem does not arise for the parameter space under study.

$$(c/h)^* + (g/h)^* = A(z^*)^\alpha (u^*)^{1-\alpha} - \gamma z^* \tag{14b}$$

$$\gamma \left[\psi(1-\sigma) - 1 \right] = \rho - \tilde{r}^* \tag{14c}$$

$$\gamma = B(1 - u^* - x^*)^\eta \tag{14d}$$

$$\tilde{r}^* = \gamma \left[1 + \frac{\eta u^*}{1 - u^* - x^*} \right] \tag{14e}$$

together with the time constraint (6). Along the balanced growth path, $g(t)$ and $T(t)$ grow at the endogenous rate γ in order to avoid that g/h and T/h are zero in the limit.[8]

Equation (14a) is simply the intratemporal optimality condition between consumption and leisure, which is equal to the after-tax real wage expressed in terms of the price of the consumption good including the cost of holding money. Expression (14b) denotes the resource constraint evaluated along the balanced growth path. The otherwise standard Euler equation in a model with non-separable leisure is represented by (14c), where the long-run growth rate depends on the after-tax real rate of return on capital. The law of motion for human capital along the balanced growth path is included in (14d). Finally, the equality between the net rate of return of physical and human capital is summarized by (14e). By substituting (14e) into (14c), it becomes clear that the endogenous growth rate γ is only a function of schooling time, the time devoted to work and parameter values of the model.

2. Growth and Welfare effects of Alternative Fiscal Policies

2.1   Preliminaries

The following step is to provide numeric estimates of the effects of alternative fiscal policies on both growth and welfare by taking into account the model described in the previous section. For that purpose, it is assumed that the economy is initially along a balanced growth path. Let $(c(\tau), x(\tau))$ denote the corresponding paths of consumption and leisure associated with the existing fiscal policy $\tau \equiv \tau(\tau_k, \tau_n, \mu, g, T)$, and $k^*(0)$ and $h^*(0)$ as the initial

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[8] Both government expenditures and lump-sum transfers are also allowed to grow at the same rate as output along the transition path once a change in fiscal policy is implemented.

endowments of physical and human capital, respectively. If an alternative fiscal policy $\hat{\tau}$ is unexpectedly announced, the economy moves out of its initial allocation in order to converge to a new balanced growth path denoted as $(c(\hat{\tau}), x(\hat{\tau}))$. The new fiscal policy is assumed to remain constant over time. As usual, the household has perfect foresight once the new policy is announced.

Following Lucas (1987), define ζ as the compensating consumption supplement necessary for the household to be indifferent between the existing policy τ and the new fiscal policy $\hat{\tau}$. Accordingly, the welfare gain of a fiscal reform is measured as the value of ζ that solves:

$$\int_0^\infty e^{-\rho t} U\big[(1+\zeta)c(\tau), x(\tau)\big] dt = \int_0^\infty e^{-\rho t} U\big[c(\hat{\tau}), x(\hat{\tau})\big] dt \tag{15}$$

For clarity purposes, it is convenient to disentangle the welfare gain (or loss) ζ into three major components as in Cassou and Lansing (2003): a long-run level effect (ζ_{level}), a long-run growth effect (ζ_{growth}), and a transition (short-run) effect (ζ_{trans}).[9] As shown in the appendix, the sum of these three effects yields the net welfare gain ζ_{net} implicitly given by (15).

Along the paper, a tax reform may be defined alternatively in two ways. The first of them assumes that only one of the distorting taxes available changes keeping government expenditures constant. This requires that any imbalance in the government budget constraint (in a present-value sense) is financed by lump-sum taxes. The alternative case implies changing two distorting taxes at a time so that the intertemporal government budget constraint is satisfied, while keeping $T(t)$ and $g(t)$ fixed. These two possibilities are considered in the computations below.

2.2   Calibration

The model is now calibrated for the Mexican economy. For clarity purposes, the distinction is made between those parameters borrowed from the literature and those specially fixed to match some observed variables

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[9] The long-run growth effect measures the welfare change due exclusively to a change in the growth rate γ whenever a new fiscal policy is adopted. Similarly, the long-run level effect captures the welfare change due to a change in the level of variables along the new balanced growth path. Finally, short-run changes in the variables of interest and their effect on welfare is accounted for the transition effect. Either a higher growth rate or a higher level of long-run consumption and leisure yields higher welfare, whereas a short-run fall in both consumption and leisure leads to lower welfare.

from the data. For convenience, both initial output and the initial stock of human capital are normalized to unity as in Lucas (1990).

The following parameter values are either taken from the literature or from the data:

(i) α = 0.45. The share of capital income in total output for Mexico is carefully estimated by Bernanke and Gürkaynak (2001) for the period 1980 – 1995.

(ii) η = 0.55. The elasticity of the learning function is slightly lower than the value implicit in the estimates reported in Rosen (1976);

(iii) σ = 1.5. The number given to the inverse of the intertemporal elasticity of substitution is a standard parameter value (cf. Kydland and Prescott (1982) and Prescott (1986));

(iv) μ = 0.272. This number corresponds to the annual average growth rate of the monetary base in Mexico for the period 1988 - 2002;

(v) τ_k = 0.085 and τ_n = 0.125. The values for the effective tax rates on physical capital and labor income in Mexico, respectively, are well within the range reported in the first part of this essay;

(vi) g/h = 0.132. Given the normalization in both initial output and human capital, this value represents the share of government expenditures (including public investment) in net national product NNP (ignoring imports and exports) for the period 1988 – 2002.

Parameters that are jointly calibrated to match some features of the data include the following:

(i) A = 0.653. This technology parameter value yields an output equal to 1 in the benchmark economy;

(ii) B = 0.051. The marginal productivity of schooling time is fixed so that the growth rate γ along the balanced growth path is 1.54 percent. This last number is consistent with the GDP per capita growth rate in Mexico for the period 1988 – 2000, according to data by Heston et al. (2002).[10]

(iii) ρ = 0.02. The value for the subjective discount rate yields a reasonable after-tax real rate of return on capital of 3.9 percent along the balanced growth path;

(iv) ϕ = 0.047. The parameter for the cash-in-advance constraint is fixed so that the seigniorage-net national product ratio is 0.90 percent,

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[10] The calibration for the benchmark economy implies an inflation rate of 25.7 along the balanced growth path, according to equation (9). Remarkably, this number roughly corresponds to the average inflation rate in Mexico for the period 1988 – 2002.

which is simply the average value observed in Mexico for the period 1988 – 2002;

(v) ψ = 0.45. The weight of consumption in total utility is chosen so that hours worked along the balanced growth path are about one third of household's endowed time.[11] This share is just consistent with the data as reported by the *Encuesta Nacional sobre Uso del Tiempo* 2002 by INEGI, where population between 20 and 59 years spend about one third of their discretionary time (i.e., time not spent sleeping or in personal maintenance) working for the market.[12]

Parameter values are conveniently summarized in table 1. As it may be observed, the ratio of lump-sum transfers over human capital along the balanced growth path implied by the calibration above and equation (10) is -0.016.[13] The corresponding consumption-output ratio for the benchmark economy is 0.705, a number roughly consistent with the share of consumption of non-durables and services in net national product (ignoring imports and exports) for the period 1988 – 2002 in Mexico.

Before presenting the results, it is important to remark that all the numeric exercises shown below exhibit a unique negative eigenvalue. This means that, at least for the parameter space under study, there is a (locally) unique, saddle path stable manifold. In addition, a unique steady state is always found for all the exercises considered. As mentioned above, this last result is not trivial given that both utility and human capital technology are a function of non-qualified leisure in this model.

Table 1
Parameter Values for the Benchmark Economy

Technology parameters
α = 0.45, *A* = 0.653, *B* = 0.051, η = 0.55
Preference parameters
ρ = 0.02, σ = 1.5, ψ = 0.45, ϕ = 0.047
Monetary and fiscal policy parameters
μ = 0.272, τ_k = 0.085, τ_n = 0.125, $(g/h)^*$ = 0.132, $(T/h)^*$ = -0.016

[11] Krusell and Rios-Rull (1999) also use this parameter value to calibrate the U.S. economy.
[12] Unfortunately the *Encuesta Nacional sobre Uso del Tiempo* started in the year 2002, so this is the only information available about the allocation of time at the national level in Mexico.
[13] Alternatively, this number may be interpreted as the primary deficit of the government in terms of output along the balanced growth path.

2.3 Results

The first series of tax reform exercises is presented in table 2. The first part of the table assumes that lump-sum taxes are available to restore any imbalance in the government's budget constraint whenever a distorting tax is changed. For convenience, the first row reports the results for the growth rate, welfare, and levels of some variables of interest along the balanced growth path under the benchmark economy. Naturally, the welfare estimates are zero in this case.

The first tax reform exercise simply decreases the growth rate of money from 27.2 to 1.54 percent so that the inflation rate is zero under the benchmark (see equation (9)). As a result, the growth rate γ slightly increases to 1.55 percent as reported by the second row of table 2. There is a negligible overall welfare gain of 0.05 percent, consisting of a 0.35 percent fall due to a long-run level effect, a 0.42 percent increase due to the long-run growth effect, and a 0.02 percent fall explained by a transitional (short-run) effect. Time devoting to schooling and leisure, as well as the consumption-output ratio, remain nearly unchanged.

Now an alternative tax reform exercise is considered. The third row shows the results assuming that the tax on capital income is entirely eliminated in the spirit of Chamley (1986). The increase in the growth rate is too small, even though the relative large fall in τ_k. This result may not be very surprising to the reader: in this model, the long-run growth rate of the economy is basically explained by the time devoted to education and working

Table 2
Tax reform simulations

	μ	τ_k	τ_n	Y	ζ_{level}	ζ_{growth}	ζ_{trans}	ζ_{net}	u^*	v^*	x^*	$(c/y)^*$
Benchmark	**0.272**	**0.085**	**0.125**	**1.54**	**0**	**0**	**0**	**0**	**0.315**	**0.114**	**0.571**	**0.705**
A. Lump sum taxation												
Decrease μ	0.015	0.085	0.125	1.55	-0.35	0.42	-0.02	0.05	0.317	0.115	0.568	0.704
Decrease τ_k	0.272	0	0.125	1.55	6.38	0.3	-5.98	0.7	0.316	0.115	0.569	0.699
Decrease τ_n	0.272	0.085	0	1.65	-4.42	4.7	-0.18	0.1	0.337	0.129	0.534	0.704
B. Distorting taxation												
Decrease μ	0.015	0.104	0.125	1.55	-1.89	0.37	1.4	-0.12	0.316	0.115	0.569	0.706
Decrease μ	0.015	0.085	0.141	1.54	0.18	-0.22	0.01	-0.03	0.314	0.113	0.573	0.705
Decrease τ_k	1.488	0	0.125	1.5	7.97	-1.68	-5.87	0.42	0.307	0.109	0.584	0.699
Decrease τ_k	0.272	0	0.195	1.48	8.74	-2.74	-5.8	0.2	0.302	0.106	0.592	0.7
Decrease τ_n	2.306	0.085	0	1.58	-1.32	1.54	-0.07	0.15	0.322	0.119	0.559	0.704
Decrease τ_n	0.272	0.237	0	1.65	-16.84	4.26	11.5	-1.08	0.335	0.128	0.537	0.712

Note: $(c/y)^*$ denotes the ratio of private consumption over net national product along the balanced growth path. Estimates for the growth rate λ and welfare ζ are given in percentage terms.

activities, which are not substantially affected by changes in capital income taxes. On the other hand, the increase in net welfare is higher than before (0.70 percent as compared to 0.05 percent). Such an increase is mostly due to a positive and large long-run level effect.

The next tax reform simulation eliminates the tax on labor income. The increase in the growth rate to 1.65 percent is the highest of all the three exercises: the elimination of labor income taxes leads households to devote more time to education and working activities, thus increasing the long-run growth rate. Nevertheless, the increase in net welfare is just ranked second: even though the growth effect increases welfare in 4.7 percent, this is easily compensated by a fall of 4.4 percent from the long-run level effect.

The second part of table 2 now eliminates lump-sum taxation from the analysis. Thus any tax reform in place involves simultaneous changes in two distorting taxes in order to balance the intertemporal budget constraint of the government. The first and second rows of part B assume a decrease in the growth rate of money to 1.54 percent with simultaneous increases in either capital or labor income taxes to 10.4 and 14.1 percent, respectively. The results are about the same as those under lump-sump taxation, with the exception of welfare. In the first case, both the level and the transition effects are magnified in absolute value for a resulting net welfare fall of 0.12 percentage points. When labor taxes are increased to compensate for the fall in seigniorage revenue, the fall in the growth effect dominates the long-run level effect for a net welfare loss of 0.03 percentage points.

The next two rows present simulations where the tax on capital income is eliminated and lost revenue is replaced either with higher seigniorage or labor income taxation. As shown, this exercise either requires a money growth rate of about 149 percent or a labor income tax of 19.5 percent. The results in both cases are qualitatively similar: there is a relatively small fall in the growth rate (in relation to its benchmark) explained by the fall in schooling and working time, and a small increase in net welfare, motivated mostly by the large increase from the level effect.

Finally, the last two rows perform a tax reform exercise involving zero taxes on labor income. As a result of the large inflation involved when revenue is raised through seigniorage, the growth rate decreases from the corresponding 1.65 percent value under lump sum taxation to 1.58 percent, although this rate is still above its benchmark value. The positive effect of growth on welfare results in a net increase in household's utility. As for capital income taxes, the growth rate is just the same if compared to the lump-sum taxation case, but now net welfare is negative explained by the large fall from the level effect.

From table 2, the result that *large* increases in the growth rate of money (and thus inflation) have a small effect on both long-run growth and welfare should be interpreted with caution. As argued elsewhere (Benabou (1991),

Wright (1991)), this type of models seems appropriate for moderate inflation rates only. For growth rates of money well above 148 percent like in the present case, there is a presumption that additional social costs not well captured in this type of models may be present (see, for example, Cooley and Hansen (1989)). On the other hand, the negligible effects of *high* inflation rates on long-run growth found along table 2 are inconsistent with empirical evidence (cf. Levine and Renelt (1992), Fischer (1991, 1993) and Barro (1995, 1997)). This theoretical inconsistency is pursued further in Jones and Manuelli (1995) and Chari et al. (1995). In particular, after calibrating a variety of endogenous growth models with money, Chari et al. (1995) find that an increase of at least 10 percentage points in the growth rate of money is unable to reproduce the negative effect of 0.2 to 0.7 percentage points on output growth typically found in the data. The intuition is that changes in output growth rates require changes in real rates of return to capital. However, changes in inflation rates in this type of models have trivial effects on real rates of return and thus on output growth rates (cf. Jones and Manuelli (1995)). In the present model, real rates of return depend on household's allocation of time which is not substantially affected by large increases in the growth rate of money.[14]

Once this observation is taken into account, the numeric simulations in table 2 imply that the policymaker might be faced with conflicting decisions at the time of implementing a tax reform. To see this more clearly, consider first the case of lump-sum taxation. In terms of growth rates, the most desirable policy among all the simulations performed would be to completely eliminate labor income taxes. Nevertheless, such a policy does not yield the highest welfare among all the tax reforms under study. If household's welfare is rather the most important criterion to evaluate the desirability of a tax reform, then capital income taxes should be eliminated: welfare gains under such a policy are about seven times larger than under the elimination of labor income taxes.[15]

The same conflicting decision emerges under distorting taxes. Once again the most desirable tax reform among all in terms of growth rates is the elimination of labor income taxes compensated now by higher taxes on capital income. However, such a policy yields the largest fall in welfare from all the simulations presented. If welfare is the relevant policy criterion instead and large increases in seigniorage are ignored according to the previous discussion, then capital income taxes should be eliminated and replaced with

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[14] This last result does not depend on the value for the degree of the liquidity constraint ϕ. For example, Chari et al. (1995) arrive to a similar conclusion under $\phi = 1$.

[15] If welfare effects are studied in more detail, eliminating capital income taxes is too costly in the short-run (given the corresponding substitution from consumption to physical capital), and the gains of such a reform are only perceived in the long run. For labor income taxes, the negative effect in short-run welfare is small, and the long run welfare gains from the growth effect are enough to compensate for the welfare loss derived from the level effect.

higher labor income taxes. However, the problem with such a choice is that it delivers the lowest growth rate among all.

So far, the previous simulations have kept fixed the share of government expenditures in total output. However, sometimes it is discussed that a fiscal reform in Mexico should allow for higher government expenditures in order to finance important social needs such as education, health and infrastructure, among others (OECD (2004), Foro Consultivo Científico y Tecnológico (2004), Webb (2001), Dalsgaard (2000)). If such a proposal is adopted, there are two issues of interest from a general equilibrium perspective. First, there is a concern on the effect of higher government spending itself on both the long-run growth rate and welfare of the economy. In addition, it remains the issue of which among all the tax instruments necessary to finance this extra expenditure is the least distorting of all.

Table 3 shows now the effect of higher government expenditure in terms of human capital on growth, welfare and relevant variables of the model. As before, the table is divided in two parts, depending on whether either lump-sum or distorting taxes are available to keep the intertemporal budget constraint of the government balanced. For convenience, the first row again reproduces the results under the benchmark economy.

The row just below the benchmark reports the effect of an increase in the $(g/h)^*$ ratio from 13.2 to 15 percent when lump-sum taxes are available. The long-run growth rate slightly increases from its benchmark value of 1.54 to 1.56 percent. The intuition of this result is simple: as the ratio of consumption over output decreases about 2 percentage points, the household must devote a lower fraction of her time to leisure and more to working and schooling activities. Thus the reallocation of time is responsible for the increase in the growth rate, not the increase in government expenditures *per se*.[16] Nevertheless, the fall in net welfare is substantial in this case (2.4 percent). If the $(g/h)^*$ ratio increases even further to 20 percent, the growth rate is now 1.63 (for a similar reason as before) but the net welfare loss increases about 3.8 times in absolute value with respect to the previous case for an astonishing net welfare loss of 9.2 percent.

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[16] This result is also found elsewhere in the literature (cf. Devereux and Love (1995), Mendoza et al. (1997), and Baier and Glomm (2001)). See the end of this section for a brief discussion on this issue.

Table 3

Simulations for changes in $(g/h)^*$

	$(g/h)^*$	μ	τ_k	τ_n	γ	ζ_{level}	ζ_{growth}	ζ_{trans}	ζ_{net}	u^*	v^*	x^*	$(c/y)^*$
Benchmark	**0.132**	**0.272**	**0.085**	**0.125**	**1.54**	**0**	**0**	**0**	**0**	**0.315**	**0.114**	**0.571**	**0.705**
					A. Lump sum taxation								
Increase $(g/h)^*$	0.15	0.272	0.085	0.125	1.56	-3.3	0.91	-0.04	-2.43	0.319	0.117	0.564	0.687
Increase $(g/h)^*$	0.2	0.272	0.085	0.125	1.63	-12.53	3.45	-0.14	-9.22	0.331	0.125	0.544	0.638
					B. Distorting taxation								
Adjusting μ	0.15	0.837	0.085	0.125	1.54	-2.56	0	0	-2.56	0.315	0.114	0.571	0.687
Adjusting τ_k	0.15	0.272	0.126	0.125	1.56	-6.62	0.82	2.98	-2.82	0.319	0.116	0.565	0.688
Adjusting τ_n	0.15	0.272	0.085	0.159	1.53	-2.17	-0.49	0.02	-2.64	0.313	0.112	0.575	0.687
Adjusting μ	0.2	2.574	0.085	0.125	1.54	-9.65	0	0	-9.65	0.315	0.114	0.571	0.637
Adjusting τ_k	0.2	0.272	0.244	0.125	1.63	-26.29	3.61	11.88	-10.8	0.332	0.126	0.542	0.634
Adjusting τ_n	0.2	0.272	0.085	0.256	1.49	-8.22	-2.05	0.1	-10.17	0.305	0.108	0.587	0.636

Note: $(c/y)^*$ denotes the ratio of private consumption over net national product along the balanced growth path. Estimates for the growth rate γ and welfare ζ are given in percentage terms

The second part of table 3 reports similar exercises under distorting taxation. The idea is that increases in relative government expenditure have to be financed with increases in a single distorting tax at a time. The first three rows show an increase in the $(g/h)^*$ ratio from its benchmark value to 15 percent, financed alternatively by higher taxes on money holdings, capital and labor income, respectively. The last three rows report a similar exercise when $(g/h)^*$ increases even further to 20 percent.

As it may be noticed, increases in relative government expenditure require large increases in the growth rate of money as high as to 257 percent when $(g/h)^* = 0.20$. Even though these large increases in μ, the long-run growth rate γ remains unchanged, a result consistent with the discussion above. On the other hand, the fall in welfare is only slightly larger if compared to its corresponding lump-sum taxation case. Once again, these results should be viewed with caution as the model may not account for additional welfare costs with inflation rates well above 50 percent.

If the analysis is rather restricted to capital and labor income taxes, the results are clear under the two alternative scenarios for the ratio $(g/h)^*$: the growth rate γ increases relative to its benchmark if capital income taxes are used, but it decreases if labor income taxes are in place instead. As before, an increase in the capital income tax does not have an additional effect on household's allocation of time. Thus the growth rate is the same as under lump-sum taxation. In contrast, the increase in labor income taxes makes the household both to work less and devote less time to schooling activities. As a result, the growth rate falls in relation to its benchmark value. On the other hand, net welfare naturally decreases even further (as compared to the lump-sum case) under any scenario, the fall being slightly larger when capital income taxes are used. Such a decrease is mostly explained by the large fall in welfare coming from the long-run level effect, as the government is consuming more resources along the new balanced growth path.[17]

There are two important observations from table 3. First, the policymaker once again might be faced with conflicting policies. Under lump-sum taxes, higher government expenditures increase the long run rate of the economy by the indirect effect on the household's allocation of time, but welfare decreases significantly as a result, the fall being larger the larger the growth rate. If distorting taxes are available instead, imposing higher taxes on capital income is the best policy in terms of long-run growth rates but it is the worst of all using a welfare criterion.

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[17] An interesting thing to notice from these exercises is the composition of the welfare effect for each case. Even though increases in both capital and labor income taxes bring about similar effects in net welfare regardless of the increase in $(g/h)^*$, the composition of this net effect is substantially different: increases in capital income taxes involve larger effects in both the short-run and long-run levels if compared to increases in labor income taxes. Thus a reform with higher capital income taxes under this situation would be too costly to implement in the short run.

Second, restricting the analysis to the distorting taxation case, the highest growth rate obtained for a 20 percent share of government expenditures is 1.63 percent. Remarkably, this growth rate is roughly similar to the one obtained under fixed government expenditures and zero labor income taxes compensated by higher capital income taxes, as shown by the last row of table 2. Nevertheless, the difference in the net welfare loss between these policies is too large (about 9 percentage points). In other words, if the policymaker is interested in increasing the growth rate of output, a fiscal reform involving higher government expenditures would simply be too costly to implement in terms of social welfare, given that an equally effective but less costly alternative is available.

Before closing this section, it is of interest to compare some of the results reported here with those found elsewhere in the literature, where models are typically calibrated for the U. S. economy. The first issue is related to the welfare cost of inflation. Using an exogenous growth framework, Cooley and Hansen (1991) find that moving towards a zero inflation rate brings about more costs than benefits if distorting taxes are involved to balance the intertemporal budget constraint of the government. As shown in part B of table 2, the endogenous growth model used here provides supporting evidence in the same direction as Cooley and Hansen (1991).[18]

The second issue concerns about the effect of distorting taxes on growth. In particular, all the simulations in table 2 show relatively small effects of income taxes on growth in general. This result is typically argued to be the most plausible case (cf. Stokey and Rebelo (1995), Mendoza et al. (1997)). The final topic is related to the effect of a higher ratio of government expenditures to output on long-run growth. Like the simulations presented in table 3, Devereux and Love (1995) and Mendoza et al. (1997) find a positive effect of a higher share of government expenditures on growth due to the household's reallocation of time in a human-capital style model of endogenous growth.[19] Similarly, Baier and Glomm (2001) find an inverted u-shape relationship between the government's share of output and growth in a model where government expenditures enter into utility and production functions. Thus, for relative small values of government expenses over output (as assumed here), an increase in such a ratio in that model also delivers a positive effect on growth.

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[18] Aiyagari (1990) also argues that moving to a zero inflation rate brings about more social costs than benefits.
[19] Devereux and Love (1995) perform simulation exercises ignoring the balance in the intertemporal budget constraint of the government. The results by Mendoza et al. (1997) assume that the increase in government's share of output is financed exclusively by lump-sum taxes.

3. *Concluding Remarks*

The goal of this paper has been two-fold. First, understand the effects of revenue-neutral tax reforms on growth and welfare for the Mexican economy, where the tax instruments available are lump-sum, seigniorage, and factor income taxes. Second, analyze the implications of a higher ratio of government expenditures to output on long-run growth and welfare. For that purpose, a neoclassical endogenous growth model has been presented, where a representative household with endogenous labor supply must use money in order to purchase consumption goods. As is well known, the advantage of this type of models is the special emphasis given to distorting taxation on the decision making of households and firms from a general equilibrium perspective.

After carefully calibrating the model for the Mexican economy, it is found numerically that any tax reform that keeps constant the share of government expenditures in total output has a relatively small effect on both growth and welfare. For example, for all the exercises considered, the growth rate may increase from 1.54 to at most 1.65 percent, whereas the maximum increase (decrease) in welfare is about 0.70 (-1.1) percentage points. In contrast, welfare (but not growth rates) is highly sensitive to changes in the government expenditure-output ratio. It is found that if this ratio increases from its benchmark value of 13.2 to 20 percent, the growth rate may increase up to 1.63 percent, with an astonishing net welfare loss of about 10.8 percent if capital income taxes are increased to balance the government's budget. A major conclusion from this analysis is that if the government is concerned about increasing the long-run rate of the economy, an appropriate tax reform that changes two distorting taxes and keeps government expenditures constant at the same time, should definitively be preferred to a policy involving increases in *wasteful* government expenditures given the huge negative effect on welfare from the latter alternative. In other words, a growth-enhancing policy based on higher wasteful government expenditures is simply too costly in terms of social welfare.

A second major conclusion is the small positive effect of a zero inflation policy on long-run growth. In particular, moving the historical inflation rate in Mexico down to zero increases the growth rate from 1.54 to just 1.55. The reason is that changes in the inflation rate do not affect significantly both the time devoted to work and schooling activities, which are the engines of long-run growth in the model. As already mentioned, this result is consistent with theoretical and empirical findings elsewhere. Thus the concern about the presumably negative effects of a lower monetary growth rate policy (as the one pursued during the last years in Mexico) on output growth seems unwarranted.

Finally, numeric simulations show that the policymaker might be faced with conflicting alternatives at the time of implementing a fiscal reform. In particular, it is found that a growth-enhancing reform does not necessarily increase net welfare, a result also found by Cassou and Lansing (2003) for a model with useful public expenditures. As explained in the text, the reason is that the positive effect of higher growth on welfare is only one component in total household's utility. It may be the case that either long-run level or transition effects (or both) due to the tax reform itself may have an opposite impact on total welfare. In the simulations presented above, there are some situations where the fiscal reform that yields the higher long-run growth rate simultaneously yields the lowest welfare among all the alternatives considered, and vice versa. The lesson here is that the policymaker should be aware of these trade-offs at the time of designing a fiscal reform, and that the choice of such a reform in practice might well end up depending on the policymaker's objective.

There are two important shortcomings in the present model. First, consumption taxes are completely ignored from the analysis. As found by Pecorino (1993, 1994), Coleman (2000) and Cassou and Lansing (2003), an increase in consumption taxes may usually be the preferable choice at the time of implementing a tax reform. Thus it would be interesting to see how the results above are affected under this additional tax instrument. The second observation relates to the modeling assumption about government expenditures. As presented, the paper assumes that government expenditures are simply thrown away: they neither provide utility nor affect the productivity of physical or human capital. In such a case, it might be interesting to extend the model in the spirit of Turnovsky (2000), Baier and Gloom (2001), and Cassou and Lansing (2003) to check how the results discussed above are affected.

Appendix

Following the method of Cassou and Lansing (2003), this appendix explains in detail how to disentangle the net welfare gain (or loss) ζ from equation (15) into three components: a long-run level effect, a long-run growth effect, and a transitional effect. First define baseline utility $U_{baseline}$ under the existing fiscal policy $\tau \equiv \tau(\tau_k, \tau_n, \mu, g, T)$ as:

$$U_{baseline} = \int_0^\infty \frac{e^{-\rho t}\left[c(\tau)^\psi x(\tau)^{1-\psi}\right]^{1-\sigma}}{1-\sigma}\, dt \tag{A1}$$

Based on the expression above, equation (15) may be rewritten as

$$U_{reform} = (1+\zeta)^{\psi(1-\sigma)} U_{baseline} \tag{A2}$$

where U_{reform} denotes household's utility under the new tax policy $\hat{\tau}$. The net welfare change ζ_{net} from a fiscal reform in percentage terms is thus given by $\zeta_{net} \equiv 100\zeta$, where ζ is given by expression (A2).

Now consider the case where the economy is initially along a balanced growth path. Define $\overline{U}$ as the utility level under such a path. By definition, consumption now grows at the constant rate γ whereas leisure remains constant. Taking these facts into account in equation (A1), the baseline utility level along the balanced growth path $\overline{U}_{baseline}$ is given by

$$\overline{U}_{baseline} = \left[\frac{1}{1-\sigma}\right]\left[\frac{1}{\rho - \psi(1-\sigma)\gamma}\right]\left((c^*)^\psi (x^*)^{1-\psi}\right)^{1-\sigma} \tag{A3}$$

where (c^*, x^*) are the levels of consumption and leisure along the balanced growth path. The second expression in brackets from the right-hand side of (A3) captures the effect of long-run growth γ on utility whereas the last term measures the corresponding effect from the levels of consumption and leisure. From the discussion above, the change in steady-state welfare ζ_{ss} may be defined as

$$\zeta_{ss} = 100\left[\left(\frac{\overline{U}_{reform}}{\overline{U}_{baseline}}\right)^{\frac{1}{\psi(1-\sigma)}} - 1\right] \tag{A4}$$

where $\overline{U}_{reform}$ is the utility level along the new balanced growth path once the tax reform is put into place. Now denote ζ_{level} and ζ_{growth} as the long-run level effect and the long-run growth effect on welfare, respectively, in the spirit of expression (A3). Therefore, it must be the case that

$$1 + \zeta_{level} + \zeta_{growth} = 1 + \zeta_{ss}/100$$

$$= \left(\frac{\overline{U}_{reform}}{\overline{U}_{baseline}} \right)^{\frac{1}{\psi(1-\sigma)}}$$

$$= (1 + W_a)(1 + W_b)$$

where $W_a = \left(\overline{U}_{reform} \right)^{\frac{1}{\psi(1-\sigma)}} - 1$ and $W_b = \left(\overline{U}_{baseline} \right)^{\frac{-1}{\psi(1-\sigma)}} - 1$. As discussed by Cassou and Lansing (2003), a solution for ζ_{level} and ζ_{growth} above may be given by

$$\zeta_{level} = W_a + W_a W_b \left(\frac{|W_a|}{|W_a| + |W_b|} \right)$$

and

$$\zeta_{growth} = W_b + W_a W_b \left(\frac{|W_b|}{|W_a| + |W_b|} \right)$$

Finally, given ζ_{net} (obtained from the numerical simulation) and ζ_{ss} (computed above), the transition effect ζ_{trans} is simply defined as the residual $\zeta_{trans} = \zeta_{net} - \zeta_{ss}$.

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