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MACROECONOMIC IMPLICATIONS OF ALTERNATIVE TAX REGIMES: THE CASE OF GREECE

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ABSTRACT

This paper uses a Dynamic General Equilibrium model that incorporates a detailed fiscal policy structure to examine how changes in the tax mix influence economic activity and welfare in the Greek economy. The results suggest that tax reforms that reduce the labour and capital income tax rates and increase the consumption tax rate lead to higher levels of output, consumption and private investment. If the goal of tax policy is to promote economic growth by changing the tax mix, then it should reduce the capital income tax rate and increase the consumption tax rate. In contrast, a lifetime welfare promoting policy would be to cut the labour income tax rate and increase the consumption tax rate.

Keywords: Fiscal Policy; Transitional dynamics; Economic growth; Welfare

JEL Classification: E62, 052

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1. Introduction

This paper examines how changes in the tax mix (defined as distribution of revenue by type of tax) influence economic activity and welfare in the Greek economy. To do so, this paper conducts tax policy analysis using a Dynamic General Equilibrium model which incorporates a detailed fiscal (tax-spending) policy structure. Following Mendoza and Tezar (1998) and Cooley and Hansen (1992), the paper examines tax policy experiments in which a permanent reduction in one distortionary tax rate is met by a permanent change in another distortionary tax rate so that fiscal policy is inter-temporally solvent. I explore the effects from re-allocating the tax burden upon the dynamic paths and the steady state levels of key macroeconomic variables, as well as upon output growth and general equilibrium welfare.

The tax mix has gained a lot of policy attention among European Countries. Recently, there are recommendations to the European Countries to re-allocate their tax burden by decreasing the labour income tax rate and increasing the consumption tax rate, on the grounds that lower labour income tax rates will boost employment and output growth (see European Commission (2008a) and Daveri and Tabellini (2000)). On the other hand, the increased capital mobility in the enlarged European Union may lead to lower tax rates on capital income (see e.g. European Commission (2008b) and Mendoza and Tezar (2002)). In that case, labour income or consumption tax rates need to increase to make up for the loss in capital tax revenue.

Based on calibrated Dynamic General Equilibrium models for the U.S., Cassou and Lansing (2004), Mendoza and Tezar (1998) and Cooley and Hansen (1992) show that changes in the tax mix can produce sizable effects on the dynamic paths and the steady state levels of key macroeconomic variables.[1] Stokey and Rebelo (1995) and Lucas (1990) find that the effects on long-run growth of reforming the U.S. tax system are likely to be small.[2] From a normative point of view, Mendoza et

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[1] See Papageorgiou (2009a), Jones (2002), Jonnson and Klein (1996) and Braun (1994) for the general equilibrium effects of shocks on labour and capital income tax rates. See Gali et al. (2007), Burnside et al. (2004), Ardagna (2001), Ohanian (1997), Ludvigson (1996) for General Equilibrium Models that study the effects of changes in governments purchases.

[2] Empirical evidence suggests that distortionary tax rates have a negative impact on employment and investment (see e.g. Daveri and Tabellini (2000) and Mendoza et al. (1996, 1997)). However, the effects on long-run growth are found to be mixed. Mendoza et al. (1996, 1997) argue that tax rates on labour and capital income affect mostly transitional rather long run growth. On the other hand, Kneller et al. (1999, 2001) show that income taxes have a significant impact on long-run growth. These conflicting predictions result from the alternative specification of the estimated equation, the

al. (1997), Cooley and Hansen (1992) and Lucas (1990) show that the welfare effects of reforming the U.S. tax structure may be substantial.

As regards European economies, it is not until relatively recently that Dynamic General Equilibrium models have been applied to the study of the macroeconomic effects of changes in the tax mix. Angelopoulos et al. (2008) examine the effects of alternative tax structures on long-run growth and welfare for the UK; Ohanian et al. (2008) and Prescott (2004) examine the impact of labour income tax rates on employment for major OECD countries and Daveri and Maffezzoli (2000) examine the effects of altering the tax structure on unemployment for selected European countries.[3]

This paper is a further attempt to remedy this omission by employing a Dynamic General Equilibrium model for Greece, capable of analyzing the implications of changes in the tax mix for the aggregate Greek economy. To my knowledge, this is the first study that analyzes the implications of changes in the tax policy mix for the Greek economy within a Dynamic General Equilibrium framework. The interest in conducting tax policy analysis for Greece stems from the fact that tax rates in Greece have been increased since the early 80s and there was a sharp increase in the tax burden after the mid 90s reflecting the efforts for lower deficits (see e.g. Papageorgiou (2009b), European Commission (2008a, 2008b) and Martinez-Mongay (2000)). Also, note that such policy reforms are particularly important in the face of, sooner or later, unavoidable policy changes necessitated by chronic imbalances like the accumulation of high levels of public debt.

The model captures several observed features present in actual tax structures such as tax rates on labour income, capital income and consumption, as well as the taxation of dividends. The government uses tax revenues plus the issue of new government bonds to finance three activities: public consumption that provides utility to households, public investment that augments public capital and lump-sum transfers that augment household income.

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formulation of the government budget constraint and the inability of the empirical methodology to separate between transition and long-run effects of tax policy.

[3] Dynamic general equilibrium models that examine the welfare effects of alternative tax structures for European countries were also analyzed by Jonsson and Klein (2003) for Sweden and Heer and Trede (2003) for Germany.

The approach of this paper can be summarized as follows. First, the model is calibrated on data for the Greek economy over 1960:1-2005:4. Then, departing from the benchmark economy, the paper examines tax reforms in which a permanent reduction in one of the three distortionary tax rates (capital, labour, consumption) is met by a permanent change in another distortionary tax rate so that fiscal policy is inter-temporally solvent. That is, the present value of tax revenues equals the present value of total government spending plus initial payments on debt.[4] Attention is then directed to examining the effects from changes in the tax mix on the dynamic paths and the long- run equilibrium of some key macroeconomic variables such as output, private consumption, private investment, hours worked and primary deficit-to-GDP. The effects on output growth paths arising from transitional dynamics are also considered. Moreover, the paper examines the quantitative implications from changes in the tax mix for general equilibrium welfare. The latter is defined to be the discounted inter-temporal utility.

The results suggest that there are considerable differences in the observed dynamic paths, as well as the steady state levels of key macroeconomic variables across the different tax regimes. Tax reforms in which a reduction in the capital income tax rate is met by an increase in the consumption tax rate, increase output and private investment both in the short and long run (new steady state). For instance, a one percentage point decrease in the capital income tax rate compensated by an increase in the consumption tax rate increases long-run output, consumption and investment by 0.78%, 0.54% and 2% respectively. When the cut in the capital income tax rate is met by an increase in the labour income tax rate, the increase in long-run output, consumption and investment is lower than the case in which the cut in the capital income tax rate is met by an increase in the consumption tax rate. In both cases, the primary deficit-to-GDP ratio increases in the short run, while it decreases in the long run.

A permanent reduction in the labour income tax rate that is met by a permanent increase in the consumption tax rate increases output, consumption, investment and hours worked both in the short and long run. The opposite results are

[4] Compared to Mendoza and Tezar (1998) and Cooley and Hansen (1992), this paper focuses on changes in tax rates that are within the historical experience of the Greek economy. By contrast, they examine tax reforms that replace one distortionary tax with another.

observed when the capital tax rate increases in order to meet the loss in labour tax revenue. Cuts in the consumption tax rate that are compensated by increases in labour or capital income tax rates have a negative impact on output and private investment both in the short and long run.

Concerning the behavior of output growth during the transition, the results suggest that if the goal of tax policy is to promote growth by replacing one distortionary tax rate with another, then it should reduce the tax rate on capital income and increase the tax rate on consumption. The effects on growth from changes in the tax mix along the transition path are found to be quantitatively small and parallel to those obtained in previous studies. For instance, a one percentage point reduction in the capital income tax rate that is met by an increase in the consumption tax rate raises average annual output growth by about 0.03% over the first five years of transition (see e.g. Stokey and Rebelo (1995)).

The results also suggest that if the goal of tax policy is to promote long-run welfare, then it should decrease the capital income tax rate and increase the consumption tax rate. On the other hand, when transition dynamics are taken into account, tax reforms that reduce the labour income tax rate and increase the consumption tax rate are the most desirable of the tax reforms considered since they lead to the highest lifetime welfare gain. For instance, the welfare gain of a one percentage point reduction in the labour income tax rate accommodated by an increase in the consumption tax rate is about 0.30% of extra consumption in each time period.

The rest of the paper is as follows. Section 2 presents the theoretical model. Section 3 discusses calibration and the model's long-run solution. Section 4 contains the main results and section 5 concludes.

2. The theoretical model

The model economy consists of a large number of identical households, a large number of firms, and a government. Households own physical capital, make investment decisions and rent labour and capital services to firms in perfectly competitive markets. As owners of the firms, households receive profits in the form of dividends. Firms behave competitively and produce a homogeneous product by using private capital, labour and public capital. The government in this economy levies taxes on labour and capital income and on consumption. It then uses tax revenues and bonds to finance three activities: public consumption that provides utility to households, public investment that augments public capital, and lump-sum transfers to households.

2.1. Households

Let N_t represent the number of identical households indexed by the superscript h, at the beginning of period t. Household population grows according to a deterministic law of motion:

$$N_{t+1} = \gamma_n N_t,\ \gamma_n \geq 1 \text{ and } N_0 > 0 \text{ is given} \tag{1}$$

Let $u\left(C_t^h, L_t^h\right)$ denote the representative household's temporal (per period) utility function in period t, where C_t^h denotes total consumption services enjoyed by the household which is a weighted average of private and public consumption services:

$$C_t^h = C_t^{h^p} + \vartheta \bar{G}_t^c \tag{2}$$

where $C_t^{h^p}$ is private consumption in period t, L_t^h is leisure in period t and $\bar{G}_t^c$ is average (per household) public consumption goods and services provided by the government in period t.[5]

The preferences of the representative household are characterized by the lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^{*t} u\left(C_t^h, L_t^h\right) \tag{3}$$

where E_0 denotes expectations conditional on the informational set of the household at the beginning of period zero and $\beta^* \in (0,1)$ is the discount factor. Notice that

[5] Thus, $\bar{G}_t^c = G_t^c / N_t$, where G_t^c is total public consumption services.

public consumption goods and services influence private utility through the parameter $\vartheta \in [-1,1]$.[6]

The temporal utility function is of the form:

$$u\left(C_t^h, L_t^h\right) = \frac{\left[\left(C_t^h\right)^{\gamma}\left(L_t^h\right)^{1-\gamma}\right]^{1-\sigma} - 1}{1-\sigma} \tag{4}$$

where $\gamma \in (0,1)$ is a preference parameter indicating the relative preference of consumption over leisure in the same period and $\sigma \geq 0$ is the coefficient of relative risk aversion.

The household is endowed with one unit of time in each period and divides it between work effort H_t^h and leisure L_t^h. Thus, the time constraint that the representative household faces in each period is:

$$L_t^h + H_t^h = 1 \tag{5}$$

The household saves in the form of physical capital I_t^h and in the form of one period real government bonds B_{t+1}^h. It receives labour income, $w_t Z_t H_t^h$, capital income $r_t^k K_t^h$, and interest income from government bonds, $r_t^b B_t^h$, where w_t is the wage rate per efficient unit of labour hours, $Z_t H_t^h$, and r_t^k, r_t^b are the real returns to private capital K_t^h and government bonds B_t^h, respectively. Z_t is labour augmenting technology which evolves according to the deterministic law of motion $Z_{t+1} = \gamma_z Z_t$, where $\gamma_z \geq 1$ and $Z_0 > 0$ is given. Two additional sources of income are the firm's profits that are distributed in the form of dividends, Π_t^h, and average (per household) lump-sum government transfers, $\overline{G}_t^{tr}$.[7] The household also pay taxes on consumption

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[6] If $\vartheta > 0$, the marginal utility of consumption decreases with an increase in $\overline{G}_t^c$. The opposite is true when $\vartheta < 0$. More specifically, if $\vartheta > 0$ private and public consumption are substitutes (e.g. private security and state police). On the other hand, if $\vartheta < 0$ private and public consumption are complements (e.g. low quality public education requires additional time and money for private courses). If $\vartheta = 1$ public and private consumption are perfect substitutes. Finally, if $\vartheta = 0$, government consumption does not affect household preferences. See also Kollintzas and Vassilatos (2000), Finn (1998) and Christiano and Eichenbaum (1992) for similar formulations.

[7] Thus, $\overline{G}_t^{tr} = G_t^{tr} / N_t$, where G_t^{tr} is total lump-sum transfers.

and on income from labour and capital earnings. Thus, the representative household's budget constraint in each period is:

$$\left(1+\tau_t^c\right)C_t^{h^p}+I_t^h+B_{t+1}^h= \\ \left(1-\tau_t^l\right)w_t Z_t H_t^h+\left(1-\tau_t^k\right)\left(r_t^k K_t^h+\Pi_t^h\right)+\left(1+r_t^b\right)B_t^h+\bar{G}_t^{tr} \tag{6}$$

K_0^h, B_0^h given

where $0 \le \tau_t^c < 1$ is the proportional tax rate on consumption, $0 \le \tau_t^l < 1$ is the proportional tax rate on labour income and $0 \le \tau_t^k < 1$ is the proportional tax rate on income from capital earnings and dividends. Note that dividends and capital income are taxed at the same rate τ_t^k.

All households view $\tau_t^l, \tau_t^k, \tau_t^c, \bar{G}_t^c, \bar{G}_t^{tr}, \Pi_t^h, w_t$, r_t^k and r_t^b as determined outside their control when making their decisions.

The law of motion for private capital stock is:

$$K_{t+1}^h=\left(1-\delta^p\right)K_t^h+I_t^h-\frac{\xi}{2}\left(\frac{K_{t+1}^h}{K_t^h}-\gamma_n\gamma_z\right)^2 K_t^h \tag{7}$$

where $\delta^p \in (0,1)$ is the depreciation rate of private capital stock and $\xi \ge 0$ is a parameter that captures internal adjustment costs on investment.[8] The above specification implies that adjustment costs are absent in the steady state.

Taking prices $\left\{r_t^k, r_t^b, w_t, \Pi_t^h\right\}_{t=0}^{\infty}$ and fiscal policy $\left\{\bar{G}_t^c, \bar{G}_t^{tr}, \tau_t^l, \tau_t^k, \tau_t^c\right\}_{t=0}^{\infty}$ as given, the representative household chooses a sequence $\left\{C_t^{h^p}, L_t^h, H_t^h, I_t^h, K_{t+1}^h, B_{t+1}^h\right\}_{t=0}^{\infty}$ in order to maximize (3)-(4) subject to the constraints (5)-(7), the initial conditions for K_0^h, B_0^h plus the non-negatively constraints for $C_t^{h^p}, L_t^h, H_t^h, K_{t+1}^h, B_{t+1}^h$. The first-order conditions for an interior solution include the constraints and the following conditions:

$$\frac{u_{L_t^h}}{u_{C_t^{h^p}}}=\frac{\left(1-\tau_t^l\right)}{\left(1+\tau_t^c\right)}w_t Z_t \tag{8a}$$

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[8] Lapatinas (2009) finds that adjustment costs are important in determining investment dynamics in Greece.

$$\frac{u_{C_t^{h^p}}}{\left(1+\tau_t^c\right)}\left[1+\xi\left(\frac{K_{t+1}^h}{K_t^h}-\gamma_n\gamma_z\right)\right]=$$
$$=\beta^* E_t\left[\frac{u_{C_{t+1}^{h^p}}}{\left(1+\tau_{t+1}^c\right)}\left(\left(1-\tau_{t+1}^k\right)r_{t+1}^k+\left(1-\delta^p\right)+\xi\left(\frac{K_{t+2}^h}{K_{t+1}^h}-\gamma_n\gamma_z\right)\frac{K_{t+2}^h}{K_{t+1}^h}-\frac{\xi}{2}\left(\frac{K_{t+2}^h}{K_{t+1}^h}-\gamma_n\gamma_z\right)^2\right)\right] \tag{8b}$$

$$\frac{u_{C_t^{h^p}}}{\left(1+\tau_t^c\right)}=\beta^* E_t\left[\frac{u_{C_{t+1}^{h^p}}}{\left(1+\tau_{t+1}^c\right)}\left(1+r_{t+1}^b\right)\right] \tag{8c}$$

$$\lim_{t\to\infty}\beta^{*t}E_0 u_{C_t^{h^p}}K_{t+1}^h=0 \tag{8d}$$

$$\lim_{t\to\infty}\beta^{*t}E_0 u_{C_t^{h^p}}B_{t+1}^h=0 \tag{8e}$$

Equation (8a) is the intratemporal condition for the hours worked and states that the marginal rate of substitution between leisure and consumption in the same period should equal to the after-tax wage adjusted by the consumption tax rate. Conditions (8b) and (8c) are the Euler equations for K_{t+1}^h and B_{t+1}^h, respectively. They have the standard interpretation that if the household chooses consumption optimally, it exactly equates the cost (in utility terms) from saving one more unit this period with the benefit (in utility terms) of consuming the invested product of the unit saved next period. Finally, conditions (8d) and (8e) are the transversality conditions which state that optimizing households will not hold any valuable assets at the end of the time horizon.

2.2. Firms

There is a large number of identical firms indexed by the superscript f.[9] The representative firm produces a homogeneous product, Y_t^f, by using private capital, K_t^f, private labour, H_t^f, and average (per firm) public capital, $\bar{K}_t^g$.[10] The representative firm has access to the following production function:

$$Y_t^f=\left(K_t^f\right)^{a_1}\left(Z_t H_t^f\right)^{a_2}\left(\bar{K}_t^g\right)^{a_3} \tag{9}$$

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[9] For simplicity it is assumed that in each period the number of firms equals the number of households.

[10] Thus, $\bar{K}_t^g=K_t^g/N_t$, where K_t^g is aggregate public capital stock.

where $a_i \in (0,1)$, $i = 1,2,3$ is the output elasticity of private capital, of labour and public capital, respectively.[11] The production function exhibits constant returns to all three inputs, that is, $a_1 + a_2 + a_3 = 1$. This implies that the firm realizes an economic profit equal to the difference between the value of output and the payments made to the private factors.

The firm chooses K_t^f and H_t^f in order to maximize period-by period profits by taking average public capital, $\bar{K}_t^g$, market prices and policy variables as given. Thus, the problem of the representative firm may be defined as:

$$\max_{K_t^f, H_t^f} \Pi_t^f = Y_t^f - r_t^k K_t^f - w_t Z_t H_t^f \tag{10}$$

subject to

$$Y_t^f \leq \left(K_t^f\right)^{a_1} \left(Z_t H_t^f\right)^{a_2} \left(\bar{K}_t^g\right)^{a_3}, \quad a_1 + a_2 + a_3 = 1 \tag{11}$$

$$K_t^f, H_t^f \geq 0 \tag{12}$$

The first-order conditions are:

$$r_t^k = a_1 \frac{Y_t^f}{K_t^f} \tag{13}$$

$$w_t = a_2 \frac{Y_t^f}{Z_t H_t^f} \tag{14}$$

and the implied economic profits are $\Pi_t^f = (1 - a_1 - a_2) Y_t^f > 0$. Conditions (13) and (14) have the standard interpretation that the real rental rate of capital and the real wage rate equal the marginal product of capital and labour respectively. Note that profits are not taxed at the firm's level. Thus, profits are taxed only once as dividends at the household level which is consistent with the Greek tax code that avoids double taxation of dividends.[12]

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[11] This production function captures the notion that the quality of public capital influence private productivity. Thus, public capital generates positive externalities to individual firms. See also Lansing (1998) for a similar formulation.

[12] See e.g. European Commission (2008a).

2.3. Government budget constraint

As already noted, the government levies taxes on consumption and on income from labour and capital earnings. Total tax revenues plus the issue of new one-period government bonds, B_{t+1}, are used to finance total government consumption G_t^c that provides utility to households, total government investment G_t^i that augments public capital and provides externalities to firms and total lump-sum government transfers G_t^{tr}. Moreover, government pays interest payments on past debt, B_t. Thus, the budget constraint of the government in aggregate terms at time t is:

$$\begin{aligned} B_{t+1} + \tau_t^c \sum_{h=1}^{N_t} C_t^{h^p} + \tau_t^l w_t Z_t \sum_{h=1}^{N_t} H_t^h + \tau_t^k \sum_{h=1}^{N_t} \left(r_t^k K_t^h + \Pi_t^h \right) = \\ = G_t^c + G_t^{tr} + G_t^i + \left(1 + r_t^b\right) B_t \end{aligned} \tag{15}$$

The law of motion for aggregate public capital which is enhanced by government's investment is given by:

$$K_{t+1}^g = \left(1 - \delta^g\right) K_t^g + G_t^i, \qquad K_0^g > 0 \text{ given} \tag{16}$$

where $\delta^g \in (0,1)$ is the depreciation rate of public capital stock. The government also faces a No-Ponzi constraint:

$$\lim_{T \to \infty} \left[\prod_{j=1}^{T} \frac{1}{\left(1 + r_j^b\right)} \right] B_{T+1} = 0 \tag{17}$$

which jointly with (15) implies that the present value of tax revenues equals the present value of government spending plus payments on initial debt.

2.4. The solution of the model

2.4.1. Competitive equilibrium

A competitive equilibrium is a sequence (of random variables),

$\left\{ C_t^{h^p}, L_t^h, H_t^h, I_t^h, K_{t+1}^h, B_{t+1}^h, \Pi_t^h; Y_t^f, K_t^f, H_t^f, \bar{K}_t^g, \Pi_t^f; w_t, r_t^b, r_t^k; \tau_t^l, \tau_t^k, \tau_t^c, \bar{G}_t^c, \bar{G}_t^{tr}, \bar{G}_t^i \right\}_{t=0}^{\infty}$ such that:

i) given the sequence of population and labour augmenting technological process $\left\{ N_t, Z_t \right\}_{t=0}^{\infty}$, the sequence of prices, profits and government fiscal policy,

$\left\{w_t, r_t^b, r_t^k; \Pi_t^h, \Pi_t^f; \tau_t^l, \tau_t^k, \tau_t^c, \bar{G}_t^c, \bar{G}_t^{tr}, \bar{G}_t^i\right\}_{t=0}^{\infty}$, and the initials conditions for the state variables, the allocation $\left\{C_t^{h^p}, L_t^h, H_t^h, I_t^h, K_{t+1}^h, B_{t+1}^h; Y_t^f, K_t^f, H_t^f, \bar{K}_t^g\right\}_{t=0}^{\infty}$ solves the problem of the representative household and the representative firm

ii) given the sequence $\left\{C_t^{h^p}, L_t^h, H_t^h, I_t^h, K_{t+1}^h, B_{t+1}^h; Y_t^f, K_t^f, H_t^f, \bar{K}_t^g\right\}_{t=0}^{\infty}$, the sequence $\left\{w_t, r_t^k, r_t^b; \Pi_t^h, \Pi_t^f; \tau_t^l, \tau_t^k, \tau_t^c, \bar{G}_t^c, \bar{G}_t^{tr}, \bar{G}_t^i\right\}_{t=0}^{\infty}$ clears the capital, labour, dividend and the bond markets, i.e. $\sum_{h=1}^{N_t} K_t^h = \sum_{f=1}^{N_t} K_t^f$, $\sum_{h=1}^{N_t} H_t^h = \sum_{f=1}^{N_t} H_t^f$, $\sum_{h=1}^{N_t} \Pi_t^h = \sum_{f=1}^{N_t} \Pi_t^f$ and $B_t = \sum_{h=1}^{N_t} B_t^h$, respectively

iii) given the sequence $\left\{C_t^{h^p}, L_t^h, H_t^h, I_t^h, K_{t+1}^h, B_{t+1}^h, \Pi_t^h; Y_t^f, K_t^f, H_t^f, \bar{K}_t^g, \Pi_t^f\right\}_{t=0}^{\infty}$, the sequence $\left\{\tau_t^l, \tau_t^k, \tau_t^c, \bar{G}_t^c, \bar{G}_t^{tr}, \bar{G}_t^i,\right\}_{t=0}^{\infty}$ satisfies the government budget constraint.

2.4.2. Stationary competitive equilibrium

In the long run, all aggregate variables (except total hours of work, H_t) grow at the same constant rate $\gamma_n \gamma_z$ (balance growth path), where γ_n is the growth rate of population and γ_z is the growth rate of the deterministic labour-augmenting technology process. All variables are transformed into per-effective units to eliminate growth and to make them stationary. Thus, for any economy-wide variable $X_t \equiv \left(Y_t, C_t, I_t, K_t, K_t^g, B_t, G_t^c, G_t^{tr}, G_t^i\right)$ define: [13]

$x_t \equiv \frac{X_t}{N_t Z_t} \equiv \left(\frac{Y_t}{N_t Z_t}, \frac{C_t}{N_t Z_t}, \frac{I_t}{N_t Z_t}, \frac{K_t}{N_t Z_t}, \frac{K_t^g}{N_t Z_t}, \frac{B_t}{N_t Z_t}, \frac{G_t^c}{N_t Z_t}, \frac{G_t^{tr}}{N_t Z_t}, \frac{G_t^i}{N_t Z_t}\right)$. Per capita hours worked are $h_t = \frac{H_t}{N_t}$ since in the long run hours grow only at the population growth rate, γ_n. The stationary competitive equilibrium is implicitly determined by the following equations:

$$\frac{\left(c_t^p + \vartheta g_t^c\right)}{y_t} = a_2 \frac{\left(1-\tau_t^l\right)}{\left(1+\tau_t^c\right)} \frac{\gamma}{\left(1-\gamma\right)} \frac{1-h_t}{h_t} \qquad (18a)$$

[13] Capital letters denote aggregate variables.

$$\frac{\left[\left(c_t^p+\vartheta g_t^c\right)^{\gamma}\left(1-h_t\right)^{(1-\gamma)}\right]^{1-\sigma}}{\left(1+\tau_t^c\right)\left(c_t^p+\vartheta g_t^c\right)}\left[\frac{\partial i_t}{\partial k_{t+1}}\right]= \\ =\beta E_t\left[\frac{\left[\left(c_{t+1}^p+\vartheta g_{t+1}^c\right)^{\gamma}\left(1-h_{t+1}\right)^{(1-\gamma)}\right]^{1-\sigma}}{\left(1+\tau_{t+1}^c\right)\left(c_{t+1}^p+\vartheta g_{t+1}^c\right)}\left(\left(1-\tau_{t+1}^k\right)a_1\frac{y_{t+1}}{k_{t+1}}+\frac{\partial i_{t+1}}{\partial k_{t+1}}\right)\right] \tag{18b}$$

$$\frac{\left[\left(c_t^p+\vartheta g_t^c\right)^{\gamma}\left(1-h_t\right)^{(1-\gamma)}\right]^{1-\sigma}}{\left(1+\tau_t^c\right)\left(c_t^p+\vartheta g_t^c\right)}=\beta E_t\left[\frac{\left[\left(c_{t+1}^p+\vartheta g_{t+1}^c\right)^{\gamma}\left(1-h_{t+1}\right)^{(1-\gamma)}\right]^{1-\sigma}}{\left(1+\tau_{t+1}^c\right)\left(c_{t+1}^p+\vartheta g_{t+1}^c\right)}\left(1+r_{t+1}^b\right)\right] \tag{18c}$$

$$\gamma_n\gamma_z k_{t+1}=\left(1-\delta^p\right)k_t+i_i-\frac{\xi}{2}\left(\frac{\gamma_n\gamma_z k_{t+1}}{k_t}-\gamma_n\gamma_z\right)^2 k_t \tag{18d}$$

$$\gamma_n\gamma_z k_{t+1}^g=\left(1-\delta^g\right)k_t^g+g_t^i \tag{18e}$$

$$y_t=\left(k_t\right)^{a_1}\left(h_t\right)^{a_2}\left(k_t^g\right)^{a_3} \tag{18f}$$

$$y_t=c_t^p+i_t+g_t^c+g_t^i \tag{18g}$$

$$\gamma_n\gamma_z b_{t+1}-\left(1+r_t^b\right)b_t+\tau_t^c c_t^p+\tau_t^l a_2 y_t+\tau_t^k\left(a_1 y_t+a_3 y_t\right)= \\ =g_t^c+g_t^{tr}+g_t^i \tag{18h}$$

where

$$\beta=\beta^*\gamma_z^{\gamma(1-\sigma)-1}$$

$$\frac{\partial i_t}{\partial k_{t+1}}=1+\xi\left(\frac{\gamma_n\gamma_z k_{t+1}}{k_t}-\gamma_n\gamma_z\right)$$

$$\frac{\partial i_{t+1}}{\partial k_{t+1}}=\left(1-\delta^p\right)+\xi\left(\frac{\gamma_n\gamma_z k_{t+2}}{k_{t+1}}-\gamma_n\gamma_z\right)\frac{\gamma_n\gamma_z k_{t+2}}{k_{t+1}}-\frac{\xi}{2}\left(\frac{\gamma_n\gamma_z k_{t+2}}{k_{t+1}}-\gamma_n\gamma_z\right)^2$$

$w_t=a_2\dfrac{y_t}{h_t}$ and $r_t^k=a_1\dfrac{y_t}{k_t}$

It can be easily verified that $\left\{y_t, c_t^p, i_t, h_t, k_{t+1}, k_{t+1}^g, r_t^b, b_{t+1}\right\}$ completely characterize the competitive equilibrium. Thus, the stationary competitive equilibrium is explicitly defined by the above eight non-linear difference equations in $\left\{y_t, c_t^p, i_t, h_t, k_{t+1}, k_{t+1}^g, r_t^b, b_{t+1}\right\}$ for given paths of the six policy instruments $\left\{\tau_t^l, \tau_t^k, \tau_t^c, g_t^c, g_t^{tr}, g_t^i\right\}_{t=0}^{\infty}$.

2.4.3. Steady-state

A steady state is defined as a situation where all stationary variables remain constant. Thus, $x_{t+1} = x_t = x_{t-1} \equiv x$ for all t, where x is the long-run value of the variable x_t. The following equations summarize the steady state of the economy:

$$\frac{k}{y} = \frac{a_1\left(1-\tau_0^k\right)}{\frac{1}{\beta} - \left(1-\delta^p\right)} \tag{19a}$$

$$\frac{i}{y} = \left[\gamma_n \gamma_z - \left(1-\delta^p\right)\right] \frac{a_1\left(1-\tau_0^k\right)}{\frac{1}{\beta} - \left(1-\delta^p\right)} \tag{19b}$$

$$r^b = \frac{1-\beta}{\beta} \tag{19c}$$

$$\frac{c^p}{y} = 1 - \left[\gamma_n \gamma_z - \left(1-\delta^p\right)\right] \frac{a_1\left(1-\tau_0^k\right)}{\frac{1}{\beta} - \left(1-\delta^p\right)} - \frac{g_0^c}{y} - \frac{g_0^i}{y} \tag{19d}$$

$$h = \frac{a_2\left(\frac{\gamma}{1-\gamma}\right)\left(\frac{1-\tau_0^l}{1+\tau_0^c}\right)}{\frac{c^p + \vartheta g_0^c}{y} + a_2\left(\frac{\gamma}{1-\gamma}\right)\left(\frac{1-\tau_0^l}{1+\tau_0^c}\right)} \tag{19e}$$

$$\frac{k^g}{y} = \frac{(g_0^i / y)}{\gamma_n \gamma_z - \left(1-\delta^g\right)} \tag{19f}$$

$$y = \left(\left(\frac{a_1\left(1-\tau_0^k\right)}{\frac{1}{\beta} - \left(1-\delta^p\right)}\right)^{a_1} \left(\frac{a_2\left(\frac{\gamma}{1-\gamma}\right)\left(\frac{1-\tau_0^l}{1+\tau_0^c}\right)}{\frac{c^p + \vartheta g_0^c}{y} + a_2\left(\frac{\gamma}{1-\gamma}\right)\left(\frac{1-\tau_0^l}{1+\tau_0^c}\right)}\right)^{a_2} \left(\frac{(g_0^i / y)}{\gamma_n \gamma_z - \left(1-\delta^g\right)}\right)^{a_3}\right)^{\frac{1}{1-a_1-a_3}} \tag{19g}$$

$$\frac{b}{y}\left(\gamma_n\gamma_z-\frac{1}{\beta}\right)+\tau_0^c\frac{c^p}{y}+\tau_0^l a_2+\tau_0^k\left(a_1+a_3\right)=\frac{g_0^c}{y}+\frac{g_0^{tr}}{y}+\frac{g_0^i}{y} \tag{19h}$$

which is a system of eight equations in eight unknowns $\left\{y,c^p,i,h,k,k^g,r^b,b\right\}$.

3. Calibration and long-run solution

3.1. Calibration

The model is calibrated for the Greek economy. The data source is the OECD Economic Outlook, unless otherwise stated. The data set comprises quarterly data at constant 1995 prices and covers the period 1960:1-2005:4.[14]

For the series of hours work to be compatible with the model economy, I assume that the time endowment is $(365/4)\times(15 \text{ hours per day})=1369$ hours per quarter. The average value of per capita hours of work is found to be $h=0.20$.

The steady state values of the effective tax rates on capital income, labour income and consumption are set equal to their average values over the period 2000-2005 from annual constructed effective tax rates.[15] I choose this period in order to capture recent trend in taxation; see also Mendoza and Tezar (1998). The effective tax rate on consumption is $\tau_0^c=0.20$ and the effective tax rates on labour income and capital income are $\tau_0^l=0.30$ and $\tau_0^k=0.27$, respectively.

Following Kollintzas and Vassilatos (2000) and Correia et al. (1995), I set the curvature parameter in the utility function σ equal to 2. The preference parameter ϑ which measures the degree of substitutability/complementarity between private and public consumption is set equal to zero; see also Finn (1998) and Christiano and

[14] Data for hours of work in the OECD Economic Outlook is available only on annual frequency over the period 1983-2005. Prior to 1983 the series are taken from Christodoulakis et. al (1997). To derive quarterly observations annual series are interpolated. The interpolation procedure is described in Appendix A. Moreover, quarterly series for private and public capital stocks were generated using a perpetual inventory method; see Appendix B for details.

[15] The effective tax rates on labour income, on capital income and consumption were constructed following Papageorgiou (2009b), who assumes that the self-employed earn both labour and capital income. Broadly speaking, the effective tax rates are constructed from information provided by the National Accounts as the ratios between the tax revenues from particular taxes and the corresponding tax bases. See also Martinez-Mongay (2000) and Mendoza et al. (1994). Appendix that describes how the effective tax rates were constructed is available upon request.

Eichenbaum (1992). This zero value implies that public consumption is a pure resource drain on the economy. The value of population growth γ_n is computed from population data and is set equal to 1.0014. The growth rate of technological process γ_z is set equal to 1.005 which is the average quarterly growth rate of real per capita GDP in the USA (see e.g. Kehoe and Prescott (2002)).

Following the study of Kollintzas and Vassilatos (2000), the values of the two physical depreciation rates, δ^p and δ^g are set equal to 0.007 and 0.0078, respectively (implying 2.79% and 3.12% annually). The initial level of technological process Z_0 is set equal to 1 since it is a scale parameter which affects only the scale of the economy; see King and Rebelo (1999).

One issue raised when computing the labour and capital shares in output is how to treat the income earned by the self-employed; see also Cooley and Prescott (1995). The income of self-employed is a combination of labour and capital income and as a result a part of their income should be treated as labour income. In the National Accounts there is no distinction between labour and capital income earned by the self-employed and all of their income is treated as capital income. In order to estimate a proxy for the labour income of the self-employed, I assume that the opportunity cost of being a self-employed is the labour income that would have earned had they been working as employees. Such an opportunity cost can be estimated by the average wage of the employees. Thus, the share of labour in output, a_2, is computed from data assuming that the self-employed earn an imputed wage.[16]

More specifically, the labour's share a_2 is computed as: $a_2 = \dfrac{WSSS + WSE}{NGDP}$, where $WSSS$ denotes total compensation of employees[17], *WSE* is the imputed wage of the self-employed and *NGDP* is nominal GDP. Following Fiorito and Padrini (2001), I assume that each self-employed person "pays himself" the same annual wage - net of social security contributions paid by the employers - as that earned by the average employee. In that case, the imputed wage of the self employed is

[16] This seems to be a reasonable assumption for Greece since the fraction of self-employment is 49%.

[17] $WSSS$ in the national accounts is equal to wages and salaries plus employers' social security contributions plus employer's contributions to private pension funds.

$WSE = \left(\frac{WSSS - SSCER}{EE} \right) \times ES$, where $SSCER$ are social security contributions paid by the employers, EE is the number of the employees (dependent employment) and ES is the number of the self-employed. The share of labour income is found to be 0.60.[18]

Following Baxter and King (1993), the exponent of public capital in the production function a_3 is set equal to 0.034, which is the average public investment to output ratio in the data. The capital share is then calibrated as $a_1 = 1 - a_2 - a_3$ and its value is 0.3660.

The value of the adjustment cost parameter ξ is set equal to 10 following Mendoza and Tezar (1998).

Given the long-run value of private investment to GDP, i/y, which is set equal to its average value derived from data, the time discount factor β and the ratio of private capital to GDP k/y are jointly calibrated from the steady state version of the Euler equation for private capital (19a) and the law of motion of private capital accumulation (19b). Their values are found to be $\beta = 0.9901$ and $k/y = 15.7364$, respectively. The preference parameter γ, which is the weight for consumption relative to leisure, is calibrated from the condition with respect to labour (19e) consistent with a labour allocation equal to 20% of time. Given the value of β, the Euler equation for government bonds (19c) implies a steady state quarterly value for the real interest rate on public debt equal to 0.01 (implying 4% annually). The steady state version of the law of motion of public capital accumulation (19f) implies a steady state quarterly value of public capital to GDP equal to $k^g / y = 2.3995$.

The resulting long-run solution of the model is then derived by substituting the parameters into equations (19a)-(19h) and solving for the model's endogenous variables. In this solution, the annual long-run debt-to-GDP ratio is set equal to 0.64, which is the average value over the period 1970-2005. This implies a quarterly value of 2.5600. In that case, the long-run value of government transfers to GDP is endogenously determined from the government budget constraint (19h). Table 1

[18] Note that if I do not assume an imputed wage for self-employed (i.e. $WSE = 0$), then the labour share is considerably lower and equal to 0.31.

summarizes the calibrated parameters and Table 2 reports the average values found in data and the implied long-run equilibrium solution of the model economy. The results suggest that the model's long-run equilibrium solution is in line with data, which implies that the pre-tax reform equilibrium is a reasonable platform for tax reform analysis.

Table 1: Calibration

Parameter or Variable	Description	Value	Source
a_2	Labour elasticity in production	0.60	Data
a_3	Public capital elasticity in production	0.034	Set equal to g_o^i / y
a_1	Private capital elasticity in production	0.3660	Calibrated as 1- a_2 - a_3
γ_n	Population growth rate	1.0014	Data
γ_z	Growth rate of labour augmenting technology	1.005	Set
δ^p	Private capital quarterly depreciation rate	0.0070	Set
δ^g	Public capital quarterly depreciation rate	0.0078	Set
Z_0	Initial level of technological process	1	Set
ξ	Capital adjustment cost parameter	10	Set
σ	Curvature parameter in the utility function	2	Set
γ	Consumption weight in utility function	0.3161	Calibrated from (19e)
k / y	Private Capital to output ratio	15.7364	Calibrated from (19a) and (19b)
k^g / y	Public Capital to output ratio	2.3995	Calibrated from (19f)
β	Time discount factor	0.9901	Calibrated from (19a) and (19b)
ϑ	Substitutability between private and public consumption in utility	0	Set
g_0^c / y	Government consumption to output ratio	0.1469	Data
g_o^i / y	Government investment to output ratio	0.0340	Data
τ_0^l	Tax rate on labour income	0.30	Data
τ_0^k	Tax rate on capital income	0.27	Data
τ_0^c	Tax rate on consumption	0.20	Data

Table 2: Data Averages and Long-Run Solution

Variable	Description	Data Averages	Long-Run Solution
c/y	Consumption to output ratio	0.6472	0.6091
i/y	Private investment to output ratio	0.21	0.21
h	Hours at work	0.20	0.2099
k/y	Private capital to output ratio	11.9371	15.7364
k^g/y	Public capital to output ratio	1.7850	2.3995
r^b	Real return to government bonds	0.011	0.010
b/y	Public debt to output ratio	2.56	2.56
g_0^{tr}/y	Government transfers to output ratio	0.1636	0.2196
TR/y	Tax Revenue to output ratio	0.2916	0.4098

Notes: (i) Quarterly data over the period 1960:1-2005:4 (ii) Data average for r^b is over the period 1998:1-2005:4 (iii) Quarterly series for private and public capital stocks were generated using a perpetual inventory method; see Appendix B for details.

3.2. Linearization and approximate solution

Conditions (18a)-(18b) and (18d)-(18g) are linearized around the logarithms of steady state. The variables in the log-linearized system are expressed as percentage deviations from the respective steady state values, $\hat{x}_t \equiv \ln x_t - \ln x$, where x is the steady-state value of x_t. Tax rates, $\tau_t^l, \tau_t^k, \tau_t^c$, are kept constant over time at its data average, while the three categories of government spending instruments, g_t^c, g_t^{tr}, g_t^i, remain fixed at its long-run levels implied by the model, g_0^c, g_0^{tr}, g_0^i.

The linearized conditions constitute a second-order difference equation system in 6 unknowns, namely, $\left\{\hat{y}_t, \hat{c}_t^p, \hat{i}_t, \hat{h}_t, \hat{k}_t, \hat{k}_t^g\right\}$, of the form $\mathrm{E}_t\left(A_1\hat{x}_{t+1} + A_0\hat{x}_t\right) = 0$, where $\hat{x}_t \equiv \left[\hat{y}_t, \hat{c}_t^p, \hat{i}_t, \hat{h}_t, \hat{k}_t, \hat{k}_t^g\right]'$ and A_1, A_0 are constant matrices of dimension 6×6 and 6×6 respectively. To transform the system into an equivalent first order one, introduce an auxiliary variable $k2 : k2_t \equiv k_{t+1} \Rightarrow k2_{t+1} \equiv k_{t+2}$ and so increase the dimension of the system by adding the extra equation $k2_t - k_{t+1} = 0$. Thus, the system reduces to the following first-order difference equation system, in 7 unknowns, $\mathrm{E}_t\left(A_1\hat{x}_{t+1} + A_0\hat{x}_t\right) = 0$, where $\hat{x}_t \equiv \left[\hat{y}_t, \hat{c}_t^p, \hat{i}_t, \hat{h}_t, \hat{k}_t, \hat{k}_t^g, \hat{k}2_t\right]'$, $k2_t \equiv k_{t+1}$ and A_1, A_0 are constant matrices of dimension 7×7 and 7×7. The final system is a first-order difference equation system of the form $\mathrm{E}_t\left(A_1\hat{x}_{t+1} + A_0\hat{x}_t\right) = 0$ in seven variables, where the two state variables are $\left(\hat{k}_t, \hat{k}_t^g\right)$ and the five control variables are $\left(\hat{y}_t, \hat{c}_t^p, \hat{i}_t, \hat{h}_t, \hat{k}2_t\right)$. The system is solved using the generalized Schur decomposition method proposed by Klein (2000). The general solution of the above system can be written as:

$$\hat{d}_t^c = M\hat{k}_t^s \tag{20}$$

$$\hat{k}_{t+1}^s = P\hat{k}_t^s \tag{21}$$

where $\hat{d}_t^c$ is the vector of the control variables, $\hat{k}_t^s$ is the vector of the endogenous state variables and M, P are constant matrices of dimension 5×2 and 2×2 respectively. Given the sequences of $\left(\hat{y}_t, \hat{c}_t^p, \hat{i}_t, \hat{h}_t, \hat{k}2_t\right)$, condition (18c) is used to compute the path for the real return to government bonds and condition (18h) is used to compute the path for the public debt given its initial value. I report that when I use the calibrated values in Table 1, all eigenvalues are real and there are two eigenvalues with absolute value less than one, so the model exhibits saddle path stability. Combined with the single long-run solution, this implies a unique solution.

3.3. Methodological issues and computation of the transition following a tax reform

Following Mendoza and Tezar (1998) and Cooley and Hansen (1992), I examine tax policy experiments in which a permanent reduction in one of the three distortionary tax rates (capital, labour, consumption) is met by a permanent change in another distortionary tax so that the present value of total tax revenues equals the present value of total government spending plus initial payments on debt (i.e., fiscal policy is inter-temporally solvent). The three types of government spending instruments, g_t^c, g_t^{tr}, g_t^i, remain fixed at its pre-tax reform equilibrium levels, g_0^c, g_0^{tr}, g_0^i.

Combining the government's budget constraint (18h) and the No-Ponzi condition, the government budget constraint can be written in present value terms as:

$$\begin{aligned}\sum_{t=0}^{T}\left(\gamma_n\gamma_z\right)^t d_t\left[\tau_0^c c_t^p + \tau_0^l a_2 y_t + \tau_0^k\left(a_1 + a_3\right) y_t\right] = \\ = \sum_{t=0}^{T}\left(\gamma_n\gamma_z\right)^t d_t\left(g_0^c + g_0^{tr} + g_0^i\right) + \left(1 + r_0^b\right) b_0\end{aligned} \tag{22}$$

where,

$$d_t = \prod_{j=1}^{t} \frac{1}{\left(1 + r_j^b\right)}, \text{ and } d_0 = 1$$

The left-hand side of (22) is the present value of tax revenues; the right-hand side is the present value of government spending plus payments on initial debt and d_t is the discount factor.

For fiscal policy to be inter-temporally solvent, equation (22) must be satisfied when the government changes the tax mix. More specifically, given a permanent reduction in one of the three distortionary tax rates, an initial guess is made for the permanent level of another distortionary tax rate that is adjusted so that equation (22) is satisfied. After setting the two tax rates equal to their new values, the new steady state is characterized by the equilibrium conditions (19a)-(19i). The system is solved and the new transition paths of the endogenous variables towards the steady state are given by the linear equations (20)-(21). Then, setting as initial conditions the pre-tax reform equilibrium values of the state variables, an equilibrium sequence of prices and quantities is computed for $T = 2500$ periods to ensure that the economy has convergence close enough to the new steady state. Given these sequences, equation (22) is evaluated to check if fiscal policy is solvent. Depending on the outcome, a new guess is made for the particular tax rate that is adjusted and the above procedure is repeated until equation (22) is satisfied. Note that along the transition path to the new steady state, government debt net of interest payments adjusts to fill any gap between government spending and tax revenue in any given period.

4. Transitional dynamics, growth and welfare effects of alternative tax structures

This section first examines the effects of changing the composition of distortionary taxes on the dynamic paths and the steady state levels of some key macroeconomic variables. Then, it provides a quantitative comparison of the output growth paths arising from transition dynamics across the different tax regimes. Finally, it examines the effects on long-run and lifetime welfare associated with the alternative tax structures.

Following the methodology described in the previous section, I study tax policy experiments in which a 1 percentage point reduction in one of the three distortionary tax rates (capital, labour, consumption) is met by a permanent increase in another distortionary tax rate. Each tax policy experiment i is labeled as P_i. Table 3 summarizes the tax policy experiments and the implied tax rates. It has to be noted that the changes in the tax rates and the implied tax ratios are within the historical (recent) experience for the Greek economy. Moreover, under all tax policy experiments, the solution is a saddle path.

Table 3: Tax Rates under each Tax Regime

Policy i	τ^l	τ^k	τ^c
Benchmark Economy	0.30	0.27	0.20
P_1: A 1 percentage point reduction in the capital income tax rate compensated by an increase in the labour income tax rate	0.3050	0.26	0.20
P_2: A 1 percentage point reduction in the capital income tax rate compensated by an increase in the consumption tax rate	0.30	0.26	0.2030
P_3: A 1 percentage point reduction in the labour income tax rate compensated by an increase in the capital income tax rate	0.29	0.2916	0.20
P_4: A 1 percentage point reduction in the labour income tax rate compensated by an increase in the consumption tax rate	0.29	0.27	0.2061
P_5: A 1 percentage point reduction in the consumption tax rate compensated by an increase in the capital income tax rate	0.30	0.3083	0.19
P_6: A 1 percentage point reduction in the consumption tax rate compensated by an increase in the labour income tax rate	0.3170	0.27	0.19

4.1. Transitional dynamics and long-run Effects of Alternative Tax Structures

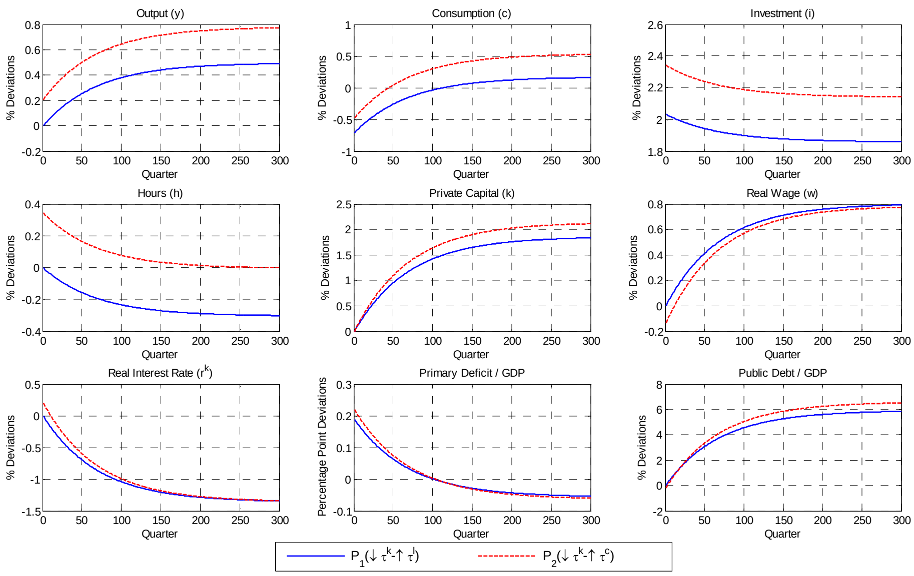
This subsection looks at the effects of changing the composition of distortionary taxes on the dynamic paths and the steady state levels of some key macroeconomic variables.

4.1.1 Tax reforms that reduce the tax rate on capital income

First, I examine the effects of tax reforms that reduce the capital income tax rate and increase: a) the labour income tax rate and b) the consumption tax rate.

Figure 1 displays the transition paths for some key macroeconomic variables expressed as percentage deviations from the pre-tax reform equilibrium. A solid line refers to the case in which the decrease in the capital income tax rate is met by an increase in the labour income tax rate and a dashed line refers to the case in which the decrease in the capital income tax rate is met by an increase in the consumption tax rate.

Figure 1: Transitional Dynamics of Tax Reforms that Reduce the Capital Income Tax Rate



Notes: (i) The series plotted are percentage deviations from the pre-tax reform equilibrium, except primary deficit-to-GDP ratio which is percentage-point deviations from the pre-tax reform equilibrium (ii) A positive change in the primary deficit-to-GDP means that the primary balance deteriorates with respect to the pre-tax reform equilibrium

First, consider the case in which the decrease in the capital tax rate is met by an increase in the labour tax rate. There are two opposite effects on labour supply. The intratemporal and intertemporal substitution effects caused by the decrease in the after-tax return to labour lead households to decrease labour supply on impact. On the other hand, the intertemporal substitution effect produced by the increase in the after-tax to investment induces households to increase labour supply on impact.[19] As Figure 1 shows, labour supply remains unchanged on impact period. Consequently, output is also unchanged.

The higher after-tax return to investment induces households to consume less and to invest more relative to the pre-tax reform economy on impact. Households

[19] There is also a wealth effect caused by the higher labour income tax rate that induces households to increase labour supply. On the other hand, there is a wealth effect produced by the lower tax rate on capital income that induces households to decrease labour supply.

want to accumulate more capital in the future and since private capital is predetermined in the short run, more future capital formation requires an investment boom on impact period. Consequently, private investment increases by about 2%, while consumption decreases by 0.71%. Note that real wages and the real interest rate remain unchanged on impact period since labour supply and the capital-to-labour ratio are unchanged.

Concerning the effects on public finances, the primary deficit-to-GDP ratio increases on impact since the decrease in the consumption to output ratio allows lower consumption tax revenues as share of output relative to the pre-tax reform economy. Thus, the higher labour tax revenues cannot meet the decrease in capital and consumption tax revenues.

In the following periods of transition, even though work effort decreases along the dynamic path, the higher level of the private capital stock leads to higher output.[20] The real interest rate adjusts downwards so that households decrease investment demand to allow their consumption to be smoothed over time. The primary deficit-to-GDP ratio declines along the transition path since the increase in the consumption to output ratio allows for higher consumption tax revenues as share of output. However, the deterioration of the primary deficit-to-GDP ratio in the early years of transition leads to an increase in the debt-to-GDP ratio.

In the long run, output, private consumption and private investment (private capital) increase by 0.5%, 0.17 and 1.87%, respectively. By contrast, hours of work are 0.30% lower. There is an improvement in the primary deficit-to-GDP ratio in the long run, reflecting the servicing of a higher public debt-to-GDP ratio. These results are consistent (even though quantitatively different) with the findings of Cooley and Hansen (1992), who show that replacing the capital tax rate with a labour tax rate increases output, consumption and capital, while it decreases labour supply.

Let us now consider the case in which the decrease in the capital tax rate is met by an increase in the consumption tax rate. The propagation mechanism and the qualitative effects on macroeconomic variables are the same as in the previous case. However, the distortions are found to be less costly. The main reason is that the higher

[20] Public capital remains unchanged both on impact and along the transition path since government investment remains fixed at its pre-tax reform equilibrium value.

consumption tax rate does not lead to a heavier taxation of future consumption relative to current consumption, but imposes the same burden. Therefore, the intertemporal substitution effect on consumption induces a smoother response of consumption over all periods. In addition, the intertemporal substitution effect induced by the decrease in the marginal product of labour is now weaker. As a result, the negative effect on labour supply comes mainly from the intratemporal substitution effect. On the other hand, the wealth and the intertemporal substitution effects caused by the increase in the after-tax return to investment tend to increase labour supply.

As Figure 1 shows, the net effect on labour supply is positive and there is an increase in work effort by 0.34%. Therefore, output increases by about 0.21%. Private investment increases by about 2.34% relative to the pre-tax reform equilibrium, while consumption decreases by 0.48%. Moreover, the real interest rate increases on impact, while real wages decrease. The primary deficit-to-GDP ratio increases because consumption tax revenues cannot meet the loss in capital tax revenues. This is mainly justified by the decrease in the consumption to output ratio, which allows for lower consumption tax revenues as share of output relative to the pre-tax reform economy.

In the following periods of transition, even though work effort decreases, output continues to increase since private capital increases. The primary deficit-to-GDP ratio declines along the transition path since the increase in consumption-to-output ratio increases consumption tax revenues as share of output. On the other hand, the public debt-to-GDP ratio increases along the transition path due to the deterioration of the primary deficit in the early years of transition.

Concerning the long-run effects, output, private consumption and private investment (private capital) increase by 0.78%, 0.54% and 2.16%, respectively. By contrast, hours of work are 0.006% lower. There is also an improvement in the primary deficit-to-GDP ratio in the long run, reflecting the servicing of a higher public debt-to-GDP ratio.

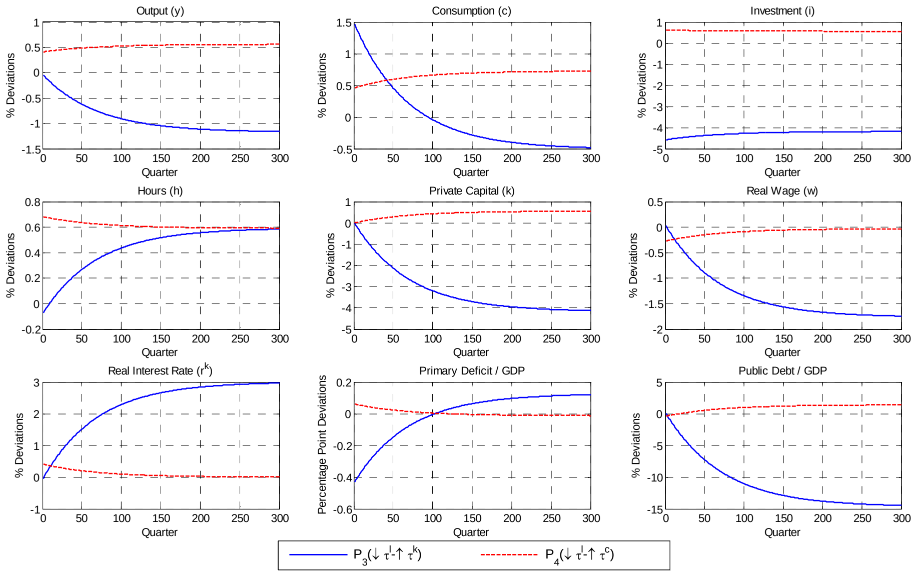
Finally, note that the increase in output, private consumption and capital is higher than the case in which the decrease in the capital tax rate is met by an increase in the labour tax rate. These results are in line with Cooley and Hansen (1992), as well as with the empirical evidence which suggests that labour tax rates are more harmful for the macroeconomy than consumption tax rates (see e.g. Daveri and Tabellinni (2000)).

4.1.2 Tax reforms that reduce the tax rate on labour income

Second, I examine the effects on the dynamic paths and the steady state levels of tax reforms that reduce the labour income tax rate and increase: a) the capital income tax rate and b) the consumption tax rate.

Figure 2 displays the transition paths for some key endogenous variables expressed as percentage deviations from the pre-tax reform equilibrium. A solid line refers to the case in which the decrease in the labour income tax rate is met by an increase in the capital income tax rate and a dashed line refers to the case in which the decrease in the labour income tax rate is met by an increase in the consumption tax rate.

Figure 2: Transitional Dynamics of Tax Reforms that Reduce the Labour Income Tax Rate



Notes: See Figure 1

In the case in which the decrease in labour income tax rate is met by an increase in the capital income tax rate, the intratemporal and intertemporal substitution effects caused by the increase in the after-tax return to labour tend to increase labour supply. On the other hand, the intertemporal substitution effect caused by the decrease in the after-tax return to investment tends to decrease labour supply.

As Figure 2 shows, the net effect on impact period is a decrease in labour supply and output by about 0.07% and 0.04%, respectively. The lower after-tax return to investment induces households to consume more and to invest less relative to the benchmark economy. As a result, consumption increases on impact by about 1.47%, while investment decreases by 4.54%. The real interest rate increases in order for the markets to clear, while real wages increase due to the lower labour supply. The primary deficit-to-GDP ratio decreases because the higher consumption-to-output ratio allows higher consumption tax revenues as share of GDP.

In the subsequent periods of transition, labour supply increases. However, the low levels of the future private capital stock lead to lower levels of output relative to the benchmark economy. The real interest rate adjusts upwards so as to allow households to smooth consumption over time, while real wages decrease relative to the pre-tax reform economy.

In the long run, output, private consumption and private investment (private capital) decrease by 1.17%, 0.50% and 4.1% respectively, while labour supply increases by 0.59%. The primary deficit-to-GDP ratio deteriorates in the long run, reflecting the need for servicing a lower public debt-to-GDP ratio.

Consider next the case in which the decrease in the labour tax rate is met by an increase in the consumption tax rate. Both tax rates affect the same decision margin (consumption-labour choice), but in the opposite direction. As Figure 2 shows, labour supply, output, private consumption and private investment on impact period increase by 0.68%, 0.40%, 0.46% and 0.61%, respectively. The real interest rate increases, while real wages decrease.

In the following periods of transition, the higher labour supply increases the marginal product of private capital implying higher future capital formation. Therefore, along the transition path, output and private capital (investment) are higher relative to the pre-tax reform economy. The primary deficit-to-GDP ratio deteriorates slightly in the early years of transition since the higher consumption tax revenue cannot meet the loss in labour tax revenue. Consequently, the public debt-to-GDP ratio increases in the following years of transition.

In the long run, output, labour supply, private consumption and private capital (investment) are 0.56%, 0.59%, 0.73% and 0.56% higher relative to the benchmark economy. However, real wages and the real interest rate return to their pre-tax reform values since the labour-to-output and capital-to-output ratios remain unchanged. The primary deficit-to-GDP ratio improves in the long run, whereas the public debt-to-GDP is higher due to the deterioration of primary deficits in the early years of transition.

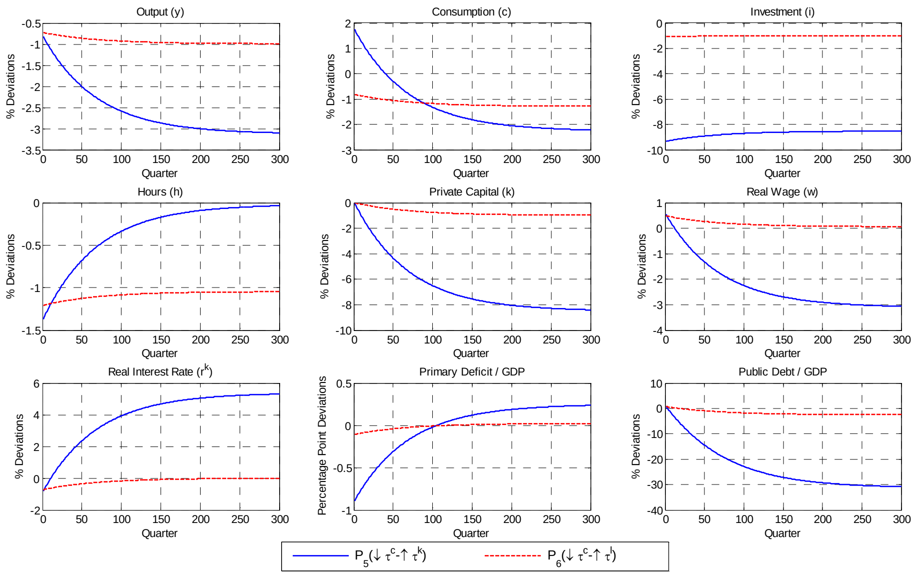
The above results are in line (albeit quantitatively different) with the findings of Mendoza and Tezar (1998) for the U.S. economy. For instance, he finds that substituting the labour tax rate with a consumption tax rate increases output and private capital by about 8% in the long-run.

4.1.3 Tax reforms that reduce the tax rate on consumption

Third, I examine the effects on the dynamic paths and the steady state levels of tax reforms that reduce the tax rate on consumption and increase a) the capital income tax rate and b) the labour income tax rate.

Figure 3 displays the transition paths for some key macroeconomic variables expressed as percentage deviations from the benchmark economy. A solid line refers to the case of reducing the consumption tax rate and increasing the capital income tax rate and a dashed line refers to the case of reducing the consumption tax rate and increasing the labour income tax rate.

Figure 3: Transitional Dynamics of Tax Reforms that Reduce the Consumption Tax Rate



Notes: See Figure 1

As Figure 3 shows, when the reduction in the consumption tax rate is met by an increase in the capital income tax rate, households find it optimal to consume more and work less relative to the pre-tax reform equilibrium. Consumption is 1.75% higher on impact, while labour supply decreases by about 1.37%. As a result, output decreases by 0.83%. Private investment also decreases by 9.32%, while there is an improvement in the primary deficit-to-GDP ratio since tax revenues from consumption increase significantly.

Even though work effort increases in the subsequent periods, the lower private capital stock leads to a decrease in output along the dynamic path. Real wages decrease in the subsequent periods of transition due to the decrease in the output-to-labour ratio, while the real interest rate adjusts upwards allowing households to smooth consumption over time. As a result, consumption decreases relative to the pre-tax equilibrium in the following periods of transition.

In the long run, output, consumption, hours worked and private capital (private investment) are 3.1%, 2.24%, 0.02% and 8.16% respectively lower relative to the benchmark economy. The primary deficit-to-GDP ratio deteriorates in the long run reflecting the servicing of the lower public debt-to-GDP ratio.

Consider next the case in which the decrease in the consumption tax rate is compensated by an increase in the labour income tax rate. As already explained, both tax rates affect the same marginal decision, but in the opposite direction. Figure 3 shows that the distortions from the higher tax rate on labour are more costly than the benefits from the lower consumption tax rate. Therefore, output, consumption, hours worked and private investment decrease on impact and along the transition path.

In the long run, output, private consumption, hours worked and private capital (private investment) are 0.98%, 1.28%, 1.04% and 0.98% lower relative to the pre-tax reform economy. Note that real wages and the real interest rate return to its pre-tax reform equilibrium values since the labour to output and capital to output ratios remain unchanged. Finally, there is deterioration in the primary deficit-to-GDP ratio, which reflects the servicing of a lower debt-to-GDP ratio.

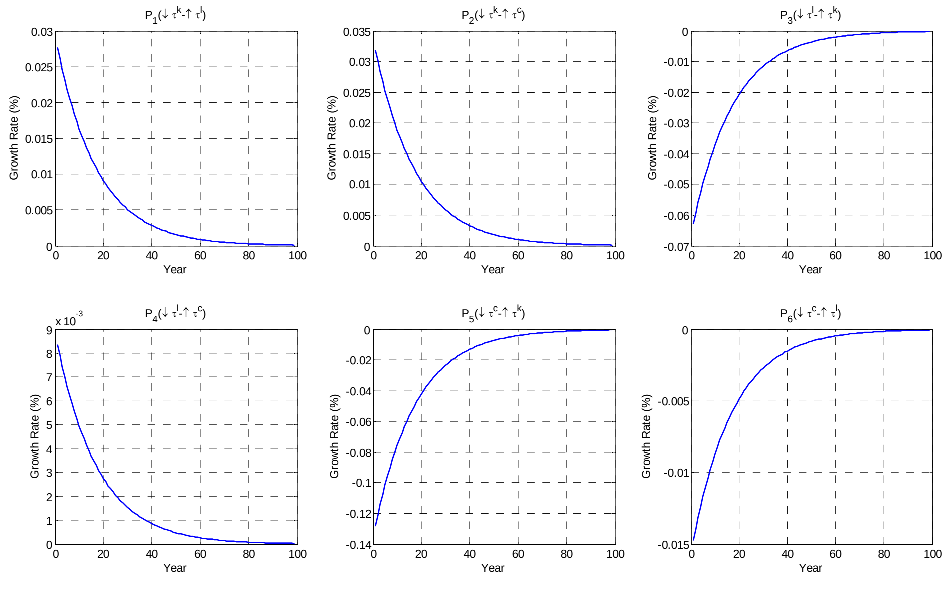
4.2. Growth rate paths arising from transitional dynamics

This subsection provides a quantitative comparison of the output growth paths arising from transitional dynamics (i.e. the growth rate of output in per effective units) across the different tax regimes. Since long-run growth is exogenous, shifts in the growth rates are only temporary.

Figure 4 shows the annual output growth rate paths arising from transitional dynamics.[21] A quantitative summary of the transition paths is presented in Table 4.

The first line of Table 4 and subplot (1,1) of Figure 4, where (1,1) refers to raw and column numbers respectively, show that reducing the capital tax rate and increasing the labour tax rate yields an output growth gain both on impact and along the dynamic path. Output growth is between 0.028% and 0.016% over the first ten years following the change in the tax mix. When the consumption tax rate increases to meet the loss in capital tax revenue, output growth also increases both on impact and along the dynamic path. As subplot (1,2) shows, its value is between 0.03% and 0.02% during the first decade.

Figure 4: Output Growth Rates ($\ln\left(y_{t+1} / y_t\right) \times 100$) Arising from Transitional Dynamics



Note: Impact Period is not shown in the subplots

Decreasing the labour income tax rate and increasing the capital income tax rate, produces an output growth slowdown on impact period by about 0.07%. In the later periods of transition, output growth is between -0.06% and -0.04% for about a decade. When substituting the decreased labour tax rate with a higher consumption tax rate,

[21] Quarterly observations generated by the model have been transformed into annual observations following Christiano (1989). In particular, a four period sum is taken of data and every fourth resulting observation is sampled as an annual observation.

growth on impact period is about 0.41%. However, in the subsequent periods of transition the effects on growth are trivial. As already explained, this is justified by the fact that both tax rates affect the same margin (consumption-leisure choice) and the responses are found to be very smooth.

Decreasing the consumption tax rate and increasing the capital income tax rate produces a growth slowdown both on impact and along the transition path. After the impact period, output growth rates are between -0.13% and -0.08% for about a decade. Finally, when the decrease in the consumption tax rate is met by an increase in the labour income tax rate, there is a growth slowdown on impact period by about -0.73%. In the subsequent periods, the effects on growth are found to be small and about 0.01% during the first decade.

Table 4: Output Growth Rates ($\ln\left(y_{t+1} / y_t\right) \times 100$) Arising from Transitional Dynamics

Policy i	**Growth Rate (%) on Impact Period**	**Average Annual Growth Rates (%) over the first four Five-Years Time Intervals***			
		1	**2**	**3**	**4**
$P_1\left(\tau^k \downarrow, \tau^l \uparrow\right)$	0.01%	0.025%	0.018%	0.0138%	0.011%
$P_2\left(\tau^k \downarrow, \tau^c \uparrow\right)$	0.22%	0.029%	0.023%	0.016%	0.012%
$P_3\left(\tau^l \downarrow, \tau^k \uparrow\right)$	-0.07%	-0.06%	-0.04%	-0.032%	-0.023%
$P_4\left(\tau^l \downarrow, \tau^c \uparrow\right)$	0.41%	0.008%	0.006%	0.004%	0.003%
$P_5\left(\tau^c \downarrow, \tau^k \uparrow\right)$	- 0.87%	-0.114%	-0.09%	-0.065%	-0.048%
$P_6\left(\tau^c \downarrow, \tau^l \uparrow\right)$	- 0.73%	-0.013%	-0.01%	-0.008%	-0.006%

* Impact period is not taken into account.

It is interesting to note that transitions dynamics are found to be quite lengthy for most of the tax experiments considered since it takes more than 50 years for the economy to reach its pre-tax reform balance growth path. Thus, growth rates are affected by transitional dynamics for a long period of time. However, as Figure 4 and Table 4 illustrate, the quantitative effects are found to be very small.

The above results are in line with the empirical findings of Mendoza et al. (1996,1997), who argue that tax rates affect transition growth. Moreover, it should be noted that the quantitative implications that are obtained for the growth rates along the transition path parallel those obtained in endogenous growth models in which tax policy changes have permanent effects on long-run growth. For instance, Stokey and Rebelo (1995) in various endogenous growth models find that eliminating all income taxes produce long-run growth effects between 0 and 3.3 percentage points.

To summarize, if the goal of tax policy is to promote growth by replacing one distortionary tax rate with another, then it should reduce the capital income tax rate, while simultaneously increase either the consumption or the labour income tax rate.

4.3. Welfare effects of alternative tax structures

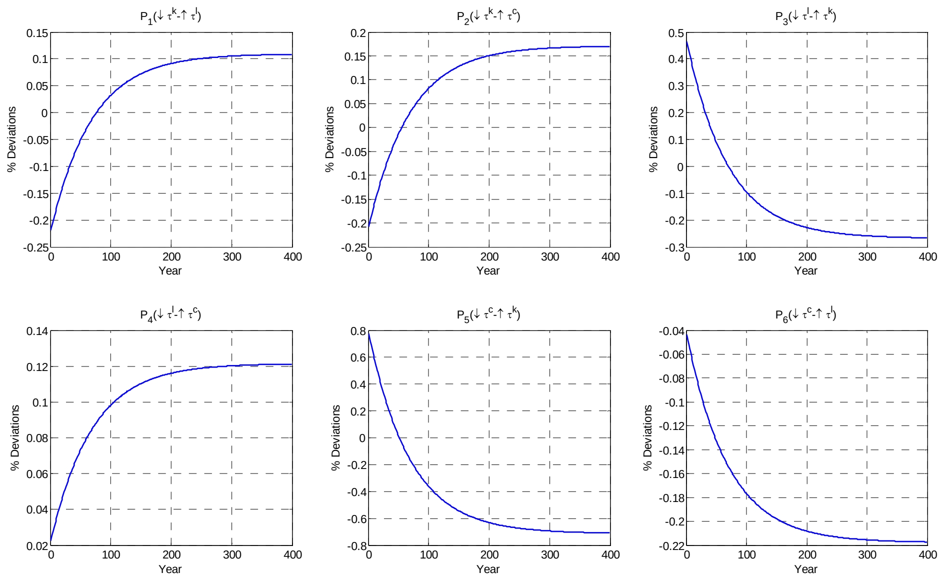
This subsection provides a quantitative comparison of the welfare gains or losses associated with the alternative tax mixes.

Following among others Cooley and Hansen (1992) and Lucas (1990), I compute the permanent percentage change in private consumption that leaves households indifferent between lifetime utility obtained by remaining in the pre-tax reform equilibrium and the lifetime utility obtained by undertaking the tax reform. This percentage change is defined as x. This number measures the increase/decrease in consumption required to provide households with the same lifetime utility level as in an economy with a different tax structure. If $x > 0$ there is a welfare gain of moving from the benchmark tax structure to the tax structure under regime i and vice versa for $x < 0$. First, I compute the steady state welfare gains/losses by comparing the lifetime welfare between pre-tax reform and post-tax reform steady states. Then, I compute the lifetime welfare by taking into account the transition from the steady state of the pre-tax reform economy to the new steady state (Appendix C describes how the steady state and lifetime welfare gains or losses are computed). Table 5 shows the value of x implied by each tax regime, while Figure 5 plots the utility levels for the first 400 quarters expressed as percentage deviations from the utility level of the pre-tax reform economy.

Table 5: Steady State and Lifetime Welfare Comparisons of Alternative Tax Structures

Policy i	x **Steady State Welfare Gain / Loss**	x **Lifetime Welfare Gain / Loss**
$P_1\left(\tau^k\downarrow,\tau^l\uparrow\right)$	0.3461%	0.0749%
$P_2\left(\tau^k\downarrow,\tau^c\uparrow\right)$	0.5416%	0.2289%
$P_3\left(\tau^l\downarrow,\tau^k\uparrow\right)$	-0.8480%	-0.2430%
$P_4\left(\tau^l\downarrow,\tau^c\uparrow\right)$	0.3842%	0.3027%
$P_5\left(\tau^c\downarrow,\tau^k\uparrow\right)$	-2.2550%	-1.0295%
$P_6\left(\tau^c\downarrow,\tau^l\uparrow\right)$	-0.6887%	-0.5447%

Figure 5: Utility



Consider first the steady state welfare consequences of the alternative tax policies. Table 5 illustrates that reducing the capital income tax rate and increasing the labour income tax rate produces a steady state welfare gain equal to 0.3461%. This number measures the permanent percentage increase in consumption required to provide households with the same utility as in an economy with a lower tax rate on capital and a higher tax rate on labour. Decreasing the capital income tax rate and increasing the consumption tax rate leads to a steady state welfare gain equal to 0.5416%.

Reducing the labour income tax rate and increasing the capital income tax rate produces a steady state welfare loss equal to 0.8480%. On the contrary, if the decrease in the labour income tax rate is met by an increase in the consumption tax rate, there is a steady state welfare gain equal to 0.3842%. Cuts in the consumption tax rate that are accommodated by increases in capital or labour income tax rates lead to a welfare loss equal to 2.255% and 0.6887%, respectively.

Consider next the effects on lifetime welfare by taking into account the transition from the steady state of the pre-tax reform economy to the new steady state. Table 5 illustrates that reducing the capital income tax rate and increasing the labour income tax rate produces a lifetime welfare gain equal to 0.0749%, which is about 78% lower than the steady state welfare gain. This is because consumption falls sharply during the early years of transition implying a large cost of transitional dynamics and a lower utility level (see also subplot (1,1) of Figure 5). Decreasing the capital income tax rate and increasing the consumption tax rate leads to a lifetime welfare gain equal to 0.2289%, which is also lower than the steady state welfare gain. As subplot (1,2) shows, the low levels of consumption and leisure lead to a lower utility level in the early years of transition.

Reducing the labour income tax rate and increasing the capital income tax rate leads to a lifetime welfare loss equal to 0.2430%. This value is considerably lower than the steady state welfare loss since there are transitional gains from the increase in consumption in the early years of transition that increase utility (see subplot (1,3)). The case in which the decrease in the labour income tax rate is met by an increase in the consumption tax rate produces a lifetime welfare gain equal to 0.3027%, which is close to the steady state welfare gain. The result that the lifetime welfare gain is higher than the case in which a decrease in the capital income tax rate is met by an increase in the consumption tax rate, is consistent with the findings of Ardagna (2001) and Mendoza and Tezar (1998). They show that when transitional dynamics are taken into account, the labour tax rate is more distortionary than the capital tax rate.

Consider next the case in which there is a cut in the consumption tax rate that is met by an increase in the capital income tax rate. Table 5 shows that there is a lifetime welfare loss equal to 1.0295%. This value is about 50% lower than the steady state welfare loss since there is an increase in utility in the early years of transition resulting from the increase in consumption and leisure. Finally, a permanent reduction in the consumption tax rate accommodated by an increase in the labour income tax rate leads to a lifetime welfare loss equal to 0.5447%.

It is important to note that these results are consistent with previous findings in the literature. For example, Mendoza and Tezar (1998) find that replacing the capital income tax rate with a consumption tax rate leads to a long run welfare gain equal to 9.8%, while replacing the labour income tax with a consumption tax rate leads to a steady state welfare gain equal to 4.8%. However, when the costs of transition are taken into account, the welfare gains are about 78% and 35% respectively lower. These numbers are in line with the results reported in Table 5. Finally, Cooley and Hansen (1992) for the U.S. economy find that eliminating the capital tax rate and increasing the labour tax rate and the consumption tax rate leads a welfare gain equal to 5.6% and 6.7%, respectively. However, when transitional dynamics are taken into accounts the welfare gains are about 60% lower.

To sum up, if the goal of tax policy is to promote long run welfare, then it should decrease the capital income tax rate and increase the consumption tax rate. On the other hand, when transition dynamics are taken into account, tax reforms that reduce the labour income tax rate and increase the consumption tax rate are the most desirable of the tax reforms considered since they lead to the highest lifetime welfare gain.

4.3.1. Sensitivity analysis

This section provides a sensitivity analysis and examines how steady state welfare is affected when different combinations of tax rates on labour income, capital income and consumption are used to raise the same amount of total tax revenues; see also Cooley and Hansen (1992). More specifically, I compare the steady state welfare gains/losses for different combination of tax ratios $\left(\tau^k / \tau^l\right)$, $\left(\tau^k / \tau^c\right)$, $\left(\tau^l / \tau^c\right)$ that give raise to the same total steady state tax revenues, which are equal to the steady state tax revenues of the pre-tax reform equilibrium.

Figure 6: Steady State Welfare Comparisons

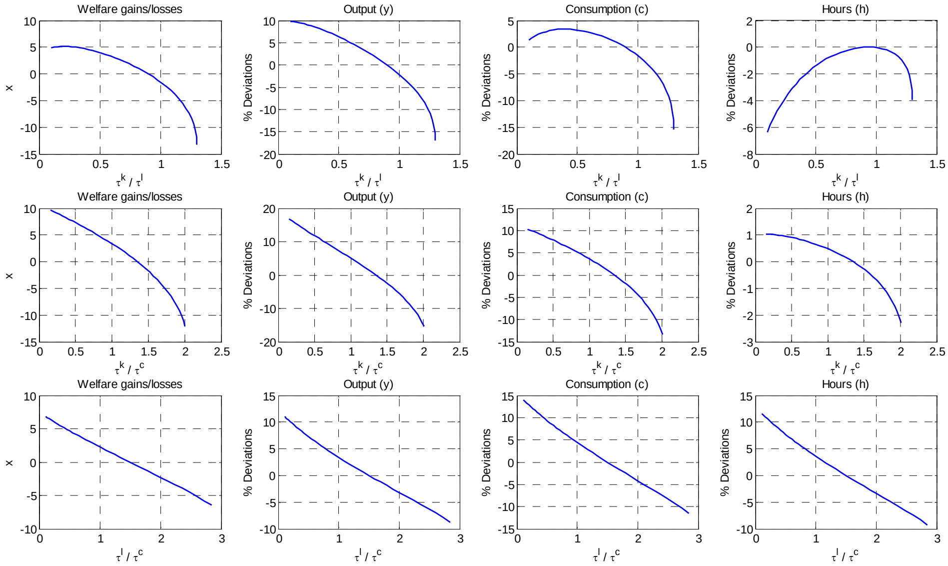


Figure 6 shows the steady state welfare gains/losses for these tax experiments, as well as the steady state output, consumption and hours worked expressed as percentage deviations relative to their pre-tax reform values. Subplot (1,1) of Figure 6 shows that as the ratio $\left(\tau^k / \tau^l\right)$ decreases (i.e. the tax rate on capital income decreases and the tax rate on labour income increases) from its pre-tax reform value, steady state welfare gain increases. Long-run output and consumption increase relative to their pre-tax reform values, while labour supply decreases (see subplots (1,2), (1,3) and (1,4) respectively). The same comments apply to the case in which the ratio $\left(\tau^k / \tau^c\right)$ decreases from its pre-tax reform value (see subplots (2,1)-(2,4)). However, note that the steady state welfare gains, as well as the increase in long-run output, consumption and hours worked are higher than in the previous case. Finally, subplot (3,1) shows that as the ratio $\left(\tau^l / \tau^c\right)$ decreases from its pre-tax reform value, there is a steady state welfare gain, while long-run output, consumption and hours increase relative to their pre-tax reform values.

5. Concluding remarks

This paper has examined how changes in the tax mix (defined as distribution of revenue by type of tax) influence economic activity and welfare in the Greek economy.

The results suggest that tax reforms in which a reduction in the capital income tax rate is met by an increase in the consumption tax rate, increase output and private investment both in the short and long run. When the cut in the capital income tax rate is met by an increase in the labour income tax rate, the increase in long-run output and private investment is lower than the case in which the cut in the capital income tax rate is met by an increase in the consumption tax rate. In both cases, the primary deficit-to-GDP ratio increases in the short run, while it decreases in the long run.

A permanent reduction in the labour income tax rate that is met by a permanent increase in the consumption tax rate increases output, private consumption, private investment and hours worked both in the short and long run. The opposite results are observed when the capital tax rate increases in order to meet the loss in labour tax revenue. Cuts in the consumption tax rate that are compensated with increases in labour or capital income tax rates have a negative impact on output and private investment both in the short and long-run.

In addition, the results suggest that if the goal of tax policy is to promote growth by replacing one distortionary tax rate with another, then it should reduce the tax rate on capital income and increase the tax rate on consumption. On the other hand, if the goal of tax policy is to promote lifetime welfare, then it should decrease the labour income tax rate and increase the consumption tax rate.

For future work it would be interesting to introduce heterogeneous agents and to examine the distributional consequences of alternative tax structures.

Appendix

A. Interpolation of Hours Worked

To derive quarterly series for hours of work from the corresponding annual series, the interpolation procedure uses information in total employment since total employment series is available at quarterly frequency. More specifically, the interpolation rule is the following:

$$h_{i,j} = h_i \left(\frac{ET_{i,j}}{ET_i} \right) \tag{A.1}$$

where $i = 1960 - 2005$, $j = 1,...4$, and $h_{i,j}$ are hours worked in year i and quarter j respectively.

B. Construction of capital stock series

The private capital stock is generated using a perpetual inventory method. Given an initial capital stock in 1960, real total fixed investment I_t is accumulated using the law of motion of capital $K_{t+1} = \left(1 - \delta^p\right) K_t + I_t$. The depreciation rate δ^p is set equal to 0.007. Following Conesa et al. (2007), the initial value for the private capital stock is chosen such that the capital-to-output ratio in 1960 matched the average capital-to-output ratio over the period 1961:2-1965:4. Using data for real government investment, the same method used for the construction of public capital stock series. The value of the depreciation rate δ^g is set equal to 0.0078.

C. Welfare comparisons

a) Lifetime welfare comparisons

The instantaneous utility function (4) expressed in stationary terms is:

$$u\left(c_t, 1 - h_t\right) = \frac{M_t \left[\left(c_t\right)^{\gamma} \left(1 - h_t\right)^{1-\gamma} \right]^{1-\sigma} - 1}{1 - \sigma} \tag{C1}$$

where $M_t = Z_0^{\gamma(1-\sigma)} \gamma_Z^{t\gamma(1-\sigma)}$ are exogenous variables and $c_t = c_t^p + \vartheta g_0^c$ denotes the composite consumption. The lifetime welfare under the base tax structure is:

$$\bar{V} = \sum_{t=0}^{\infty} \tilde{\beta}^t \frac{\left[\left(c\right)^{\gamma} \left(1 - h\right)^{1-\gamma} \right]^{1-\sigma} - 1}{1 - \sigma} \tag{C2}$$

where c and h are constant along the balanced growth path and $0 < \tilde{\beta} = \beta^{*}\gamma_{Z}^{\gamma(1-\sigma)} < 1$, $Z_0 = 1$. The lifetime welfare following a policy change is:

$$V^{*} = \sum_{t=0}^{\infty} \tilde{\beta}^{t} \frac{\left[\left(c_t^{*}\right)^{\gamma} \left(1-h_t^{*}\right)^{1-\gamma} \right]^{1-\sigma} - 1}{1-\sigma} \tag{C3}$$

We find the value of x that satisfies the following equation:

$$V^{*} - \sum_{t=0}^{\infty} \tilde{\beta}^{t} \frac{\left[\left((1+x)c\right)^{\gamma} \left(1-h\right)^{1-\gamma} \right]^{1-\sigma} - 1}{1-\sigma} = 0 \tag{C4}$$

Combining (C2) and (C4) and performing the calculations we get that:

$$V^{*} = \left(1+x\right)^{\gamma(1-\sigma)} \sum_{t=0}^{\infty} \tilde{\beta}^{t} \frac{\left[\left(c\right)^{\gamma} \left(1-h\right)^{1-\gamma} \right]^{1-\sigma} - 1}{1-\sigma}$$

or

$$V^{*} = \left(1+x\right)^{\gamma(1-\sigma)} \bar{V} \Rightarrow x = \left[\left(\frac{V^{*}}{\bar{V}} \right)^{\frac{1}{\gamma(1-\sigma)}} - 1 \right] \times 100 \tag{C5}$$

where V^{*} and $\bar{V}$ are given by (C3) and (C2) respectively. In the simulations, the time horizon for the calculation of V^{*} is $T = 2500$ periods/quarters.

b) Steady state welfare comparisons

For steady state comparisons, note that the steady state utility in the post-tax reform equilibrium is:

$$V^{*ss} = \sum_{t=0}^{\infty} \tilde{\beta}^{t} \frac{\left[\left(c^{*}\right)^{\gamma} \left(1-h^{*}\right)^{1-\gamma} \right]^{1-\sigma} - 1}{1-\sigma} = \frac{1}{1-\tilde{\beta}} \frac{\left[\left(c^{*}\right)^{\gamma} \left(1-h^{*}\right)^{1-\gamma} \right]^{1-\sigma} - 1}{1-\sigma}, \quad 0 < \tilde{\beta} < 1 \tag{C6}$$

where c^{*} and h^{*} are constant along the balanced growth path. We then find the value of x that satisfies the following equation:

$$V^{*ss} - \left(1+x\right)^{\gamma(1-\sigma)} \bar{V}^{ss} = 0 \tag{C7}$$

where $\bar{V}^{ss} = \dfrac{1}{1-\tilde{\beta}} \dfrac{\left[(c)^{\gamma}(1-h)^{1-\gamma}\right]^{1-\sigma} - 1}{1-\sigma}$ is the steady state utility in the pre-tax reform equilibrium. Solving (C7) for x we get that $x = \left[\left(\dfrac{V^{*ss}}{\bar{V}^{ss}}\right)^{\frac{1}{\gamma(1-\sigma)}} - 1\right] \times 100$

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