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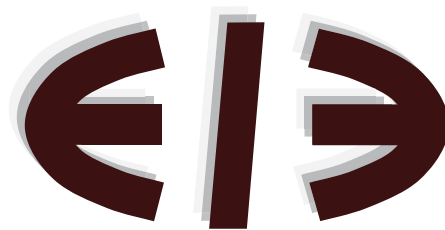
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Fiscal policy experiments: the case of Greece

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Abstract

This dissertation investigates the macroeconomic implications of alternative tax regimes for the case of Greece. For this purpose, an one-sector general equilibrium model is constructed in which heterogeneous agents differ in productivity and holdings of capital in the sense of incurring transaction costs for participating in the capital market. A Cobb-Douglas production function is employed that can capture the capital-skill complementarity effect and the difference in productivities of the skilled and unskilled workers. With regards to fiscal policy experiments, this dissertation examines tax structures where a permanent reduction in each of the three main tax instruments namely, consumption, labour and capital income tax is compensated by a permanent increase in one of the remaining two policy instruments such that the government budget constraint is tax revenue neutral. The government levies taxes on consumption, labour income and capital income in order to finance its only activity, government consumption. Next, the model economy is calibrated to the Greek economy to reflect the great ratios over 1960:1-2005:4 and then, it studies the long-run, welfare and transitional effects of the undertaken analysis. The sensitivity analysis shows that the quantitative and qualitative findings are quite robust.

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1 Introduction

Over the last three decades there have been many empirical studies that point out significant increases in wages and labour supplied by skilled workers in relation to unskilled workers and thus, a widening of the skill premium. The latter defined as the ratio of the wage rate that skilled labour receive divided by the wage rate of unskilled labour can be viewed as a measure of wage inequality. One of the most studied question for the U.S. economy as Krusell *et al.* (1997) note is "Why has the skill premium risen during a period of substantial growth in the relative supply of skilled labour?". This question along with the renewed empirical interest of Grilliches-observed capital-skill complementarity hypothesis have produced a huge bulk of literature on these issues mainly for two reasons: a) there are measurement problems and researchers can not directly account for the skill premium and b) it is now widely recognised that skilled labour and capital are more complementary compared to unskilled labour and capital. On that basis, many studies attempt to account for those elements by enriching the standard Cobb-Douglas production function. In general, two types of enrichment can be noted: a) production functions that incorporate the notion of skilled-biased technological change and b) production functions that incorporate the notion of factor-biased technological change. Skilled-biased technological change implies that skilled labour (e.g. more educated) can benefit more as opposed to unskilled labour whenever a change in technology is realised. However, skilled-biased technological change is factor-neutral. By contrast, factor-biased technological change can therefore control for the effect of explaining relative changes in labour returns stemming from factor-driven changes along the assembly line.

Based on those developments, another strand of literature has been expanding quickly, that of heterogenous agent models which examines alternative tax structures, growth and welfare effects and distributional consequences, among others. The main reason for this expansion is that researchers not only can experiment with various distortionary taxes and study the macroeconomic effects for an economy but also infer from a more micro-persective angle on Patero-improving policies and incorporate a more pragmatic tax system, such as tax progressivity. For instance, studies that use a constant elasticity of substitution production function and depending on which point the economy is on the Laffer curve, find that a change in the capital income tax rate can affect the tax base of the other group (e.g. unskilled workers) populating the economy, and tax revenues levied from that group can either increase or decrease. There are three works in the literature that can be deemed as anchor papers; that of a) Judd (1985), b) Chamley

(1986) and c) Lucas (1990). Based on these studies, there are papers that engage with the optimal taxation theory and other that examine tax regimes in permanent reductions in tax rates. The most studied tax instrument is capital income tax since it is the driving force of the findings in heterogeneous agents models within a dynamic general equilibrium (DGE) setup.

In the optimal taxation theory as Angelopoulos *et al.* (2012) mention there is a branch of literature in which returns to skill are exogenous, government can affect the after-tax income distribution and support the poorer group by taxing more the rich group. In addition, studies that introduce tax progressivity and assume that returns to skill are endogenously determined deduce that increasing tax progressivity lead to a reduced capital stock. However, taking into consideration time-consistency issues, conclusions can vary significantly. For instance, optimal fiscal policy under time-inconsistent framework suggests a zero taxation on capital over the long-run e.g. Chari and Kehoe (1999). By contrast, under time-consistent setup a positive tax rate is recommended e.g. Krusell (2002) and Angelopoulos *et al.* (2011b).

On the permanent reductions in taxes side of things, papers within the representative or heterogeneous agents framework support that a reduction in capital tax leads to welfare gains in the long-run. However, heterogeneous agents modelling indicates that the distributional effects of such tax regimes can unequally affect the groups in the economy e.g. Domeij and Heathcote (2004). More recent studies investigate alternative tax structures by relaxing the rational expectations assumption e.g. Giannitsarou (2006) and instead assume an adaptive learning process on behalf of households towards equilibrium. In a heterogeneous agents model, the study of Angelopoulos *et al.* (2011) shows that this process translates into an asymmetric distribution of information following a tax regime and agents can behave erroneously. Although, that behaviour can delay the adjustment to a new steady state since agents have heterogeneous initial conditions for learning, it can boost the propagation mechanism of a tax reform creating spillover effects to all learners.

One common feature of the above studies is the use of a constant elasticity of substitution production function (CES) to capture skilled-biased technological change while having the ability to choose different degrees of capital-skill complementarity on a) physical capital stock or b) on capital equipment and capital structures. The advantage of CES functions is that depending on the degree of capital-skill complementarity among skilled and unskilled workers and in addition, whether there are agents in the economy that depend more on wage incomes or not, researchers can test a) the significance of productive capital in the economy and b) the importance of the

source of heterogeneity, in determining the effects on the skill-premium and welfare benefits. The source of heterogeneity is crucial in demonstrating distributional implications and it is usually modelled as market imperfections along with skill heterogeneity. The most conventional way to account for market imperfections is to incorporate quadratic cost functions e.g. Benigno (2009) that can capture transaction and intermediation costs in capital and asset market, respectively.

As noted above, although the results of tax reforms can differ depending on the values of the parameters in a CES production function and the way the researcher(s) construct the model¹ there are, in general, a few robust results stemming from DCE models that have also been verified in heterogeneous agent models: a) the growth effects of alternative tax regimes are more likely to be small b) the welfare effects can be considerable,² c) policies that reduce capital income taxation induce welfare gains in the long-run even if labour income is taxed more heavily in order to offset for the low collection of capital revenues and d) tax cuts in capital income do not uniformly affect the workers in the economy.

In Greece, the study of alternative tax regimes and their implications in a dynamic general equilibrium setup was absent prior to 2009. For instance, the first fully micro-founded DSGE model for Greece was published in 2013.³ In addition, the first paper that investigates alternative tax structures is authored by Papageorgiou (2009). The model employs a neoclassical utility for the representative household, the three main types of tax and government spending instruments, government bonds and a standard Cobb-Douglas production function with labour-augmenting technology. From this time forth, a few number of studies have been published examining the quantitative and qualitative effects of various fiscal policy regimes e.g. Papageorgiou *et al.* (2011), Papageorgiou (2011), (2012). However, all these papers build upon the framework of Papageorgiou (2009) with small additions or modifications each time. For instance, the studies of Papageorgiou (2009) and Papageorgiou *et al.* (2011) share the same framework, with the only difference being the assumption of exogenous stochastic $AR(1)$ processes for each of the three main tax instruments and government components, in the latter study. The same author published another paper in 2011 by constructing the same setup

¹For instance, Asimakopoulos (2014) in his PhD thesis, Chapter 1 finds that the optimal fiscal policy in the long-run implies a non-zero and positive tax rate on capital income together with highly progressive labour income taxes.

²However, there are few studies that investigate the welfare side of tax mix.

³It is a DSGE model tailored for a small open economy. In May 2014, a DSGE model for policy simulations was published at the Bank of Greece. For more details see Papageorgiou (2014).

but instead it does not assume adjustment costs on investment, as the aforementioned studies do. Overall, those studies do not address distributional consequences that arise under heterogeneous agent models, among others.

In absence of any tax policy study in a heterogeneous agents framework for the case of Greece, this dissertation attempts to fill this gap and provide quantitative - qualitative results on transitional, welfare and distributional issues. In order to answer these issues we construct a dynamic general equilibrium model with two types of agents: skilled and unskilled workers that differ in productivity. In addition, we introduce transaction costs in capital holdings which is also another dimension that workers differ. There is government in the form of government consumption and it is assumed to influence the neoclassical non-separable utility of households. The government activity is financed by tax revenues on consumption, labour and capital income. Departing from usual practice, we assume a Cobb-Douglas production function which incorporates the notion of skilled-biased technological change and can capture the difference in workers' productivities, as they are expressed in their respective labour shares. Therefore, the skill premium is present in the economy, exceeds unity and it is viewed as wage inequality. Having calibrated the model to reflect the main characteristics of the Greek economy for the period 1960:1-2005:4, we experiment with alternative tax regimes where an one per cent permanent reduction in each of the three tax instruments is residually offset by an increase in one of the remaining two separately, in order to maintain the tax revenue neutrality of the government budget constraint. For each tax regime, we investigate the long-run and welfare effects with reference to the initial steady-state and conduct sensitivity analysis of the results by removing the influence of government consumption from households utility.

There are three key results stemming from our fiscal policy experiments. First, policies that reduce capital income tax and increase labour income tax or consumption tax lead to a welfare gain in the steady state of 0.56% and 1.19%, respectively. To the contrary, policies that decrease labour income tax and meet the budget constraint by an increase in capital income tax or consumption tax lead to welfare loss -0.66% and welfare gain 0.88% , respectively. Second, the skill premium translated into wage inequality is widened under policies that reduce capital income tax. These policies result in high wage inequality and the latter is at its maximum value 0.118% under the tax regime that reduce capital income tax and increase consumption tax. The opposite is true when a reduction in consumption tax is met by an increase in labour income tax. Third, if policy is keen to take into consideration the transitional dynamics towards a new steady state then, the reduction in labour income tax met by an increase in the consumption tax is recommended. All

the above findings are robust, as the sensitivity analysis indicates.

The remainder of this dissertation is as follows. Chapter 2 presents the model and the calibration procedure. Chapter 3 elaborates upon the policy experiment results and reports the sensitivity analysis. It also states the conclusions. Lastly, an Appendix is provided containing supplementary information on selected topics in this dissertation.

2 The model

We construct an one-sector dynamic general equilibrium model where time is infinite and take discrete values. In the economy, there are two types of representative households, representative firms and a government. One group of households is assumed to be skilled workers that have college education, while the other consists of unskilled workers with no college education. Skilled workers are more productive as opposed to unskilled workers. Both parties supply labour to the firms and earn wages. In addition, households own capital and incur transaction costs for participating in capital markets. It is presumed that unskilled workers have higher transaction costs and the latter comprise an additional source of heterogeneity among them.

Firms produce a homogeneous good by using capital and hiring labour from skilled and unskilled labour. A Cobb-Douglas production function is employed that can capture capital-skill complementarity, as well as the different role the productivities of each type of labour play in output. There will therefore be a skill premium and it is defined as the wage of skilled labour divided by the wage of unskilled labour.

With regards to the government, it can influence households' utility through government consumption. At its disposal, there exist three main tax policy instruments: a) consumption tax, b) capital income tax and c) labour income tax. In addition, it is assumed that the government runs a balanced budget constraint and total tax revenues are used to finance its only available activity: public consumption.

Finally, each firm acts in a competitive environment and earn zero economic profits whereas households maximise their utility by taking factor prices and policy as given.

The total population size of the economy is indexed by $i = 1, 2, \dots, N$ and consists of two sub-populations: a) the population size of the skilled workers indexed by $p^h = 1, 2, \dots, N^h$ and b) the population size of the unskilled workers indexed by $p^l = 1, 2, \dots, N^l$. We assume that $N^h < N^l$ and for convenience, we work with population shares when it comes for calibration. Consequently, $n^h \equiv N^h/N$, $n^l \equiv N^l/N$ and $1 \equiv n^h + n^l$. For simplicity, it is assumed

$N^f = N$ meaning that each worker have ownership on one firm. Lastly, the population shares do not exhibit growth and are exogenous.

2.1 Private sector and skilled workers

For each representative infinitively-lived household $p^h = 1, 2, \dots, N^h$ the expected lifetime utility is given by:

$$E_o \sum_{t=0}^{\infty} \beta^t U(C_t^h, L_t^h, \overline{G}_t) \quad (1)$$

where E_o is the expectations operator and it is conditional on all the information contained at time zero, β^t is the subjective rate of time preference $0 < \beta < 1$ and C_t^h, L_t^h are consumption and leisure at time t , respectively. However, C_t^h is composite consumption $C_t^h \equiv C_t^h + \varphi \overline{G}_t$ where $\overline{G}_t = G_t/N$ stands for per capita utility that p^h households acquire from government consumption and $\varphi \in [-1, 1]$ measures the influence of government consumption relatively to consumption.⁴ At each time, each household has endowment of one unit of time which allocate between labour and leisure. For simplicity, we normalise the total time endowment of each household to 1, so that we can denote leisure as $L_t^h \equiv 1 - e_t^h$ and state the total time constraint as $L_t^h + e_t^h = 1$. Composite consumption and leisure enter the utility in a non-separable way and the per period instantaneous utility function $U : \mathbb{R}_+^2 \rightarrow \mathbb{R}$ has log-linear form:

$$U(C_t^h, L_t^h, \overline{G}_t) = \frac{\left[(C_t^h + \varphi \overline{G}_t)^\gamma (L_t^h)^{1-\gamma} \right]^{1-\sigma} - 1}{1-\sigma} \quad (2)$$

is continuous, strictly increasing on \mathbb{R}_+^2 , twice continuously differentiable on \mathbb{R}_{++}^2 , strictly concave in its arguments (\mathbb{R}_{++}^2), bounded with partial derivatives satisfying the lnada conditions. The parameter $\gamma > 0$ represents the weight placed on leisure relative to consumption. $\sigma \geq 0$ is the coefficient of relative risk aversion attached to U and can be interpreted as the smaller its value is, the higher the willingness of each household is to substitute consumption against leisure across time.

In each period, each household earn labour income $w_t^h e_t^h$ and capital income $r_t K_t^h$, where w_t^h is the wage rate being offered to a high ability worker

⁴If $\varphi > 0$ private and public consumption are substitutes. If $\varphi < 0$ private and public consumption are complements, if $\varphi = 0$, \overline{G}_t has no effect on household's utility and if $\varphi = 1$ there are perfect substitutes.

for supplying labour e_t^h to a firm whereas r_t is the return to capital. Investment I_t^h can be considered as savings in the form of physical capital K_t^h and the latter is subject to a constant linear depreciation rate $0 < \delta < 1$. In addition, each p^h household incurs a cost of holding capital which it is assumed to take the form of a convex quadratic function $\psi^h (K_t^h)^2$. $\psi^h > 0$ denotes the magnitude of the transactions costs that can exist due to market/government regulations, among others⁵. Thus, at each time t the budget constraint assuming away dividend holdings is given by:⁶

$$(1 + \tau_t^c)C_t^h + K_{t+1}^h = (1 - \tau_t^l)w_t^h e_t^h + (1 - \delta)K_t^h + (1 - \tau_t^k)r_t K_t^h - \psi^h (K_t^h)^2 \quad (3)$$

where K_t^h is the beginning-of-period public physical capital stock at time $t + 1$ and it is predetermined, while $0 \leq \tau_t^c, \tau_t^l, \tau_t^k < 1$ are tax rates on consumption, labour income and capital income, respectively.⁷ Capital stock is being accumulated according to:

$$K_{t+1}^h = I_t^h + (1 - \delta)K_t^h, \quad \forall t > 0 \quad (4)$$

It is worth mentioning that the transactions costs are present in the steady state.⁸

Each household chooses a sequence $\{C_t^h, e_t^h, K_{t+1}^h\}_{t=0}^\infty$ to maximise (1) constrained by (3) and the total time constraint $L_t^h + e_t^h = 1$, by taking factor prices $\{w_t^h, w_t^l, r_t\}_{t=0}^\infty$, policy instruments $\{\tau_t^c, \tau_t^l, \tau_t^k, \overline{G}_t\}_{t=0}^\infty$ and the initial condition for K_o^h as given. The Lagrangian, after subbing $L_t^h = 1 - e_t^h$ into (2), is formed as:⁹

$$L = E_o \sum_{t=0}^{\infty} \left\{ \beta^t U(C_t^h, e_t^h, \overline{G}_t) + \lambda_t \left[\begin{aligned} &(1 - \tau_t^l)w_t^h e_t^h + (1 - \delta)K_t^h + \\ &\quad + (1 - \tau_t^k)r_t K_t^h - \\ &- \psi^h (K_t^h)^2 - K_{t+1}^h - (1 + \tau_t^c)C_t^h \end{aligned} \right] \right\} \quad (5)$$

⁵From micro perspective, this formation of the transactions costs can be deemed as an ad-hoc assumption. However, it allows to introduce heterogeneity in capital holdings and also to avoid having an under-identified system.

⁶Assuming that households do not hold private shares does not affect the analysis because as it is shown in the section of the firms and in Appendix, factor prices earn their marginal product and in equilibrium, profits are zero.

⁷ K_o is considered as given in our analysis. The same applies to e_o, C_o . All of these are positive, as the domain of the utility indicates.

⁸The usefulness of it is that in the long-run the Euler equations of both types of workers are not reduced to one.

⁹We can use the Lagrangian maximisation method because the utility function is strictly increasing in its arguments and as a result, household's budget constraint holds with equality, otherwise we would have used the Kuhn-Tucker approach.

where λ_t is the non-negative Lagrange multiplier associated with the household's budget constraint. The first-order conditions (FOCs) are:

$$\frac{\partial L}{\partial C_t^h} = \beta^t \frac{\gamma \left[(C_t^h + \varphi \overline{G}_t)^\gamma (1 - e_t^h)^{1-\gamma} \right]^{1-\sigma}}{(C_t^h + \varphi \overline{G}_t)} = \lambda_t (1 + \tau_t^c) \quad (6)$$

$$\frac{\partial L}{\partial e_t^h} = \beta^t \frac{(1 - \gamma) \left[(C_t^h + \varphi \overline{G}_t)^\gamma (1 - e_t^h)^{1-\gamma} \right]^{1-\sigma}}{(1 - e_t^h)} = \lambda_t [(1 - \tau_t^l) w_t^h] \quad (7)$$

$$\frac{\partial L}{\partial K_{t+1}^h} = -\lambda_t + E_t [\lambda_{t+1} (1 - \delta + (1 - \tau_{t+1}^k) r_{t+1} - 2\psi^h K_{t+1}^h)] \quad (8)$$

Dividing (6) and (7) we obtain the intratemporal labour supply equation:

$$\frac{(1 - \gamma) (C_t^h + \varphi \overline{G}_t)}{\gamma (1 - e_t^h)} = \frac{[(1 - \tau_t^l) w_t^h]}{(1 + \tau_t^c)} \quad (9)$$

which is an optimality condition and states that p^h households should be indifferent between L_t^h and C_t^h as long as the ratio of after-tax wage and adjusted consumption remains constant over time. Combining (6) and (8) we have an intertemporal condition, the well-known Euler equation (EE):

$$\begin{aligned} & \frac{\left[(C_t^h + \varphi \overline{G}_t)^\gamma (1 - e_t^h)^{1-\gamma} \right]^{1-\sigma}}{(1 + \tau_t^c) (C_t^h + \varphi \overline{G}_t)} = \\ & = \beta E_t \left\{ \frac{\left[(C_{t+1}^h + \varphi \overline{G}_{t+1})^\gamma (1 - e_{t+1}^h)^{1-\gamma} \right]^{1-\sigma} (1 - \delta + (1 - \tau_{t+1}^k) r_{t+1} - 2\psi^h K_{t+1}^h)}{(1 + \tau_{t+1}^c) (C_{t+1}^h + \varphi \overline{G}_{t+1})} \right\} \end{aligned} \quad (10)$$

which states that skilled workers equate the marginal utility at time t with the discounted expected marginal utility at time $t + 1$.

To complete the analysis and rule out infinite capital accumulation, we need to impose the transversality condition $\lim_{t \rightarrow \infty} \beta^t E_t \frac{\partial U(\cdot)}{\partial C_t^h} K_{t+1}^h = 0$.¹⁰

2.2 Private sector and unskilled workers

The setup of the unskilled workers is modelled similarly to the unskilled workers but the main difference is that for each household $p^l = 1, 2, \dots, N^l$ the magnitude of the transactions costs $\psi^l > 0$ is higher for p^l households since

¹⁰The transversality condition is both necessary and sufficient in order to have a well-defined maximisation problem. This stems from the concavity of households' utility.

they are supposed to be the low-income group in the economy. Thus, unskilled workers face more barriers to access capital. The total time constraint is $L_t^l \equiv 1 - e_t^l$, the expected temporal utility function and budget constraint of unskilled workers are respectively:

$$E_o \sum_{t=0}^{\infty} \beta^t \left\{ \frac{\left[(C_t^l + \varphi \overline{G}_t)^\gamma (1 - e_t^l)^{1-\gamma} \right]^{1-\sigma} - 1}{1 - \sigma} \right\} \quad (11)$$

$$(1 + \tau_t^c)C_t^l + K_{t+1}^l = (1 - \tau_t^l)w_t^l e_t^l + (1 - \delta)K_t^l + (1 - \tau_t^k)r_t K_t^l - \psi^l (K_t^l)^2, \quad \forall t > 0 \quad (12)$$

Equation (12) reads as follows: each unskilled worker supply labour e_t^l to a firm and earn wage w_t^l . Moreover, households own physical capital K_t^l which has return r_t , depreciates at a constant linear rate $0 < \delta < 1$ and in addition, they incur transaction costs $\psi^l > 0$ due to capital holdings. Capital can be rented out to the firms and for that, p^l households receive capital income $r_t K_t^l$. The law of capital accumulation is:

$$K_{t+1}^l = I_t^l + (1 - \delta)K_t^l, \quad \forall t > 0 \quad (13)$$

Each household chooses a sequence $\{C_t^l, e_t^l, K_{t+1}^l\}_{t=0}^{\infty}$ to maximise (11) constrained by (12) and the total time constraint $L_t^l + e_t^l = 1$, by taking factor prices $\{w_t^h, w_t^l, r_t\}_{t=0}^{\infty}$, policy instruments $\{\tau_t^c, \tau_t^l, \tau_t^k, \overline{G}_t\}_{t=0}^{\infty}$ and the initial condition for K_o^l as given. The Lagrangian and FOCs are presented below:

$$L = E_o \sum_{t=0}^{\infty} \left\{ \beta^t U(C_t^l, e_t^l, \overline{G}_t) + \lambda_t \left[\begin{array}{l} (1 - \tau_t^l)w_t^l e_t^l + (1 - \delta)K_t^l + \\ + (1 - \tau_t^k)r_t K_t^l - \\ - \psi^l (K_t^l)^2 - K_{t+1}^l - (1 + \tau_t^c)C_t^l \end{array} \right] \right\} \quad (14)$$

FOCs:

$$\frac{\partial L}{\partial C_t^l} = \beta^t \frac{\gamma \left[(C_t^l + \varphi \overline{G}_t)^\gamma (1 - e_t^l)^{1-\gamma} \right]^{1-\sigma}}{(C_t^l + \varphi \overline{G}_t)} = \lambda_t (1 + \tau_t^c) \quad (15)$$

$$\frac{\partial L}{\partial e_t^l} = \beta^t \frac{(1 - \gamma) \left[(C_t^l + \varphi \overline{G}_t)^\gamma (1 - e_t^l)^{1-\gamma} \right]^{1-\sigma}}{(1 - e_t^l)} = \lambda_t [(1 - \tau_t^l)w_t^l] \quad (16)$$

$$\frac{\partial L}{\partial K_{t+1}^l} = -\lambda_t + E_t [\lambda_{t+1} (1 - \delta + (1 - \tau_{t+1}^k)r_{t+1} - 2\psi^l K_{t+1}^l)] \quad (17)$$

where from (15), (16) we obtain the labour-supply decision of the unskilled workers and from (15), (17) the Euler equation, respectively:

$$\frac{(1 - \gamma) (C_t^l + \varphi \overline{G}_t)}{\gamma (1 - e_t^l)} = \frac{[(1 - \tau_t^l)w_t^l]}{(1 + \tau_t^c)} \quad (18)$$

$$\begin{aligned}
& \frac{\left[(C_t^l + \varphi \overline{G}_t)^\gamma (1 - e_t^l)^{1-\gamma} \right]^{1-\sigma}}{(1 + \tau_t^c) (C_t^l + \varphi \overline{G}_t)} = \\
& = \beta E_t \left\{ \frac{\left[(C_{t+1}^l + \varphi \overline{G}_{t+1})^\gamma (1 - e_{t+1}^l)^{1-\gamma} \right]^{1-\sigma} (1 - \delta + (1 - \tau_{t+1}^k) r_{t+1} - 2\psi^l K_{t+1}^l)}{(1 + \tau_{t+1}^c) (C_{t+1}^l + \varphi \overline{G}_{t+1})} \right\}
\end{aligned} \tag{19}$$

Equation (18) states that p^l households should be indifferent between L_t^l and C_t^l as long as the ratio of after-tax wage and adjusted consumption remains constant over time and equation (19) is the optimality condition for allocating consumption across periods.

To preclude infinite capital accumulation, we impose the transversality condition $\lim_{t \rightarrow \infty} \beta^t E_t \frac{\partial U(\cdot)}{\partial C_t^l} K_{t+1}^l = 0$.

2.3 Private firms

Each price-taking firm $f = 1, 2, \dots, N^f$ chooses to hire labour and capital from both high- and low-skilled workers in order to produce a homogenous final product Y_t^f .¹¹ In particular, private firms target to maximise profits:¹²

$$\max_{\{K_t^f, e_t^{h,f}, e_t^{l,f}\}_{t=0}^\infty} \Pi_t^f = Y_t^f - r_t K_t^f - w_t^h e_t^{h,f} - w_t^l e_t^{l,f} \tag{20}$$

subject to a constant-return-to-scale (CRTS) Cobb-Douglas production function $Y_t^f : \mathbb{R}_+^2 \rightarrow \mathbb{R}_+$:

$$Y_t^f = Z_t \left(K_t^f \right)^{\alpha_1} \left(e_t^{h,f} \right)^{\alpha_2} \left(e_t^{l,f} \right)^{\alpha_3} \tag{21}$$

where $Z_t > 0$ is the Total Factor Productivity (TFP) and it is presumed to follow an exogenous univariate stochastic $AR(1)$ process:

$$Z_t = \rho^Z Z_{t-1} + \varepsilon_t^Z \tag{22}$$

The correlation coefficient ρ^Z take values such that $|\rho^Z| < 1$ and $\varepsilon_t^Z \sim i.i.d.N(0, 1)$ is a white-noise shock. In addition, K_t^f denotes the capital stock employed by each firm f , and $e_t^{h,f}$, $e_t^{l,f}$ reflect the amount of labour of the skilled and unskilled workers that each firm hire respectively. $\alpha_1 \in (0, 1)$ is the capital share of output, $\alpha_2 \in (0, 1)$ and $\alpha_3 \in (0, 1)$ are respectively the skilled and unskilled workers labour's share of output or their productivities. The

¹¹The aggregate output is $Y_t = N_t^f Y_t^f$.

¹² P_t does not appear in front of the production function. It equals one in a Walrasian economy.

assumption of CRTS means that: $\alpha_1 + \alpha_2 + \alpha_3 = 1$. From the firm's static maximisation problem we can obtain the factor prices.

FOC with respect to r_t :

$$\frac{\partial \Pi_t^f}{\partial K_t^f} = Z_t \alpha_1 \left(K_t^f\right)^{\alpha_1-1} \left(e_t^{h,f}\right)^{\alpha_2} \left(e_t^{l,f}\right)^{\alpha_3} = r_t \quad (23)$$

$$r_t = \alpha_1 \frac{Y_t^f}{K_t^f} \quad (24)$$

which is the return to capital and equals its marginal product.

FOC with respect to w_t^h :

$$\frac{\partial \Pi_t^f}{\partial e_t^{h,f}} = Z_t \alpha_2 \left(K_t^f\right)^{\alpha_1} \left(e_t^{h,f}\right)^{\alpha_2-1} \left(e_t^{l,f}\right)^{\alpha_3} = w_t^h \quad (25)$$

$$w_t^h = \alpha_2 \left(\frac{Y_t^f}{e_t^{h,f}}\right) \quad (26)$$

which is the wage rate being offered to a skilled worker and equals its marginal product.

Finally, the FOC with respect to w_t^l :

$$\frac{\partial \Pi_t^f}{\partial e_t^{l,f}} = Z_t \alpha_3 \left(K_t^f\right)^{\alpha_1} \left(e_t^{h,f}\right)^{\alpha_2} \left(e_t^{l,f}\right)^{\alpha_3-1} = w_t^l \quad (27)$$

$$w_t^l = \alpha_3 \left(\frac{Y_t^f}{e_t^{l,f}}\right) \quad (28)$$

These three optimality conditions (24),(26) and (28) imply that in equilibrium, factor prices earn their marginal products and profits are equal to zero (no-arbitrage conditions).¹³ The capital-skill complementarity hypothesis, which is deemed as the major driving force of the skill premium, is incorporated into the marginal product of each of the two types of workers in a sense that skilled workers have higher marginal product than the unskilled. Hence, this results in a skill premium, defined as w_t^h/w_t^l , higher than one. Furthermore, *ceteris paribus*, the skill premium increases if the ratio of unskilled to skilled hours worked increase as well since $w_t^h/w_t^l = \alpha_2 e^l / \alpha_3 e^h$.

¹³See Appendix for a short proof of it.

2.4 Government budget constraint

Following the studies of Giannitsarou (2006) and Garcia-Mila *et al.* (2010) we do not include each of the three main components of government spending¹⁴. It is assumed that it takes the form of government consumption. Thus, in each period total public consumption $\overline{G}_t N$ is financed by taxes on consumption $\tau_t^c(N^h C_t^h + N^l C_t^l)$, on capital income $\tau_t^k(r_t N^h K_t^h + r_t N^l K_t^l)$ and on labour income $\tau_t^l(w_t^h N^h e_t^h + w_t^l N^l e_t^l)$. In absence of government debt it is assumed that the government runs a balanced budget. Hence, the per agent government budget constraint is:

$$\begin{aligned} \overline{G}_t = & \tau_t^c(n^h C_t^h + n^l C_t^l) + \\ & + \tau_t^l(w_t^h n^h e_t^h + w_t^l n^l e_t^l) \\ & + \tau_t^k(r_t n^h K_t^h + r_t n^l K_t^l) \end{aligned} \quad (29)$$

where $\tau_t^c, \tau_t^l, \tau_t^k$ are exogenously set and \overline{G}_t is residually adjusted to balance the budget constraint.

2.5 Market-clearing conditions

Total market supply must equal total market demand in order to close our model. Below, the market-clearing conditions are reported:

In the labour market:

$$e_t^{h,f} = n^h e_t^h \quad (30)$$

$$e_t^{l,f} = n^l e_t^l \quad (31)$$

In the capital market:

$$K_t^f = n^h K_t^h + n^l K_t^l \quad (32)$$

In the goods market:

$$Y_t^f = n^h C_t^h + n^l C_t^l + n^h I_t^h + n^l I_t^l + n^h \psi^h (K_t^h)^2 + n^l \psi^l (K_t^l)^2 + \overline{G}_t \quad (33)$$

2.6 Decentralised competitive equilibrium

Given the initial conditions for K_o^h, K_o^l , the paths of the three policy instruments $\{\tau_t^c, \tau_t^l, \tau_t^k\}_{t=0}^\infty$, the TFP $\{Z_t\}_{t=0}^\infty$ and population shares n^f, n^h, n^l the decentralised competitive equilibrium (DCE) comprises a vector of prices $\{r_t, w_t^h, w_t^l\}_{t=0}^\infty$, quantities $\{C_t^h, C_t^l, e_t^h, e_t^l, K_{t+1}^h, K_{t+1}^l, K_t^f, e_t^{l,f}, e_t^{h,f}, Y_t^f\}_{t=0}^\infty$ and

¹⁴In models that incorporate public sector the main governments components are five since total wage bill and government transfers to public employees, are included.

the endogenously determined policy instrument $\{\overline{G}_t\}_{t=0}^{\infty}$ such that a) the quantities solve the households' maximisation problem, b) firms maximise profits operating in a competitive market, c) the government budget constraint is satisfied for any feasible policy and d) all markets clear. There are thirteen endogenous variables and therefore, the DCE is a system of thirteen non-linear equations with rational expectations. In addition, there is no growth in the economy and variables are expressed in per agent terms by definition. For convenience, we substitute out the variables $K_t^f, e_t^{l,f}, e_t^{h,f}$ with the market-clearing quantities and thus, at each time t , the DCE is described by eleven equations-unknowns $\left\{C_t^h, C_t^l, e_t^h, e_t^l, K_{t+1}^h, K_{t+1}^l, Y_t^f; r_t, w_t^h, w_t^l\right\}_{t=0}^{\infty}$. In particular, we use the intratemporal and intertemporal conditions of the skilled and unskilled workers, the budget constraint of the skilled workers, the production function, the government budget constraint, the aggregate resource constraint and we substitute out the factor returns with the first-order conditions for $K_t^f, e_t^{h,f}$ and $e_t^{l,f}$.¹⁵

2.7 Calibration

The model is calibrated to reflect the main characteristics of the Greek economy. Data averages are extracted from the study of Papageorgiou *et al.* (2011), unless otherwise explicitly stated, who employ quarterly data at constant 1995 prices for the period 1960:1-2005:4.

Therefore, we set the physical capital depreciation rate δ equal to 0.0070 (0.0279 annually). Regarding the discount factor, there exists two widely used approaches for calibrating β . On one hand, β is set at a value that match the K/Y ratio observed in the data and it is calibrated from the Euler equation. The second approach is to use the following formula $\beta = 1/r + 1$ and set r equal to the ex-post real interest rate. We employ the second method as there is no data for the transaction costs. Then, setting $r = 0.011$ which is the value of the real interest rate for government bonds, β is found to be 0.9891. In turn, we use that value and the Euler equations (10), (19) to calibrate the transaction costs of the skilled and unskilled workers, for a given value of capital-to-output ratio $K^f/Y^f = 15.7364$. Then, the transactions costs are found to be $\psi^h = 0.0001$ and $\psi^l = 0.0002$.

The total labour share is set at 0.5715 as that of Papageorgiou and Kazanas (2013). Similar values are reported in Gogos *et al.* (2012) and Papageorgiou (2012). Skilled labour share α_2 is set at 0.3425 and α_3 is resid-

¹⁵Resorting to the Walras's law, we drop the budget constraint of the unskilled workers. This stems from the fact that if $N - 1$ markets clear then, all clear as well. Additionally, to save space, we summarise the DCE equations in Appendix.

ually calibrated as $\alpha_3 = 0.5715 - \alpha_2$. The former is the average value for high- and medium-skilled labour compensation over the period 1995-2009 and the dataset employed is that of EU KLEMS. Capital's share of output α_1 is calibrated as $\alpha_1 = 1 - \alpha_2 - \alpha_3$ and equals 0.4285. The long-run productivity Z is set equal to 1. Regarding the $AR(1)$ components of Z_t we set $\rho^Z = 0.6700$ and $\sigma_Z = 0.0171$. Similar values are also chosen in Papageorgiou and Kazanas (2013).

With regards to fiscal policy instruments, effective tax rates on capital income, labour income and consumption are those found in Papageorgiou and Kazanas (2013) and their values are respectively $\tau^k = 0.21$, $\tau^l = 0.31$ and $\tau^c = 0.16$. These are data averages over the period 2000:1- 2011:4. The selection of that period instead of 1960:1-2005:4 is two-fold: a) to capture relatively recent trends in the Greek tax system and b) to serve the purpose of our fiscal policy experiments (e.g. distributional issues) since the outburst of the Greek crisis in 2009-10, taxes are being edging up. Following most of the RBC literature, the influence of government consumption on households utility φ is set at 0.1. Finally, government consumption share $s^g = \overline{G_t}/Y^f$ is set at 0.1469 when it comes for calibration purpose.

The weight on consumption γ relative to leisure is calibrated for a given value of time allocation $e^h = e^l = 0.20$ and is set at 0.3607, which is the mid-point value of γs obtained from the steady-state version of households labour supply equations.¹⁶ That value is numerically very close to the values that have been found in relevant studies, such as Papageorgiou (2009) and Papageorgiou and Kazanas (2013). The weight on leisure is then residually calibrated as $1 - \gamma = 0.6393$. In addition, the curvature parameter σ is set equal to 2 as it is usual practice in the DGE literature. The population shares of skilled and unskilled workers are respectively set at $n^h = 0.4$ and $n^l = 0.6$. Since we assume that households invest in the form of savings a reasonable way which is widely used in the literature, is to look for evidence on the percentage of households that have or have not savings within certain levels of money. However, the Greek Household Budget Survey does not allow for that kind of information. Thus, as noted in the description of the model we assume $n^h < n^l$.

One issue besides the measurement of the transaction costs refers to the skill premium. Although, there are very few references on it for Greece the study of Chassamboulli and Palivos (2013) use as skill premium the value 1.482 which has been taken from the empirical paper Prodromidis and Prodromidis (2008), in order to calibrate a version of the Diamond-Mortensen-

¹⁶In the study, the total time endowment is assumed to be $(365) \times (15 \text{ hours per day}) = 1369$ hours per quarter.

Pissarides model. The skill premium is obtained from regressions over 1988-1999. However, there is no distinction between very high (e.g. PhD) and high education. As it usual practice to define the skill premium as the ratio amongst those who have a BA and those who have not, we look for more detailed studies. Thus, we follow the study of Livanos and Pouliakas (2011) who employ micro-data from the Greek Labour Force Survey (2002-2003) and also, present a thorough distinction of labour education returns. The skill premium is then found to be $w^h/w^l = 978/850 = 1.1505$. The skill premium that the model's solution provides is 1.1769. It worth mentioning, that the analysis above can be deemed as a robust way of calibrating the skill premium. For instance, an alternative way of matching the skill premium is to find these values for the labour shares of output that correspond to the skill premium observed in data. However, in our model we use the dataset of EU KLEMS for the α s and then begin our calibration. The following table concisely reports the values for the parameters.

Table 1: Calibration

Parameter	Description	Value
$0 \leq \delta^h \leq 1$	Capital depreciation rate of skilled workers	0.0070
$0 \leq \delta^l \leq 1$	Capital depreciation rate of unskilled workers	0.0070
$0 < \beta < 1$	Discount factor of households	0.9891
$\sigma \geq 0$	Curvature of the utility function	2
$0 < n^h < 1$	Population share of skilled workers	0.4
$0 < n^l < 1$	Population share of unskilled workers	0.6
$0 < \alpha_1 < 1$	Capital's share of output	0.4285
$0 < \alpha_2 < 1$	Skilled labour's share of output	0.3425
$0 < \alpha_3 < 1$	Unskilled labour's share of output	0.2290
$\gamma > 0$	Weight of consumption	0.3607
$1 - \gamma > 0$	Weight of leisure	0.6393
Z	Long-run Productivity	1
$\psi^h > 0$	Transaction costs of skilled workers	0.0001
$\psi^l > 0$	Transaction costs of unskilled workers	0.0002
$0 \leq \tau^k < 1$	Tax rate on capital income	0.21
$0 \leq \tau^l < 1$	Tax rate on labour income	0.31
$0 \leq \tau^c < 1$	Tax rate on consumption	0.16
$0 < \rho^Z < 1$	Persistence of Z_t	0.6700
$\sigma_Z > 0$	Standard deviaton of ε_t^Z	0.0171

Using the parameter values from Table 1 we can obtain the long-run solution of the model in which tax instruments are kept at their sample averages. Table 2 below, collates the steady-state values of the model with data averages.

Table 2: Data averages and steady-state values

Parameter	Data average	Value
$\frac{n^h C^h + n^l C^l}{Y^f}$	0.6472	0.7301
$n^h C^h / Y^f$	N.A.	0.4412
$n^l C^l / Y^f$	N.A.	0.2889
K^f / Y^f	15.7364	13.9458
$n^h K^h / Y^f$	N.A.	7.9690
$n^l K^l / Y^f$	N.A.	5.9768
e	0.20	0.2027
e^h	N.A.	0.2073
e^l	N.A.	0.1997
w^h	N.A.	2.6015
w^l	N.A.	2.2104
w^h / w^l	1.1505	1.1769
$\frac{w^h n^h e^h + w^l n^l e^l}{Y^f}$	N.A.	0.5624
r	0.011	0.027
s^g	0.1469	0.3475
TR / Y^f	0.2916	0.3187

Notes: TR and N.A. denote total tax revenues and non-available respectively

e denotes the weighted average of e s: $e = n^h e^h + n^l e^l$

Even though there are no data averages for some great ratios in order to perform comparisons, Table 2 suggests that the pre-tax reform long-run solution of the model is in line with data.

It is worth reporting that wage-to-output ratio for countries like Greece is around 60% based on evidence from OECD. Additionally, as noted above, we only model government consumption. In reality, government spending in Greece amounts to around 35% – 40%. Therefore, we can consider the above status quo as a benchmark model and start experimenting with various fiscal policy structures. Additionally, we mention that the long-run solution satisfies the Blanchard-Kahn conditions for a saddle-path.

3 Policy experiments and results

In this section, we perform policy experiments that are budget-neutral, report the long-run and welfare effects of each policy and ultimately, state the results. In particular, we examine different scenarios where a 1% permanent reduction in each one of the following distortionary tax rates τ^k, τ^l, τ^c is compensated by a 1% permanent increase in one of the residually-adjusted tax rates. Therefore, it is assumed that the economy is in the pre-tax reform

equilibrium and then, we change one of the exogenous tax instruments and allow one of the remaining two to adjust to balance the government budget constraint. We classify each experiment i as P_i . Table 3 below, summarises the quantitative results of our scenarios under various tax mix.

Table 3: Policy experiments under various tax regimes

Policy i	τ^k	τ^l	τ^c
Pre-tax reform values	0.21	0.31	0.16
P_1 : 1% decrease in τ^k met by an increase in τ^l	0.20	0.3172	0.16
P_2 : 1% decrease in τ^k met by an increase in τ^c	0.20	0.31	0.1656
P_3 : 1% decrease in τ^l met by an increase in τ^k	0.2231	0.30	0.16
P_4 : 1% decrease in τ^l met by an increase in τ^c	0.21	0.30	0.1676
P_5 : 1% decrease in τ^c met by an increase in τ^k	0.2270	0.31	0.15
P_6 : 1% decrease in τ^c met by an increase in τ^l	0.21	0.3228	0.15

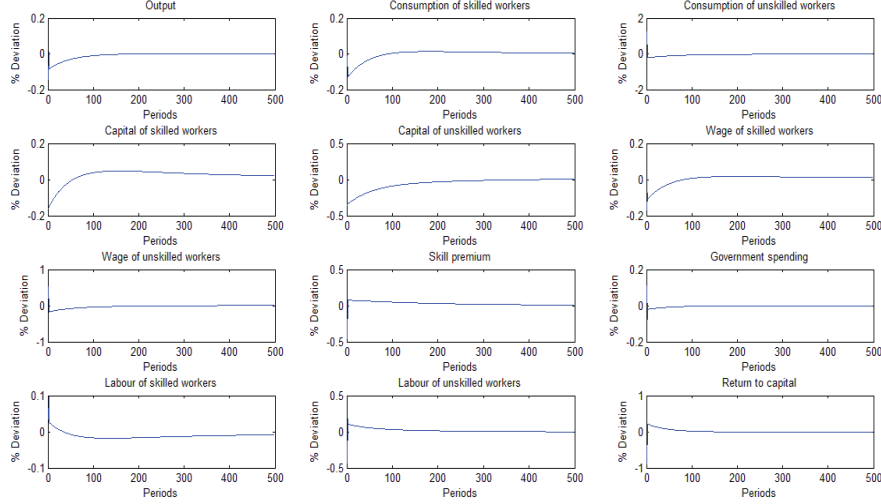
For each policy we plot the transitional dynamics for $T = 500$ and time T index denotes quarters. As stated above, at $T = 0$ the economy is in the benchmark equilibrium. For $T > 0$ a policy P is in effect shaping the dynamics, and at $T = 500$ it is assumed that the economy is on the path towards the new steady-state equilibrium. Alongside the dynamics, the long-run results are reported.

3.1 Transitional dynamics and long-run effects under capital income tax reduction

In this subsection, we present the transitional dynamics of P_1 and P_2 , where the residual distortionary instruments are τ^l and τ^c , respectively. We plot the dynamics for the sequence $\left\{ C_t^h, C_t^l, e_t^h, e_t^l, K_{t+1}^h, K_{t+1}^l, Y_t^f, s_t^g, w_t^h, w_t^l, w_t^h/w_t^l, r_t \right\}$. The solid line displays the dynamics as percentage deviation from the benchmark economy.

Firstly, we examine the dynamics and the long-run effects of P_1 . Figure 1, depicts the transitional paths for the above twelve variables.

Figure 1: Transitional dynamics where a decrease in capital income tax is met by an increase in labour income tax



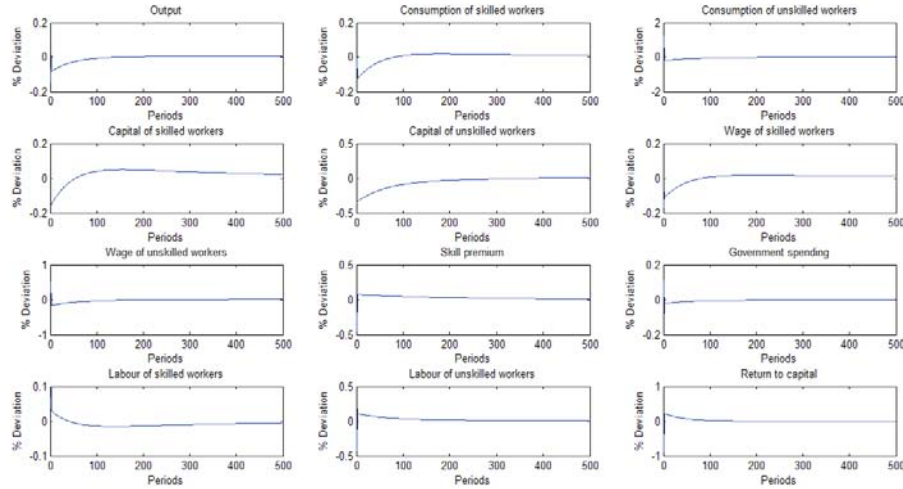
A lower capital income tax along with an increase in labour income tax results in a reduction in capital holdings for both workers in the early quarters. This means that the wealth effect of having a higher labour tax overshoots the wealth effect of having a lower capital income tax. On labour supply, there are two effects: a) the intratemporal effect and b) the intertemporal effect. From a) we know that for the skilled workers a lower wage due to a higher labour tax, leads to lower consumption and as a result, increase in labour supply. From b) a cut in capital tax makes investment more attractive in the future so that savings rise today and as a result consumption falls. This effect is reinforced by our "assumption" that $\sigma = 2$ meaning that the substitution effect is higher than the income effect. Concerning the unskilled workers, they benefit from government consumption which is increased due to the low interest rate in the first quarters and also, the income effect is more intense for them, initially. Additionally, they incur a lower opportunity cost of leisure and subsequently, there is an increase in their labour supply. In general, low total consumption induce lower consumption revenues and thus, government spending is reduced in the early quarters. Then, it slowly increases to address the low consumption of the unskilled workers (as noted above). Lastly, the skill premium is lower in the very early phases of the reform due to a) lower output and b) the reduction in the wage rate of unskilled workers, but in the following periods is edging up as total capital, output and wage rates recover from the effects of the policy.

In the long-run, the sequence $\{Y^f, w^h, w^l, w^h/w^l, K^h, K^l, e^h, e^l, C^h, C^l, s^g\}$

has values 0.25%, 0.8%, 0.7%, 0.08%, 1.2% and 1.3%, respectively. The rest of the variables are settled at lower levels.

Let us now consider the effects of P_2 where the adjustment mechanism stems from an increase in the consumption tax. Figure 2, depicts the transitional paths for this case.

Figure 2: Transitional dynamics where a decrease in capital income tax is met by an increase in consumption tax



As can be seen, the transitional paths and qualitative mechanisms remain the same as in P_1 . We only focus on the effects of the increase in the consumption tax since it is the driving force in this case. A higher tax rate on consumption induce less distortionary effects to the economy due to the fact that both households are able to smooth consumption over the infinite horizon. This stems directly from the intertemporal condition of households. The main negative impact on labour supply is from the lower marginal rate of substitution between consumption and leisure. However, this negative effect is partially offset by the wealth effect of having a higher after-tax return to investment, in the future.

In turn, the long-run effects. The consumption of high- and low-skilled workers are 0.4% and 0.2% higher compared to the pre-reform long-run equilibrium, respectively. Output, wage of skilled and unskilled workers, capital of skilled and unskilled workers are also higher by 0.5%, 0.8%, 0.6%, 1.4% and 1.5%, correspondingly. The remaining variables are below the original steady state.

Comparing policy one and two, we note higher levels of output, consumption and capital stock under P_2 . Thus, labour taxes hurt the economy and

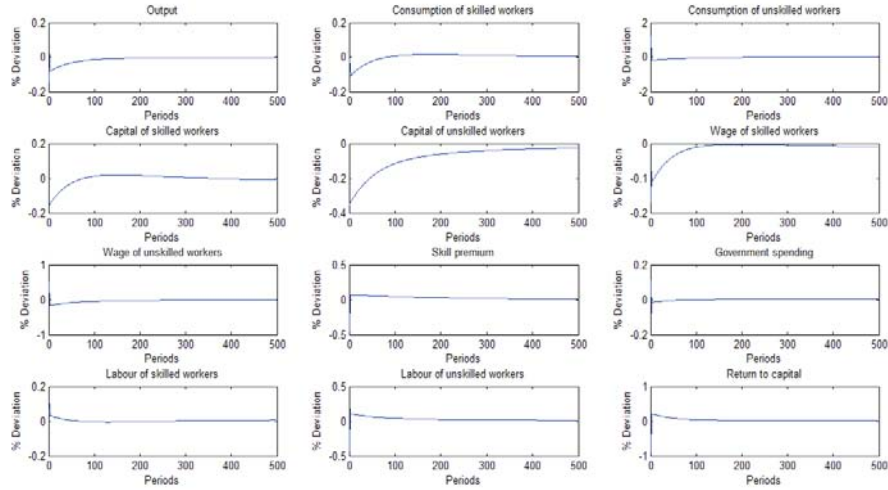
agents more than consumption taxes.

3.2 Transitional dynamics and long-run effects under labour income tax reduction

In this subsection, we present P_3 and P_4 that is, a 1% decrease in labour income tax is offset by an increase in a) capital income tax and b) consumption tax rate respectively, so that the pre-tax and post-tax budget constraints are numerically equal.

Figure 3, depicts the transitional dynamics of policy P_3 .

Figure 3: Transitional dynamics where a decrease in labour income tax is met by an increase in capital income tax



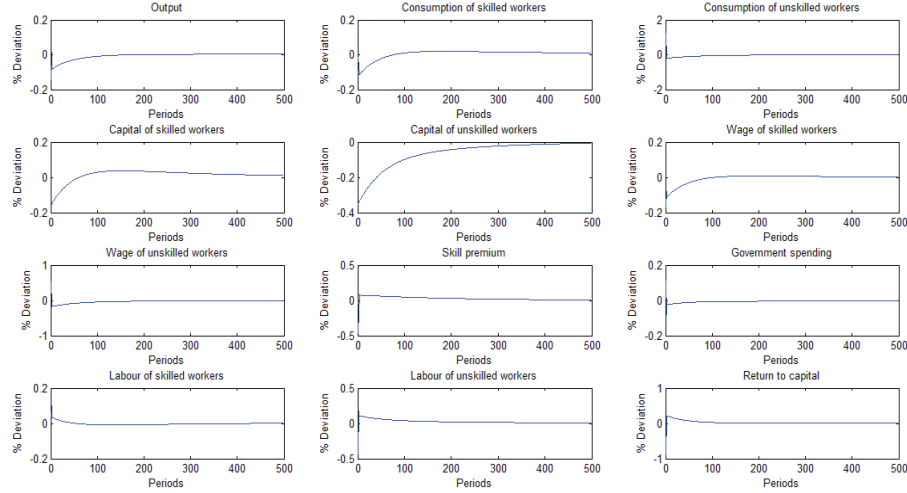
We can deduce that the unskilled workers face a strong negative welfare effect because they own lower capital than skilled workers as they incur higher transaction costs to access capital markets. Thus, a stronger reduction is noted in the early quarters, as well as a slower adjustment towards equilibrium compared to skilled workers. The substitution effects on both types of workers have the effect of increasing labour supply. The interest rates move strongly in the early quarters in order to ensure that markets clear since capital stock and output will settle at lower levels. For instance, the skill premium is relatively stable from $T = 0$ onwards. In addition, government consumption follows the movements of the interest rates in the first quarters. However, it reverts to the new steady-state path quickly since higher total

consumption allows for higher consumption tax revenues. Overall, a quick adjustment process underpins the whole economy.

The long-run effects suggest a lower level of output by 0.3% and the sequence $\{w^h, w^l, w^h/w^l, K^h, K^l, e^h, e^l, C^h, C^l, s^g\}$ has values -1% , -0.9% , -0.1% , -1.6% , -1.7% , 0.7% , 0.6% , 0.07% , 0.2% , 0.08% , respectively.

Next, we consider policy P_4 where an increase in the consumption tax residually adjusts to satisfy the government budget. Figure 4, depicts the transitional paths for this case.

Figure 4: Transitional dynamics where a decrease in labour income tax is met by an increase in consumption tax



From the intertemporal conditions we know that both households are able to smooth consumption over time. Both tax rates influence the intratemporal condition of both workers but a lower labour tax rate increase the marginal rate of substitution between consumption and leisure while the opposite is true for the case of a higher consumption tax rate. We can note the adjustment role of return to capital in the economy. In the early quarters it decreases, boosting government consumption to substitute for private consumption. Then, increases to push capital holdings and output up. Government spending is negative since lower labour income revenues can not be offset by the higher consumption revenues. In the labour market, wage rates adjust according to the underlying labour supply conditions for each type of worker. However, a lot of adjustment take place in the early quarters. This mainly depend upon whether, at each time T , the positive substitution effect

(incentive to increase labour) is lower or higher than the negative income effect (households put more weight on leisure), in magnitude. The aforementioned argument is fostered by the adjustment dynamics that can be noted in output. Ultimately, both wage rates are settled at a lower level in due course as a result of a higher labour-to-output ratio.

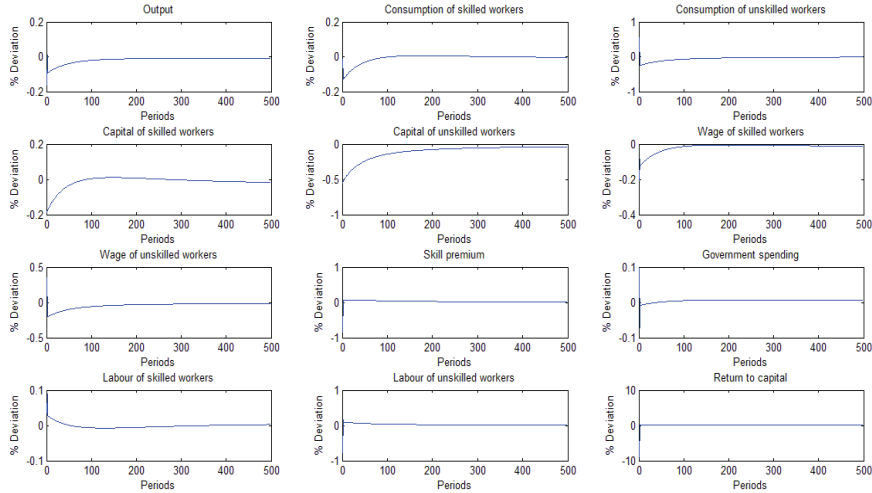
In the long-run, the sequence $\{Y^f, w^h, w^l, w^h/w^l, K^h, K^l, e^h, e^l, C^h, C^l, s^g\}$ has values above the benchmark steady state by 0.33%, -0.02%, -0.06%, 0.04%, 0.26%, 0.28%, 0.36%, 0.4%, 0.65%, 0.64%, respectively.

3.3 Transitional dynamics and long-run effects under consumption income tax reduction

In this subsection, we present P_5 and P_6 that is, a 1% decrease in consumption income tax is offset by an increase a) in capital income tax and b) in labour income tax rate respectively, so that the pre-tax and post-tax budget constraint are numerically equal.

Figure 5, portraits the transitional dynamics of policy P_5 .

Figure 5: Transitional dynamics where a decrease in consumption tax is met by an increase in capital income tax



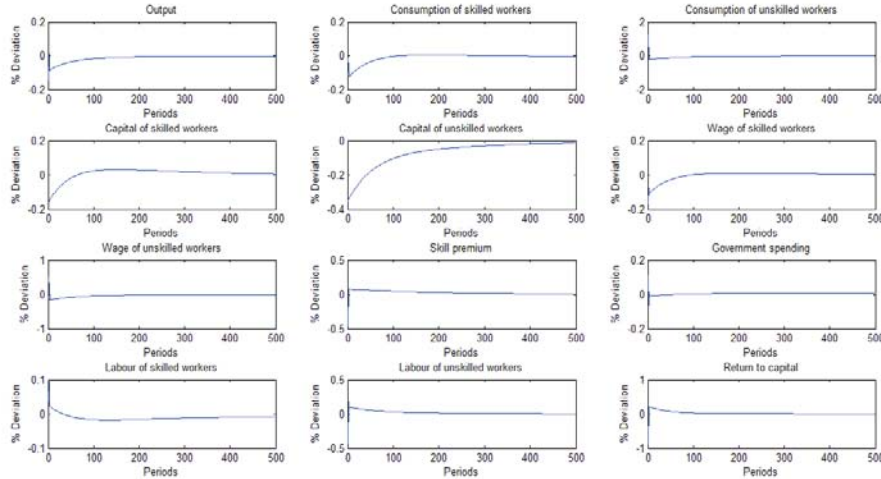
The higher capital income tax has adverse effect in capital holdings of both workers and particularly for the unskilled workers since they are the low-income group. As capital constitutes the main component in the economy, output decrease as well. The interest rate reduce in the early stages of adjustment in order to boost investment and capital accumulation. Then, it

becomes completely horizontal. This is because capital-to-output ratio is unchanged across quarters. Regarding consumption, we notice that it is optimal for the unskilled workers to consume more and work less in the early phases of the dynamic path and the opposite is true for the skilled workers. The reasoning is that consumption tax rate is reduced but capital tax is increased, widening the "capital inequality" among skilled and unskilled workers. In the labour market, in the very early quarters the marginal product of labour of the unskilled workers follow the decrease in output and the opposite is true for the skilled workers. Wage rates follow those movements in opposite directions and the skill premium is very close to the new steady state after the first 100 quarters. Government consumption shows "flexibility" on the early impact quarters and adjusts for private consumption and interest rate movements, since consumption revenues are quickly stabilised followed by a rapid recover in capital income tax revenues.

In the long-run, the sequence $\{Y^f, w^h, w^l, w^h/w^l, K^h, K^l, e^h, e^l, C^h, C^l\}$ has values compared to the benchmark steady state -0.8% , -1.3% , -1.1% , -0.1% , -2.5% , -2.6% , 0.5% , 0.3% , -0.7% , -0.4% , respectively. Return to capital and government spending are settled at 1.7% and 0.6% above the pre-tax equilibrium.

Next, we consider the policy P_6 where a decrease in consumption tax is met by an increase in labour income tax. Figure 6, depicts the transitional paths for this case.

Figure 6: Transitional dynamics where a decrease in consumption tax is met by an increase in labour income tax



The effects of this tax regime are similar to the cases where even though

a decrease in the consumption income tax has positive wealth effect across periods, heavier taxation on labour income is more distortionary for the households diminishing any positive influence of a decreased tax rate on consumption. This has negative impact on the labour supplied by both households resulting in a higher skill premium in the early quarters. Firms offer higher wages in order to hire relatively more labour but eventually, the skill premium settles at lower post-tax level. On the other hand, higher capital-to-output ratio imply a decreasing return to capital on the transitional path.

In the long-run, output, capital stock of skilled workers, capital stock of unskilled workers, labour supply of skilled and unskilled households and consumption of skilled and unskilled workers are settled at lower levels compared to the benchmark model, having values 0.4%, 0.35%, 0.38%, 0.4%, 0.5%, 0.83%, 0.82%, respectively. Wage rates are 0.03% and 0.09% higher respectively, the skill premium is lower by 0.05% and government spending is higher by 0.5%.

3.4 Steady-state welfare comparisons of each policy

In this subsection, we summarise the long-run effects of the above six policies and report the welfare gain/loss associated with each policy, at the steady state. To quantify them, we follow the literature e.g. Lucas (1990) and define a measure ω to reflect the permanent change in the composite consumption that give each type of household the same discounted utility between the pre-tax reform steady state and the post-tax reform steady-state.¹⁷ If $\omega > 0$ then households have a welfare gain by moving from pre-tax equilibrium to the post-tax and *vice versa*.

Table 5 presents the long-run and welfare effects. All variables other than utilities are expressed as percentage deviations from the pre-tax reform economy. In addition, we define total utility in a Benthamite fashion that is, $U = n^h U^h + n^l U^l$ where U^h and U^l denote the utilities of p^h and p^l households respectively.

¹⁷See Appendix for a derivation of this parameter.

Table 5: Long-run and welfare effects

Para meter	P_1 ($\downarrow \tau^k, \uparrow \tau^l$)	P_2 ($\downarrow \tau^k, \uparrow \tau^c$)	P_3 ($\downarrow \tau^l, \uparrow \tau^k$)	P_4 ($\downarrow \tau^l, \uparrow \tau^c$)	P_5 ($\downarrow \tau^c, \uparrow \tau^k$)	P_6 ($\downarrow \tau^c, \uparrow \tau^l$)
Y^f	0.250	0.499	-0.332	0.336	-0.864	-0.440
w^h	0.830	0.809	-1.092	-0.026	-1.386	0.034
w^l	0.740	0.689	-0.985	-0.069	-1.193	0.089
w^h/w^l	0.088	0.118	-0.108	0.042	-0.195	-0.055
K^h	1.278	1.477	-1.682	0.265	-2.520	-0.339
K^l	1.350	1.567	-1.770	0.290	-2.664	-0.380
e^h	-0.574	-0.307	0.768	0.363	0.529	-0.475
e^l	-0.486	-0.188	0.658	0.406	0.332	-0.530
C^h	-0.019	0.455	0.074	0.663	-0.746	-0.838
C^l	-0.169	0.295	0.268	0.650	-0.478	-0.819
r	-1.049	-1.006	1.417	0.058	1.773	-0.075
s^g	-0.125	-0.449	0.083	-0.467	0.699	0.573
U^h	-30.16	-30.05	-30.50	-30.15	-30.77	-30.52
U^l	-67.59	-67.48	-67.76	-67.50	-68.00	-67.88
U	-52.62	-52.50	-52.86	-52.56	-53.11	-52.94
ω	0.56	1.19	-0.66	0.88	-1.96	-1.09

As can be seen, policies that reduce capital income tax have strong positive welfare effects but can lead to a higher wage inequality. On the other hand, policies that decrease consumption tax rates by either increasing labour or capital tax have negative impact on welfare. In particular, P_2 where the residual instrument is a rise in consumption tax has almost twofold positive welfare effect 1.19% compared to 0.56% where the adjustment stems from an increase in labour income tax. On the other hand, P_3 creates a negative welfare effect -0.66% . By contrast, P_4 has a strong positive welfare impact 0.88% and the adjustment instrument is an increase in the consumption rate. Policies P_5 and P_6 create welfare losses -1.96% and -1.09% respectively, where a cut in consumption rate is met by an increase labour and capital income tax. Overall, the policy with the higher negative effect induced is P_3 in terms of output and welfare losses, while P_2 leads to highest possible welfare gains and output increase. These findings are conformable with the literature e.g. Forni *et al.* (2010), Domeij and Heathcote (2004), Papageorgiou (2009), (2011) and Mendoza and Tesar (1998).

For the skill premium side of things, P_4 leads to an increase of wage inequality by 0.042% but not at high levels in relation to respective increases 0.088% and 0.118% induced by P_1 and P_2 . Policy P_6 has the effect of reducing the skill premium by -0.055% as opposed to P_3 and P_5 . In particular, P_6 results in the maximum reduction in wage inequality. On the other hand, P_2

is the policy that brings about the highest increase in wage inequality 0.118% consistent with Krusell *et al.* (2000) in the sense that a lower capital income tax favours skilled workers disproportionately compared to unskilled workers and therefore, the skill premium widens. The policy that induce the larger labour income for both households is P_2 . A cut in capital holdings, is met by an increase in consumption tax. However, the intertemporal conditions indicate that households can smooth consumption across periods, and labour tax rate is unchanged. This combination has the effect of maximising labour income of households. This policy is followed by policy P_4 , a lower labour tax is met by a higher consumption tax. On the contrary, policy P_5 creates the lowest labour income for households. The above results, can be indicative of the importance of having a lower tax on capital for households' income, since there is heterogeneity in capital holdings among skilled and unskilled workers due to incurred transaction costs.

To summarise, if the tax structure is set such that to maximise the welfare gains then the combination of a cut in capital tax and either an increase in labour income tax or an increase in consumption tax, is recommended. Regarding wage inequality, policy six in which a reduction in consumption tax is offset by an increase in labour income induces the highest reduction in the skill premium. On the other hand, if we account for the transitional dynamic effects then the policy should tax labour at a lower rate and increase consumption tax as we can deduce from a comparison of Figure 1. - Figure 6. The driving force for this result is that, in general, there is a considerable delay in the materialisation of benefits whereas costs have a more direct effect. This is the case for policies that reduce capital income tax. Any positive effect on productivities due to increasing capital stock is realised at a future date. However, it appears not to be the case for policies that reduce labour tax and increase the tax rate on consumption.

3.5 Sensitivity analysis

In this subsection, we conduct sensitivity analysis regarding the transitional dynamics and long-run effects. For this purpose, we set the weight on the government consumption φ equal to zero. In absence of evidence on this parameter in the literature some studies either calibrate the model by setting the weight on the government spending equal to zero or 0.1. Thus, changing the value of φ can be considered as a sensible way of checking the robustness of our results. In addition, the economic construe of $\varphi = 0$ is that government spending does not influence the utility function of households creating disutility in the economy.

On the transitional paths, we find that there is no change in the way

the economy adjust towards the new steady state for each policy. Appendix contains all the relevant graphs.

On the long-run effects, we replicate the information provided in Table 5. All variables are measured in percentage deviations from the benchmark steady state expect for utilities, and Table 6 below reports the numerical values.

Table 6: Long-run and welfare effects where $\phi = 0$

Para meter	P_1 ($\downarrow \tau^k, \uparrow \tau^l$)	P_2 ($\downarrow \tau^k, \uparrow \tau^c$)	P_3 ($\downarrow \tau^l, \uparrow \tau^k$)	P_4 ($\downarrow \tau^l, \uparrow \tau^c$)	P_5 ($\downarrow \tau^c, \uparrow \tau^k$)	P_6 ($\downarrow \tau^c, \uparrow \tau^l$)
Y^f	0.271	0.490	-0.365	0.293	-0.852	-0.286
w^h	0.834	0.806	-1.098	-0.036	-1.382	0.047
w^l	0.723	0.687	-0.960	-0.049	-1.186	0.064
w^h/w^l	0.109	0.118	-0.138	0.012	-0.197	-0.016
K^h	1.288	1.464	-1.698	0.233	-2.500	-0.307
K^l	1.370	1.553	-1.799	0.243	-2.643	-0.320
e^h	-0.557	-0.313	0.740	0.329	0.537	-0.433
e^l	-0.448	-0.195	0.601	0.343	0.339	0.449
C^h	-0.056	0.442	0.051	0.625	-0.728	-0.790
C^l	-0.155	0.278	0.243	0.608	-0.457	-0.767
r	-1.043	-1.002	1.408	0.055	1.766	-0.071
s^g	-0.126	-0.452	0.085	-0.469	0.704	0.576
U^h	-31.24	-31.11	-31.60	-31.23	-31.89	-31.63
U^l	-73.37	-73.21	-73.55	-73.23	-73.87	-73.73
U	-56.51	-56.37	-56.77	-56.43	-57.08	-56.89
ω	0.58	1.29	-0.68	1.00	-2.13	-1.24

A key finding is that although the quantitative aspect of removing government influence from household's utility is generally slightly more profound whenever there exists a positive affect on the variables and *vice versa*, the qualitative side of the results found in the previous subsection remains quite robust.

Policy three, is still the policy that bring about the highest welfare gain 1.29%, instead of 1.19% as in section 3.4. The most severe welfare loss is created by policy three -0.68% , as opposed to -0.66% where $\varphi = 0.1$. However, policies five and six have a less negative effect in this analysis.

Concerning the skill premium, policy six induce the lowest wage inequality in the economy whereas P_2 the highest. The policy that results in the larger labour income for both households is still P_2 and P_5 creates the lowest labour income for households, as in section 3.4.

3.6 Conclusions

The purpose of this dissertation is to examine the transitional, long-run, welfare effects and distributional effects of alternative tax regimes for Greece by employing a heterogeneous agents model, in absence of any study in this setup. Tax regimes are defined as policies that result in a government budget-neutral constraint. The model is a dynamic general equilibrium that incorporates heterogeneity in two dimensions a) in capital stock by presuming higher transaction costs for unskilled labour than skilled and b) in labour productivities by assuming a higher labour share for the skilled workers compared to the unskilled. The government can influence households utility through government spending. In addition, we employ Cobb-Douglas production function that captures the capital-skill complementarity effect.

The findings indicate that policies that reduce capital income tax rate lead to a positive impact on the main macroeconomic variables. In particular, cut in capital income met by increase in labour tax induce positive effects on output, wage rates and capital holdings. Moreover, when consumption adjusts to compensate for the loss in capital revenues output, the skill premium and capital holdings settle at the highest possible levels over the long-run but both skilled and unskilled workers incur the highest loss in terms of their utilities. Therefore, capital-enhancing regimes are skilled-biased.

Policies that reduce labour income tax have opposite effects. A reduction in labour tax that is offset by an increase capital tax rate decrease output, the skill premium and capital stock is negative for both type of workers. On the contrary, when a reduction in labour tax is met by an increase in consumption tax output has increased, the skill premium is widened and capital stock is at a higher level than the pre-tax reform equilibrium.

For the skill premium side of things, the highest wage inequality is brought about under the policy where a reduction in capital income tax is accompanied by an increase in consumption tax rate. In contrast, the policy in which a cut in consumption tax is accompanied by a rise in labour income tax leads to the maximum reduction in the skill premium.

Regarding welfare effects, if policy is concerned about maximising the long-run welfare effects then the suggested policy is to reduce capital income tax and offset for the loss in capital revenues by increasing the tax rate on consumption. This policy is followed by the policy where the tax structure is to reduce labour income tax and meet the total tax revenues neutrality by an increase in consumption tax rate. These findings are in line with empirical evidence that suggest avoid taxing capital over the medium and long-term horizon.

To the contrary, if policy is keen to take into consideration the transitional

dynamics towards equilibrium then it should reduce the tax rate on labour income and balance the budget constraint by an increase in the consumption tax.

The aforementioned findings, can be useful from a policy-making perspective and especially the distributional implications since Greece has to follow a strong fiscal consolidation programme in the ongoing financial crisis.

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4 Appendix

4.1 Zero economic profits

This appendix provides a short proof on the zero economic profits hypothesis. Each price-taking firm maximises the following equation:

$$\Pi_t^f = Y_t^f - r_t K_t^f - w_t^h A^h e_t^{h,f} - w_t^l A^l e_t^{l,f} \quad (34)$$

Subbing the factor returns for r_t, w_t^h, w_t^l into equation (42), we obtain:

$$\begin{aligned} \Pi_t^f &= Y_t^f - \left(\alpha_1 \frac{Y_t^f}{K_t^f} \right) K_t^f - \alpha_2 \left(\frac{Y_t^f}{A^h e_t^{h,f}} \right) A^h e_t^{h,f} - \alpha_3 \left(\frac{Y_t^f}{A^l e_t^{l,f}} \right) A^l e_t^{l,f} = \\ &= Y_t^f - \alpha_1 Y_t^f - \alpha_2 Y_t^f - \alpha_3 Y_t^f = \\ &= Y_t^f - Y_t^f (\alpha_1 + \alpha_2 + \alpha_3), \quad \alpha_1 + \alpha_2 + \alpha_3 = 1 \\ &= Y_t^f - Y_t^f = \\ &= 0 \end{aligned} \quad (35)$$

That is, in equilibrium profits are zero.

4.2 Decentralised competitive equilibrium (DCE)

In this appendix, we report the equations that summarise the DCE. Thus, at each time:

$$\frac{(1 - \gamma) (C_t^h + \varphi \overline{G}_t)}{\gamma (1 - e_t^h)} = \frac{[(1 - \tau_t^l) w_t^h]}{(1 + \tau_t^c)} \quad (36)$$

$$\begin{aligned} &\frac{\left[(C_t^h + \varphi \overline{G}_t)^\gamma (1 - e_t^h)^{1-\gamma} \right]^{1-\sigma}}{(1 + \tau_t^c) (C_t^h + \varphi \overline{G}_t)} = \\ &= \beta E_t \left\{ \frac{\left[(C_{t+1}^h + \varphi \overline{G}_{t+1})^\gamma (1 - e_{t+1}^h)^{1-\gamma} \right]^{1-\sigma} (1 - \delta + (1 - \tau_{t+1}^k) r_{t+1} - 2\psi^h K_{t+1}^h)}{(1 + \tau_{t+1}^c) (C_{t+1}^h + \varphi \overline{G}_{t+1})} \right\} \end{aligned} \quad (37)$$

$$(1 + \tau_t^c) C_t^h + K_{t+1}^h = (1 - \tau_t^l) w_t^h e_t^h + (1 - \delta) K_t^h + (1 - \tau_t^k) r_t K_t^h - \psi^h (K_t^h)^2 \quad (38)$$

$$\frac{(1 - \gamma) (C_t^l + \varphi \overline{G}_t)}{\gamma (1 - e_t^l)} = \frac{[(1 - \tau_t^l) w_t^l]}{(1 + \tau_t^c)} \quad (39)$$

$$\begin{aligned}
& \frac{\left[(C_t^l + \varphi \overline{G}_t)^\gamma (1 - e_t^l)^{1-\gamma} \right]^{1-\sigma}}{(1 + \tau_t^c) (C_t^l + \varphi \overline{G}_t)} = \\
& = \beta E_t \left\{ \frac{\left[(C_{t+1}^l + \varphi \overline{G}_{t+1})^\gamma (1 - e_{t+1}^l)^{1-\gamma} \right]^{1-\sigma} (1 - \delta + (1 - \tau_{t+1}^k) r_{t+1} - 2\psi^l K_{t+1}^l)}{(1 + \tau_{t+1}^c) (C_{t+1}^l + \varphi \overline{G}_{t+1})} \right\}
\end{aligned} \tag{40}$$

$$\begin{aligned}
Y_t^f &= n^h C_t^h + n^l C_t^l + n^h (K_{t+1}^h - (1 - \delta) K_t^h) + n^l (K_{t+1}^l - (1 - \delta) K_t^l) + \\
&+ n^h \psi^h (K_t^h)^2 + n^l \psi^l (K_t^l)^2 + \overline{G}_t
\end{aligned} \tag{41}$$

$$\begin{aligned}
\overline{G}_t &= \tau_t^c (n^h C_t^h + n^l C_t^l) \\
&+ \tau_t^l (w_t^h n^h e_t^h + w_t^l n^l e_t^l) \\
&+ \tau_t^k (r_t n^h K_t^h + r_t n^l K_t^l)
\end{aligned} \tag{42}$$

$$Y_t^f = Z_t (n^h K_t^h + n^l K_t^l)^{\alpha_1} (n^h e_t^h)^{\alpha_2} (n^l e_t^l)^{\alpha_3} \tag{43}$$

where, for factor returns we use:

$$r_t = \alpha_1 \frac{Y_t^f}{(n^h K_t^h + n^l K_t^l)} \tag{44}$$

$$w_t^h = \alpha_2 \left(\frac{Y_t^f}{n^h e_t^h} \right) \tag{45}$$

$$w_t^l = \alpha_3 \left(\frac{Y_t^f}{n^l e_t^l} \right) \tag{46}$$

4.3 Derivation of ω

This section presents the derivation of ω . The utility function having dropped any superscripts and subscripts is given by:

$$V = E_o \sum_{t=o}^{\infty} \beta^t \left\{ \frac{\left[(C_t^l + \varphi \overline{G}_t)^\gamma (1 - e_t^l)^{1-\gamma} \right]^{1-\sigma} - 1}{1 - \sigma} \right\} \tag{47}$$

We note that $\sum_{t=0}^{\infty} \beta^t = \frac{1}{1-\beta}$, since it is a geometric progression and $0 < \beta < 1$. Thus, dropping the expectations operator we obtain:

$$V = \frac{1}{1-\beta} \left\{ \frac{\left[(C_t^l + \varphi \overline{G}_t)^\gamma (1 - e_t^l)^{1-\gamma} \right]^{1-\sigma} - 1}{1-\sigma} \right\} \quad (48)$$

If we denote V^* the steady state value of the utility function in the pre-tax state and \overline{V} the value in the post-tax economy, then our goal is to find that ω that satisfies the following relationship:

$$\begin{aligned} V^* &= \frac{1}{1-\beta} \left\{ \frac{\left[[(1+\omega) (C_t^l + \varphi \overline{G}_t)]^\gamma (1 - e_t^l)^{1-\gamma} \right]^{1-\sigma} - 1}{1-\sigma} \right\} = \\ &= \frac{1}{1-\beta} (1+\omega)^{\gamma(1-\sigma)} \left\{ \frac{\left[(C_t^l + \varphi \overline{G}_t)^\gamma (1 - e_t^l)^{1-\gamma} \right]^{1-\sigma} - 1}{1-\sigma} \right\} = \\ &= \frac{1}{1-\beta} (1+\omega)^{\gamma(1-\sigma)} \overline{V} \end{aligned} \quad (49)$$

Hence, the expression of interest boils down to:

$$V^* = \frac{1}{1-\beta} (1+\omega)^{\gamma(1-\sigma)} \overline{V} \quad (50)$$

Solving for ω :

$$\omega = \left[\left(\frac{V^*}{\overline{V}} \right)^{\frac{1}{\gamma(1-\sigma)}} - 1 \right] \times 100 \quad (51)$$

4.4 Transitional dynamics when government consumption does not influence the utility function

Figure 7: Transitional dynamics where a decrease in capital income tax is met by an increase in labour income tax

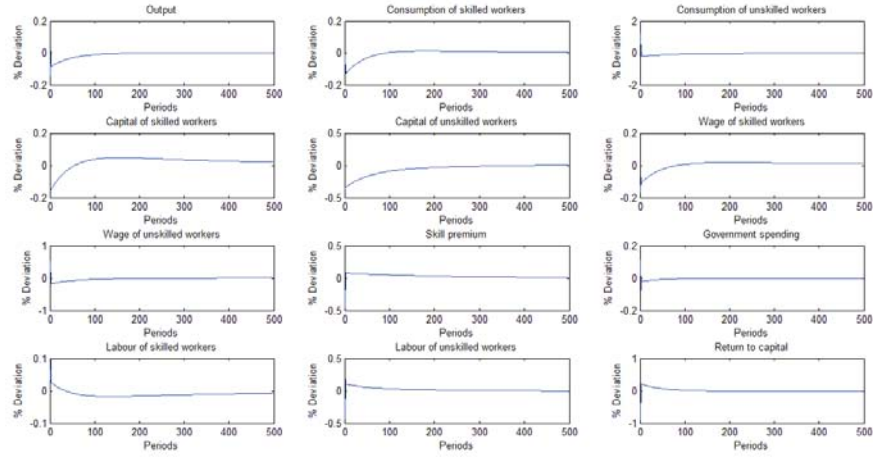


Figure 8: Transitional dynamics where a decrease in capital income tax is met by an increase in consumption tax

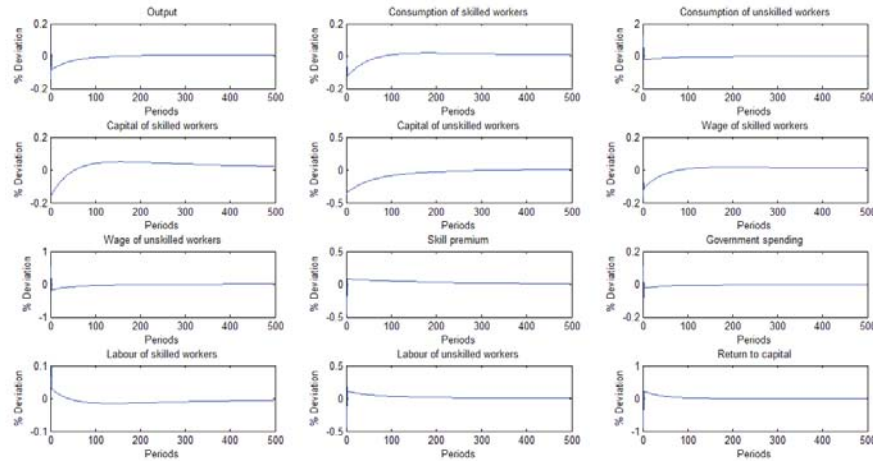


Figure 9: Transitional dynamics where a decrease in labour income tax is met by an increase in capital income tax

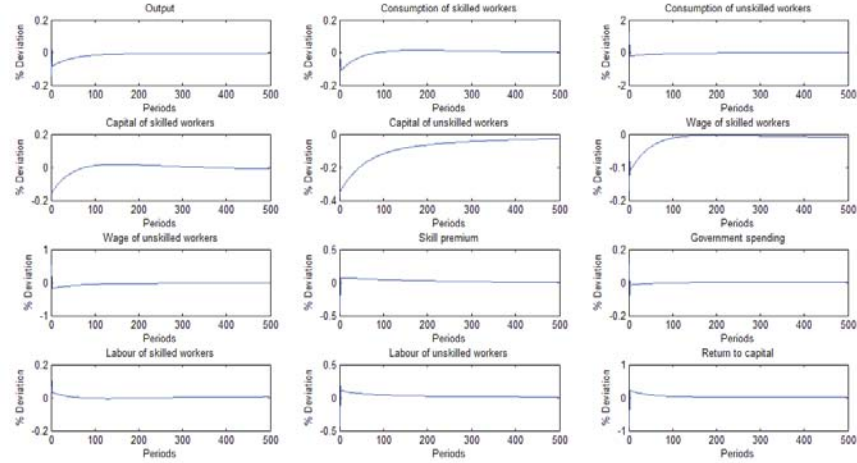


Figure 10: Transitional dynamics where a decrease in labour income tax is met by an increase in consumption tax

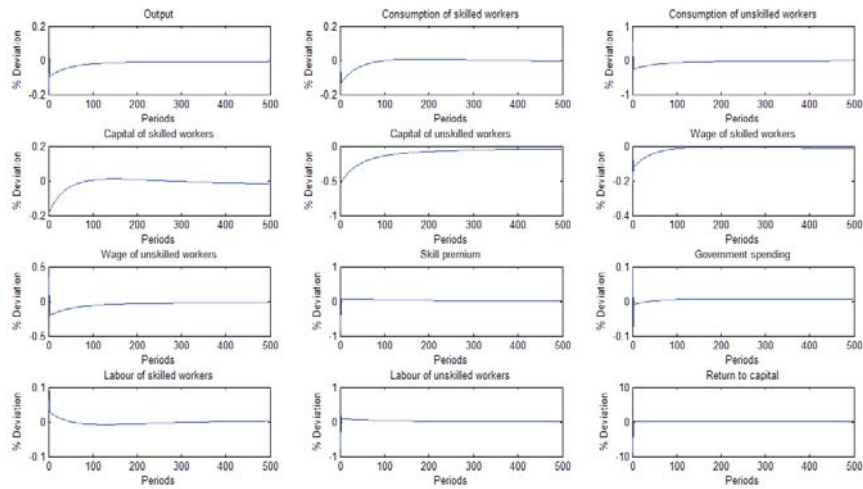


Figure 11: Transitional dynamics where a decrease in consumption tax is met by an increase in capital income tax

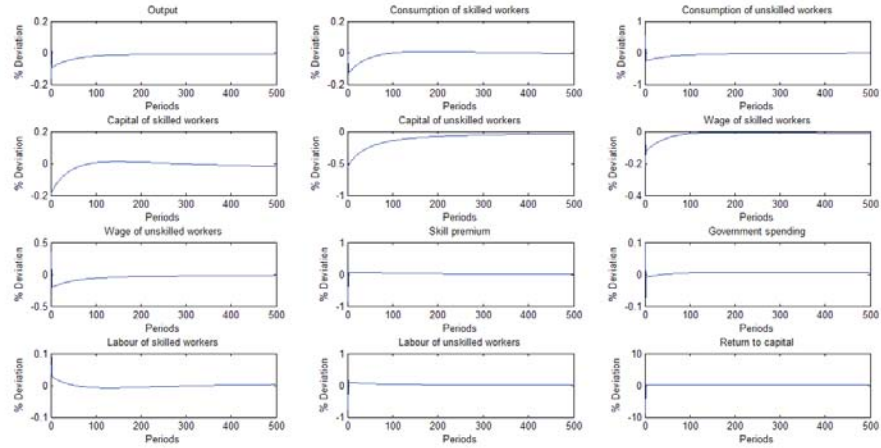


Figure 12: Transitional dynamics where a decrease in consumption tax is met by an increase in labour income tax

