Fiscal Policy and Cycles in Greece: Positive and Normative Analysis

by

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Introducing the Thesis

Modern business cycle theory starts with the view that growth and fluctuations are not distinct phenomena to be studied with separate data and different analytical tools. The influential study of Kydland and Prescott (1982) introduced the idea that it is possible to study business cycles and growth theory within the same theoretical framework. This can be done by using Dynamic Stochastic General Equilibrium (DSGE) models that integrate both growth and fluctuations. These models are fully-specified empirical model economies that are constructed to mimic important aspects of actual economies.

An important feature of DSGE models is that economic outcomes do not occur arbitrary, but instead arise as an equilibrium outcome of rational economic agents whose micro decision problems are fully dynamic. They have the advantage of stating explicitly the microeconomic decisions that produce the aggregate, macroeconomic dynamics observed in the data. An essential part of most of these models is the calibration of the model environment. Calibration is at the heart of modern quantitative macroeconomics.

The process of calibration involves choosing parameter values for the model economy so that it mimics the actual economy in the dimensions associated with long term growth. In that case, the parameters are drawn from microeconomic studies and long-run properties of the data. An alternative technique to the calibration is the process of estimation, which involves deriving the values of the parameters as the result of minimization of a given objective function involving some sample statistics as well as some model statistics.

Both methodologies have pluses and minuses. They both take into account the cross-equation restrictions implied by micro behavior and thus respect the Lucas critique (Lucas (1976)). However, the danger in using estimation methods is that the model is often judged solely on statistical criteria, such as the model’s fit to the data or the significance of the coefficient estimates. As a result, the model can be easily (too easily, as Thomas Sargent has recently pointed out) rejected and any apparent misspecification is often dealt with by generalizing the dynamic structure of the model rather than by rethinking the underlying economic theory. On the other hand, the calibration methodology ignores some of the probabilistic implications of the model, but retains others. It is a rather balanced response to professing that the model, through not correct, is still important as a vehicle for quantitative policy analysis. This is the methodology used in this Thesis.
Once the specification and the calibration of the model are accomplished, it then can be used to do “computational experiments”. The wave of models, that first followed Kydland and Prescott’s (1982) seminal work, were referred as Real Business Cycle Models, because on their emphasis on the role of real shocks, particularly technology shocks, in driving business cycle fluctuations. Real Business Cycle Models are, in general, capable of generating a number of stylized facts of the business cycle found in actual economies.

Attempts to improve the ability of Real Business Cycle models to match better important aspects of actual economies, which are important for business cycles, have focused on various types of shocks, such as fiscal and monetary policy shocks, preference shocks, external trade shocks, etc. Today, under the term DSGE models, we mean micro-founded dynamic models that incorporate, not only various shocks, but also various types of failures and imperfections, such as imperfect competition, sticky prices, wage rigidities, policy distortions, etc. In this sense, many interesting aspects of economic policy analysis can be analyzed within the DSGE framework. This is the workhorse framework in modern quantitative macroeconomics.

What the Thesis does
This thesis uses the calibration methodology to study fiscal (tax-spending) policy in postwar Greece from both a positive and normative perspective. It consists, of three chapters.

In the first chapter, I examine the evolution of the tax burden and the stylized facts of distortionary tax rates in the Greek economy over 1970-2005. In doing so, I construct effective tax rates on labor income, capital income and consumption. Particular attention is paid on the decomposition of the total tax burden on labor and capital income in terms of their components by constructing effective tax rates on personal income, self-employment income, employees’ income (wage earners), social security contributions and corporate income. Then, I use the “stylized facts” methodology of Kydland and Prescott (1990) to analyze the cyclical features of the effective tax rates and their relation with economic activity from a business cycle perspective. In order to do so, I examine the comovement properties of the deviations from trend of various effective tax rates with the cyclical components of output and the production inputs, namely, hours worked and the capital stock. Moreover, Granger
causality tests are performed in order to assess if the deviations from trend of the tax rates can help to predict future movements in the macroeconomic variables. Finally, I compare the results for the Greek economy with other Euro-zone member countries. Following the same approach, I present results for Austria, Belgium, Finland, France, Germany, Italy, Netherlands and Spain. In sum, the contribution of the first chapter in the literature is as follows. First, it presents updated estimates for the above mentioned effective tax rates that cover a long time period. There has not been another study that estimates effective tax rates on self-employment income for Euro-zone countries. Second, it analyzes the cyclical features of the effective tax rates and examines the relation between distortionary tax rates and economic activity from a business cycle perspective. Even though there are a lot of studies that examine the basic stylized facts of business cycles for European countries (see e.g. Christodoulakis et al. (1995) and Fiorito and Kollintzas (1994)), little work has been done in examining how distortionary tax rates behave over the business cycle. This chapter is a further attempt to remedy this omission.

In the second chapter, I examine the importance of fluctuations in fiscal (tax-spending) policy for the Greek business cycle. To my knowledge, Kollintzas and Vassilatos (2000) is the only study that has been applied to analyze macroeconomic fluctuations for the Greek economy within a DSGE setup. The contribution of this chapter therefore is to extend this literature. More specifically, I present an extensive analysis of the dynamic properties of a Real Business Cycle Model enriched with a wide menu of stochastic fiscal (tax-spending) policy instruments by using impulse response functions and variance decomposition. First, I look at the descriptive power of the model and then investigate the response of major macroeconomic variables to temporary and permanent changes in fiscal (tax-spending) policy variables. Moreover, to quantify the contribution of fiscal disturbances to economic fluctuations, variances are decomposed with fractions explained by innovations in technology, government consumption as share of output, government investment as share of output, the labor tax rate, the capital tax rate and the consumption tax rate. A key finding is that policy variability does matter to business cycles in Greece.

In the third chapter, I examine 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, I conduct tax policy analysis using a Dynamic General Equilibrium model which incorporates a detailed fiscal (tax-spending) policy structure.
More specifically, I examine 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 economic macroeconomic variables, as well as upon output growth and general equilibrium welfare. The latter is defined to be the discounted inter-temporal utility. In doing so, I apply the methodology used by Cooley and Hansen (1992). 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. 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 shares of public debt.

Finally, an epilogue summarizes the main conclusions of the Thesis.
To my Family
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Chapter 1

Stylized Facts of Distortionary Tax Rates in Greece and Euro-zone
1.1. Introduction

A widely accepted approach to examine the evolution and the distribution of tax burden is to construct tax indicators, the so-called effective tax rates. The benefits of constructing effective tax rates estimates are also important for analyzing the effects of tax policy changes in dynamic models; see Mendoza et al. (1994, 1997). Broadly speaking, the effective tax rates are estimated from information provided by the National Accounts as the ratios between the tax revenues from particular taxes and the corresponding tax bases.

The purpose of this chapter is twofold. First, it examines the evolution and the distribution of the tax burden in the Greek economy over the period 1970-2005. In doing so, it constructs effective tax rates on labor income, capital income and consumption following the methodology of Mendoza et al. (1994). Particular attention is paid on the decomposition of the total tax burden on labor and capital income in terms of their components by constructing effective tax rates on personal income, self-employment income, employees’ income (wage earners), corporate income and effective tax rates related to social security contributions.

Second, the chapter uses the “stylized facts” methodology of Kydland and Prescott (1990) in order to analyze the cyclical features of the effective tax rates and to examine the relation between distortionary taxation and economic activity from a business cycle perspective. Deviations from trend of effective tax rates is an indication of discretion of tax policy changes, as well as of cyclical influences (see Fiorito and Padrini (2001) and Fiorito (1997)). In this sense, the chapter examines the comovements between the deviations of effective tax rates and output from their trends to analyze how distortionary tax rates behave over the business cycle.

In addition, the chapter considers the cyclical comovements between the effective tax rates and the production inputs, namely, hours worked and the capital stock. This is motivated by the fact that many theoretical and empirical studies find that fiscal (tax-spending) policy is an important determinant of cyclical fluctuations in key macroeconomic variables (see e.g. Burnside et al. (2004), Cardia et al. (2003) and McGrattan (1994)). Moreover, Granger causality tests are performed in order to assess if deviations of the tax rates from their trend can help to predict future movements in the above macroeconomic variables. Finally, the chapter compares the results for the Greek economy with other Euro-zone member countries. Following the same approach, it
presents results for Austria, Belgium, Finland, France, Germany, Italy, Netherlands and Spain.

The contribution of this chapter to the literature may be summarized as follows. First, it presents updated estimates for the above mentioned effective tax rates that cover a long period of time. In addition, to my knowledge, there has not been another study that constructs effective tax rates on self-employment income for Euro-zone countries.\(^1\) This decomposition of the total tax burdens on labor and capital in terms of their components is particular useful for policy makers since tax reforms are not usually formulated in terms of total tax burdens on labor and capital but in terms of their components.

Second, the chapter analyzes the cyclical features of the effective tax rates and examines the relation between distortionary tax rates and economic activity from a business cycle perspective. Even though there are a lot of studies that examine the basic stylized facts of business cycles for European countries (see e.g. Christodoulakis et al. (1995) and Fiorito and Kollintzas (1994)), little work has been done in examining how distortionary tax rates behave over the business cycle. For the U.S., Strazicich (1997), Huang and Lin (1993) and Barro (1990) conclude that federal tax rates are set so as to smooth out predictable changes in government spending. Fioritio and Padrini (2001) use the “stylized facts” approach to examine the relation between distortionary taxation and labour market variables in the G7 economies. This chapter is a further attempt to remedy this omission.

The results suggest that the Greek effective tax rate on labor income has increased since 1975. After a temporary period of stabilization between 1983 and 1988, the tax rate increased further. The tax rate on capital income in Greece appears to be rather stable until the late 80s, when the tax rate increased and reached its peak in 2000. Greece faced a high increase in the tax rate on capital income during this period, while after 2000 the tax rate decreased.

The tax rates on labor and capital income in Greece are below the Euro-zone averages, while the consumption tax rate and the corporate income tax rate are close to the Euro-zone averages. In addition, the effective tax rates on personal and self-employment income are substantially lower than the Euro-zone averages.

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\(^1\) European Commission (2008a) reports total taxes paid by the self-employed as share of total tax revenues and as share of GDP, without constructing effective tax rates on self-employment income. Other studies that provide estimates for effective tax rates on labor income, capital income and consumption are Martinez-Mongay (2000), Cary and Tchilinguirian (2000) and Mendoza et al. (1997), Dimelis (1999).
Concerning the distribution of the tax burden between labor and capital income, Greece faced an increase in the tax burden on labor income relative to the tax burden on capital income from the mid 70s and until the mid 80s. The opposite is true from the mid 90s and until 2000, indicating that Greece relied relatively heavily on capital income taxation in the run-up to the Monetary Union. In addition, the results suggest that there is an unequal distribution of the tax burden between employees and self-employed in Greece since the tax rate on self-employment income is substantially lower than the tax rate on employees’ income.

In what concerns the volatility properties of the Greek effective tax rates, the tax rate on capital income exhibits higher volatility than the tax rate on consumption, which in turn, fluctuates more than the tax rate on labor income. The tax rate on corporate income is the most volatile tax rate over the business cycle since corporate taxation is characterized by long and variable lags between the emergence of income and its taxation (see e.g. European Commission (2008a)).

Concerning comovement properties, the tax rates on labor and capital income are countercyclical and synchronous with the output cycle, so that deviations of the effective tax rates from their trend are negatively associated with those of output. These findings indicate that tax rates are higher (lower) from their trend during recessions (expansions). On the other hand, the consumption tax rate is uncorrelated with the cycle, while the personal income tax rate and the tax rates on self-employment and corporate income lag positively the cycle. However, the comovements for the tax rates on self-employment and corporate income are not too significant.

In addition, the results suggest that there is a negative relation between the labor income tax rate and labor supply. The same is true for the tax rate related to social security contributions. Moreover, the tax rate on capital income leads negatively the cycle of hours worked and the predictive power of the tax rate in forecasting the cyclicality of hours worked is found to be high. The consumption tax rate leads positively the cycle of hours worked, while lagged values of the consumption tax rate produce large improvements in forecasts of future hours of work. In addition, the effective tax rates on labor and capital income lead countercyclically the cycle of the capital stock, while the consumption tax rate lags the cycle.

The results for the individual Euro-zone countries suggest that a common feature across countries is that the tax rate on capital income fluctuates more than the tax rates on consumption and labor income. In addition, deviations from trend of the
effective tax rates on labor and self-employment income, as well as the tax rate related to social security contributions, are negatively associated with those of output. Moreover, the tax rate on corporate income lags positively the output cycle, while the capital income tax rate and the consumption tax rate display a variety of patterns. Another common feature is the negative association between the deviations of the tax rate on labor income from its trend and those of hours worked. The same is true for the personal income tax rate, as well as the tax rate related to social security contributions. On the other hand, the tax rate on capital income in most cases lags positively the cycle of hours worked.

The rest of the chapter is as follows. Section 1.2 presents the Mendoza et al. (1994) methodology for the construction of the effective tax rates. Section 1.3 discusses the methodology and the variables used to construct the effective tax rates in this chapter. Section 1.4 presents the results for the effective tax rates in Greece. Section 1.5 analyzes the business cycle comovements of the Greek effective tax rates with output and the production factors, section 1.6 presents the results for the individual Euro-zone member countries and section 1.7 concludes. Appendix A briefly discusses the tax structure and the tax laws in Greece.

1.2. The Mendoza - Razin - Tezar Method

Mendoza et. al (1994) proposed a method of constructing effective tax rates by using pre-tax and post-tax income and prices. This method produces effective tax rates that correspond to realized average tax ratios. In what follows, this section sketches the model of Mendoza et al. (1994).

1.2.1. The Model

Consider an economy with three goods, consumption, $c$, labor, $l$ and capital, $k$. In this economy, households decide how much to consume and how much capital and labor to supply to firms that produce the consumption good by using labor and capital as inputs. Households’ consumption allocations of each good are denoted by the vector $h = (h_c, h_l, h_k)$. There is also a government that sets exogenous policies with respect to expenditures in each good, denoted by the vector $g = (g_c, g_l, g_k)$. The government finances its policies by levying taxes on consumption, labor and capital.
There are two price vectors, the consumer post-tax price vector \( p = (p_c, p_l, p_k) \) and the producer pre-tax price vector \( q = (q_c, q_l, q_k) \). Typically, \( p_c > q_c \), i.e., the post-tax price of consumption is higher than the pre-tax price, while \( p_l < q_l \) and \( p_k < q_k \) since the post-tax price on labor and capital are lower than the pre-tax price. Tax policy is characterized by a vector of specific tax rates \( t = (t_c, t_l, t_k) \) per unit of the corresponding good. The specific tax rate is the difference between pre and post-tax prices, \( t = p - q \), and the corresponding vector of ad valorem tax rate is \( \tau = (\tau_c, \tau_l, \tau_k) \), where \( \tau_i = \frac{t_i}{q_i} = \frac{p_i - q_i}{q_i} \), \( i = c, l, k \). Prices \( p \) and \( q \) are not readily available and it is easier to approximate measures of tax rates by multiplying \( t_i \) and \( q_i \) times an appropriate quantity measure, thus using data on tax revenues and tax bases rather than price data. The appropriate quantity measures are obtained by examining the household’s budget constraint:

\[
p(h - e - b) + p_c D = q \cdot y
\]

(1)

where \( e = (e_c, e_l, e_k) \) and \( b = (b_c, b_l, b_k) \) are vectors that represent possible endowments and government transfers of the three goods, \( y = (y_c, y_l, y_k) \) is the net output vector and \( p_c D \) is a lump-sum consumption tax. The net consumption vector to which the tax rate \( t \) applies is \((h - e - b)\). The consumption vectors for \( l \) and \( k \) are negative, while \( b_l = 0 \) since the government cannot make transfers in labor units. That is, \((h_l - e_l)\) and \((h_k - e_k - b_k)\) are negative, i.e. \((e_l - h_l)\) and \((e_k + b_k - h_k)\) represent the labor and capital supply from households, respectively. \( y_c > 0 \) measures the net output of the consumption good by the private sector and \( y_l < 0 \), \( y_k < 0 \) corresponds to the production inputs. It follows from this arrangement that \( q \cdot y \) measures profits which are part of the household’s income. Thus, the ad valorem tax rates for this economy according to Mendoza et. al. (1994) are:
The numerators in the above equations measure the difference between post-tax and the pre-tax valuation of consumption, labor and capital income respectively, which can be directly approximated by measures of tax revenues derived from each tax. In fact, the difference between the post-tax and the pre-tax values are the tax revenues from each tax obtained directly from the available data. The denominators of the above equations are measures of consumption, labor income and capital income valued at pre-tax prices and correspond to measures of the tax base. Thus, the key issue for the estimation of the vector $\tau$ is the determination of tax revenues and tax bases that reflect the corresponding measures of post-tax and pre-tax valuation of income and expenditures. The corresponding tax rate for each good is the ratio of total tax revenues from the taxation of each good to the pre-tax value of consumption, labor income and capital income respectively.

Finally, notice that the method described here produces aggregate effective tax rates that correspond to realized average tax rates. These tax rates aggregate the information on statutory taxes, credits, deductions and exemptions implicit in national accounts in a manner that captures the overall tax burden from each tax and maintains consistency with the representative agent framework.

### 1.3. Construction of Effective Tax Rates

This section describes the methodology used to construct the effective tax rates in this chapter. The methodology generally follows Mendoza et al. (1994). However, it differs in the treatment of self-employment income. Mendoza et al. (1994) assumed that all self-employment income is capital income, whereas I follow among others Conesa et al. (2007), Fiorito and Padrini (2001) and Martinez-Mongay (2000) and treat self-employment income as a combination of labor and capital income that contains a
The remuneration of labor and capital input used in production.\(^2\) A part of their income is labor income, while at the same time they receive income as owners of capital; see Lequiller and Blades (2006) and Commission of the European Communities et al. (1993).

The four-digit codes listed below identify different measures of tax revenue and correspond to the codes used in the OECD Revenue Statistics. Also listed below, are variables from OECD National Accounts: Detailed Tables and OECD Economic Outlook.\(^3\) The data set comprises annual data and covers the period 1970-2005. See also Appendix B.

**Revenue Statistics**

- 1100 = Taxes on income, profits and capital gains of individuals
- 1200 = Taxes on income, profits and capital gains of corporations
- 1300 = Unallocable between 1100, 1200
- 2100 = Social security contributions paid by the employees
- 2200 = Social security contributions paid by the employers
- 2300 = Social security contributions paid by the self-employed or unemployed
- 2400 = Unallocable between 2100, 2200, 2300
- 2000 = Total social security contributions (2000 = 2100+2200+2300+2400)
- 3000 = Taxes on payroll and workforce\(^4\)
- 4100 = Recurrent taxes on immovable property\(^5\)
- 4300 = Estate, inheritance and gift taxes
- 4400 = Taxes on financial and capital transactions\(^6\)

\(^2\) Self-employed are generally high income earners and there is a lot of variety of labor and capital income components for self-employed persons. To give two extreme examples, the capital input of a singer who is a self-employed can be almost zero, while the capital input of a farmer can be very high. Other examples are a family retail store and a family taxi firm. In these cases, the premises, equipment stock and the vehicles are the remuneration of the capital investment. There is also the remuneration of the work done (hours worked) by the owners of the enterprises; see Lequiller and Blades (2006) and OECD (2004). For this reason, the income of the self-employed is often called “mixed income” in the National Accounts.

\(^3\) The definitions of the variables used in this section are taken from OECD (2007), OECD (2006) and OECD (2004).

\(^4\) This covers taxes paid by employers, employees or the self-employed either as a proportion of payroll or as a fixed amount per person, and which do not confer entitlement to social benefits (OECD (2007)).

\(^5\) This covers taxes levied regularly in respect of the use or the ownership of immovable property. These taxes are levied on land and building, in the form of a percentage of an assessed property value based on a national rental income, sales prices, or capitalized yield and are paid both by households and corporations (OECD (2007)).
5212 = Motor vehicle taxes paid by corporations
5110 = General taxes on goods and services
5121 = Excise taxes
5123 = Import and custom Duties
5126 = Taxes on specific services

National Accounts

\[GDP = \text{Gross Domestic Product}\]
\[C = \text{Private final consumption expenditure}\]
\[GC = \text{Government final consumption expenditure}\]
\[GW = \text{Government final wage consumption}\]
\[EE = \text{Total employees (dependent employment)}\]
\[ES = \text{Self-employed}\]
\[W = \text{Wages and salaries of dependent employment}\]
\[YSE = \text{Net self-employment income received by households}\]
\[YPE = \text{Property income received by households}\]
\[YOTH = \text{Net self-employment and property income received by households} = YSE + YPE\]
\[OSC = \text{Operating surplus of incorporated enterprises}\]

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6 This includes taxes on the issue, transfer, purchase and sale of securities, taxes on cheques and taxes levied on specific legal transactions such as validation of contracts and the sale of immovable property (OECD (2007)).
7 This includes all taxes assessed on the payment of specific services, such as taxes on insurance premiums, banking services, gambling and betting stakes, transport, entertainment (OECD (2007)).
8 Dependent employment is the sum of employees working in the private and the government sector. Wages and salaries include social security contributions paid by the employees (2100), but not social security contributions paid by the employers (2200) (OECD (2006)).
9 The net self-employment income is generally defined as the gross operating surplus of unincorporated enterprises minus household consumption of fixed capital. An unincorporated enterprise is a producer unit which is not incorporated as a legal entity separate from the owner. The fixed and other assets used in unincorporated enterprises do not belong to the enterprises but to their owners. The owners are personally liable without limit for any debts or obligations incurred in the course of production. In general, the owners of these enterprises are self-employed persons. The operating surplus of unincorporated enterprises is the surplus or deficit accruing from production by unincorporated enterprises owned by households. It implicitly contains an element of work done by the owner that cannot separately identified from the return to the owner as entrepreneur (see OECD (2006) and OECD (2004)).
10 Includes mainly dividends, interest and investment receipts (OECD (2004)).
1.3.1. Effective Tax Rate on Consumption

The effective tax rate on consumption corresponds to the difference between the post-tax consumer price and the pre-tax price at which firms supply the consumption good. Thus, the effective tax rate on consumption is:

$$\tau_c = \frac{5110 + 5121 + 5123 + 5126}{C + GC - GW - 5110 - 5121 - 5123 - 5126}$$

The numerator of the above equation is the tax revenues from indirect taxation which includes general taxes on goods and services (5110) plus excise taxes (5121), plus import and custom duties (5123), plus taxes on specific services (5126). The total tax revenue from indirect taxation by definition is equal to the difference between the nominal value of aggregate consumption at post-tax and pre-tax prices. The denominator is the base of the consumption tax, which is the pre-tax value of consumption. The latter is measured as post-tax consumption expenditures minus the revenue from indirect taxation. Note that nominal consumption expenditures are at post-tax prices in the National Accounts. Thus, by subtracting from the post-tax value of consumption \((C + GC - GW)\) the difference between the post and pre-tax value of consumption \((5110+5121+5123+5126)\) - which corresponds to tax revenue from indirect taxation - we obtain the pre-tax value of consumption.11

1.3.2. Effective Tax Rate on Labor Income

One problem with the computation of the effective tax rate on labor income is that tax revenue data does not provide a breakdown of tax revenue from individual labor and capital income since code 1100 corresponds to tax revenues from the taxation of both labor and capital income of households. In order to breakdown tax revenue from labor and capital income of households from this category of tax revenues, I follow Mendoza et. al (1994) and assume that all sources of households’ income, namely labor and capital income, are taxed at the same rate. Thus, the first step in calculating the effective tax rate on labor income is to compute a personal income tax rate that applies both to labor and capital income of the household. The personal income tax rate is:

11 Government consumption is included in the denominator because Revenue Statistics reports data on indirect tax revenue that includes taxes paid by government. However, this applies only for purchases of goods and services and as a result expenditures for wages of the government employees must be deducted from government final consumption expenditure; see also Mendoza et al. (1994).
The representative households’ personal income tax rate is the ratio of total tax revenue from individual taxation (1100) – which represents the difference between post-tax and pre-tax household income – to total pre-tax household income, which is the sum of wages and salaries of employees ($W$), net self-employment and property income received by households ($YOTH$), minus social security contributions paid by the employees (2100) and the self-employed (2300). Social security contributions are deducted from the tax base since these contributions are not taxed at the personal level in Greece and in the rest of the countries considered\textsuperscript{12}; see Carey and Tchilinguirian (2000) and Appendix A.

As stated earlier, the method for calculating the labor income effective tax rate assumes that the self-employed earn both labor and capital income. In general, it is difficult to distinguish between labor and capital income from total self-employment income, since labor income of the self-employed is not observable and European countries (except Italy) do not provide such breakdown. In order to estimate a proxy for the labor income of the self-employed, it is assumed that the opportunity cost of being a self-employed is the labor income they would have earned had they been working as employees. Such an opportunity cost can be estimated by the average wage of the employees. Hence, let $EE$ be the number of employees and $ES$ be the number of self-employed persons. Per capita wages and salaries are $W / EE$. The total imputed labor income of the self-employed (that includes social security contributions paid by the self-employed) is then estimated as:

\[
WSE = \left( \frac{W}{EE} \right) \times (ES)
\]

Given the above analysis, labor income tax revenues from personal income tax on wages and salaries are $\tau_h (W + WSE - 2100 - 2300)$. Thus, the effective tax rate on labor income is then constructed as:

\[
\tau_h = \frac{1100}{W + YOTH - 2100 - 2300}
\]

\textsuperscript{12} One difference with Mendoza et al. (1994) is that they include social security contributions paid by the employees from the denominator.
\[
\tau_i = \frac{\tau_h \left( W + WSE - 2100 - 2300 \right) + 2000 + 3000}{W + WSE + 2200}
\] (8)

In addition to the tax revenues from wages and salaries the numerator incorporates all social security contributions (2000) and payroll taxes (3000) as part of the revenues from labor income taxes.\textsuperscript{13} Thus, the numerator contains all tax revenues from labor income taxation and is the difference between the post-tax and pre-tax labor income. The denominator, which is the base of the labor income tax contains wages and salaries, \( W + WSE \), as well as the social security contributions paid by the employers (2200). In other words the tax base is the total labor income of the economy and is measured in pre-tax terms.

1.3.3. Effective Tax Rate on Capital Income

Continuing with the assumption that all sources of household income are taxed under the same personal income tax rate, the tax rate on capital income is constructed by estimating first the revenue from the taxation of households’ capital income. Households’ capital income is assumed to be the net self-employment and property income received by households (\( YOTH \), minus the imputed wage of the self-employed (\( WSE \)).\textsuperscript{14} Thus, the revenue from households’ capital income tax is \( \tau_h (YOTH - WSE) \).

The effective capital income tax rate is then constructed as:

\[
\tau_k = \frac{\tau_h (YOTH - WSE) + 1200 + 4100 + 4300 + 4400 + 5212}{NOS - WSE}
\] (9)

The numerator, which represents the difference between the post-tax and the pre-tax capital income includes, in addition to households’ tax payments on capital income, \( \tau_h (YOTH - WSE) \), payments of capital income taxes made by corporations (1200), all recurrent taxes on immovable property paid by households’ and others

\textsuperscript{13} Recall that total social security contributions (2000) equals the sum of the social security contributions paid by the employees (2100) plus social security contributions paid by the employers (2200) plus social security contributions paid by the self-employed (2300). For some countries, it also includes 2400, which is social security contributions that cannot be allocated in the other categories 2100, 2200 and 2300 (see Appendix B).

\textsuperscript{14} \( WSE \) is deducted from \( YOTH \) because the latter includes both labor and capital income of the self-employed.
(4100), the revenue from specific taxes on financial and capital transactions (4400), inheritance and gift taxes (4300) and motor vehicle taxes paid by corporations (5212).  

The pre-tax capital income, which is the base for the tax, is the Net Operating Surplus, $NOS$, of the total economy minus the imputed labor income of the self-employed, $WSE$. The Net Operating Surplus is an accounting concept in the National Accounts and is used as proxy for pre-tax capital income or pre-tax profits of the total economy (see also Mendoza et. al (1994)). It is computed residually from the National Accounts as:

$$NOS = GDP - NTIND - (W + 2200) - CFC$$

(10)

where $GDP$ denotes nominal GDP, $NTIND$ denotes net indirect taxes (i.e. taxes less subsidies on production and imports) and $CFC$ denotes consumption of fixed capital. Thus, the Net Operating Surplus includes any explicit or implicit interest charges, rents or other property incomes payable on the financial assets, land or other tangible non-produced assets required to carry on the production. Note that the total income of the self-employed persons, $YSE$, is included in the operating surplus. Therefore, the imputed wage of the self-employed is deducted from the tax base in order to obtain an estimate of pre-tax income from capital.

### 1.3.4. Effective Tax Rate on total Self-Employment Income

The effective tax rate on total self-employment income (including both labor and capital income components) provides information for the tax burden on self-employed persons.

To construct the effective tax rate on self-employment income we need information for the total income (both labor and capital income) of the self-employed, which is given by $YSE$. As no data is available on the taxes paid by the self-employed,

---

15 Mendoza et al. (1994) do not include inheritance and gift taxes (4300) and motor vehicle taxes paid by corporations (5212). However, these taxes are directly charged on capital income; see also Martinez-Mongay (2000).

16 Consumption of fixed capital represents the reduction in the value of fixed assets used in production resulting from physical deterioration, normal obsolescence or normal accident damage. It is excluded from the operating surplus since there is no charge in the depreciation of fixed assets (see Martinez-Mongay (2000)).

17 Carey and Tchilinguirian (2000) and Martinez-Mongay (2000) deduct compensation of employees ($WSSS$) from (10), rather $(W + 2200)$. The difference between these two variables is that the former includes employers’ contributions to private pension funds (see OECD (2006)). I follow Mendoza et al. (1994) and I treat employers’ contributions to private pension funds as capital income since the income that individuals earn from private pension funds is considered to be interest income.
it is assumed that all income (excluding social security contributions paid by the self-employed) is taxed at the same personal income tax rate, $\tau_h$. The effective tax rate on self-employment income can then be constructed as:

$$
\tau_{se} = \frac{\tau_h(YSE - 2300) + 2300}{YSE},
$$

(11)

where the numerator contains tax revenues from the personal income tax on self-employment income, $\tau_h(YSE - 2300)$, social security contributions paid by the self-employed (2300) and the denominator, which is the tax base, contains total income of self-employed expressed in pre-tax values, $YSE$.

The assumption that the self-employed earn both labor and capital income, allows constructing an effective tax rate on the imputed labor income of the self-employed as:

$$
\tau_{se'} = \frac{\tau_h(WSE - 2300) + 2300}{WSE},
$$

(12)

where the numerator contains tax revenues from the personal income tax on the imputed net wage of the self-employed, $\tau_h(WSE - 2300)$, social security contributions paid by the self-employed and the denominator, which is the tax base, contains the imputed labor income of the self-employed.

1.3.5. Effective Tax Rate Related to Total Social Security Contributions

The effective tax rate related to social security contributions can be constructed as:

$$
\tau_{ssc} = \frac{2000 + 3000}{W + 2200 + WSE},
$$

(13)

where the numerator contains revenues from social security contributions (2000) and payroll taxes (3000) paid by the employees and the self-employed and the denominator
contains total labor income. This tax rate may also be interpreted as effective non-wage labor cost; see also Martinez-Mongay (2000).

1.3.6. Effective Tax Rate on Employees
The effective tax rate on employees’ income can be constructed as:

\[
\tau_{\text{empl}} = \frac{\tau_{s} (W - 2100) + 2100 + 2200 + 3000}{W + 2200}, \tag{14}
\]

where the numerator contains revenues from the personal income tax on wages and salaries of the employees, \( \tau_{s} (W - 2100) \), social security contributions paid by the employees and employers (2100, 2200), payroll taxes (3000) and the tax base contains total income of employees, which includes only labor income. Note that the tax rate on employees’ income shows how the tax rate on labor income would be if employees were the only production factor obtaining labor income.

1.3.7. Effective Tax Rate on Corporate Income
The effective tax rate on corporate income is constructed as:

\[
\tau_{\text{corp}} = \frac{1200}{\text{NOSC}}, \tag{15}
\]

where the numerator consists of payments on income, profits and capital gains paid by corporations (1200) and the denominator includes the net operating surplus of the incorporated enterprises.

1.4. Evolution and Distribution of the Tax Burden in Greece
This section first presents the results for the Greek effective tax rates on labor income, capital income and consumption. Then, it decomposes the total tax burden on labor and capital income.
capital income in terms of their components by examining the evolution of the effective tax rates on personal income, employees’ income (wage earners), total self-employment income, labor income of self-employed, corporate income and the effective tax rate related to social security contributions. For comparison reasons, the corresponding Euro-zone average series are also reported.

1.4.1. Effective Tax Rates on Labor Income, Capital Income and Consumption

Subplots 1-3 of Figure 1 display the time series of the effective tax rates on labor income, capital income and consumption, respectively. As can be seen, the tax rates have fluctuated since 1970. These fluctuations in general arise from fiscal policy reforms and changes in statutory tax rates, tax credits, deductions and exemptions. However, fluctuations of the effective tax rates may also be due cyclical factors and unusual shocks (see European Commission (2008a) and Mendoza et al. (1994)). This will be more clear in the next section.

**Figure 1: Effective Tax Rates on Labor Income, Capital Income and Consumption**

Subplot 1 of Figure 1 shows the tax rate on labor income has increased since 1975. After a temporary period of stabilization between 1983 and 1988, the tax rate

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20 Euro-zone average is the average data of Austria, Belgium, Finland, France, Germany, Greece, Italy, Netherlands and Spain.
increased further. The Greek tax rate on labor income lies below the Euro-zone average and its average value over the period 2000-2005 is 30%, while in Euro-zone is 40%.

As can be seen from subplot 2, the tax rate on capital income in Greece appears to be rather stable until the late 80s, when the tax rate increased and reached its peak in 2000. Greece faced a high increase in the tax rate on capital income (more than 10 percentage points) during this period, while after 2000 the tax rate decreased. Its average value tax rate over the period 2000-2005 in Greece is 27%, while in Euro-zone is 33%.

The tax rate on consumption has remained relatively stable during the 70s, while from the mid 80s has increased significantly. This increase is closely related to the introduction of the value added tax. Since 2002 the tax rate decreased in Greece, while in Euro-zone seems to be stable. Its average value over the period 2000-2005 both in Greece and Euro-zone is 19%.

Subplots 4-5 provide some evidence for the distribution of the tax burden over time among labor income, capital income and consumption. This is done by examining the evolution of the ratios of the effective tax rates over time.

Subplot 4 shows the ratio of the effective tax rate on labor income relative to the effective tax rate on capital income and thus provides some evidence for the distribution of the tax burden between these two categories of income. This ratio has increased in Greece from the mid 70s and until the mid 80s, indicating an increase in the tax burden on labor income relative to the tax burden on capital income. During this period the ratio is close to the Euro-zone average. However, between 1985 and 1990 the ratio decreased, indicating a shift towards capital income taxation relative to labor income taxation. During the mid 90s and until 2000, the ratio decreased both in Greece and in Euro-zone indicating that most countries relied relatively heavily on capital income taxation in the run-up to the Monetary Union.

Recently, there is a lot of policy attention devoted to the tax mix and there are recommendations for the European countries to re-allocate the tax burden by decreasing the tax rate on labor and increasing the consumption tax rate on the ground that lower labor tax rates will boost employment and output growth (see e.g. European Commission (2008a)). Subplot 5 displays the ratio of the effective tax rate on labor income relative to the effective tax rate on consumption. This ratio in Greece has increased between 1975 and 1980, indicating an increase in the tax burden on labor income relative to the tax burden on consumption. However, the opposite is true
between the early 80s and the mid 90s. From the mid 90s the ratio increased, while it seems to be relatively stable since 2000.

1.4.2. Decomposition of the Tax Burden on Labor and Capital Income

This section examines the evolution of the effective tax rates on personal income, employees’ income (wage earners), self-employment income, corporate income and the tax rate related to social security contributions. This decomposition is particularly useful for policy makers’ plans since tax reforms are not usually formulated in terms of total tax burdens on labor and capital but in terms of their components. Also, to my knowledge, there is no other study that constructs effective tax rates on self-employment income. Figure 2 displays the series for the effective tax rates.

Subplot 1 of Figure 2 illustrates that the personal income tax rate in Greece is relatively stable until the mid 90s. It increased from 1993 to 2000, while it seems to be stable between 2000 and 2005. Its value over 2000-2005 is 8% in Greece, well below the Euro-zone average, which is 18%.

Subplot 2 of Figure 2 shows the effective tax rate on employees’ income (wage earners), in which the tax base contains only labor income of employees. The Greek effective tax rate is generally below the Euro-zone average. However, since 2000 there is a convergence between the two tax rates. Its value over the period 2000-2005 in
Greece is 39%, while in Euro-zone is 42%. Subplot 3 displays the effective tax rate reflecting social security contributions paid by the employees. The tax rate in Greece is higher than the Euro-zone average. Its average value over the period 2000-2005 is 33%, while in Euro-zone is 28%. Thus, even though the tax rate on income of employees in Greece is lower than the Euro-zone average, the way that the tax burden is distributed between personal income taxation and social security contributions paid by employees, differs. Employees in Greece pay a lower personal income tax rate on labor income, while they pay higher social security contributions.

Subplot 4 displays the effective tax rate reflecting total social security contributions, in which the tax base includes the income of employees and the imputed labor income of the self-employed. As can be seen, the effective tax rate in Greece is lower than the Euro-zone average until 2000. Therefore, even though the effective tax rate reflecting social security contributions paid by the employees is higher than the Euro-zone average during this period, the effective tax rate when it comes to total social security contributions is lower. This is justified by the lower social security contributions paid by the self-employed in Greece relative to the Euro-zone. However, since 2000 the tax rate reflecting total social security contributions in Greece is close to the Euro-zone average. The fact that the tax rates related to total social security contributions and personal income in Greece are lower than in Euro-zone, explain the differences in the levels of the effective tax rate on total labor income between Greece and Euro-zone until the mid 90s. From the mid 90s, the differences are explained mainly by the low personal income tax rate since the levels of the tax rate reflecting total social security contributions in Greece and Euro-zone are close.

Subplot 5 shows the effective tax rate on total self-employment income. Recall that the tax base includes both labor and capital income of the self-employed. I am not aware of any other study that provides estimates for this tax rate. The results suggest that the Greek effective tax rate is significantly lower than the Euro-zone average. Its average value in Greece over 2000-2005 is 13%, well below the Euro-zone average, which is 28%. In fact, Greece has the lowest tax rate among Euro-zone countries.

Comparison of the tax rate on self-employment income with the tax rate on employees’ income (see subplots 2 and 5), provides evidence for the distribution of the tax burden between self-employed and employees. The tax rate on total self-employment income is lower than the tax rate on income of employees, both in Greece and in Euro-zone. These differences in the tax rates imply an unequal distribution of the
tax burden across employees and self-employed and provide some indication for the high fraction of self-employment as share of total employment in some countries; see Robson and Wren (1999). In Greece, the tax rate on self-employment income is three times lower than the tax rate on employees’ income, indicating a bias in favor of self-employment. The average value of the tax rate on employees’ labor income over the period 2000-2005 is 39%, while the tax rate on self-employed income is 13%. On the contrary, in Euro-zone we observe a more equitable distribution of the tax burden across employees and self-employed.

Subplot 6 presents results for the effective tax rate on labor income of self-employed. Recall that the tax base contains only the imputed labor income of the self-employed. Comparison of the tax rate on labor income of self-employed with the tax rate on employees’ income shows how the total tax burden on labor income is distributed between the labor incomes of self-employed and employees (see subplots 2 and 6). As can be seen, the tax rate on labor income of self-employed is considerably lower than that of the employees. The average value of the tax rate on labor income of self-employed over 2000-2005 is 17%, which is more than two times lower than the tax rate on income of employees. This implies that there is a bias in favor of self-employed and an unequal distribution of the tax burden on labor income across employees and self-employed. The main factor that drives the differences in the tax rates in Greece is the low level of social security contributions paid by the self-employed. On the contrary, in Euro-zone we observe a more equitable distribution of the tax burden since the tax rate on the labor income of self-employed over the period 2000-2005 is on average 37%, while the tax rate on employees is 0.42%.

Finally, subplot 7 shows the effective tax rate on corporate income. The average value of the tax rate over the period 2000-2005 in Greece is 24%, which is equal to the Euro-zone average.

---

21 One possible explanation for the differences in the levels of the tax rates may be the fact that self-employed people can more easily underreport their taxable incomes than wage earners are able to do; see Lyssiotu et al. (2004) and Pissarides and Weber (1989). However, tax evasion cannot explain the large differences in the tax rates. This is because tax evasion affects in the same direction both the numerator and the denominator of the effective tax rate.

22 It should be mentioned that the effective tax rate on corporate income is generally lower than the statutory corporate tax rate. However, it may sometimes be higher than the statutory corporate tax rate. This may depend, for instance, on the payment by corporation of taxes referring to profits earned earlier, or on taxes paid on capital gains; see European Commission (2008a).
1.4.3. Tax Revenues from Different Taxes

Figure 3 displays a breakdown of tax revenues from various sources as a share of total tax revenues for Greece and Euro-zone. As can be seen from subplot 1, the share of tax revenues from labor income taxation (including social security contributions) in total tax revenues in Greece over the period 1970-2005 is 43%, well below the Euro-zone average, which is 55%. Subplot 2 illustrates that the share of capital income tax revenues in total tax revenues in Greece amount to 18%, close to the Euro-zone average, which is 16%. On the contrary, subplot 3 shows that the share of consumption tax revenues in total tax revenues in Greece is 40%, well above the Euro-zone average, which is 29%.

Figure 3: Tax Revenues from Different Taxes as share of Total Tax Revenues

Subplot 4 shows that the share of social security contributions in total tax revenues in Greece increased since 1974 and reached its peak in 1983 but then declined in the following years. Since 2000 the share increased and is close to the Euro-zone average. Its average value over the period 1970-2005 in Greece and Euro-zone is 34% and 37%, respectively. Subplots 5-7 show the share of tax revenues from households’ labor and capital income personal taxation. The average value of total tax revenues from personal income taxation in Greece is 12%, of which 8% is from labor income taxation and 4% is from capital income taxation. These values are well below the Euro-zone average, where the share of tax revenues from personal income taxation over 1970-2005 is on average 23%. Subplots 8-9 show personal income tax revenue from labor as share
of total labor taxes and personal income tax revenue from capital as share of total capital taxes, respectively. The share for labor over the period 1970-2005 in Greece is 20%. This implies that 80% of total labor tax revenue comes from social security contributions. Finally, the share of personal income tax revenue from capital as share of total capital taxes is 26%.

Thus, overall, the vast majority of tax revenues in Greece is from labor income and consumption taxes, while revenues from personal income taxation is only a small fraction of total tax revenues.

1.5. Effective Tax Rates and Business Cycle Comovements

This section uses the “stylized facts” methodology of Kydland and Prescott (1990) in order to analyze the cyclical features of the effective tax rates and the relation between distortionary tax rates and economic activity from a business cycle perspective. To do so, it examines the comovements between the deviations from the trend of the effective tax rates with those of output and the production inputs, namely, hours worked and the capital stock. Moreover, Granger causality tests are performed in order to assess if the cyclical deviations of the tax rates can help to predict future movements in the reference macroeconomic variables.

1.5.1. Methodology

As stated earlier, fluctuations in the effective tax rates result from long-term fiscal reforms and short-term policy changes in statutory tax rates, tax credits, deductions and exemptions. However, the effective tax rates are sensitive to cyclical factors and unusual shocks that affect the measures of tax revenues and tax bases (see Mendoza et al. (1994)). For instance, thinking in terms of a tax system with progressive tax brackets, in periods in which the business cycle is moving up, brings larger fractions of income to the brackets with higher statutory tax rates and tax revenues change more than proportionately with a change in the income tax base. Consequently, the effective tax rate increases even if tax policy is unchanged. In this sense, as far as tax revenues and tax bases grow at different rates, the effective tax rates may also change over time even if the economy is in its long-run trend and tax policy is unchanged.

Given the above, an appropriate approach to examine how distortionary tax rates behave over the business cycle is to analyze the comovements between the deviations of
the effective tax rates and output from their trends. Deviations of effective tax rates from their trend is an indication of discretion of tax policy changes, as well as of cyclical influences. By examining the past, present and future comovements between the deviations of effective tax rates and output from their trends it is possible to separate discretionary policy from cyclical influences (see Fiorito and Padrini (2001) and Fiorito (1997)).

Following Hodrick and Prescott (1997) and Kydland and Prescott (1990), the trend component found in the macroeconomic series is extracted using the Hodrick and Prescott filter (henceforth, HP filter). The main characteristic of the HP procedure is that the resulting trend is stochastic and moves smoothly over time. More specifically, let \( Y_t \) denote the logarithm of a time series at time \( t = 1, \ldots, T \). Consider decomposing the series into a trend component, \( g_t \), and a cyclical component \( c_t \), so that \( Y_t = g_t + c_t \).

The HP filter defines the trend component \( g_t \) of the series \( Y_t \) as the variable that minimizes the following expression:

\[
\sum_{t=1}^{T} (Y_t - g_t)^2 + \lambda \sum_{t=2}^{T-1} \left[ (g_{t+1} - g_t) - (g_t - g_{t-1}) \right]^2
\]

(16)

The parameter \( \lambda \) is a positive number which penalizes variability in the growth rate of the trend component. Note that as \( \lambda \to 0 \) the trend component becomes equivalent to the original series, while as \( \lambda \to \infty \) the trend approaches a linear time trend. For annual data, Backus and Kehoe (1992) use a value of 100 for the smoothing parameter \( \lambda \), while Correia et al. (1992) use a value of 400. Recently, the literature has addressed a new discussion over the value of the smoothing parameter \( \lambda \) for annual data and proposed a value in the range of \( 6 \leq \lambda \leq 30 \); see among others Ravn and Uhlig (2002), Baxter and King (1999) and Hassler et al. (1994). Following Baxter and King (1999), the value of the smoothing parameter \( \lambda \) is set equal to 10 on the ground that it produces cyclical components between two and eight years and corresponds closely to a value of 1600 for quarterly data, which is commonly used in the literature.

---


24 Ravn and Uhlig (2002) propose a value in the range \( 6.25 \leq \lambda \leq 8.25 \) for annual data, on the ground that it corresponds to a value of 1600 for quarterly data.
As in Fiorito and Kollintzas (1994), the comovements between the tax rates and the relevant macroeconomic variables are characterized as follows: let $y_i(t)$ and $\tau_i(t+j)$ denote the cyclical components (i.e. deviations from trend) of the reference variable at time $t$ and the particular tax rate at time $t+j$, respectively. The strength of comovement is measured by the sample correlation coefficient $\rho(t+j)$, where $j \in [-2, 2]$. The comovements are said to be countercyclical (procyclical) as $\rho(j)$ is negative (positive).

Concerning the phase of the comovement, the tax rates are leading, synchronous or lagging the cycle of $y_i(t)$ if $|\rho(j)|$ is maximum for a negative, zero or positive $j$, respectively. This criterion is referred as the ‘peak’ criterion.

Following Stock and Watson (1999), Granger causality tests are performed in order to assess whether the deviations of the tax rates from their stochastic trend can help to predict future movements in the reference macroeconomic variables. More specifically, the tests are implemented by running a regression of the cyclical component of the reference variable $y_i(t)$ on two lags of $y_i(t)$ and the corresponding tax rate $\tau_i(t)$. Then, the same regression is performed but excluding lags of $\tau_i(t)$.

The residuals of the two regressions are used to perform the joint $F$ - test in order to test the hypothesis that the coefficients on the lagged tax rates are jointly zero (see Canova (2007)). Similarly, we can reverse the above procedure in order to assess the explanatory power of lagged $y_i(t)$ on $\tau_i(t)$. The resulting Granger causality probabilities for the null of no Granger causality are denoted by $p(\tau \rightarrow y)$ and $p(y \rightarrow \tau)$, respectively.

It is important to stress that Granger causality refers to the ability of one variable to predict another and does not imply any short of economic causality. Thus, a relatively low value of $p(\tau \rightarrow y)$ (say, less than 0.1) indicates that the addition of the tax rate $\tau_i(t)$ in the information set increases the ability of predicting the future value of $y_i(t)$.

---

25 Given the number of observations in the sample, the value required to reject the null hypothesis that the population correlation is zero in a two sided test is 0.28 at the 10% level of significance.

26 I use two lags since by adding more lags the results remain unchanged.
1.5.2. Business Cycle Comovements

This subsection examines the comovement properties of the deviations of the estimated tax rates from their stochastic trend relative to output and the production inputs, namely, hours worked and the capital stock. The results are summarized in Tables 1-3. In each table, the numbers in bold mark the highest peak correlation. Relative volatilities with respect to output, hours worked and the capital stock are also reported in order to compare volatilities across different tax rates. Finally, the last two columns in each table show the Granger causality probabilities.

1.5.2.1. Business Cycle Comovements with Real Per Capita GDP

Table 1 illustrates that the tax rate on capital income exhibits higher volatility than the tax rate on consumption, which in turn, fluctuates more than the tax rate on labor income. The capital income tax rate is more volatile than the labor income tax rate because capital and business income is generally taxed infrequently or at irregular intervals and the capital income tax base is highly volatile (see e.g. European Commission (2008a) and Fiorito (1997)). On the other hand, labor income is taxed at regular intervals and the labor income tax base is generally smoother than the capital income tax base. Consequently, the effective tax rate on labor income varies less than the tax rate on capital income over the business cycle.

Similar results are obtained for the U.S. economy by McGrattan et al. (1997), who find that the tax rate on capital income fluctuates more than the tax rate on labor income and both tax rates fluctuate more than output. The high volatility of the consumption tax rate relative to the labor income tax rate might be explained by the fact that the consumption tax base includes the nonwage component of government consumption, which generally exhibits higher volatility than output and drives the volatility of the consumption tax rate (see Fiorito (1997)).
Table 1: Relative Volatility and Comovement with Real Per Capita GDP, $y_i$

<table>
<thead>
<tr>
<th>Variable</th>
<th>Relative Volatility</th>
<th>Comovement with Real Per Capita GDP, $\rho(y_i, x_{ii})$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sigma_x / \sigma_y$</td>
<td>$i = -2$</td>
</tr>
<tr>
<td>Tax Rate on Labor Income, $\tau^l$</td>
<td>1.27</td>
<td>0.28</td>
</tr>
<tr>
<td>Tax Rate on Capital Income, $\tau^k$</td>
<td>4.20</td>
<td>0.23</td>
</tr>
<tr>
<td>Tax Rate on Consumption, $\tau^c$</td>
<td>2.57</td>
<td>0.12</td>
</tr>
<tr>
<td>Tax Rate on Personal Income, $\tau^h$</td>
<td>3.53</td>
<td>0.20</td>
</tr>
<tr>
<td>Tax Rate on Employees, $\tau^{empl}$</td>
<td>1.25</td>
<td>0.22</td>
</tr>
<tr>
<td>Tax Rate on Total Self-employment Income, $\tau^{se}$</td>
<td>4.99</td>
<td>0.17</td>
</tr>
<tr>
<td>Tax Rate on Labor Income of Self-Employed, $\tau^{l,se}$</td>
<td>5.38</td>
<td>0.17</td>
</tr>
<tr>
<td>Tax Rate on Corporate Income, $\tau^{corp}$</td>
<td>8.51</td>
<td>-0.21</td>
</tr>
<tr>
<td>Tax Rate related to Social Security Contributions, $\tau^{ssc}$</td>
<td>1.74</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Note: Real per capita GDP is measured at factor prices (i.e. excluding taxes less subsidies on production)
The volatility of the personal income tax rate over the business cycle is high relative to the volatilities of the rest tax rates and results from the progressivity that characterizes actual tax systems. Thinking in terms of a tax system with progressive tax brackets, in periods in which the business cycle is moving up, brings larger fractions of income to the brackets with higher statutory tax rates and tax revenues from personal income change more than proportionately with a change in the income tax base. Consequently, the effective tax rate on personal income varies over the cycle. In this sense, the volatility of the personal income tax rate also influences to some extent the volatilities of all income tax rates.

The tax rate on employees’ income has about the same volatility with the tax rate on total labor income of households. This is also true for the tax rate reflecting social security contributions since it is related to labor income.

The tax rates on total self-employment income and on the imputed labor income of the self-employed have about the same volatility, which is found to be high relative to the volatilities of the rest tax rates. Finally, the tax rate on corporate income is the most volatile tax rate since corporate taxation is characterized by long and variable lags between the emergence of income and its taxation. This is due notably to the possibilities to defer taxation because of previously incurred losses (see European Commission (2008a)). Moreover, corporate profits are highly volatile over the business cycle and this implies an additional source of volatility (see van den Noord (2000) and Fiorito (1997)).

Concerning comovement properties, the tax rates on labor and capital income are countercyclical and synchronous with the cycle, so that deviations of the effective tax rates from their trend are negatively associated with those of output. The Granger causality probabilities indicate that the tax rates on labor and capital do not produce any improvement in forecasts of output and vice versa, which confirms the previous result that most of the cyclical comovements are synchronous. These findings indicate that taxes are higher (lower) from their trend during recessions (expansions). Tavli and Vegh (2005) argue that countercyclical movements in the tax rates tend to reinforce the business cycle. The tax rate on employees has the same behavior as the labor income tax rate, while the consumption tax rate is uncorrelated with the cycle since comovements are not statistically significant.

The tax rate on personal income lags procyclically the cycle, which indicates that a rise in the output cycle is expected to be followed by an increase in the effective
tax rate. This positive lagging behavior might be related to the progressivity of the tax system since an output expansion moves households’ income to tax brackets with higher statutory tax rates. As a result, the increase in tax revenues is higher than the increase in the tax base, which leads to an increase in the effective tax rate. In this sense, the personal income tax rate behaves as an automatic stabilizer dampening cycles (see Fiorito and Padrini (2001) and Fiorito (1997)). The above arguments are also consistent with the fact that the predictive power of the output cycle in forecasting the behavior of the tax rate is high.

The tax rate on total self-employment income lags procyclically the cycle, however, comovements are not too significant. The same is true for the tax rate on the imputed labor income of self-employed.

The corporate income tax rate lags positively the cycle, a result that might be explained by the fact that corporate taxation is characterized by long and variable lags between the emergence of income and its taxation. In addition, corporate profits are generally procyclical (see Fiorito (1997)). However, the correlations are not too significant.

Finally, the tax rate reflecting social security contributions lags negatively the cycle. This negative lagging behavior might be due to the existence of statutory contribution ceilings; see Appendix A. Consequently, as income rises, a larger share of income falls above the contribution ceilings and the effective tax rate decreases.

To sum up, the tax rates on labor and capital income are negatively associated with the output cycle, while the tax rate on consumption is uncorrelated with the cycle. Moreover, the personal income tax rate, the tax rates on self-employment income and the corporate income tax rate lag positively the cycle. However, the correlations for the tax rates on self-employment and corporate income are not too significant. Finally, it should be stressed that the countercyclical behavior of labor and income tax rates found in data can be accounted for by real business cycle models that incorporate a tax policy structure (see e.g. Jonsson and Klein (1996) and McGrattan (1994)).

1.5.2.2. Business Cycle Comovements with Hours Worked

Table 2 summarizes the results for the cross-correlations between the cyclical components of the effective tax rates and per capita hours worked. Results for volatility (relative to hours worked) and Granger causality probabilities are also reported.
As it can be seen from Table 2, the correlation between the tax rate on labor income and hours worked is synchronous with a negative sign, which indicates a negative relation between the labor tax rate and labor supply. The predictive contents of the labor income tax rates and hours worked are found be insignificant as suggested by the Granger causality probabilities, indicating that most comovements are synchronous. The same comments apply for the tax rate on employees’ income.

The tax rate on capital income negatively leads the cycle, which indicates that a rise (fall) in the cyclical component of the tax rate is associated with a fall (rise) in the cycle in hours worked. It is worth to mention that the correlation coefficient is higher than that of the tax rate on labor income. Moreover, as suggested by the Granger causality probability, the predictive power of the tax rate in forecasting the cyclicality of hours worked is found to be high.

The consumption tax rate leads positively the cycle, while lagged values of the consumption tax rate produce large improvements in forecasts of future hours of work. The same is true for lagged values of hours worked, whose predictive power in forecasting the cyclicality of the consumption tax rate is relatively high.

The personal income tax rate leads negatively the cycle, however, the comovements are not too significant. In addition, the tax rates on self-employment and corporate income are uncorrelated with the cycle of hours worked. On the other hand, the tax rate reflecting social security contributions is synchronous with a negative sign, which indicates a negative relation with hours worked. It should be stressed that the correlation coefficient is higher than correlation coefficients of the labor and capital income tax rates.
Table 2: Relative Volatility and Comovement with Per Capita Hours Worked, $h_i$

<table>
<thead>
<tr>
<th>Variable $x$</th>
<th>Relative Volatility</th>
<th>Comovement with Per Capita Hours Worked $\rho(h_i, x_{t+i})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_x / \sigma_h$</td>
<td>$i = -2$</td>
<td>$i = -1$</td>
</tr>
<tr>
<td>Tax Rate on Labor Income, $\tau^l$</td>
<td>1.91</td>
<td>0.10</td>
</tr>
<tr>
<td>Tax Rate on Capital Income, $\tau^k$</td>
<td>6.32</td>
<td>0.07</td>
</tr>
<tr>
<td>Tax Rate on Consumption, $\tau^c$</td>
<td>3.88</td>
<td><strong>0.43</strong></td>
</tr>
<tr>
<td>Tax Rate on Personal Income, $\tau^h$</td>
<td>5.31</td>
<td>0.02</td>
</tr>
<tr>
<td>Tax Rate on Employees, $\tau^{empl}$</td>
<td>1.88</td>
<td>0.18</td>
</tr>
<tr>
<td>Tax Rate on Total Self-employment Income, $\tau^{se}$</td>
<td>7.51</td>
<td>-0.07</td>
</tr>
<tr>
<td>Tax Rate on Labor Income of Self-Employed, $\tau^{l-se}$</td>
<td>8.10</td>
<td>-0.3</td>
</tr>
<tr>
<td>Tax Rate on Corporate Income, $\tau^{corp}$</td>
<td>12.82</td>
<td>-0.07</td>
</tr>
<tr>
<td>Tax Rate related to Social Security Contributions, $\tau^{ssc}$</td>
<td>2.63</td>
<td>0.14</td>
</tr>
</tbody>
</table>
To summarize, the cyclical components of the effective tax rates on labor and capital income, as well as the tax rate reflecting social security contributions are related with a cyclical decline in hours worked. On the other hand, the consumption tax rate is positively related with the cycle of hours worked. These results can be accounted for by dynamic general equilibrium models in which higher tax rates on consumption and on labor and capital income produce income and substitutions effects over the households’ choice between labor and leisure. If the substitution effect dominates the income effect, labor supply decreases and vice versa (see e.g. Burnside et al. (2004) and Braun (1994)).

1.5.2.3. Business Cycle Comovements with Real Per Capita Capital Stock

Table 3 summarizes the results for the cross-correlations between the cyclical components of the effective tax rates and real per capita capital stock. Results for standard deviations (relative to per capita capital stock) and Granger causality probabilities are also reported.

The tax rates on labor and capital income lead countercyclically the cycle of capital stock, indicating that a rise in the cyclical component of the tax rates is expected to be followed by a fall in the stock of capital. Moreover, the Granger causality probability concerning the tax rate on capital income implies that cyclical movements in the tax rate substantially help to predict future cyclical movements of the capital stock. In addition, it is interesting to note that the correlation coefficient for the tax rate on capital income is about two times higher than the correlation coefficient of the labor income tax rate.

The tax rate on consumption lags countercyclically the cycle, suggesting that a rise in the stock of capital is expected to be followed by a decrease in the consumption tax rate. On the other hand, the tax rate on personal income leads countercyclically the cycle of the capital stock. Even though the comovements are not too significant, the predictive power of the personal income tax rate in forecasting future movements in the stock of capital is found to be substantially high.

The correlations for the tax rates on self-employment and corporate income are insignificant. Finally, the tax rate on employees and on social security contributions are countercyclically synchronous with the cycle.
Table 3: Relative Volatility and Comovement with Real Per Capita Capital Stock, \( k_i \)

<table>
<thead>
<tr>
<th>Variable ( x )</th>
<th>Relative Volatility</th>
<th>Comovement with Per Capita Capital Stock ( \rho(k_i, x_{i+1}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \sigma_x / \sigma_k )</td>
<td>( i = -2 )</td>
</tr>
<tr>
<td>Tax Rate on Labor Income, ( \tau^l )</td>
<td>2.87</td>
<td>-0.02</td>
</tr>
<tr>
<td>Tax Rate on Capital Income, ( \tau^k )</td>
<td>9.52</td>
<td>0.01</td>
</tr>
<tr>
<td>Tax Rate on Consumption, ( \tau^c )</td>
<td>5.83</td>
<td>0.25</td>
</tr>
<tr>
<td>Tax Rate on Personal Income, ( \tau^p )</td>
<td>7.99</td>
<td>-0.17</td>
</tr>
<tr>
<td>Tax Rate on Employees, ( \tau^{empl} )</td>
<td>2.94</td>
<td>0.06</td>
</tr>
<tr>
<td>Tax Rate on Total Self-employment Income, ( \tau^{se} )</td>
<td>12.04</td>
<td>-0.13</td>
</tr>
<tr>
<td>Tax Rate on Labor Income of Self-Employed, ( \tau^{l.se} )</td>
<td>12.40</td>
<td>-0.11</td>
</tr>
<tr>
<td>Tax Rate on Corporate Income, ( \tau^{corp} )</td>
<td>19.37</td>
<td>-0.02</td>
</tr>
<tr>
<td>Tax Rate related to Social Security Contributions, ( \tau^{ssc} )</td>
<td>3.95</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Note: The capital stock was generated using a perpetual inventory method. See Appendix B for details.
To sum up, the effective tax rate on labor and capital income lead countercyclically the stock of capital. These results can be accounted for by dynamic general equilibrium models in which tax policy instruments are exogenous and stochastic. Higher income tax rates decrease the after-tax return to investment and produce an intertemporal substitution effect that leads households to decrease current investment and future capital stock accumulation (see e.g. Braun (1994)).

1.6. International Perspectives

This section first presents the evolution of the effective tax rates for the individual Euro-zone member countries. These countries are Austria, Belgium, Finland, France, Germany, Greece, Italy, Netherlands, and Spain. Then, following the methodology described in the previous section it applies the “stylized facts” approach in order to examine the cyclical features of distortionary tax rates and their relation to economic activity.

1.6.1. Evolution and Distribution of the Tax Burden in Euro-zone Countries

Figure 4 displays the time series of the effective tax rates on labor income, capital income and consumption for the Euro-zone countries. Leaving aside methodological differences, the results present a high degree of similarity with previous studies in terms of trends and to a lesser extent in terms of levels (see e.g. European Commission (2008a), Martinez-Mongay (2000) and Carey and Tchilinguirian (2000)). However, the results reported here are “first best”, in the sense that the data set is updated and covers a longer period of time.27

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27 European Commission (2008a), which also provides updated estimates, present effective tax rates only after 1995. Martinez-Mongay (2000) also provides estimates for the effective tax rates since 1970. However, the data input he uses is taken from two different data bases (AMECO and OECD) and many time series used for the construction of the effective tax rates are approximated combining these two different data bases that may not be compatible or not updated synchronous.
Figure 4: Effective Tax Rates on Labor Income, Capital Income and Consumption

Figure 4 shows that in all countries, the tax rate on labor income has increased from 1970 and until the mid 80s. The highest increases are found in Belgium, France, Italy and Spain, where the tax rate on labor increased on average by about 10 percentage points. However, since the mid 80s the tax rate on labor is characterized by a period of stabilization, with the exceptions of Austria, Greece, Italy, and to lesser extent Spain, where the tax rate increased. Since 2000 the tax rate is relatively stable in most countries.

The tax rate on capital income displays a variety of patterns and fluctuates a lot over time. Nevertheless, the tax rate has increased from the mid 90s and until 2000 in Belgium, France, Germany, Greece, Italy and Spain. Since 2000, the tax rate on capital income is either stable or decreasing with the exceptions of Netherlands and Spain where the capital tax rate is increasing.

The tax rate on consumption has decreased during the 70s in countries with relatively high consumption tax rates (Austria, Belgium and France), while it increased during the early 80s in Finland, Germany, Greece, Italy, Netherlands and Spain.

By international comparison, Greece has the lowest average values of the tax rate levels on labor and capital income over the period 1970-2005. On the other hand, the highest tax rate levels are found in Belgium, France and Finland.

Figure 5 shows the evolution of the ratios of the effective tax rates over time and provides information for the relative distribution of the tax burden.
The ratio of the effective tax rate on labor income relative to the effective tax rate on capital income is generally constant until the late 70s in most countries, with the exceptions of Greece and Italy where the ratio increased in the former case and decreased in the latter. From the early 80s the ratio increased in Belgium, France, Germany and Netherlands, indicating an increase in the tax burden on labor income relative to the tax burden on capital income. On the other hand, the ratio decreased from 1995 to 2000 in Finland, France, Germany, Greece, Netherlands and to a lesser extent in Austria, Belgium and Spain, indicating that most countries relied relatively heavily on capital income taxation in the run-up to the Monetary Union.

The ratio of the effective tax rate on labor income relative to the effective tax rate on consumption increased until the mid 80s in Austria, Belgium, France and Germany. This implies that the tax burden on labor income increased relative to the tax burden on consumption. In Greece and Spain the ratio increased until the mid 80s but then declined. After the mid 80s the ratio seems to be rather stable in most countries, while is increasing in Greece and Italy and decreasing in Netherlands.

Figure 6 displays the effective tax rates on total self-employment income and on employees. As can be seen, the tax rate on self-employment income has increased since 1970 in most countries, while from the early 90s it is relatively stable. By international comparison, Greece has the lowest tax rate, while Netherlands has the highest.
Comparison of the tax rate on self-employment income with the tax rate on employees’ income provides some evidence for the distribution of the tax burden between self-employed and employees. With the exception of Netherlands, the tax rate on total self-employment income over the last decade is lower than the tax rate on employees. It is about 15 percentage points lower in Austria, Belgium, Italy and Germany, while it is more than 20 percentage points lower in France and Greece. These differences in the tax rates imply an unequal distribution of the tax burden across employees and self-employed.

Finally, Figure 7 shows the tax rate on effective tax rate on corporate income. As can be seen, the tax rate fluctuates a lot over time and there is no common pattern across countries.²⁸

²⁸ See Devereux et al. (2008), De Mooij and Nicodeme (2008) and Devereux and Sorensen (2006) for recent issues concerning corporate tax policy.
1.6.2. Business Cycle Comovements

This section examines the cross-correlations of the cyclical components of the estimated tax rates with the cyclical components of output and the production inputs, namely, hours worked and the capital stock. Results are reported for the effective tax rates on labor and capital income, the consumption tax rate, the personal income tax rate, the tax rate on total self-employment income, the tax rate on corporate income and the tax rate related to social security contributions. It should be stressed that the goal of this section is just to report these facts and not to provide a theoretical framework for explaining the reported facts.

1.6.2.1. Business Cycle Comovements with Real Per Capita GDP

Table 4 shows the relative volatilities and the business cycle comovements between the effective tax rates and real per capital GDP.

As can be seen, in each country the tax rate on capital income is more volatile than the consumption and the labor income tax rate, while the tax rate on corporate income is the most volatile tax rate. The relative volatilities of the tax rates on consumption and labor and capital income do not differ much across countries. The same is true for the rest tax rates with the exception of the corporate income tax rate, where there are large differences in the relative volatilities across countries.
Table 4: Relative Volatility and Comovement with Real per Capita Output

<table>
<thead>
<tr>
<th>Variable</th>
<th>Relative Volatility</th>
<th>Comovement with Output, $\rho(y_t, x_{it})$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sigma_x / \sigma_y$</td>
<td>$i = -2$</td>
</tr>
<tr>
<td>Tax Rate on Labor Income, $\tau_l$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greece</td>
<td>1.27</td>
<td>0.28</td>
</tr>
<tr>
<td>Austria</td>
<td>1.36</td>
<td>0.10</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.80</td>
<td>0.19</td>
</tr>
<tr>
<td>Finland</td>
<td>1.43</td>
<td>-0.01</td>
</tr>
<tr>
<td>France</td>
<td>1.02</td>
<td>0.11</td>
</tr>
<tr>
<td>Germany</td>
<td>1.09</td>
<td>0.11</td>
</tr>
<tr>
<td>Italy</td>
<td>2.67</td>
<td>-0.40</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1.94</td>
<td>-0.25</td>
</tr>
<tr>
<td>Spain</td>
<td>1.64</td>
<td>-0.22</td>
</tr>
<tr>
<td>Tax Rate on Capital Income, $\tau_k$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greece</td>
<td>4.20</td>
<td>0.23</td>
</tr>
<tr>
<td>Austria</td>
<td>7.83</td>
<td>0.36</td>
</tr>
<tr>
<td>Belgium</td>
<td>1.89</td>
<td>-0.19</td>
</tr>
<tr>
<td>Finland</td>
<td>6.84</td>
<td>-0.45</td>
</tr>
<tr>
<td>France</td>
<td>4.65</td>
<td>0.14</td>
</tr>
<tr>
<td>Germany</td>
<td>6.42</td>
<td>-0.19</td>
</tr>
<tr>
<td>Italy</td>
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</tr>
<tr>
<td>Netherlands</td>
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</tr>
<tr>
<td>Spain</td>
<td>3.71</td>
<td>0.05</td>
</tr>
<tr>
<td>Tax Rate on Consumption, $\tau_c$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greece</td>
<td>2.57</td>
<td>0.12</td>
</tr>
<tr>
<td>Austria</td>
<td>2.51</td>
<td>0.14</td>
</tr>
<tr>
<td>Belgium</td>
<td>1.66</td>
<td>0.20</td>
</tr>
<tr>
<td>Finland</td>
<td>1.49</td>
<td>0.50</td>
</tr>
<tr>
<td>France</td>
<td>2.27</td>
<td>0.30</td>
</tr>
<tr>
<td>Germany</td>
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<td>-0.42</td>
</tr>
<tr>
<td>Italy</td>
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<td>0.41</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2.28</td>
<td>0.24</td>
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<tr>
<td>Spain</td>
<td>2.77</td>
<td>0.29</td>
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</table>
Table 4 (continued)

<table>
<thead>
<tr>
<th>Tax Rate on Personal Income, $\tau^h$</th>
<th>$\sigma_y / \sigma_y$</th>
<th>$i = -2$</th>
<th>$i = -1$</th>
<th>$i = 0$</th>
<th>$i = 1$</th>
<th>$i = 2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece</td>
<td>3.53</td>
<td>0.20</td>
<td>-0.06</td>
<td>-0.23</td>
<td>0.31</td>
<td>0.10</td>
</tr>
<tr>
<td>Austria</td>
<td>3.47</td>
<td>0</td>
<td>-0.22</td>
<td>-0.21</td>
<td>0.17</td>
<td>0.21</td>
</tr>
<tr>
<td>Belgium</td>
<td>1.25</td>
<td>0.18</td>
<td>0.01</td>
<td>-0.48</td>
<td>-0.14</td>
<td>0.01</td>
</tr>
<tr>
<td>Finland</td>
<td>1.97</td>
<td>0.10</td>
<td>0.10</td>
<td>0.02</td>
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</tr>
<tr>
<td>France</td>
<td>5.04</td>
<td>0.35</td>
<td>0.22</td>
<td>0.05</td>
<td>-0.05</td>
<td>-0.19</td>
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<td>Germany</td>
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<td>-0.10</td>
<td>-0.05</td>
<td>-0.20</td>
</tr>
<tr>
<td>Italy</td>
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<td>0.14</td>
<td>-0.60</td>
<td>-0.19</td>
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<td>0.24</td>
</tr>
<tr>
<td>Netherlands</td>
<td>4.36</td>
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<td>-0.20</td>
<td>0.15</td>
<td>0.50</td>
<td>0.60</td>
</tr>
<tr>
<td>Spain</td>
<td>3.26</td>
<td>-0.24</td>
<td>-0.05</td>
<td>0.07</td>
<td>0.23</td>
<td>0.29</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Tax Rate on total Self-Employment Income, $\tau^{se}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece</td>
</tr>
<tr>
<td>Austria</td>
</tr>
<tr>
<td>Belgium</td>
</tr>
<tr>
<td>Finland</td>
</tr>
<tr>
<td>France</td>
</tr>
<tr>
<td>Germany</td>
</tr>
<tr>
<td>Italy</td>
</tr>
<tr>
<td>Netherlands</td>
</tr>
<tr>
<td>Spain</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Tax Rate on Corporate Income, $\tau^{corp}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece</td>
</tr>
<tr>
<td>Austria</td>
</tr>
<tr>
<td>Belgium</td>
</tr>
<tr>
<td>Finland</td>
</tr>
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<td>France</td>
</tr>
<tr>
<td>Germany</td>
</tr>
<tr>
<td>Italy</td>
</tr>
<tr>
<td>Netherlands</td>
</tr>
<tr>
<td>Spain</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tax Rate related to Social Security Contributions, $\tau^{ssc}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece</td>
</tr>
<tr>
<td>Austria</td>
</tr>
<tr>
<td>Belgium</td>
</tr>
<tr>
<td>Finland</td>
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<td>Germany</td>
</tr>
<tr>
<td>Italy</td>
</tr>
<tr>
<td>Netherlands</td>
</tr>
<tr>
<td>Spain</td>
</tr>
</tbody>
</table>

Note: Real per capita GDP is measured at factor prices (i.e. excluding taxes less subsidies on production)
Concerning comovement properties, a common feature across countries is that deviations from trend of the effective tax rates on labor and self-employment income, as well as the tax rate related to social security contributions, are negatively associated with those of output. In addition, the tax rate on corporate income lags positively the output cycle, while the personal income tax rate, the capital income tax rate and the consumption tax rate display a variety of patterns.

More specifically, the tax rate on labor income leads negatively the cycle in Italy, Netherlands and Spain, while it is countercyclical and synchronous with the cycle in Austria, Belgium, Finland, France and Greece. On the other hand, the labor tax rate lags negatively the cycle in Germany.

The tax rate on capital income is synchronous with a negative sign in Belgium, Greece and Italy, so that deviations of the effective tax rate from its trend are negatively associated with those of output. In Austria, Finland, France and Netherlands the tax rate lags positively the cycle, indicating that a rise in output should anticipate an increase in the capital tax rate. In this sense, the tax rate behaves as an automatic stabilizer dampening cycles.

The tax rate on consumption leads positively the cycle in Austria, Finland, Italy and Netherlands, which indicates that higher consumption taxes are followed by an increase in output. In Germany, the consumption tax rate leads negatively the cycle, so that a rise in the tax rate is expected to be followed by a decrease in output. In Belgium, France, Greece and Spain, the consumption tax rate lags positively the cycle. However, comovements for Greece are not significant.

The personal income tax rate leads countercyclically the cycle in Austria, Germany, Italy and Spain, while is synchronous with a negative sign in Belgium. These results suggest that in most countries a rise of the personal income tax rate above its trend is expected to be followed by a decrease in output. In France, the personal income tax rate leads procyclically the cycle, while it lags procyclically the cycle in Greece and Netherlands. In Finland, the personal income tax rate lags countercyclically the cycle, but the comovements are not too significant.

The tax rate on total self-employment income leads countercyclically the cycle in Spain and is synchronous with a negative sign in Austria, Belgium and Netherlands. In France and Italy the tax rate leads positively the cycle, while it lags positively the cycle in Greece and negatively in Finland and Germany. However, comovements for Greece and Finland are not too significant.
The corporate income tax rate lags procyclically the cycle in Austria, Finland, France, Greece and Netherlands, while it leads procyclical the cycle in Spain and is synchronous with the cycle in Belgium. Italy’s pattern is difficult to recognize since there is a conflict between a procyclically leading and a countercyclical and synchronous phase.

Finally, the tax rate on social security contributions leads countercyclically the cycle in Finland and Italy, while is countercyclical and synchronous with the cycle in Austria, Belgium and France. These results indicate that higher (lower) tax rates on social security contributions are related with a deterioration (improvement) in economic activity. In Greece, Germany and Netherlands the tax rate lags countercyclically the cycle, indicating that a rise in output is expected to be followed by a decrease in the tax rate.

To sum up, the results suggest that the tax rate on labor and self-employment income and the tax rate reflecting social security contributions are negatively associated with the output cycle. On the other hand, the pattern of comovements for the effective tax rate on capital is less uniform among Euro-zone countries, where the capital tax rate is either synchronous with a negative sign or lags procyclically the cycle. Concerning the tax rate on consumption, the comovements are either procyclically leading or countercyclically lagging. The personal income tax rate seems to be countercyclically leading, while the corporate income tax in most cases displays a procyclically lagging behavior.

1.6.2.2. Business Cycle Comovements with Hours Worked

Table 5 summarizes the results for the cross-correlations between the cyclical components of the effective tax rates and per capita hours worked.

A common feature across countries is the negative association between the deviations of the tax rate on labor income from its trend and those of hours worked. The same is true for the personal income tax rate, as well as the tax rate related to social security contributions. On the other hand, the tax rate on capital income lags positively the cycle, while the rest tax rates display a variety of patterns.

More specifically, the tax rate on labor income leads countercyclically the cycle of hours worked in Austria, Germany, Italy and Netherlands and is synchronous with a negative sign in Belgium and Greece. These results indicate that a rise in labor income
taxes should anticipate a fall in labor supply. In Spain, the tax rate lags procyclically the cycle, while in Finland and France the tax rate countercyclically lags the cycle.

Table 5: Relative Volatility and Comovement with Per Capita Hours Worked

<table>
<thead>
<tr>
<th>Variable</th>
<th>Relative Volatility</th>
<th>Comovement with Per Capita Hours Worked, $\rho(h_i, x_{i+1})$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sigma_x / \sigma_h$</td>
<td>$i = -2$</td>
</tr>
<tr>
<td>Tax Rate on Labor Income, $\tau^l$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greece</td>
<td>1.91</td>
<td>0.10</td>
</tr>
<tr>
<td>Austria</td>
<td>2.70</td>
<td>-0.37</td>
</tr>
<tr>
<td>Belgium</td>
<td>1.96</td>
<td>0.26</td>
</tr>
<tr>
<td>Finland</td>
<td>1.61</td>
<td>0.00</td>
</tr>
<tr>
<td>France</td>
<td>1.29</td>
<td>-0.08</td>
</tr>
<tr>
<td>Germany</td>
<td>0.38</td>
<td>-0.27</td>
</tr>
<tr>
<td>Italy</td>
<td>3.42</td>
<td>-0.26</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1.67</td>
<td>-0.38</td>
</tr>
<tr>
<td>Spain</td>
<td>1.19</td>
<td>-0.24</td>
</tr>
</tbody>
</table>

| Tax Rate on Capital Income, $\tau^k$ |                     |          |          |          |          |          |
| Greece                      | 6.32                | 0.07     | **-0.35** | -0.04    | 0.04    | -0.02   |
| Austria                     | 15.58               | 0.18     | 0.01     | 0.12     | **0.19** | -0.17   |
| Belgium                     | 4.62                | -0.04    | **-0.29** | **-0.29** | -0.17   | -0.26   |
| Finland                     | 7.74                | -0.65    | -0.31    | 0.29     | **0.74** | 0.58    |
| France                      | 5.86                | -0.14    | -0.04    | 0.18     | **0.20** | 0.16    |
| Germany                     | 2.25                | -0.05    | **0.54**  | -0.17    | -0.29   | -0.24   |
| Italy                       | 6.74                | -0.17    | -0.44    | -0.11    | **0.48** | 0.46    |
| Netherlands                 | 4.78                | -0.05    | 0.04     | 0.23     | **0.36** | 0.07    |
| Spain                       | 2.70                | 0.08     | 0.32     | **0.50** | 0.41    | 0.09    |

| Tax Rate on Consumption, $\tau^c$ |                     |          |          |          |          |          |
| Greece                       | 3.88                | **0.43** | 0.05     | -0.36    | -0.19   | -0.20   |
| Austria                      | 5.00                | 0.11     | **0.27** | 0.13     | -0.15   | -0.10   |
| Belgium                      | 4.06                | 0.25     | 0.22     | -0.05    | **-0.33** | -0.07   |
| Finland                      | 1.69                | 0.45     | **0.59** | 0.34     | 0.04    | -0.22   |
| France                       | 2.86                | 0.37     | 0.33     | 0.21     | -0.34   | **-0.42** |
| Germany                      | 0.75                | 0.03     | **0.32** | -0.17    | -0     | 0.04    |
| Italy                        | 3.43                | 0.04     | **-0.16** | 0.11    | 0.03    | 0.08    |
| Netherlands                  | 1.96                | 0.35     | 0.29     | 0.27     | -0.03   | **-0.38** |
| Spain                        | 2.00                | 0.34     | 0.25     | 0.05     | -0.25   | **-0.50** |
Table 5 (continued)

<table>
<thead>
<tr>
<th>Tax Rate on Personal Income, $\tau^h$</th>
<th>$\sigma_i / \sigma_h$</th>
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<th>$i = -1$</th>
<th>$i = 0$</th>
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</tr>
<tr>
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<td>0.16</td>
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<td>-0.43</td>
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<tr>
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<td>0.22</td>
<td>0.33</td>
<td>0.09</td>
<td>-0.10</td>
</tr>
<tr>
<td>Germany</td>
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<td>0.31</td>
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<td>-0.08</td>
</tr>
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</tr>
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<td>-0.28</td>
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<tr>
<td>Finland</td>
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<td>0.10</td>
<td>-0.07</td>
<td>-0.35</td>
<td>-0.47</td>
</tr>
<tr>
<td>France</td>
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<td>0.10</td>
<td>0.25</td>
<td>0.04</td>
<td>-0.20</td>
</tr>
<tr>
<td>Germany</td>
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<td>0.22</td>
<td>0.39</td>
<td>-0.17</td>
<td>-0.21</td>
</tr>
<tr>
<td>Italy</td>
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<td>-0.33</td>
<td>-0.05</td>
<td>0.35</td>
<td>0.30</td>
</tr>
<tr>
<td>Netherlands</td>
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<td>-0.07</td>
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<td>-0.44</td>
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<table>
<thead>
<tr>
<th>Tax Rate on Corporate Income, $\tau^{corp}$</th>
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<th></th>
<th></th>
</tr>
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<tr>
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<tr>
<td>Finland</td>
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<td>-0.05</td>
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</tr>
<tr>
<td>France</td>
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<td>-0.32</td>
<td>0.21</td>
<td>0.24</td>
<td>0.29</td>
</tr>
<tr>
<td>Germany</td>
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<td>0.36</td>
<td>-0.22</td>
<td>-0.18</td>
<td>-0.21</td>
</tr>
<tr>
<td>Italy</td>
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<td>-0.19</td>
<td>0.19</td>
<td>0.31</td>
</tr>
<tr>
<td>Netherlands</td>
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<td>-0.09</td>
<td>0.32</td>
<td>0.43</td>
<td>0.16</td>
</tr>
<tr>
<td>Spain</td>
<td>6.03</td>
<td>0.18</td>
<td>0.38</td>
<td>0.42</td>
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<td>-0.21</td>
</tr>
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<table>
<thead>
<tr>
<th>Tax Rate related to Social Security Contributions, $\tau^{ssc}$</th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece</td>
<td>2.63</td>
<td>0.14</td>
<td>-0.10</td>
<td>-0.43</td>
<td>-0.25</td>
<td>-0.20</td>
</tr>
<tr>
<td>Austria</td>
<td>1.76</td>
<td>0</td>
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<td>-0.16</td>
<td>0.08</td>
<td>0.16</td>
</tr>
<tr>
<td>Belgium</td>
<td>1.99</td>
<td>0.27</td>
<td>-0.18</td>
<td>-0.53</td>
<td>-0.42</td>
<td>-0.29</td>
</tr>
<tr>
<td>Finland</td>
<td>2.42</td>
<td>-0.28</td>
<td>-0.13</td>
<td>-0.24</td>
<td>-0.35</td>
<td>-0.47</td>
</tr>
<tr>
<td>France</td>
<td>2.08</td>
<td>0.03</td>
<td>-0.14</td>
<td>-0.30</td>
<td>-0.26</td>
<td>-0.22</td>
</tr>
<tr>
<td>Germany</td>
<td>0.33</td>
<td>0.10</td>
<td>0.14</td>
<td>-0.14</td>
<td>-0.14</td>
<td>0.11</td>
</tr>
<tr>
<td>Italy</td>
<td>3.61</td>
<td>-0.16</td>
<td>-0.22</td>
<td>-0.06</td>
<td>0.13</td>
<td>-0.08</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2.62</td>
<td>0.06</td>
<td>-0.30</td>
<td>-0.59</td>
<td>-0.38</td>
<td>-0.03</td>
</tr>
<tr>
<td>Spain</td>
<td>1.30</td>
<td>-0.15</td>
<td>-0.20</td>
<td>-0.12</td>
<td>0.10</td>
<td>0.26</td>
</tr>
</tbody>
</table>
The tax rate on capital income lags positively the cycle in Austria, Finland, France and Netherlands. These results indicate that a rise in hours worked is expected to be followed by an increase in the capital tax rate. In Belgium and Greece the tax rate leads the cycle countercyclically, while in Germany it leads the cycle procyclically and in Spain is procyclical and synchronous with the cycle.

The consumption tax rate leads procyclically the cycle in Austria, Finland, Germany and Greece, indicating that a rise in the consumption tax rate is followed by an increase in labor supply. On the other hand, the consumption tax rate lags negatively the cycle of hours worked in Belgium, France, Netherlands and Spain. Therefore, a rise in labor supply is followed by a decrease in the consumption tax rate.

The personal income tax rate leads countercyclically the cycle in Austria, Belgium, Germany, Greece and Netherlands, while it is synchronous with a negative sign in Belgium. In Italy and Spain the tax rate lags procyclically the cycle, while it lags countercyclically the cycle in Finland.

The tax rate on total self-employment income leads negatively the cycle in Austria and Spain and is synchronous with a negative sign in Belgium and Netherlands. Thus, in these countries there is a negative relation between the cyclical components of hours worked and the tax rate. In Germany the tax rate is synchronous with a positive sign, while in Italy it lags procyclically the cycle. In Finland the tax rate lags negatively the cycle, while in Greece is uncorrelated with the cycle of hours worked.

The comovements of the corporate tax rate in most cases lag procyclically the cycle of hours worked. Namely, the correlations for Greece, Finland, Italy and Netherlands are positively lagging, whereas in Spain are procyclical and synchronous. On the other hand, the correlations lead procyclically the cycle in Germany, countercyclically in France and are synchronous and countercyclical in Belgium.

Concerning the tax rate related to social security contributions, in most countries there is a negative relation between the cyclical components of the tax rate and hours worked. The cyclical comovements are found to be synchronous, with the exceptions of Finland and Spain where the tax rate leads the cycle countercyclically and procyclically, respectively.

To sum up, there is a negative relation between the comovements of the cyclical components of hours worked and the tax rate on labor income. The same is true for the tax rate on personal income and the tax rate related to social security contributions. On the other hand, the tax rates on capital and corporate income in most cases lag
procyclically the cycle of hours worked. The tax rate on consumption either leads procyclically or lags countercyclically the cycle, while the comovements for the tax rate on self-employment display a variety of patterns. The negative correlation between the labor income tax rate and labor supply is also found in Fiorito and Padrini (2001). Moreover, empirical evidence provided by Cardia et al. (2003) shows that there is a negative relation between labor tax rates and labor supply.

1.6.2.3. Business Cycle Comovements with Real per capita Capital Stock

Table 6 summarizes the results for the cross-correlations between the cyclical components of the effective tax rates and real per capita capital stock.

A common pattern across countries is that the tax rates on labor and capital income in most cases lead countercyclically the cycle of the capital stock. Moreover, the evidence suggest that there is a negative relation between the tax rate related to social security contributions and the capital stock.

The tax rate on labor income negatively leads the cycle in Greece, Italy and Netherlands, indicating that a rise in the labor income tax rate is expected to be followed by a decrease in the stock of capital. On the other hand, in Austria and Germany the labor tax rate leads positively the cycle, whereas in France and Spain the tax rate lags positively the cycle and in Belgium is countercyclical and synchronous with the cycle.

The tax rate on capital income leads negatively the cycle of the capital stock in Belgium, Greece and Italy, while it leads positively the cycle in Spain and is countercyclical and synchronous in Germany. In Finland and France the tax rate lags positively the cycle, while it is uncorrelated with the cycle of the capital stock in Austria and Netherlands.

The consumption tax rate lags countercyclically the cyclical component of the capital stock in Austria, Greece, France and Spain, indicating that a rise in the stock of capital is expected to be followed by a decrease in the consumption tax rate. On the other hand, the consumption tax rate leads positively the cycle in Belgium, Finland and Netherlands, whereas in Italy the tax rate is uncorrelated with the cycle.

Personal income tax rates lead countercyclical the cycle of the capital stock in Greece and Italy, while they lag procyclically the cycle in Netherlands and Spain. In Germany, the personal tax rate leads positively the cycle, whereas in France it is uncorrelated with the cycle. In Finland and France the tax rate lags countercyclically the cycle, however, comovements for France are not significant.
The tax rate on total self-employment income leads negatively the cycle in France, Italy and Netherlands, while it lags procyclically the cycle in Austria and Germany. The tax rate lags positively the cycle in Spain and negatively in Finland, while it is uncorrelated with the cycle in Belgium and Greece.

Table 6: Relative Volatility and Comovement with Real Per Capita Capital Stock

<table>
<thead>
<tr>
<th>Variable</th>
<th>Relative Volatility</th>
<th>Comovement Real Per Capita Capital Stock, $\rho(k, x_{it})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tax Rate on Labor Income, $\tau^l$</td>
<td>$\sigma_x / \sigma_k$</td>
<td>$i = -2$</td>
</tr>
<tr>
<td>Greece</td>
<td>2.87</td>
<td>-0.02</td>
</tr>
<tr>
<td>Austria</td>
<td>4.33</td>
<td>0.30</td>
</tr>
<tr>
<td>Belgium</td>
<td>1.56</td>
<td>0.09</td>
</tr>
<tr>
<td>Finland</td>
<td>4.33</td>
<td>-0.08</td>
</tr>
<tr>
<td>France</td>
<td>3.33</td>
<td>-0.14</td>
</tr>
<tr>
<td>Germany</td>
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<td>0.20</td>
</tr>
<tr>
<td>Italy</td>
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<td>-0.52</td>
</tr>
<tr>
<td>Netherlands</td>
<td>5.51</td>
<td>-0.31</td>
</tr>
<tr>
<td>Spain</td>
<td>3.34</td>
<td>-0.08</td>
</tr>
</tbody>
</table>

| Tax Rate on Capital Income, $\tau^k$ |        |        |        |        |        |
| Greece | 9.51 | 0.01 | -0.53 | -0.38 | -0.05 | 0.29 |
| Austria | 24.57 | 0.12 | -0.05 | 0.06 | 0.19 | 0 |
| Belgium | 3.67 | -0.38 | -0.27 | -0.01 | 0.04 | 0.03 |
| Finland | 20.75 | -0.15 | 0.26 | 0.57 | 0.60 | 0.22 |
| France | 15.16 | -0.26 | -0.07 | 0.20 | 0.40 | 0.24 |
| Germany | 2.94 | 0.05 | 0.11 | -0.52 | -0.24 | 0.17 |
| Italy | 14.50 | -0.07 | -0.24 | -0.02 | 0.06 | -0.03 |
| Netherlands | 15.57 | 0.11 | 0.14 | 0.20 | 0.15 | 0.01 |
| Spain | 7.53 | 0.39 | 0.42 | 0.30 | 0 | -0.28 |

| Tax Rate on Consumption, $\tau^c$ |        |        |        |        |        |
| Greece | 5.83 | 0.25 | 0.16 | -0.25 | -0.31 | -0.09 |
| Austria | 8.01 | 0.23 | 0.20 | -0.12 | -0.25 | -0.18 |
| Belgium | 3.23 | 0.17 | 0.33 | 0.12 | -0.06 | -0.05 |
| Finland | 4.52 | 0.49 | 0.34 | 0.01 | -0.33 | -0.42 |
| France | 7.40 | 0.22 | 0.05 | -0.22 | -0.58 | -0.56 |
| Germany | 0.97 | -0.08 | -0.15 | -0.47 | -0.16 | -0.08 |
| Italy | 7.38 | 0.02 | -0.14 | -0.14 | -0.15 | 0.15 |
| Netherlands | 6.46 | 0.56 | 0.48 | 0.12 | -0.37 | -0.55 |
| Spain | 5.61 | 0.03 | -0.08 | -0.33 | -0.63 | -0.56 |
### Table 6 (continued)

<table>
<thead>
<tr>
<th>Tax Rate on Personal Income, $\tau^h$</th>
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Note: The capital stock was generated using a perpetual inventory method. See Appendix B for details.
The corporate income tax rate leads negatively the cycle in Belgium and lags positively the cycle in Austria, France and Netherlands and negatively in Spain. In Finland and Greece the corporate tax rate is synchronous with a positive sign, while in Germany and Italy is synchronous with a negative sign.

Finally, the tax rate on social security contributions lead countercyclically the cycle in France and Italy and lead positively the cycle in Germany. In Finland and Spain the tax rate lags positively the cycle, while in Austria it lags the cycle negatively. The tax rate is countercyclically synchronous with the cycle in Belgium, Greece and Netherlands.

1.7. Concluding Remarks

This chapter examined the evolution and the distribution of the tax burden in the Greek economy over the period 1970-2005 by constructing effective tax rates on labor income, capital income and consumption following the methodology of Mendoza et al. (1994). Particular attention was paid on the decomposition of the total tax burden on labor and capital income in terms of their components by constructing effective tax rates on personal income, self-employment income, employees’ income (wage earners), corporate income and tax rates reflecting social security contributions. Then, the chapter followed the “stylized facts” methodology of Kydland and Prescott (1990) in order to analyze the cyclical features of the effective tax rates and to examine the relation between distortionary tax rates and economic activity from a business cycle perspective. Moreover, Granger causality tests were performed in order to assess if deviations of the tax rates from their trend can help to predict future movements in key macroeconomic variables. For comparison reasons, results for other eight Euro-zone member countries were also reported.

The results suggest that the Greek effective tax rate on labor income has increased since 1975, while the tax rate on capital income in Greece appears to be rather stable until the late 80s, when the tax rate increased and reached its peak in 2000. Greece faced a high increase in the tax rate on capital income during this period, while after 2000 the tax rate decreased.

The tax rates on labor and capital income in Greece are below the Euro-zone averages, while the consumption tax rate and the corporate income tax rate are close to the Euro-zone averages. The effective tax rates on personal income and on self-
employment income are substantially lower than the Euro-zone average. Concerning the distribution of the tax burden between labor and capital income, Greece faced an increase in the tax burden on labor income relative to the tax burden on capital income from the mid 70s and until the mid 80s. The opposite is true during the mid 90s and until 2000. In addition, the results suggest that there is an unequal distribution of the tax burden between employees and self-employed in Greece.

In what concerns the volatility properties of the Greek effective tax rates, the tax rate on capital income exhibits higher volatility than the tax rate on consumption, which in turn, fluctuates more than the tax rate on labor income. Moreover, the tax rate on corporate income is the most volatile tax rate over the business cycle.

Concerning comovement properties, the tax rates on labor and capital income are countercyclical and synchronous with the output cycle, so that deviations of the effective tax rates from their trend are negatively associated with those of output. These findings indicate that tax rates are higher (lower) from their trend during recessions (expansions). On the other hand, the consumption tax rate is uncorrelated with the cycle, while the personal income tax rate and the tax rates on self-employment and corporate income lag positively the cycle. However, the comovements for the tax rates on self-employment and corporate income are not too significant.

In addition, the results show that there is a negative relation between the labor income tax rate and labor supply. The same is true for the tax rate related to social security contributions. The tax rate on capital income leads negatively the cycle of hours worked, which indicates that a rise (fall) in the tax rate from its trend is expected to be followed by a fall (rise) in the cycle in hours worked. Moreover, as suggested by the Granger causality probability, the predictive power of the tax rate in forecasting the cyclicality of hours worked is found to be high. The consumption tax rate leads positively the cycle of hours worked, while lagged values of the consumption tax rate produce large improvements in forecasts of future hours of work. In addition, the effective tax rates on labor and capital income lead countercyclically the cycle of the capital stock, while the consumption tax rate lags the cycle.

The results for the individual Euro-zone countries suggest that a common feature across countries is that the tax rate on capital income fluctuates more than the tax rates on consumption and labor income. In addition, deviations from trend of the effective tax rates on labor and self-employment income, as well as the tax rate related to social security contributions, are negatively associated with those of output.
Moreover, the tax rate on corporate income lags positively the output cycle, while the capital income tax rate and the consumption tax rate display a variety of patterns. Another common feature is the negative association between the deviations of the tax rate on labor income from its trend and those of hours worked. The same is true for the personal income tax rate, as well as the tax rate related to social security contributions. On the other hand, the tax rate on capital income lags positively the cycle of hours worked in most cases.
Chapter 2

Stochastic Fiscal Policy and the Greek Business Cycle
2.1. Introduction

This chapter examines the importance of fluctuations in fiscal (tax-spending) policy for the Greek business cycle. To do so, it presents an extensive analysis of the dynamic properties of an enriched Real Business Cycle Model using impulse response functions and variance decomposition.

Stochastic fiscal policy has been found to be an important determinant of business cycles in the U.S. data by explaining a significant fraction of the variance of output and other major macroeconomic variables; see Jones (2002), Braun (1994) and McGrattan (1994). Jonsson and Klein (1996) show that this is also true for the Swedish economy.29

As refers to the Greek economy, it is not until relatively recently that real business cycle models have been applied to the study of macroeconomic fluctuations. Kollintzas and Vassilatos (2000) model the Greek economy as a small open economy with transaction costs in foreign markets. They introduce stochastic government spending behavior but do not take into account fluctuations in distortive taxes. However, there are strong reasons to believe that fluctuations in both categories of fiscal policy instruments can account for some of the key features of the Greek business cycle since both tax rates and government spending as share of output have changed considerably over time (see e.g. Bosworth and Kollintzas (2001), Martinez-Mongay (2000) and European Commission (2000, 2008a)).

There are some stylized facts about the Greek cycle that should be stressed. Private consumption is less volatile than output, private investment is about three times more volatile than output and private and public capital stocks fluctuate much less than output. Hours worked fluctuate less than output, while labor productivity and real wages fluctuate as much as output.30

What is less known about the Greek business cycle is the behavior of fiscal variables over the cycle. Government consumption fluctuates less than output and is uncorrelated with the cycle. On the other hand, government investment is about three times more volatile than output and leads positively the cycle. Government transfers fluctuate more than output and lead negatively the cycle. The effective tax rates on labor

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30 For the basic stylized facts of business cycles in the U.S. and several European countries see Stock and Watson (1999), Christodoulakis et al. (1995) and Fiorito and Kollintzas (1994).
and capital income are synchronous with a negative sign with the output cycle, while the effective tax rate on consumption is uncorrelated with the cycle.

The approach of this chapter can be summarized as follows. In order to study the importance of fluctuations in distortive taxes and government spending for the Greek business cycle, I employ a Dynamic Stochastic General Equilibrium model that captures several observed features built in actual tax structures such as tax rates on labor income, capital income and consumption, depreciation allowance and the taxation of dividends. The government uses the tax revenues plus the issue of new government bonds to finance three activities: public consumption that provide utility to households, public investment that augments public capital and lump sum transfers that augment households income.

I calibrate the model for the Greek economy over the period 1960:1-2005:4. First, I look at the descriptive power of the model and then investigate the response of major macroeconomic variables to temporary and permanent changes in fiscal policy variables. I am especially interested in studying the effects of tax rate increases given 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. European Commission (2000, 2008a) and Martinez-Mongay (2000)). Moreover, to quantify the contribution of fiscal disturbances to economic fluctuations, variances are decomposed with fractions explained by innovations in technology, government consumption as share of output, government investment as share of output, the labor tax rate, the capital tax rate and the consumption tax rate.

The results suggest that the model does quite well in reproducing the key stylized facts of the Greek business cycle. The volatilities of investment and hours worked generated by the model are the same as those found in data. The volatilities of private consumption, as well as private and public capital, are equally well captured. The model also produces very satisfactory results for the persistence and comovement properties of the key macroeconomic variables.

Impulse response analysis shows that temporary increases in the labor income tax rate reduce output, labor supply and private capital more than similar increases in capital income or consumption tax rates. In addition, permanent increases in the tax rates on labor and capital income decrease long-run output, private consumption, private investment and hours worked more than permanent increases in the consumption tax rate. For instance, a 1% permanent increase in the tax rate on capital income decreases
long-run output and private investment by 0.21% and 0.44% respectively, while a 1% permanent increase in the tax rate on labor income decreases long-run output and private investment by 0.21%. Higher consumption tax rates allow a higher increase in tax revenues as share of GDP than higher labor or capital income tax rates. Moreover, debt financed temporary increases in government consumption and government investment as shares of output lead to short-run increases in output and labor supply.

Variance decomposition suggests that a significant portion of the variance of output, private consumption, private investment, hours worked, labor productivity and private capital can be explained by innovations in the tax rates on labor and capital income. Innovations in government consumption and government investment as shares of output and the tax rate on consumption have smaller contribution. The results suggest that only 44.62% of the variance of output is due to technology shocks, while 30.80% is explained by innovations in the labor income tax rate and 19.78% by innovations in the capital income tax rate. However, for short term horizons, innovations in technology have a larger effect on output. The contribution of labor and capital tax rates is also found to be large concerning fluctuations in the rest of endogenous variables. For instance, the tax rates on labor and capital income contribute respectively 54.69% and 19.77% in the variation of hours worked, while only 13.24% of the variation is due to technology shocks. Moreover, the tax rates on labor and capital income contribute respectively 49.38% and 20.48% in the variation of consumption, while the contribution of the capital tax rate is also found to be large to fluctuations in private investment since it explains about 43% of its total variance.

The rest of the chapter is as follows. Section 2.2 presents the theoretical model. Section 2.3 discusses calibration, the long-run solution and the model’s descriptive power. Section 2.4 presents the responses of key endogenous variables to temporary and permanent changes in innovations of exogenous fiscal policy variables and discusses the contribution of these shocks to the variance of endogenous variables. Section 2.5 concludes.
2.2. 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 labor and capital services to firms in perfectly competitive markets. As owners of firms, households receive profits in the form of dividends. Firms behave competitively and produce a homogeneous product by using private capital, labor and public capital. The government levies taxes on labor and capital income and on consumption. It then uses its 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.

2.2.1. 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:

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

Let $u(C^h_t, L^h_t)$ denote the representative household’s temporal (per period) utility function in period $t$, where $C^h_t$ denotes total consumption services enjoyed by the household which is a weighted average of private and public consumption services:

$$C^h_t = C^{h^*}_t + \vartheta \bar{G}^c_t$$  \hspace{1cm} (2)

where $C^{h^*}_t$ is private consumption in period $t$, $L^h_t$ is leisure in period $t$ and $\bar{G}^c_t$ is average (per household) public consumption goods and services provided by the government in period $t$.\(^{31}\)

The preferences of the representative household are characterized by the lifetime utility function:\(^{32}\)

\(^{31}\) Thus, $\bar{G}^c_t = G^c_t / N_t$, where $G^c_t$ is total public consumption services.
\[ E_0 \sum_{t=0}^{\infty} \beta^t u\left(C_t^h, L_t^h\right) \] (3)

where \( E_0 \) denotes expectations conditional on the informational set of the household at the beginning of period zero and \( \beta^t \in (0,1) \) is the discount factor. Notice that public consumption goods and services influence private utility through the parameter \( \theta \in [-1,1] \).\(^{33}\) The temporal utility function is of the form:

\[
u\left(C_t^h, L_t^h\right) = \left[\left(C_t^h\right)^\gamma \left(L_t^h\right)^{1-\gamma}\right]^{-\sigma/\gamma} - 1 \] (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:

\[ L_t^h + H_t^h \leq 1 \] (5)

---

\(^{32}\) For the instantaneous utility function \( u\left(C_t^h, L_t^h\right) \) the following assumptions hold:

a) It is continuously differentiable in \( C_t^h \) and \( L_t^h \), where \( C_t^h = C_t^{h\theta} + \theta G_t^e \)
b) It is strictly increasing in \( C_t^h \) and \( L_t^h \)
c) It is strictly concave in \( C_t^h \) and \( L_t^h \)
d) Inada conditions hold, \( \lim_{C_t^h \to +\infty} u_{C_t^h} (C_t^h, L_t^h) = \infty \), \( \lim_{C_t^h \to +\infty} u_{L_t^h} (C_t^h, L_t^h) = 0 \)
and \( \lim_{L_t^h \to +\infty} u_{L_t^h} (C_t^h, L_t^h) = \infty \), \( \lim_{L_t^h \to +\infty} u_{C_t^h} (C_t^h, L_t^h) = 0 \)

\(^{33}\) If \( \theta > 0 \), the marginal utility of consumption decreases with an increase in \( G_t^e \). The opposite is true when \( \theta < 0 \). More specifically, if \( \theta > 0 \) private and public consumption are substitutes (e.g. private security and state police). On the other hand, if \( \theta < 0 \) private and public consumption are complements (e.g. low quality public education requires additional time and money for private courses). If \( \theta = 1 \) public and private consumption are perfect substitutes. Finally, if \( \theta = 0 \), government consumption does not affect household preferences. See also Kollintzas and Vassilatos (2000), Finn (1998) and Christiano and Eichenbaum (1992) for similar formulations.
The household saves in the form of physical capital $I^h_t$ and in the form of one period real government bonds $B^h_{t+1}$. It receives labor income, $w_i Z_i H^h_t$, capital income $r^k_i K^h_t$, and interest income from government bonds, $r^b_i B^h_t$, where $w_i$ is the wage rate per efficient unit of labor hours, $Z_i H^h_t$, and $r^k_i$, $r^b_i$ are the real returns to private capital $K^h_t$ and government bonds $B^h_t$, respectively. $Z_i$ is labor augmenting technology which evolves according to the deterministic law of motion $Z_{t+1} = \gamma Z_t$, where $\gamma > 1$ and $Z_0 > 0$ is given. Two additional sources of income are the firm’s profits that are distributed in the form of dividends, $\Pi^h_t$, and average (per household) lump-sum government transfers, $\bar{G}^\tau_t$. The household also pay taxes on consumption and on income from labor and capital earnings. Thus, the representative household’s budget constraint in each period is:

$$
(1 + \tau^c_i) C^h_t + I^h_t + B^h_{t+1} \leq \left(1 - \tau^c_i\right) w_i Z_i H^h_t + \left(1 - \tau^c_i\right) (r^k_i K^h_t + \Pi^h_t) + \left(1 + r^b_i\right) B^h_t + \bar{G}^\tau + \Phi \tau^h_i \delta^\tau K^h_t
$$

$k_0, B^h_0$ given

where $0 \leq \tau^c_i < 1$ is the proportional tax rate on consumption, $0 \leq \tau^k_i < 1$ is the proportional tax rate on labor income and $0 \leq \tau^b_i < 1$ is the proportional tax rate on income from capital earnings and dividends. Note that dividends, capital income and bond interest are taxed at the same rate $\tau^b_i$. The term $\Phi \tau^h_i \delta^\tau$ represents the depreciation allowance built in the Greek tax code, where the parameter $\Phi \geq 0$ determines the method of depreciation allowance. When $\Phi = 1$ there is a straight line depreciation allowance. When $\Phi > 1$ there is an accelerated depreciation. $^{35}$

All households view $\tau^c_i, \tau^k_i, \tau^b_i, \bar{G}^\tau, \bar{G}^\tau_t, \Pi^h_t, w_i, r^k_i$ and $r^b_i$ as determined outside their control when making their decisions.

The law of motion for private capital stock is:

$^{34}$Thus, $\bar{G}^\tau_t = G^\tau_t / N_t$, where $G^\tau_t$ is total lump-sum transfers.

$^{35}$Accelerated depreciation implies that $\Phi > 1$ in the early years of an asset’s life, but $\Phi < 1$ in later years. In the case of accelerated depreciation $\Phi$ can be interpreted as a weighted-average value over the asset’s entire life. See also Guo and Lansing (1997) for a further discussion.
\[ K_{t+1}^h = (1 - \delta^p) K_t^h + I_t^h - \frac{\xi}{2} \left( \frac{K_{t+1}^h}{K_t^h} - \gamma_n \gamma_z \right)^2 K_t^h \]  

(7)

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

Taking prices \( \{r_t, r^h_t, w_t, \Pi_t^h\}_{t=0}^{\infty} \) and fiscal policy \( \{G_t, \bar{G}_t^h, \tau_t, \bar{\tau}_t^h, \bar{\tau}_t^c\}_{t=0}^{\infty} \) as given, the representative household chooses a sequence \( \{C_t^h, L_t^h, H_t^h, I_t^h, K_{t+1}^h, B_{t+1}^h\}_{t=0}^{\infty} \) 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 \( C_t^h, H_t^h, L_t^h, K_{t+1}^h, B_{t+1}^h \). The first-order conditions for an interior solution include the constraints and the following conditions:

\[
\frac{u_{c_t^h}}{u_{c_t^h}} = \frac{(1 - \tau_t^c)}{(1 + \tau_t^c)} w_t Z_t 
\]

(8a)

\[
\frac{u_{c_t^h}}{(1 + \tau_t^c)} \left[ 1 + \xi \left( \frac{K_{t+1}^h}{K_t^h} - \gamma_n \gamma_z \right) \right] = \beta' E_t \left[ \frac{u_{c_{t+1}^h}}{(1 + \tau_{t+1}^c)} \left( 1 + \tau_{t+1}^c \right) + (1 - \delta^p) + \xi \left( \frac{K_{t+1}^h}{K_t^h} - \gamma_n \gamma_z \right) \frac{K_{t+2}^h}{K_t^{h_2}} - \frac{\xi}{2} \left( \frac{K_{t+1}^h}{K_t^h} - \gamma_n \gamma_z \right)^2 + \Phi \tau_{t+1}^c \delta^p \right] 
\]

(8b)

\[
\frac{u_{c_t^h}}{(1 + \tau_t^c)} = \beta' E_t \left[ \frac{u_{c_{t+1}^h}}{(1 + \tau_{t+1}^c)} (1 + \tau_{t+1}^c) \right] 
\]

(8c)

\[
\lim_{t \to \infty} \beta^t E_t u_{c_t^h} K_{t+1}^h = 0 
\]

(8d)

\[
\lim_{t \to \infty} \beta^t E_t u_{c_t^h} B_{t+1}^h = 0 
\]

(8e)

Equation (8a) is the intratemporal condition for the hours worked and states that the marginal rate of substitution between leisure and consumption at 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.

The assumptions made for the utility function and the private capital transition process combined with the transversality conditions ensure that the first-order conditions are necessary and sufficient for an optimum.

2.2.2. Firms

There is a large number of identical firms indexed by the superscript \( f \).\(^3\)\(^6\) The representative firm produces a homogeneous product, \( Y^f_t \), by using private capital, \( K^f_t \), private labor, \( H^f_t \), and average (per firm) public capital, \( \bar{K}^p_t \).\(^3\)\(^7\) The representative firm has access to the following production function:

\[
Y^f_t = A_t \left( K^f_t \right)^{a_1} \left( Z, H^f_t \right)^{a_2} \left( \bar{K}^p_t \right)^{a_3}
\]  

(9)

where \( a_i \in (0,1), \ i = 1, 2, 3 \) is the output elasticity of private capital, labor and public capital, respectively.\(^3\)\(^8\) \( A_t \) characterizes the stochastic total factor productivity whose evolution will be specified in the next section. 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 \( K^f_t \) and \( H^f_t \) in order to maximize period by period profits by taking average public capital, \( \bar{K}^p_t \), market prices and policy variables as given. Thus, the problem of the representative firm may be defined as:

---

\(^3\)\(^6\) For simplicity it is assumed that the number of firms equals the number of households in each period.

\(^3\)\(^7\) Thus, \( \bar{K}^p_t = K^p_t / N^f_t \), where \( K^p_t \) is aggregate public capital stock.

\(^3\)\(^8\) 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.
\[
\max_{K_t^f, H_t^f} \Pi_t^f = Y_t^f - r_t^k K_t^f - w_t Z_t H_t^f
\]

subject to

\[
Y_t^f \leq \left( K_t^f \right)^{a_1} \left( Z_t H_t^f \right)^{a_2} \left( \overline{K}_t^f \right)^{a_3}, \quad a_1 + a_2 + a_3 = 1
\]

\[
K_t^f, H_t^f \geq 0
\]

The first-order conditions are:

\[
r_t^k = a_1 \frac{Y_t^f}{K_t^f}
\]

\[
w_t = a_2 \frac{Y_t^f}{Z_t H_t^f}
\]

and the implied economic profits are \( \Pi_t^f = (1 - a_1 - a_3)Y_t^f > 0 \). 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 labor 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.\(^{39}\)

2.2.3. Government Budget Constraint

The inter-temporal budget constraint of the government in aggregate terms is:

\[
B_{t+1} + \tau_t c \sum_{h=1}^{N_c} C_t^{h,c} + \tau_t w_t Z_t \sum_{h=1}^{N_c} H_t^{h,c} + \tau_t k \sum_{h=1}^{N_c} \left( r_t^k K_t^h + \Pi_t^h \right) =
\]

\[
= G_t^c + G_t^{w} + G_t^i + \left( 1 + r_t^h \right) B_t + \Phi \tau_t^k \delta^p \sum_{h=1}^{N_c} K_t^h
\]

\(^{39}\) See e.g. European Commission (2008a) and Appendix A.
where $G^c_t, G^r_t, G^i_t$ are respectively total government consumption, total government transfers and total government investment at time $t$, and $B_{t+1}$ is the end of period total stock of new one-period government bonds issued by the government.

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

$$K^g_{t+1} = (1 - \delta^g) K^g_t + G^i_t, \quad K^g_0 > 0 \text{ given} \tag{16}$$

where $\delta^g \in (0,1)$ is the depreciation rate of public capital stock.

### 2.2.4. Stochastic Environment

The exogenous stochastic variables are the aggregate productivity, $A_t$, and the six policy instruments $G^c_t, G^r_t, G^i_t, \tau^c_t, \tau^r_t, \tau^i_t$. Define $s^c_t \equiv \frac{G^c_t}{Y_t}, s^r_t \equiv \frac{G^r_t}{Y_t}$ and $s^i_t \equiv \frac{G^i_t}{Y_t}$ to be the three categories of government spending as shares of aggregate output. Following Jones (2002) and Kollintzas and Vassilatos (2000) it is assumed that $A_t, s^c_t, s^r_t, s^i_t, \tau^c_t, \tau^r_t, \tau^i_t$ follow univariate stochastic AR(1) process of the form:

$$\ln A_{t+1} = (1 - \rho^a) \ln A_t + \rho^a \ln A_t + \varepsilon^a_{t+1} \tag{17a}$$
$$\ln s^c_{t+1} = (1 - \rho^c) \ln s^c_t + \rho^c \ln s^c_t + \varepsilon^c_{t+1} \tag{17b}$$
$$\ln s^r_{t+1} = (1 - \rho^r) \ln s^r_t + \rho^r \ln s^r_t + \varepsilon^r_{t+1} \tag{17c}$$
$$\ln s^i_{t+1} = (1 - \rho^i) \ln s^i_t + \rho^i \ln s^i_t + \varepsilon^i_{t+1} \tag{17d}$$
$$\ln \tau^c_{t+1} = (1 - \rho^c) \ln \tau^c_t + \rho^c \ln \tau^c_t + \varepsilon^c_{t+1} \tag{17e}$$
$$\ln \tau^r_{t+1} = (1 - \rho^r) \ln \tau^r_t + \rho^r \ln \tau^r_t + \varepsilon^r_{t+1} \tag{17f}$$
$$\ln \tau^i_{t+1} = (1 - \rho^i) \ln \tau^i_t + \rho^i \ln \tau^i_t + \varepsilon^i_{t+1} \tag{17g}$$

where,
\( A_0, s_0^u, s_0^l, \sigma_0^u, \sigma_0^l, \tau_0^k, \tau_0^c \) are the means of the respective stochastic processes; 
\( \rho_A, \rho_k, \rho_{ul}, \rho_l, \rho_k, \rho_c \) are the first order correlation coefficients; and 
\( \varepsilon_{t+1}^u, \varepsilon_{t+1}^g, \varepsilon_{t+1}^i, \varepsilon_{t+1}^l, \varepsilon_{t+1}^k, \varepsilon_{t+1}^c \) are i.i.d shocks.

2.2.5. Solution of the Model

2.2.5.1. Competitive Equilibrium

A competitive equilibrium is a sequence (of random variables),
\[ C_t^{h^u}, L_t^h, H_t^h, I_t^h, K_t^h(t), B_t^h(t), \Pi_t^f, Y_t^f, K_t^f, H_t^f, R_t^g(t), \Pi_t^f, \omega_t^c, r_t^k, \tau_t^l, \tau_t^c, \tau_t^k, \tau_t^c, \sigma_t^u, \sigma_t^g, \sigma_t^i, \sigma_t^l, \sigma_t^k, \sigma_t^c \] such that:

i) given the sequence of technology, population and labor augmenting technological process \( \{A_t, N_t, Z_t\}_{t=0}^\infty \), the sequence of prices, profits and government fiscal policy, 
\[ w_t, r_t^k, r_t^h, \Pi_t^f, \Pi_t^i, \tau_t^l, \tau_t^c, \sigma_t^u, \sigma_t^g, \sigma_t^i, \sigma_t^l, \sigma_t^k, \sigma_t^c \] and the initials conditions for the state variables \( \{K_0^h, K_0^g, B_0^h\} \), the allocation \( \{C_t^{h^u}, L_t^h, H_t^h, I_t^h, K_t^h(t), B_t^h(t), Y_t^f, K_t^f, H_t^f, R_t^g(t)\}_{t=0}^\infty \) solves the problem of the representative household and of the representative firm

ii) given the sequence \( \{C_t^{h^u}, L_t^h, H_t^h, I_t^h, K_t^h(t), B_t^h(t), Y_t^f, K_t^f, H_t^f, R_t^g(t)\}_{t=0}^\infty \), the sequence \( w_t, r_t^k, r_t^h, \Pi_t^f, \Pi_t^i, \tau_t^l, \tau_t^c, \sigma_t^u, \sigma_t^g, \sigma_t^i, \sigma_t^l, \sigma_t^k, \sigma_t^c \) clears the capital, labor, dividend and the bond markets, i.e. 
\[ \sum_{h=1}^{N_t} K_t^h = \sum_{h=1}^{N_t} K_t^l, \sum_{h=1}^{N_t} H_t^h = \sum_{h=1}^{N_t} H_t^l, \sum_{h=1}^{N_t} \Pi_t^f = \sum_{h=1}^{N_t} \Pi_t^f \] and \( B_t = \sum_{h=1}^{N_t} B_t^h \), respectively

iii) given the sequence \( \{C_t^{h^u}, L_t^h, H_t^h, I_t^h, K_t^h(t), B_t^h(t), \Pi_t^f, Y_t^f, K_t^f, H_t^f, R_t^g(t), \Pi_t^f\}_{t=0}^\infty \), the sequence \( \{r_t^l, \tau_t^c, \sigma_t^u, \sigma_t^g, \sigma_t^i, \sigma_t^l, \sigma_t^k, \sigma_t^c\}_{t=0}^\infty \) satisfies the government budget constraint.

2.2.5.2. Stationary Competitive Equilibrium

In the long-run, all aggregate variables (except total hours of work, \( H_t \)) grow at the same constant rate \( \gamma, \gamma_z \) (balance growth path), where \( \gamma_n \) is the growth rate of
population and \( \gamma_z \) is the growth rate of the deterministic labor 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 \( X_t \equiv \left( Y_t, C_t, I_t, K_t, K^g_t, B_t, G_t^c, G_t^p, G_t^i \right) \) define:\(^{40}\)

\[
x_t \equiv \frac{X_t}{N_t Z_t} = \left( \frac{Y_t}{N_t Z_t}, \frac{C_t}{N_t Z_t}, \frac{I_t}{N_t Z_t}, \frac{K_t}{N_t Z_t}, \frac{K^g_t}{N_t Z_t}, \frac{B_t}{N_t Z_t}, \frac{G_t^c}{N_t Z_t}, \frac{G_t^p}{N_t Z_t}, \frac{G_t^i}{N_t Z_t} \right)
\]

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 \( \gamma_n \). The stationary competitive equilibrium is implicitly determined by the following equations:

\[
\left( c_t^p + \delta s^c_t y_t \right) = a_2 \left( 1 - \tau_t^i \right) \frac{\gamma}{1 + \tau_t^e} \left( 1 - h_t \right) \frac{1}{h_t}
\]

\[
\left[ \left( c_t^p + \delta s^c_t y_t \right) \right]^{(1 - \gamma)^{\sigma}} \left[ \begin{array}{c}
\partial \tilde{e}_t
\end{array} \right] =
\]

\[
= \beta E_t \left[ \left[ \left( c_t^p + \delta s^c_t y_t \right) \right]^{(1 - h_t)^{(1 - \gamma)}} \left( 1 + \tau_t^e \right) \right]^{(1 - \tau_t^e)} \left( 1 - \tau_t^e \right) \frac{y_t^i}{\delta k_t} + \frac{\partial \tilde{e}_t}{\partial k_t}
\]

\[
\gamma_{t+1} = \left( 1 - \delta^p \right) k_t + i_t - \frac{\varepsilon}{2} \left( \gamma_{t+1} \gamma_{t+1} \right) k_t + \frac{\varepsilon}{2} \left( \gamma_{t+1} \gamma_{t+1} \right) k_t
\]

\[
\gamma_{t+1} = \left( 1 - \delta^g \right) k_t + s^g_t y_t
\]

\[
y_t = A_t (k_t)^{\alpha_t} (h_t)^{\alpha_t} (k_t^g)^{\alpha_t}
\]

\[
y_t = c_t^p + i_t + s_t^c y_t + s_t^g y_t
\]

\(^{40}\) Capital letters denote aggregate variables.
\[
\gamma \alpha, \gamma b_{t+1} - \left(1 + r^t_1 \right) b_t + \tau^t c_t^p + \tau^t a_2 y_t + \tau^t (a_1 y_t + a_3 y_t) = \\
= s_t^i y_t + s_t^p y_t + s_t^i y_t + \Phi \tau_t \delta^p k_t 
\] 

where

\[
\beta = \beta \gamma z^{(1-\alpha)-1} 
\]

\[
\frac{\partial \bar i_t}{\partial k_{t+1}} = 1 + \xi \left( \frac{\gamma a \gamma z k_{t+1}}{k_t} - \gamma a \gamma z \right) 
\]

\[
\frac{\partial \bar i_{t+1}}{\partial k_{t+1}} = (1 - \delta^p) + \Phi \tau_t \delta^p + \xi \left( \frac{\gamma a \gamma z k_{t+1}}{k_{t+1}} - \gamma a \gamma z \right), 
\]

\[
\bar w_t = a_2 \frac{y_t}{h_t} \text{ and } \bar r_t = a_1 \frac{y_t}{k_t} 
\]

It can be easily verified that \{\gamma, c_p, i_t, h_t, k_{t+1}, k_{t+1}^g, \bar r_t, \bar b_{t+1}\} completely characterize the competitive equilibrium. Thus, the stationary competitive equilibrium is explicitly defined by the above eight non-linear difference equations in \{\gamma, c_p, i_t, h_t, k_{t+1}, k_{t+1}^g, \bar r_t, \bar b_{t+1}\} for given paths of technology \{A_t\}_{t=0}^\infty and the six policy instruments \{\tau_t, \tau_t^k, \tau_t^c, s_t, s_t^p, s_t^i\}_{t=0}^\infty.

**2.2.5.3. Steady-State**

A steady state is defined as a situation where all stationary variables remain constant and there are no shocks. Thus, \(x_{t+1} = x = x_{t-1} = x\) 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:

\[
\frac{k}{y} = \frac{a_1 \left(1 - \tau_0^k \right)}{\beta (1 - \delta^p) - \Phi \tau_0^k \delta^p} 
\]

\[
\frac{i}{y} = \left[\gamma a \gamma z - (1 - \delta^p)\right] \frac{a_1 \left(1 - \tau_0^k \right)}{\beta (1 - \delta^p) - \Phi \tau_0^k \delta^p} 
\]

\[
\bar r^b = \frac{1 - \beta}{\beta} 
\]
\[
\frac{c^\rho}{y} = 1 - \left[ \gamma \gamma - (1 - \delta) \right] \frac{a_1 \left( 1 - \tau_0^i \right)}{\beta} \left( 1 - \delta \right) - s_0^i - s_0^j \tag{19d}
\]

\[
h = \frac{a_2 \left( \gamma \gamma - \frac{1 - \tau_0^i}{1 + \tau_0^i} \right)}{\frac{c^\rho}{y} + \beta s_0^i + a_2 \left( \gamma \gamma - \frac{1 - \tau_0^i}{1 + \tau_0^i} \right)} \tag{19e}
\]

\[
\frac{k^g}{y} = \frac{s_0^i}{\gamma_n \gamma - (1 - \delta^g)} \tag{19f}
\]

\[
y = A_0 \left( \frac{a_1 \left( 1 - \tau_0^i \right)}{\beta} \left( 1 - \delta \right) - \Phi \tau_0^i \delta \right) \left( \frac{a_2 \left( \gamma \gamma - \frac{1 - \tau_0^i}{1 + \tau_0^i} \right)}{\beta} \right) s_0^i \left( \gamma_n \gamma - (1 - \delta) \right)^{\frac{1}{1-a_1-a_2}} \tag{19g}
\]

\[
b \left( \gamma_n \gamma - \frac{1}{\beta} \right) + \tau_0^i \frac{c^\rho}{y} + \tau_0^i a_2 + \tau_0^i \left( a_1 + a_2 \right) = s_0^i + s_0^j + \Phi \tau_0^i k \tag{19h}
\]

which is a system of eight equations in eight unknowns \( \{ y, c^\rho, i, h, k, k^g, \tau^b, b \} \).

### 2.3. Calibration, Long Run Solution and the Model’s Descriptive Power

#### 2.3.1. Calibration and Long Run Solution

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.\(^{41}\)

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

\(^{41}\) 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 C. Moreover, quarterly series for private and public capital stocks are generated using a perpetual inventory method; see Appendix C for details.
The steady state values of the tax rates on capital income, labor income and consumption are set equal to their average values over the period 1960-2005 from quarterly constructed effective tax rates.\textsuperscript{42} The effective tax rate on consumption is $\tau^c_0 = 0.19$ and the effective tax rates on labor and capital income are $\tau^l_0 = 0.21$ and $\tau^k_0 = 0.19$, respectively.

Following Kollintzas and Vassilatos (2000) and Correia et al. (1995), I set the curvature parameter in the utility function $\sigma$ equal to 2. The preference parameter $\vartheta$ which measures the degree of substitutability/complementarity between private and public consumption is set equal to zero in order to allow exploration of the maximum effects of public consumption\textsuperscript{43}; see also Finn (1998) and Christiano and Eichenbaum (1992). This zero value implies that public consumption is a pure resource drain on the economy. The value of population growth $\gamma_n$ is computed from population data and is set equal to 1.0014. The growth rate of technological process $\gamma_z$ 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, $\delta^p$ and $\delta^c$ are set equal to 0.007 and 0.0078, respectively (implying 2.79% and 3.12% annually). The parameter $\Phi$, which determines the method of depreciation allowance, is set equal to zero since the construction of the effective tax rate on capital by definition already incorporates all exemptions for capital income taxation built in the tax code; see Mendoza et al. (1994). The initial level of technological process $Z_0$ and the level of long-run aggregate productivity $A_0$ are set equal to 1 since they are scale parameters which affect only the scale of the economy; see King and Rebelo (1999).

One issue raised when computing the labor and capital shares in output is how to treat the income earned by the self-employed; see also Cooley (1995). The income of self-employed is a combination of labor and capital income and as a result a part of their income should be treated as labor income. In the National Accounts there is no distinction between labor 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 labor income of the self-employed, I assume that the opportunity cost of being a self-

\textsuperscript{42} Appendix C describes how the effective tax rates are constructed.

\textsuperscript{43} See Fiorito and Kollintzas (2004) for an investigation of the relation between private and public consumption.
employed is the labor 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 labor in output, $a_2$, is computed from data assuming that the self-employed earn an imputed wage.\footnote{This seems to be a reasonable assumption for Greece since the fraction of self-employment is 49\%.}

More specifically, the labor’s share $a_2$ is computed as:

$$a_2 = \frac{WSSS + WSE}{NGDP},$$

where $WSSS$ denotes total compensation of employees,\footnote{$WSSS$ in the national accounts is equal to wages and salaries plus employers’ social security contributions plus employers’ contributions to private pension funds.} $WSE$ 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

$$WSE = \left(\frac{WSSS - SSCER}{EE}\right) \times ES,$$

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 labor income is found to be 0.60.\footnote{Note that if I do not assume an imputed wage for self-employed (i.e. $WSE = 0$), then the labor share is considerably lower and equal to 0.31.}

Following Baxter and King (1993), the exponent of public capital in the production function $a_3$ is set equal to the mean share of public investment $s_o^t$ which is computed from data and its value is 0.034. 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 $\xi$ is chosen so that to pin down as close as possible the relative volatility of private investment to output; this is done for $\xi = 10.4780$.

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 $\beta$ 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 $\beta = 0.9883$ and $k/y = 15.7364$, respectively. The preference parameter $\gamma$, which is the weight for consumption relative to leisure, is calibrated from the condition with respect to labor (19e) consistent with a
labor allocation equal to 20% of time. Given the value of $\beta$, the Euler equation for government bonds (19c) implies a steady state quarterly value for the real interest rate on public debt equal to 0.0119 (implying 4.75% 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 $k^\xi / y = 2.3995$.

The parameters $\rho_\delta, \rho_\nu, \rho_\lambda, \rho_\kappa, \rho_\ell$ were estimated via OLS from their respective stochastic processes. The same applies to the standard deviations $\sigma_\delta, \sigma_\nu, \sigma_\lambda, \sigma_\kappa, \sigma_\ell$. The values $s^\sigma_0, s_0^{\nu}, s_0^\ell$ were set equal to their respective mean values computed from data. Concerning the persistence and the volatility of the Solow residual I choose $\rho_\delta$ and $\sigma_\delta$ so that the actual and simulated series have the same variance and first-order serial correlation (see e.g. Correia et al. (1995) and Greenwood and Huffman (1991)).

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, $s_0^\sigma$, is endogenously determined from the government budget constraint (19h).

Table 1 summarizes the calibrated parameters and Table 2 reports the average values found in data and the implied long-run solution of the model economy. The results suggest that the model’s long-run solution is in line with data averages.

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47 Jones (2002) and McGrattan (1994) also assume stochastic process of tax rates on a quarterly basis. This is justified by the fact that even though tax schedules might be fixed over the course of a year, tax rates can still vary on a quarterly basis as households move across tax brackets.
<table>
<thead>
<tr>
<th>Parameter or Variable</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_2$</td>
<td>Labor elasticity in production</td>
<td>0.60</td>
<td>Data</td>
</tr>
<tr>
<td>$a_3$</td>
<td>Public capital elasticity in production</td>
<td>0.034</td>
<td>Set equal to $S_{aq}$</td>
</tr>
<tr>
<td>$a_1$</td>
<td>Private capital elasticity in production</td>
<td>0.3660</td>
<td>Calibrated as 1 - $a_2 - a_3$</td>
</tr>
<tr>
<td>$\gamma_n$</td>
<td>Population growth rate</td>
<td>1.0014</td>
<td>Data</td>
</tr>
<tr>
<td>$\gamma_z$</td>
<td>Growth rate of labor augmenting technology</td>
<td>1.005</td>
<td>Set</td>
</tr>
<tr>
<td>$\delta^p$</td>
<td>Private capital quarterly depreciation rate</td>
<td>0.0070</td>
<td>Set</td>
</tr>
<tr>
<td>$\delta^g$</td>
<td>Public capital quarterly depreciation rate</td>
<td>0.0078</td>
<td>Set</td>
</tr>
<tr>
<td>$\Phi$</td>
<td>Degree of depreciation allowance</td>
<td>0</td>
<td>Set</td>
</tr>
<tr>
<td>$A_0$</td>
<td>Long run aggregate productivity</td>
<td>1</td>
<td>Set</td>
</tr>
<tr>
<td>$Z_0$</td>
<td>Initial level of technological process</td>
<td>1</td>
<td>Set</td>
</tr>
<tr>
<td>$\xi$</td>
<td>Capital adjustment cost parameter</td>
<td>10.4780</td>
<td>Set</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Curvature parameter in the utility function</td>
<td>2</td>
<td>Set</td>
</tr>
<tr>
<td>$\vartheta$</td>
<td>Substitutability between private and public consumption in utility</td>
<td>0</td>
<td>Set</td>
</tr>
<tr>
<td>$k / y$</td>
<td>Consumption weight in utility function</td>
<td>0.2889</td>
<td>Calibrated from (19e)</td>
</tr>
<tr>
<td>$k^g / y$</td>
<td>Public capital to output ratio</td>
<td>15.7364</td>
<td>Calibrated from (19a) and (19b)</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Time discount factor</td>
<td>0.9883</td>
<td>Calibrated from (19a) and (19b)</td>
</tr>
<tr>
<td>$s_y$</td>
<td>Government consumption to output ratio</td>
<td>0.1469</td>
<td>Data</td>
</tr>
<tr>
<td>$s_i$</td>
<td>Government investment to output ratio</td>
<td>0.0340</td>
<td>Data</td>
</tr>
<tr>
<td>$s_t$</td>
<td>Government transfers to output ratio</td>
<td>0.1636</td>
<td>Data</td>
</tr>
<tr>
<td>$\tau^l_0$</td>
<td>Tax rate on labor income</td>
<td>0.21</td>
<td>Data</td>
</tr>
<tr>
<td>$\tau^c_0$</td>
<td>Tax rate on capital income</td>
<td>0.19</td>
<td>Data</td>
</tr>
<tr>
<td>$\tau^c_0$</td>
<td>Tax rate on consumption</td>
<td>0.19</td>
<td>Data</td>
</tr>
<tr>
<td>$\rho_A$</td>
<td>Persistent parameter of $A_t$</td>
<td>0.6700</td>
<td>Set</td>
</tr>
<tr>
<td>$\rho_g$</td>
<td>Persistent parameter of $S^{i}_{gt}$</td>
<td>0.9493</td>
<td>Estimation</td>
</tr>
<tr>
<td>$\rho_g$</td>
<td>Persistent parameter of $S^{q}_{st}$</td>
<td>0.9830</td>
<td>Estimation</td>
</tr>
<tr>
<td>$\rho_i$</td>
<td>Persistent parameter of $S^{c}_{ct}$</td>
<td>0.9757</td>
<td>Estimation</td>
</tr>
<tr>
<td>$\rho_l$</td>
<td>Persistent parameter of $\tau^l_{st}$</td>
<td>0.9937</td>
<td>Estimation</td>
</tr>
<tr>
<td>$\rho_k$</td>
<td>Persistent parameter of $\tau^k_{st}$</td>
<td>0.9662</td>
<td>Estimation</td>
</tr>
<tr>
<td>$\rho_c$</td>
<td>Persistent parameter of $\tau^c_{st}$</td>
<td>0.9480</td>
<td>Estimation</td>
</tr>
<tr>
<td>$\sigma_A$</td>
<td>Standard deviation of innovation $\varepsilon^a_t$</td>
<td>0.0171</td>
<td>Set</td>
</tr>
<tr>
<td>$\sigma_g$</td>
<td>Standard deviation of innovation $\varepsilon^g_t$</td>
<td>0.0289</td>
<td>Estimation</td>
</tr>
<tr>
<td>$\sigma_g$</td>
<td>Standard deviation of innovation $\varepsilon^q_t$</td>
<td>0.0392</td>
<td>Estimation</td>
</tr>
<tr>
<td>$\sigma_i$</td>
<td>Standard deviation of innovation $\varepsilon^c_t$</td>
<td>0.0467</td>
<td>Estimation</td>
</tr>
<tr>
<td>$\sigma_l$</td>
<td>Standard deviation of innovation $\varepsilon^l_t$</td>
<td>0.0152</td>
<td>Estimation</td>
</tr>
<tr>
<td>$\sigma_k$</td>
<td>Standard deviation of innovation $\varepsilon^k_t$</td>
<td>0.1166</td>
<td>Estimation</td>
</tr>
</tbody>
</table>
Table 2: Data Averages and Long Run Solution

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Data Averages</th>
<th>Long Run Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c/y$</td>
<td>Consumption to output ratio</td>
<td>0.6472</td>
<td>0.6091</td>
</tr>
<tr>
<td>$i/y$</td>
<td>Private investment to output ratio</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>$h$</td>
<td>Hours at work</td>
<td>0.20</td>
<td>0.2099</td>
</tr>
<tr>
<td>$k/y$</td>
<td>Private capital to output ratio</td>
<td>15.7364</td>
<td>15.7364</td>
</tr>
<tr>
<td>$k^g/y$</td>
<td>Public capital to output ratio</td>
<td>2.3995</td>
<td>2.3995</td>
</tr>
<tr>
<td>$r^b$</td>
<td>Real return to government bonds</td>
<td>0.011</td>
<td>0.0119</td>
</tr>
<tr>
<td>$b/y$</td>
<td>Public debt to output ratio</td>
<td>2.56</td>
<td>2.56</td>
</tr>
<tr>
<td>$s^g_0$</td>
<td>Government transfers to output ratio</td>
<td>0.1636</td>
<td>0.1228</td>
</tr>
<tr>
<td>$TR/y$</td>
<td>Total tax revenues to output ratio</td>
<td>0.2916</td>
<td>0.3177</td>
</tr>
</tbody>
</table>

Notes: (i) Quarterly data over the period 1960:1-2005:4 (ii) $b/y$ has been computed from annual series as $4 \times (b/y)$ over the period 1970-2005 (iii) 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 C for details.

2.3.2. Linearization and Approximate Solution

Conditions (18a)-(18h) which describe the Competitive Equilibrium of the model economy 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, $\hat{x}_t = \ln x_t - \ln x$, where $x$ is the steady-state value of $x_t$.

The linearized Competitive Equilibrium conditions constitute a second-order stochastic difference equation system in 8 unknowns, namely, \( \{\hat{y}_t, \hat{c}^p_t, \hat{i}_t, \hat{h}_t, \hat{k}_t, \hat{k}^g_t, \hat{r}^b_t, \hat{b}_t\} \), of the form
\[
E_t \left( A_2 \hat{x}_{t+2} + A_1 \hat{x}_{t+1} + A_0 \hat{x}_t + B_2 \hat{z}_{t+1} + B_0 \hat{z}_t \right) = 0,
\]
where $\hat{x}_t = [\hat{y}_t, \hat{c}^p_t, \hat{i}_t, \hat{h}_t, \hat{k}_t, \hat{k}^g_t, \hat{r}^b_t, \hat{b}_t]^T$, $\hat{z}_t = [\hat{A}_1, \hat{s}_t^p, \hat{s}_t, \hat{s}_t^g, \hat{\sigma}_t, \hat{\epsilon}_t, \hat{\nu}_t]^T$ and $A_2, A_1, A_0, B_2, B_0$ are constant matrices of dimension $8 \times 8, 8 \times 8, 8 \times 8, 8 \times 7$ and $8 \times 7$ respectively.

To transform the system into an equivalent first-order one, I 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 stochastic difference equation system in 9 unknowns, 
\[ E_t \left( A_t \dot{x}_{t+1} + A_0 \dot{x}_t + B_1 \dot{z}_{t+1} + B_0 \dot{z}_t \right) = 0 \], where \( \dot{x}_t = [\dot{y}_t, \dot{c}_t^p, \dot{i}_t, \dot{h}_t, \dot{k}_t, \dot{k}_s, \dot{r}_t^b, \dot{h}_r, \dot{k}_2]^T \), \( k_2 \equiv k_{t+1}, \)
\[ \dot{z}_t = [\dot{A}_t, \dot{s}_t^c, \dot{s}_t^e, \dot{s}_t^p, \dot{\xi}_t, \dot{\xi}_t, \dot{\xi}_t, \dot{\xi}_t]^T \] and \( A_t, A_0, B_1, B_0 \) are constant matrices of dimension \( 9 \times 9, 9 \times 9, 9 \times 7 \) and \( 9 \times 7 \) respectively. \( \dot{z}_{t+1} \) can be substituted into the system from the respective AR(1) process of the exogenous state variables in (17a)-(17g), 
\[ \dot{z}_{t+1} = R \dot{z}_t + \epsilon_{t+1} \]. By taking expectations, we get \( E_t \dot{z}_{t+1} = E_t R \dot{z}_t \). Thus, the system can be written as 
\[ E_t \left( A_t \dot{x}_{t+1} + A_0 \dot{x}_t + B_1 \dot{z}_{t+1} + B_0 \dot{z}_t \right) = 0 \], where \( \dot{B} = B_t R + B_0 \). The final system is a first-order stochastic difference equation system of the form 
\[ E_t \left( A_t \dot{x}_{t+1} + A_0 \dot{x}_t + \dot{B} \dot{z}_t \right) = 0 \] in nine variables, where the three state variables are \( \left( \dot{k}_t, \dot{k}_s, \dot{h}_t \right) \) and the six control variables are \( \left( \dot{y}_t, \dot{c}_t^p, \dot{i}_t, \dot{h}_t, \dot{r}_t^b, \dot{k}_2 \right) \). 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:

\[
\begin{align*}
\hat{d}_t^c &= M \hat{k}_t^s + N \hat{z}_t \\
\hat{k}_t^s &= P \hat{k}_t^s + Q \hat{z}_t \\
\hat{z}_{t+1} &= R \hat{z}_t + \epsilon_{t+1}
\end{align*}
\]

where \( \hat{d}_t^c \) is the vector of the control variables, \( \hat{k}_t^s \) is the vector of the endogenous state variables, \( \hat{z}_t \) is the vector with the exogenous state variables and \( M, N, P, Q \) are constant matrices of dimension \( 6 \times 3, 6 \times 7, 3 \times 3 \) and \( 3 \times 7 \) respectively. I report that when I use the calibrated values in Table 1, all eigenvalues are real and there are three 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.

2.3.3. Simulation Results for the Model Economy

The descriptive power of the model is evaluated by comparing the second moment properties generated by the model to those in the actual Greek data over the period 1960:1-2005:4. Tables 3, 4 and 5 summarize the results for standard deviations, first-
order autocorrelations and cross-correlations with output for both the actual and the simulated series.  

Table 3: Relative Volatility $x = \sigma_x / \sigma_y$

<table>
<thead>
<tr>
<th>Variable</th>
<th>Actual Data</th>
<th>Simulated Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private consumption, $c$</td>
<td>0.6056</td>
<td>0.4630</td>
</tr>
<tr>
<td>Private investment, $i$</td>
<td>2.9147</td>
<td>2.9152</td>
</tr>
<tr>
<td>Hours of work, $h$</td>
<td>0.5703</td>
<td>0.5856</td>
</tr>
<tr>
<td>Labor productivity, $y/h$</td>
<td>0.9943</td>
<td>0.5366</td>
</tr>
<tr>
<td>Real wage per hour, $w$</td>
<td>1.0709</td>
<td>0.5366</td>
</tr>
<tr>
<td>Private capital, $k$</td>
<td>0.2074</td>
<td>0.1029</td>
</tr>
<tr>
<td>Public capital, $g$</td>
<td>0.2157</td>
<td>0.1205</td>
</tr>
<tr>
<td>Standard deviation of output, $\sigma_y$</td>
<td>0.0268</td>
<td>0.0268</td>
</tr>
</tbody>
</table>

Notes: (i) Quarterly data over the period 1960:1-2005:4 (ii) All variables are in logs and have been detrended with the H-P filter with a smoothing parameter of 1600. Aggregate quantities of $y, c, i, h, k, g$ in period $t$ have been first transformed in per-capita unit terms by dividing them with $N_t$.

From inspection of Table 3, we can see that the model does quite well in predicting the variability of the key macroeconomic variables. The volatilities of investment as well as the hours worked are the same as those found in data. The volatility of private consumption is equally well captured. On the other hand, the volatilities of productivity and real wage compensation produced by the model are less volatile than those found in data. Chairini and Piselli (2005) obtain similar results for the Italian economy and argue that Real Business Cycle models cannot reproduce the high volatilities of labor productivity and real wages found in many European countries, even if non-Walrasian features are introduced in these models. Finally, the model correctly predicts that the private and public capital stocks fluctuate much less than output.

48 The model has been simulated 2000 times, with each simulation being 284 periods long, where the first 100 observations has been discarded to ensure that the simulated series start from an ergodic distribution. To get the business cycle behavior of the series, both the actual and simulated data were logged and then filtered by using the Hodrick-Prescott filter with a smoothing parameter of 1600. The moments summarizing the cyclical behavior are computed from the filtered data and averaged across the 2000 simulations.
Concerning persistence properties, Table 4 illustrates that the model produces very satisfactory results for the first-order autocorrelation of hours worked, labor productivity and the two forms of capital stock. The persistence generated by the model for the consumption and private investment is high (but not as high as in data), in contrast with Kollintzas and Vassilatos (2000) whose model predicts zero value for the autocorrelation coefficient of private investment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Actual Data</th>
<th>Simulated Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output, ( y )</td>
<td>0.52</td>
<td>0.52</td>
</tr>
<tr>
<td>Private consumption, ( c )</td>
<td>0.87</td>
<td>0.57</td>
</tr>
<tr>
<td>Private investment, ( i )</td>
<td>0.92</td>
<td>0.54</td>
</tr>
<tr>
<td>Hours of work, ( h )</td>
<td>0.68</td>
<td>0.58</td>
</tr>
<tr>
<td>Labor productivity, ( y/h )</td>
<td>0.43</td>
<td>0.53</td>
</tr>
<tr>
<td>Real wage per hour, ( w )</td>
<td>0.79</td>
<td>0.53</td>
</tr>
<tr>
<td>Private capital, ( k )</td>
<td>0.95</td>
<td>0.92</td>
</tr>
<tr>
<td>Public capital, ( k^c )</td>
<td>0.96</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Notes: see Table 3

From inspection of Table 5, we can see that the model does well in reproducing the comovement properties of the various variables in terms of signs and, to some extent magnitude, with the exception of hours of work and the real wage compensation. The model predicts strong instead of weak correlation between these two variables and GDP. The Greek labor market does not seem to follow well the Warlasian framework. Kollintzas and Vassilatos (2000) also stress this issue and argue that this is due to the highly centralized labor markets, while Lapatinas (2009a) provides evidence of high adjustment costs associated with adjusting employment in the Greek economy. The model, however, is more successful in what concerns the relation of current output with past and future hours worked and real wages. In addition, one should stress the success of the model to produce the general behavior of average productivity, as well as the way past and future consumption and investment are related to current output.

Thus, overall, the model does quite well in reproducing the key stylized facts of the Greek Business Cycle.
Table 5. Co-movement $\rho(y_t, x_{s,t})$

<table>
<thead>
<tr>
<th>Variable</th>
<th>Actual Data</th>
<th>Simulated Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$i = -2$</td>
<td>$i = -1$</td>
</tr>
<tr>
<td>Output, $y$</td>
<td>0.15</td>
<td>0.52</td>
</tr>
<tr>
<td>Private consumption, $c$</td>
<td>0.43</td>
<td>0.49</td>
</tr>
<tr>
<td>Private investment, $i$</td>
<td>0.45</td>
<td>0.53</td>
</tr>
<tr>
<td>Hours of work, $h$</td>
<td>0.16</td>
<td>0.28</td>
</tr>
<tr>
<td>Labor productivity, $y/h$</td>
<td>0.06</td>
<td>0.36</td>
</tr>
<tr>
<td>Real wage per hour, $w$</td>
<td>0.37</td>
<td>0.32</td>
</tr>
<tr>
<td>Private capital, $k$</td>
<td>-0.16</td>
<td>-0.01</td>
</tr>
<tr>
<td>Public capital, $k^p$</td>
<td>0.12</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Notes: see Table 3

2.4. Impulse Responses and Variance Decomposition

This section first computes the responses of some key endogenous variables to a one-period (i.e., temporary) and infinite period (i.e., permanent) unitary increases in the innovations of the exogenous fiscal (tax-spending) policy variables. Then, variance decomposition is used to assess the importance of technology and fiscal policy shocks for the behavior of endogenous variables.

2.4.1. Impulse Response Analysis

This subsection computes the responses of some key endogenous variables to temporary and permanent unitary increases in the innovations of the exogenous fiscal policy variables (consumption tax rate, labor and capital income tax rate, government consumption as share of output and government investment as share of output).49

2.4.1.1. Effects of Shocks to Labor Income Tax Rate

Figures 1 and 2 display the response of some key endogenous macroeconomic variables to temporary and permanent changes in the labor income tax rate, respectively.


and Edelberg et. al (1999) provide an empirical examination of government spending and tax shocks on aggregate economic activity.
A temporary increase in the labor income tax rate causes a negative wealth effect that induces households to decrease consumption and leisure (or to increase labor supply). On the other hand, the higher tax rate reduces the after-tax return to labor inducing an intratemporal substitution effect that leads households to reduce work effort and consumption on impact. As the impulse shows, the intratemporal substitution effect dominates the wealth effect and leads households to reduce work effort and consumption. The decrease in labor supply is further enhanced by an intertemporal substitution effect caused by the decrease in the after-tax return to investment. The
lower labor supply shifts down the marginal product of private capital and households want to accumulate less capital in the future. In the short run, capital is predetermined and as a result less future capital accumulation requires a decrease in investment on impact period. Output also decreases on impact due to the decrease in labor supply. Moreover, the real interest rate decreases on impact since the predetermined capital stock is cooperating with less units of labor. The decrease in real interest rate clears the markets and further enhances the intertemporal substitution effect. Real wages increase on impact due to the decrease in labor supply. Finally, the primary deficit-to-GDP declines since the increase in the labor income tax rate increases tax revenue from labor income taxation.

In the following periods of transition, the wealth effect dominates the intratemporal substitution effect and labor supply increases. However, output continuous to decline since the private and public capital stocks decrease. The real interest rate adjusts downwards so that households increase investment demand to allow their consumption to be smoothed over time.

When the shock is temporary, the above responses die out as the economy returns to its initial steady state, while when the shock is permanent the responses persist until the economy converges to a new steady state. In the new steady state, output, hours worked, consumption, investment and private capital fall by about 0.21%, while there is an improvement in the fiscal balance since the primary deficit-to-GDP falls by 0.6%. Finally, note that in the long-run the labor to output and the capital to output ratios are unchanged. As result, real wages and the real interest rate return to their initial steady state value.

It should be noted that the above results are consistent with the empirical evidence. For instance, Daveri and Tabellini (2000) and Mendoza et al. (1997) show that labor income tax rates have a negative effect on labor supply and investment.

2.4.1.2. Effects of Shocks to Capital Income Tax Rate

Figures 3 and 4 respectively show the response of some key endogenous macroeconomic variables to temporary and permanent change in the capital income tax rate.
A temporary increase in the capital income tax rate has a negative wealth effect that induces households to decrease consumption and leisure. However, the first order effect is the decrease in the after-tax return to investment. This produces an intertemporal substitution effect in consumption and labor supply that dominates the wealth effect and leads households to increase current consumption and decrease work effort. The decrease in work effort shifts down the marginal product of private capital and as a result households want to accumulate less capital in the future. In the short run,
private capital is predetermined and less future capital formation requires a decrease in investment on impact period. Output also decreases on impact due to the decrease in labor supply. However, the decrease in labor supply and output is lower than the case of a labor income tax rate increase because there is no intratemporal effect on labor. The real interest rate decreases on impact since a predetermined capital stock is cooperating with less units of labor. On the other hand, real wages increase on impact due to the decrease in labor supply. The primary deficit-to-GDP declines since the increase in the capital income tax rate increases tax revenues from capital income taxation. Moreover, the higher private consumption increases tax revenues from consumption taxes. However, the increase in tax revenues as share of GDP is lower than in the case of an increase in the labor tax rate.

In the subsequent periods of transition, the lower capital stock reduces the marginal product of labor producing a weak intratemporal substitution effect in favor of leisure. This effect however is dominated by the wealth effect which leads to an increase in labor supply in later periods. Even though labor supply increases, output continues to decline due to the lower private and public capital stocks. The real interest rate adjusts upwards so as to smooth consumption over time.

Similar comments apply to the differences in the effects of temporary and permanent changes in the capital income tax rate as in the case of a change in the labor income tax rate. When the shock is permanent, output, consumption, private investment and labor supply in the new long-run are respectively 0.21%, 0.13%, 0.44% and 0.06% lower than the initial equilibrium. Moreover, the decrease in output, consumption, investment and labor supply on impact period is bigger relative to the case in which the shock is temporary. This is justified by the fact that in the latter case the intertemporal substitution effect is weaker.

It is important to mention here that permanent increases in the capital tax rate reduce private investment and private capital more than permanent increases in the labor tax rate. This is mainly justified by the strong intertemporal substitution effect induced by the higher tax rate on capital, which leads to high levels of current consumption and hence less future capital formation. On the other hand, temporary changes in labor tax rates produce quantitatively bigger and much persistent effects on output than temporary changes in capital tax rates. This is explained by the intratemporal effect on labor supply and the higher autoregressive coefficient of the labor income tax rate. This result is consistent with the findings of Braun (1994) for the U.S. economy, who shows
that a temporary increase in the labor tax rate has a larger impact on output than a capital tax rate increase. Finally, notice that an increase in the labor tax rate reduces primary deficit-to-GDP more than an increase in the capital tax rate.

2.4.1.3. Effects of Shocks to Consumption Tax Rate

Figures 5 and 6 show the response of some key endogenous macroeconomic variables to a temporary and permanent change in the consumption tax rate, respectively.

Figure 5: Response to a Temporary 1% Increase in the Consumption Tax Rate

Figure 6: Response to a Permanent 1% Increase in the Consumption Tax Rate
The propagation mechanism of a temporary and a permanent increase in the consumption tax rate is similar to that of an increase in the labor tax rate. However, the responses are much weaker and smoother. The main reason is that the higher consumption tax rate does not lead to a heavier taxation of future consumption relative to current consumption but imposes the same burden on current and future consumption. Therefore, the intertemporal effect on consumption induces a very smooth response of consumption over all periods. On impact period, consumption is decreased due to the intratemporal substitution effect caused by the decrease in the after-tax return to labor. The intertemporal effect on labor supply caused by the decrease in the marginal product of labor and in the after-tax return to investment is weak. As a result, the initial response of hours comes mainly from the intratemporal effect and is much weaker than that caused by a labor tax rate shift. Eventually, the response of output and investment is weaker and smoother relative to the responses following a labor tax rate shift. However, it should be stressed that temporary increases in the consumption tax rate decrease output and labor supply more than temporary increases in the capital tax rate.

Finally, note that the decrease in the primary deficit-to-GDP following an increase in the consumption tax rate is higher than that of a labor or capital tax rate increase. This is because output and consumption decline by about the same amount along the transition path. As a result, consumption to output ratio remains relatively unchanged and an increase in the consumption tax rate is translated to about an equal increase in tax revenues as share of GDP. The above results are consistent with the empirical evidence. For instance, Daveri and Tabellini (2000) and Mendoza et al. (1997) show that consumption tax rates are less harmful for the macroeconomy than labor or capital income tax rates.

2.4.1.4. Effects of Shocks to the Output share of Government Consumption

Figures 7 and 8 show the response of some key endogenous macroeconomic variables to a temporary and permanent increase in the share of government consumption to output, respectively. It should be noted that the increase in the share of government consumption to output is debt financed. As Burnside et. al (2004) and Baxter and King (1993) show, the direction of hours worked, private consumption and output depends on how government spending is financed (lump-sum versus distortionary taxation). I discuss this issue later.
A temporary increase in the share of GDP that goes to government consumption induces a negative wealth effect leading to a decrease in consumption and leisure.\textsuperscript{50} The impact of the higher labor supply on the future marginal product of capital is small and households do not desire to increase capital stock. Thus, there is a decrease in

\textsuperscript{50}Gali et al. (2007) show that the interaction of rule-of-thump behavior by some consumers (for which consumption equals labor income) and sticky prices, make it possible to generate an increase in private consumption in response to a shock in government consumption.
investment demand on impact period. The increase in government consumption leads to an increase in aggregate demand and as a result the real interest rate rise in order for the markets to clear. The higher interest rate induces an intertemporal substitution effect that leads to a further increase in current labor supply and a decrease in consumption. Therefore, the increase on labor supply and the decrease in consumption on impact period comes partly from the negative wealth effect and partly from the intertemporal substitution effect. The higher labor supply increases output and decreases real wages on impact. The primary deficit-to-GDP increases since there is also a decrease in the consumption to output ratio and as a result tax revenues as share of GDP from consumption taxation are lower.

In the following years of transition, the low level private capital stock leads to a decrease in output relative to its equilibrium value and output convergences to the initial equilibrium from below.

It should be mention here that the direction of changes in the hours worked and output depends on how government spending is financed (lump-sum versus distortionary taxation), on the time path of taxes and on the persistence of the spending shock. For instance, Baxter and King (1993) show that if the increase in government consumption is financed with distortionary income taxes, hours worked and output decrease. On the other hand, Burnside et al. (2004) show that when introducing habit formation, it is then possible that hours worked and output increase even in the case in which the increase in government spending is financed by distortionary taxation.

A permanent increase in the share of government consumption leads to a larger impact effect on labor supply, consumption and hours worked since the wealth effect is now stronger. The increase in labor supply raises the future marginal product of capital leading to an increase in investment demand. In later periods, labor supply is stimulated by the higher capital stock that increases the marginal product of labor inducing an intratemporal substitution effect. In the new steady state, output, labor supply and investment are 0.19% higher than the initial steady state. However, as already mentioned, the direction of changes in labor supply and output depends on how the increase in government consumption is financed (see e.g. Burnside et. al (2004) and Baxter and King (1993)). Note that in the long-run the capital to output and the labor to output ratios are unchanged. As result, the real interest rate and real wages return to their initial steady state value. Primary deficit-to-GDP increases by 1.24% since the
lower consumption to output ratio allows lower tax revenues as share of GDP from consumption taxes.

2.4.1.5. Effects of Shocks to the Output share of Government Investment

Figures 9 and 10 display the response of key endogenous macroeconomic variables to a temporary and permanent increase in the share of government investment to output, respectively.

**Figure 9: Response to a Temporary 1% Increase in the Share of Government Investment**

**Figure 10: Response to a Permanent 1% Increase in the Share of Government Investment**
A temporary, as well as permanent increase in the share of GDP that goes to public investment, introduces three forces which operate on the economy. First, there is an increase in governmental absorption of recourses which leads to a negative wealth effect. Second, there is a direct effect on output as public capital increases. Third, the marginal products of capital and labor shift over time stimulating labor supply and capital accumulation. The last two results arise from the form of the production function.

When the shock is temporary, consumption and private investment falls on impact period, while labor supply rises. In the later years, private investment increases since the marginal product of capital increases due to the higher public capital stock and labor input.

When the shock is permanent, consumption falls, while labor supply and private investment increases. In later years, as the public capital increases this fact stimulates the supply of labor and private capital through its impact on private factors marginal products. In the new steady state, output, consumption, investment and hours worked are 0.1%, 0.044%, 0.1% and 0.045% respectively higher than the initial steady state.

2.4.2. Variance Decomposition

This section quantifies the contribution of fiscal disturbances to economic fluctuations. More specifically, the total variances of the forecast errors of the endogenous variables are decomposed into fractions explained by innovations in technology, government consumption as share of output, government investment as share of output, the labor tax rate, the capital tax rate and the consumption tax rate.

Variances of the forecast errors of the endogenous variables are decomposed assuming that shocks are temporary (see also Jonsson and Klein (1996)). Let $\hat{x}$ be an $n \times 1$ vector of endogenous variables expressed as percentage deviations from the steady state, $\varepsilon$ be an $n \times 1$ vector of iid shocks and $\Sigma$ be the diagonal covariance matrix of the exogenous shocks. Let $c_{i,j,s}$ be a vector whose elements corresponds to the response after $s$ periods of the endogenous variable $\hat{x}_{i,j}$ to a one-period (i.e. temporary) shock $\varepsilon_{j,t}$ occurred in period $t$, where $\hat{x}_{i,j}$ is the $i$’th element of $\hat{x}_i$ and $\varepsilon_{j,t}$ is the $j$’th
element of \( \varepsilon_t \). The total variance of the forecast error of the \( i \)’th element of \( \hat{x}_t \) for a time horizon \( h \) is:\(^{51}\)

\[
\text{Var} \left( \hat{x}_{i,t+h} - E_t \left[ \hat{x}_{i,t+h} \right] \right) = \sum_{j=1}^{n_c} \sum_{s=0}^{h-1} c_{i,j,s}^2 \sigma_{jj}^2
\]

(23)

where \( \sigma_{jj}^2 \) is the diagonal element of \( \Sigma \) that corresponds to the variance of the \( j \)’th element of \( \varepsilon_t \). The share of total variance of the forecast error can be decomposed as:

\[
R_{ij,h} = \frac{\sigma_{ij}^2 \sum_{s=0}^{h-1} c_{i,j,s}^2}{\sum_{j=1}^{n_c} \sum_{s=0}^{h-1} c_{i,j,s}^2 \sigma_{jj}^2}
\]

(24)

which shows the fraction of the \( h \)-step ahead forecast error variance in \( \hat{x}_{i,j} \) attributed to shock \( \varepsilon_{j,t} \). It can be calculated for short run and long-run movements in \( \hat{x}_{i,j} \) by varying the forecast time horizon \( h \).

In Table 6, the variances of output, consumption, investment, hours worked, labor productivity and private capital are decomposed into the fractions explained by technology shocks, government consumption as share of output, government investment as share of output, the tax rate on labor, on capital and on consumption. This Table can be read as follows: for each variable, each line shows the fraction of variance explained by the exogenous shocks in the corresponding quarter. For example, in the first quarter, 96.4849% of the variance of output is explained by innovations in technology, 0.5721% of the variance of output is explained by innovations in government consumption as share of output, 0.1014% of the variance of output is explained by innovations in government investment as share of output, 0.8333% of the variance of output is explained by innovations in the labor tax rate, 1.7242% of the variance of output is explained by innovations in the capital tax rate and 0.2841% of the variance of output is explained by innovations in the consumption tax rate. I will first discuss the results for the fraction of variance in the long-run. Then, I will discuss the results over short and long forecast horizons by presenting the corresponding plots.

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\(^{51}\) See e.g. Canova (2007) and Hamilton (1994).
The results in Table 6 suggest that changes in fiscal variables have a significant effect on the fluctuations of the endogenous variables. More specifically, the contribution of the tax rates on labor and capital income in the variance of output is found to be high. In the limit, 44.619% of the variance of output is explained by innovations in the technology, while 30.80% is explained by innovations in the labor tax rate and 19.7779% by innovations in the capital tax rate. Government consumption and investment as shares of output and the tax rate on consumption have smaller contributions (1.0861%, 3.1266% and 0.5885%, respectively).

However, it should be mentioned that for short horizons innovations in technology have a larger effect on output. Thus, while fluctuations in the tax rates on labor and capital are important for the total variance of output, they are less important over shorter horizons (e.g. 1-12 quarters). This will become more obvious later when the fractions of variations of the endogenous variables due to exogenous shocks are plotted for intermediate forecast horizons.

It should be noted that similar results are found in McGrattan (1994) for the U.S. economy. She reports that 28% of the variance of output is explained by innovations in government consumption and 27% by innovations in the labor tax rate, while only 41% is explained by innovations in technology. In a similar line, Jonsson and Klein (1996) for the Swedish economy find that only 23% of the total output variance is explained by productivity shocks, while 52% is explained by innovations in government spending and 6% by innovations in the consumption tax rate.
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The contribution of labor and capital tax rates is also found to be large concerning fluctuations in the rest of endogenous variables. On the other hand, innovations in the tax rate on consumption can explain only a small fraction, consistent with the findings of Jonsson and Klein (1996) for the Swedish economy. More specifically, the tax rates on labor and capital income contribute respectively 49.3762% and 20.4830% in the variation of consumption. Only 18.0742% of the variation is due to technology shocks. Moreover, the tax rates on labor and capital income contribute respectively 54.6932% and 19.7735% in the variation of hours worked, while only 13.2443% of the variation is due to technology shocks. These results are consistent with the findings of Ireland (2004), who reports that only a small fraction of the variance of hours worked is explained by technology shocks. The contribution of the tax rate on capital is also found to be large to fluctuations in private investment, labor productivity and private capital since it explains respectively 43.2356%, 31.8669% and 62.3235% of their total variances.

Government consumption and investment as shares of output can explain only a small fraction of the variation of endogenous variables. Government consumption as share of output contributes about 6% to the variation of private consumption, hours of work and labor productivity. Compared to the findings of McGrattan (1994) and Jonsson and Klein (1996), innovations in government consumption have a smaller effect on the fluctuations of the endogenous variables. This is mainly justified by the lower autoregressive coefficient of government consumption as share of output relative to that of the rest exogenous variables.

Government investment as share of output contributes about 3% to the variation of output, private consumption, hours worked and labor productivity. The contribution of government investment as share of output is found to be substantially high in the variation of the public capital.

Figures 11 to 15 show forecast variances of output, consumption, investment, hours of work and private capital explained by the innovations in the exogenous variables for intermediate forecast horizons. Note that in the limit, the decomposition of variance is that displayed in Table 6.

Figure 11 shows that for short horizons, innovations in technology have a large impact on output. Thus, while fluctuations in the tax rates are important for the total variance, they are less important over shorter horizons since it takes a long time for the tax rate shocks to have an effect. The contribution of the capital tax rate explains about
9% of the variance of output after 12 quarters and the labor tax rate explains around 12% after 40 quarters.

Figure 11: Fraction of Forecast Variance of Output Explained by Innovations in Exogenous Variables

Figure 12 illustrates that for short horizons, innovations in technology have a large impact on consumption. However, the contribution of innovations in the capital tax rate is also found to be high in the short run (about 11% during the first 4 quarters). It takes a long period of time for the tax rates on labor and consumption, as well as government consumption as share of output to have an effect on consumption variance.
Figure 12: Fraction of Forecast Variance of Consumption Explained by Innovations in Exogenous Variables

Figure 13 illustrates that innovations in technology and the capital tax rate have the largest impact on investment both in the short and the long-run. The contribution of other exogenous variables is negligible even in the long-run.

Figure 13: Fraction of Forecast Variance of Investment Explained by Innovations in Exogenous Variables
Figure 14 illustrates that innovations in technology have a smaller impact on hours of worked compared to the rest endogenous variables since the tax rates on labor and capital contribute about 12% and 18% respectively during the first four quarters. The contribution of innovations in the rest of exogenous variables is negligible in the short run.

**Figure 14: Fraction of Forecast Variance of Hours Explained by Innovations in Exogenous Variables**

Finally, Figure 15 illustrates that innovations in technology and the capital tax rate contribute very substantially to the variance of private capital both in the short and long-run. The contribution of innovations in the rest of exogenous variables is negligible both in the short and long-run.
2.5. Concluding Remarks

This chapter has examined the importance of fluctuations in distortive tax rates and government spending for the Greek business cycle in a Dynamic Stochastic General Equilibrium Model.

The results suggest that the model does quite well in reproducing the key stylized facts of the Greek business cycle in terms of volatility, persistence and comovement of the key macroeconomic variables.

Impulse response analysis shows that temporary increases in the labor income tax rate reduce output, labor supply and private capital more than similar increases in capital income or consumption tax rates. In addition, permanent increases in the tax rates on labor and capital income decrease long-run output, private consumption, private investment and hours worked more than permanent increases in the consumption tax rate.

Variance decomposition suggests that a significant portion of the variance of output, private consumption, private investment, hours worked, labor productivity and private capital can be explained by innovations in the tax rates on labor and capital income. Innovations in government consumption and government investment as shares of output and the tax rate on consumption have smaller contribution. Only 44.62% of
the variance of output is due to technology shocks, while 30.80% is explained by innovations in the labor income tax rate and 19.78% by innovations in the capital income tax rate. However, for short time horizons, innovations in technology have a larger effect on output. The contribution of labor and capital tax rates is also found to be large concerning fluctuations in the rest of endogenous variables.

In future work it would be interesting to introduce real wage rigidities and/or labor adjustments costs in order to examine if the model can better account for some of the stylized facts of the labor market and then study the effects of fiscal (tax-spending) policies.
Chapter 3

Macroeconomic Implications of Alternative Tax Regimes: The Case of Greece
3.1. Introduction

This chapter 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 over 1960-2005. To do so, this chapter 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 chapter 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 labor income tax rate and increasing the consumption tax rate, on the ground that lower labor 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, labor 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. 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. From a normative point of view, Mendoza et al. (1997), Cooley


53 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 labor and capital income affect mostly transitional rather long run growth. On the other hand, Kneller et al. (1999, 2001) and Daveri and Tabellini (2000) 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 formulation of the government budget constraint and the inability of the empirical methodology to separate between transition and long run effects of tax policy.
and Hansen (1992) and Lucas (1990) show that the welfare effects of reforming the U.S. tax structure may be substantial.

As refers to the 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 U.K; Ohanian et al. (2008) and Prescott (2004) examine the impact of labor 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.54

This chapter 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 is stemming 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. European Commission (2008a, 2008b) and Martinez-Mongay (2000)).

The model captures several observed features built in actual tax structures such as tax rates on labor 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 provide utility to households, public investment that augments public capital and lump sum transfers that augment households income.

The approach of this chapter 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 chapter examines tax reforms in which a permanent reduction in one of the three distortionary tax rates (capital, labor, 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

54 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.
total government spending plus initial payments on debt.\textsuperscript{55} 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 chapter examines the quantitative implications from changes in the tax mix for long-run and lifetime welfare.

The results suggest that there are considerable differences in the observed dynamic paths, as well as the steady state levels of the endogenous 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 with an increase in the consumption tax rate increases long-run output and investment by 0.78\% and 2\% respectively. Consumption is higher in the long-run relative to the pre-tax reform equilibrium, while labor supply is lower.

When the cut in the capital income tax rate is met by an increase in the labor income tax rate, output, consumption and private investment increase in the long run, while labor supply decrease. However, 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 increases in the short-run.

A permanent reduction in the labor 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 labor tax revenue. Cuts in the consumption tax rate that are compensated with increases in labor 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, while

\textsuperscript{55} Compared to Mendoza and Tezar (1998) and Cooley and Hansen (1992), this chapter focuses on changes in tax rates that are within the historical experience of the Greek economy. On the contrary, they examine tax reforms that replace one distortionary tax with another.
simultaneously increase the tax rates on consumption or labor income. 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 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. For instance, the welfare gain of a one percentage point reduction in the capital income tax rate accommodated by an increase in the consumption tax rate is about 0.54% of extra consumption in each time period. On the other hand, when transition dynamics are taken into account, tax reforms that reduce the labor 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.

The rest of the chapter is as follows. Section 3.2 presents the theoretical model. Section 3.3 discusses calibration and the model’s long run solution. Section 3.4 contains the main results and section 3.5 concludes.

### 3.2. 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 labor 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, labor and public capital. The government in this economy levies taxes on labor 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.
3.2.1. 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:

$$N_{t+1} = \gamma_t N_t, \quad \gamma > 1 \text{ and } N_0 > 0 \text{ is given} \tag{1}$$

Let $u(C_t^h, L_t^h)$ 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:

$$C_t^h = C_t^{h^r} + \theta \bar{G}_t^c$$

where $C_t^{h^r}$ 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 $t$.\(^{56}\)

The preferences of the representative household are characterized by the lifetime utility function:\(^{57}\)

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

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 public

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\(^{56}\) Thus, $\bar{G}_t^c = G_t^c / N_t$, where $G_t^c$ is total public consumption services.

\(^{57}\) For the instantaneous utility function $u \left(C_t^h, L_t^h\right)$ the following assumptions hold:

e) It is continuously differentiable in $C_t^h$ and $L_t^h$, where $C_t^h = C_t^{h^r} + \theta \bar{G}_t^c$.

f) It is strictly increasing in $C_t^h$ and $L_t^h$.

F) It is strictly concave in $C_t^h$ and $L_t^h$.

h) Inada conditions hold, $\lim_{C_t^h \to 0} u \left(C_t^h, L_t^h\right) = \infty, \lim_{C_t^h \to \infty} u \left(C_t^h, L_t^h\right) = 0$ and $\lim_{L_t^h \to 0} u \left(C_t^h, L_t^h\right) = \infty, \lim_{L_t^h \to \infty} u \left(C_t^h, L_t^h\right) = 0$.
consumption goods and services influence private utility through the parameter \( \vartheta \in [-1,1] \).\footnote{If \( \vartheta > 0 \), the marginal utility of consumption decreases with an increase in \( \bar{G}_i^c \). 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.}

The temporal utility function is of the form:

\[
u(C_t^h, L_t^h) = \left[ \left( \frac{C_t^h}{L_t^h} \right)^\vartheta \right]^{1-\vartheta} - 1
\]

where \( \vartheta \in (0,1) \) 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:

\[
L_t^h + H_t^h \leq 1
\]

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 labor income, \( w_i Z_t H_t^h \), capital income \( r_t^h K_t^h \), and interest income from government bonds, \( r_t^h B_t^h \), where \( w_i \) is the wage rate per efficient unit of labor hours, \( Z_t H_t^h \), and \( r_t^h \) are the real returns to private capital \( K_t^h \) and government bonds \( B_t^h \), respectively. \( Z_t \) is labor augmenting technology which evolves according to the deterministic law of motion \( Z_{t+1} = \gamma Z_t \), where \( \gamma \geq 1 \) and \( Z_0 > 0 \) is given. Two additional sources of income are the firm’s profits that are distributed in the form of dividends, \( \Pi_t^h \), and average (per household) lump-sum
government transfers, $G_{tr}^p$. The household also pay taxes on consumption and on income from labor and capital earnings. Thus, the representative household’s budget constraint in each period is:

\[
(1 + r_t^c)C_t^h + I_t^h + B_{t+1}^h \leq (1 - r_t^c)w_t, H_t^h + (1 - r_t^k)(r_t^k K_t^h + \Pi_t^h) + (1 + r_t^k)B_t^h + G_{tr}^p
\]

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

All households view $r_t^l$, $r_t^k$, $r_t^c$, $G_{tr}^p$, $\Pi_t^h$, $w_t$, $K_t^h$ and $B_t^h$ as determined outside their control when making their decisions.

The law of motion for private capital stock is:

\[
K_{t+1}^h = (1 - \delta^p)K_t^h + I_t^h - \frac{\xi}{2} \left( K_{t+1}^h - \gamma \gamma_z \right)^2 K_t^h
\]

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

Taking prices $\{r_t^c, r_t^k, w_t, \Pi_t^h\}_{t=0}^\infty$ and fiscal policy $\{G_{tr}^p, G_{tr}^c, r_t^l, r_t^k, r_t^c\}_{t=0}^\infty$ as given, the representative household chooses a sequence $\{C_t^h, I_t^h, H_t^h, I_t^h, K_{t+1}^h, B_{t+1}^h\}_{t=0}^\infty$ 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 $C_t^h, H_t^h, I_t^h, K_{t+1}^h, B_{t+1}^h$. The first-order conditions for an interior solution include the constraints and the following conditions:

59 Thus, $G_{tr}^p = G_{tr}^c / N_t$, where $G_{tr}^c$ is total lump-sum transfers.

60 Lapatinas (2009b) finds that adjustment costs are important in determining investment dynamics in Greece.
\[ \frac{u_{c_{i_t}}}{u_{c_{i_{t+1}}}} = \left(1 - \tau_i^f\right) w_i Z_i \]  

(8a)

\[ \frac{u_{c_{i_{t+1}}}}{1 + \tau_i^f} \left[ 1 + \xi \left( \frac{K_{i_{t+1}}^h}{K_i^h} - \gamma_{a_i} Y_i \right) \right] = \beta E_{i_{t+1}} \left[ \frac{u_{c_{i_{t+1}}}}{1 + \tau_i^f} \right. \left(1 - r_{i_{t+1}}^f) u_{i_{t+1}} + (1 - \delta^f) + \xi \left( \frac{K_{i_{t+1}}^h}{K_i^h} - \gamma_{a_i} Y_i \right) \frac{K_{i_{t+1}}^h}{K_i^h} - \frac{\xi}{2} \left( \frac{K_{i_{t+1}}^h}{K_i^h} - \gamma_{a_i} Y_i \right) \right] \]  

(8b)

\[ \frac{u_{c_{i_{t+1}}}}{(1 + r_{i_{t+1}}^f) (1 + r_{i_{t+1}}^b)} = \beta E_{i_{t+1}} \left[ \frac{u_{c_{i_{t+1}}}}{(1 + r_{i_{t+1}}^f)} \right] \]  

(8c)

\[ \lim_{t \to \infty} \beta^{r_{t_{i_{t+1}}}} E_{i_{t+1}} K_{i_{t+1}}^h = 0 \]  

(8d)

\[ \lim_{t \to \infty} \beta^{r_{t_{i_{t+1}}}} E_{i_{t+1}} B_{i_{t+1}}^h = 0 \]  

(8e)

Equation (8a) is the intratemporal condition for the hours worked and states that the marginal rate of substitution between leisure and consumption at 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 \( K_{i_{t+1}}^h \) and \( B_{i_{t+1}}^h \), 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.

The assumptions made for the utility function and the private capital transition process combined with the transversality conditions ensure that the first-order conditions are necessary and sufficient for an optimum.

### 3.2.2. Firms

There is a large number of identical firms indexed by the superscript \( f \).\(^{61}\) The representative firm produces a homogeneous product, \( Y_{i_{t+1}}^f \), by using private capital, \( K_{i_{t+1}}^f \),

\(^{61}\) For simplicity it is assumed that in each period the number of firms equals the number of households.
private labor, $H_f^t$, and average (per firm) public capital, $\bar{K}_f^t$. The representative firm has access to the following production function:

$$Y_f^t = \left( K_f^t \right)^{a_1} \left( Z_f^t H_f^t \right)^{a_2} \left( \bar{K}_f^t \right)^{a_3}$$  \hspace{1cm} (9)

where $a_i \in (0,1), i=1,2,3$ is the output elasticity of private capital, of labor and public capital, respectively. 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 $K_f^t$ and $H_f^t$ in order to maximize period-by-period profits by taking average public capital, $\bar{K}_f^t$, market prices and policy variables as given. Thus, the problem of the representative firm may be defined as:

$$\max_{K_f^t, H_f^t} \Pi_f^t = Y_f^t - r_f^t K_f^t - w_i Z_f^t H_f^t$$  \hspace{1cm} (10)

subject to

$$Y_f^t \leq \left( K_f^t \right)^{a_1} \left( Z_f^t H_f^t \right)^{a_2} \left( \bar{K}_f^t \right)^{a_3}, \quad a_1 + a_2 + a_3 = 1$$  \hspace{1cm} (11)

$$K_f^t, H_f^t \geq 0$$  \hspace{1cm} (12)

The first-order conditions are:

$$r_f^t = a_1 \frac{Y_f^t}{K_f^t}$$  \hspace{1cm} (13)

$$w_i = a_2 \frac{Y_f^t}{Z_f^t H_f^t}$$  \hspace{1cm} (14)

and the implied economic profits are $\Pi_f^t = (1 - a_1 - a_2) Y_f^t > 0$. 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 labor respectively. Note that profits are not taxed at the firm’s level. Thus, profits are taxed only once as dividends at the household

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62 Thus, $\bar{K}_f^t = K_f^t / N_i$, where $K_f^t$ is aggregate public capital stock.

63 This production function captures the notion that the quality of public capital influence private productivity. Thus, public capital generates positive externalities to individual firms.
level which is consistent with the Greek tax code that avoids double taxation of dividends.64

3.2.3. Government Budget Constraint

As already noted, the government levies taxes on consumption and on income from labor 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 $G^c_t$ that provides utility to households, total government investment $G^i_t$ that augments public capital and provides externalities to firms and total lump-sum government transfers $G^{tr}_t$. Moreover, government pays interest payments on past debt, $B_t$. Thus, the budget constraint of the government in aggregate terms at time $t$ is:

$$B_{t+1} + \tau^c_t \sum_{h=1}^{N_t} C^h_t + \tau^i_t \sum_{h=1}^{N_t} H^h_t + \tau^b_t \sum_{h=1}^{N_t} \left( r^b_t K^h_t + \Pi^h_t \right) =$$

$$= G^c_t + G^r_t + G^i_t + \left( 1 + r^b_t \right) B_t$$

(15)

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

$$K^g_{t+1} = \left( 1 - \delta^g \right) K^g_t + G^i_t, \quad K^g_0 > 0 \quad \text{given}$$

(16)

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

$$\lim_{T \to \infty} \left( \prod_{j=1}^{T} \frac{1}{1 + r^b_j} \right) B_{T+1} = 0$$

(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.

64 See e.g. European Commission (2008a).
3.2.4. The Solution of the Model

3.2.4.1. Competitive Equilibrium

A competitive equilibrium is a sequence (of random variables),
\[
\{C^{bh}, L^{h}, H^{h}, I^{h}, K^{h}, B^{h}, \Pi^{f}, Y^{f}, K^{f}, H^{f}, \mathcal{R}^{g}, \Pi^{r}, w, r^{b}, \tau^{e}, \tau^{s}, \tau^{t}, \tau^{f}, G^{r}, \mathcal{G}^{r}, \mathcal{G}^{i}\}_{t=0}^\infty
\]
such that:

i) given the sequence of population and labor augmenting technological process \(\{N_t, Z_t\}_{t=0}^\infty\), the sequence of prices, profits and government fiscal policy, \(\{w_t, r^{b}_t, \Pi^{r}_t, \Pi^{f}_t, \tau^{e}_t, \tau^{s}_t, \tau^{t}_t, \tau^{f}_t, G^{r}_t, \mathcal{G}^{r}_t, \mathcal{G}^{i}_t\}_{t=0}^\infty\), and the initials conditions for the state variables, the allocation \(\{C^{bh}_t, L^{h}_t, H^{h}_t, I^{h}_t, K^{h}_t, B^{h}_t, Y^{f}_t, K^{f}_t, H^{f}_t, \mathcal{R}^{g}_t\}_{t=0}^\infty\) solves the problem of the representative household and the representative firm

ii) given the sequence \(\{C^{bh}_t, L^{h}_t, H^{h}_t, I^{h}_t, K^{h}_t, B^{h}_t, Y^{f}_t, K^{f}_t, H^{f}_t, \mathcal{R}^{g}_t\}_{t=0}^\infty\), the sequence \(\{w_t, r^{b}_t, \Pi^{r}_t, \Pi^{f}_t, \tau^{e}_t, \tau^{s}_t, \tau^{t}_t, \tau^{f}_t, G^{r}_t, \mathcal{G}^{r}_t, \mathcal{G}^{i}_t\}_{t=0}^\infty\) clears the capital, labor, dividend and the bond markets, i.e. \(\sum_{k=1}^{N_t} K^{h}_k = \sum_{f=1}^{N_t} K^{f}_f = \sum_{j=1}^{N_t} H^{h}_j = \sum_{j=1}^{N_t} H^{f}_j = \sum_{h=1}^{N_t} \Pi^{r}_h = \sum_{h=1}^{N_t} \Pi^{f}_h\) and \(B_t = \sum_{h=1}^{N_t} B^{h}_h\), respectively

iii) given the sequence \(\{C^{bh}_t, L^{h}_t, H^{h}_t, I^{h}_t, K^{h}_t, B^{h}_t, \Pi^{f}_t, Y^{f}_t, K^{f}_t, H^{f}_t, \mathcal{R}^{g}_t, \Pi^{r}_t\}_{t=0}^\infty\), the sequence \(\{\tau^{e}_t, \tau^{s}_t, \tau^{t}_t, \tau^{f}_t, G^{r}_t, \mathcal{G}^{r}_t, \mathcal{G}^{i}_t\}_{t=0}^\infty\) satisfies the government budget constraint

3.2.4.2. Stationary Competitive Equilibrium

In the long run, all aggregate variables (except total hours of work, \(H_t\)) grow at the same constant rate \(\gamma_a \gamma_z\) (balance growth path), where \(\gamma_a\) is the growth rate of population and \(\gamma_z\) is the growth rate of the deterministic labor-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 \(X_j \equiv (Y_t, C_t, I_t, K_t, K^{g}_t, B^{h}_t, G^{c}_t, \mathcal{G}^{r}_t, \mathcal{G}^{i}_t)\) define:\textsuperscript{65}

\textsuperscript{65} Capital letters denote aggregate variables.
\( x_i \equiv \frac{X_i}{N_i Z_i} \equiv \left( \frac{Y_i}{N_i Z_i}, \frac{C_i}{N_i Z_i}, \frac{I_i}{N_i Z_i}, \frac{K_i}{N_i Z_i}, \frac{K^g_i}{N_i Z_i}, \frac{B_i}{N_i Z_i}, \frac{G_i^c}{N_i Z_i}, \frac{G^\sigma_i}{N_i Z_i}, \frac{G_i^l}{N_i Z_i} \right) \). Per capita hours worked are \( h_i = \frac{H_i}{N_i} \) since in the long run hours grow only at the population growth rate \( \gamma_n \). The stationary competitive equilibrium is implicitly determined by the following equations:

\[
\frac{(c^p_i + \vartheta g^c_i)}{y_i} = a_i \frac{(1 - \tau^i)}{(1 + \tau^i)} \left( 1 - h_i \right) \left( 1 - \gamma \right) \quad (18a)
\]

\[
\left[ \frac{(c^p_i + \vartheta g^c_i)}{(1 + \tau^i)} \right]^{1 - \sigma} \left[ \frac{\partial i_i}{\partial k_{i+1}} \right] = \frac{1}{(c^p_i + \vartheta g^c_i)} \left[ \frac{1}{(1 + \tau^i)} \right] \left[ \frac{1}{(1 + h_i)} \right] \left[ \frac{1}{(1 + \gamma)} \right] \quad (18b)
\]

\[
\left[ \frac{(c^p_i + \vartheta g^c_i)}{(1 + \tau^i)} \right]^{1 - \sigma} = \beta E_i \left[ \frac{1}{(c^p_i + \vartheta g^c_i)} \right]^{1 - \sigma} \left[ \frac{1}{(1 + \tau^i)} \right] \left[ \frac{1}{(1 + h_i)} \right] \left[ \frac{1}{(1 + \gamma)} \right] \quad (18c)
\]

\[
\gamma_i y_i k_{i+1} = \frac{(1 - \delta^p) k_i + i - \frac{\xi}{2} \left( \frac{\gamma_i \gamma_i k_{i+1}}{k_i} - \gamma_i \gamma_i \right)^2 k_i
\]

\[
\gamma_i y_i k^g_{i+1} = \frac{(1 - \delta^g) k^g_i + g^i}
\]

\[
y_i = (k_i)^{\alpha_i} (h_i)^{\alpha_i} (k^g_i)^{\alpha_i}
\]

\[
y_i = c^p_i + i + g^c_i + g^l_i
\]

\[
\gamma_i y_i b_{i+1} = \left( 1 + r^i \right) b_i + \tau^i c^p_i + \tau^i a_2 y_i + \tau^i (a_i y_i + a_3 y_i) =
\]

\[
= g^c_i + g^\sigma_i + g^l_i
\]

where

\[
\beta = \beta \gamma_i \gamma_i^{-1}
\]

\[
\frac{\partial i_i}{\partial k_{i+1}} = 1 + \xi \left( \frac{\gamma_i \gamma_i k_{i+1}}{k_i} - \gamma_i \gamma_i \right)
\]
\[ \frac{\partial w_t}{\partial k_{t+1}} = \frac{1 - \delta^p}{y} + \varepsilon \left( \gamma a y k_{t+2}^p - \gamma a y k_{t+2}^s \right) \frac{1 - \Delta^p}{k_{t+1}} - \frac{\varepsilon}{2} \left( \frac{y a y k_{t+2}^p - y a y k_{t+2}^s}{k_{t+1}} - \gamma a y \right)^2 \]

\[ w_t = a_2 \frac{y}{h} \quad \text{and} \quad r_t^b = a_1 \frac{y}{k} \]

It can be easily verified that \( \{y_t, c_t^p, i_t, h_t, k_t^p, k_t^s, r_t^b, b_t\} \) completely characterize the competitive equilibrium. Thus, the stationary competitive equilibrium is explicitly defined by the above eight non-linear difference equations in \( \{y_t, c_t^p, i_t, h_t, k_t^p, k_t^s, r_t^b, b_t\} \) for given paths of the six policy instruments \( \{r_t^l, r_t^c, r_t^s, g_t^c, g_t^p, g_t^s\}_{t=0}^\infty \).

### 3.2.4.3. 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:

\[ k = \frac{a_1 (1 - \tau^k_0)}{1 - (1 - \delta^p)} \]  \hspace{1cm} (19a)

\[ i = \left[ \gamma a y (1 - (1 - \delta^p)) \right] \frac{a_1 (1 - \tau^k_0)}{1 - (1 - \delta^p)} \]  \hspace{1cm} (19b)

\[ r^b = \frac{1 - \beta}{\beta} \]  \hspace{1cm} (19c)

\[ c^p = 1 - \left[ \gamma a y - (1 - \delta^p) \right] \frac{a_1 (1 - \tau^k_0)}{1 - (1 - \delta^p)} \frac{g_0^c}{g_0^p} \frac{g_0^p}{y} \]  \hspace{1cm} (19d)

\[ h = \frac{a_2 \left( \frac{\gamma}{1 - \gamma} \right) \left( \frac{1 - \tau^l_0}{1 + \tau^l_0} \right)}{y c^p + \gamma g_0^c} + a_2 \left( \frac{\gamma}{1 - \gamma} \right) \left( \frac{1 - \tau^l_0}{1 + \tau^l_0} \right) \]  \hspace{1cm} (19e)

\[ k^g = \frac{(g_0^l / y)}{\gamma a y - (1 - \delta^g)} \]  \hspace{1cm} (19f)
\( y = \left( \frac{a_i (1 - \tau_i)}{\beta (1 - \delta^\beta)} \right)^{\alpha_i} \left( \frac{a_z \left( \frac{\gamma}{1 - \gamma} \right) \left( \frac{1 - \tau_z}{1 + \tau_z} \right)}{c^\beta + \delta g^\beta + a_z \left( \frac{\gamma}{1 - \gamma} \right) \left( \frac{1 - \tau_z}{1 + \tau_z} \right)} \right)^{\alpha_z} \left( \frac{(g_0 / y)}{\gamma \gamma_z (1 - \delta^\gamma)} \right)^{\alpha_z} \)  

\( b (\gamma \gamma_z - \frac{1}{\beta}) + \tau_0^c e^p + \tau_0^l a_z + \tau_0^k (a_i + a_z) = \frac{g_0^c}{y} + \frac{g_0^l}{y} + \frac{g_0^k}{y} \)  

which is a system of eight equations in eight unknowns \( \{y, c^p, i, h, k, k^e, l^b, b\} \).

### 3.3. Calibration and Long Run Solution

#### 3.3.1. 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.\(^{66}\)

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

The steady state values of the effective tax rates on capital income, labor income and consumption are set equal to their average values over the period 2000-2005 from annual constructed effective tax rates.\(^{67}\) 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 labor 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 \( \sigma \) equal to 2. The preference parameter \( \vartheta \) which measures the degree of substitutability/complementarity between private and

---

\(^{66}\) 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 Cristodoulakis et. al (1997). To derive quarterly observations annual series are interpolated. The interpolation procedure is described in Appendix C. Moreover, quarterly series for private and public capital stocks were generated using a perpetual inventory method; see Appendix C for details.

\(^{67}\) The effective tax rates were constructed using the methodology described in Chapter 1.
public consumption is set equal to zero; see also Finn (1998) and Christiano and Eichenbaum (1992). This zero value implies that public consumption is a pure resource drain on the economy. The value of population growth $\gamma_n$ is computed from population data and is set equal to 1.0014. The growth rate of technological process $\gamma_z$ 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, $\delta^p$ and $\delta^g$ 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 labor and capital shares in output is how to treat the income earned by the self-employed; see also Cooley (1995). The income of self-employed is a combination of labor and capital income and as a result a part of their income should be treated as labor income. In the National Accounts there is no distinction between labor 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 labor income of the self-employed, I assume that the opportunity cost of being a self-employed is the labor 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 labor in output, $a_2$, is computed from data assuming that the self-employed earn an imputed wage.$^{68}$

More specifically, the labor’s share $a_2$ is computed as: $a_2 = \frac{WSSS + WSE}{NGDP}$,

where $WSSS$ denotes total compensation of employees$^{69}$, $WSE$ 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

$$WSE = \left( \frac{WSSS - SSCER}{EE} \right) \times ES,$$

where $SSCER$ are social security contributions paid by

---

$^{68}$ This seems to be a reasonable assumption for Greece since the fraction of self-employment is 49%.

$^{69}$ $WSSS$ in the national accounts is equal to wages and salaries plus employers’ social security contributions plus employer’s contributions to private pension funds.
the employers, $EE$ is the number of the employees (dependent employment) and $ES$ is the number of the self-employed. The share of labor income is found to be $0.60.70$

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 $\xi$ 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 $\beta$ 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 $\gamma$, which is the weight for consumption relative to leisure, is calibrated from the condition with respect to labor (19e) consistent with a labor allocation equal to 20% of time. Given the value of $\beta$, 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 $k^*/y = 2.3995$.

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

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70 Note that if I do not assume an imputed wage for self-employed (i.e. $WSE = 0$), then the labor share is considerably lower and equal to 0.31.
<table>
<thead>
<tr>
<th>Parameter or Variable</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_2$</td>
<td>Labor elasticity in production</td>
<td>0.60</td>
<td>Data</td>
</tr>
<tr>
<td>$a_3$</td>
<td>Public capital elasticity in production</td>
<td>0.034</td>
<td>Set equal to $g_a'y$</td>
</tr>
<tr>
<td>$a_1$</td>
<td>Private capital elasticity in production</td>
<td>0.3660</td>
<td>Calibrated as $1 - a_2 - a_3$</td>
</tr>
<tr>
<td>$\gamma_n$</td>
<td>Population growth rate</td>
<td>1.0014</td>
<td>Data</td>
</tr>
<tr>
<td>$\gamma_z$</td>
<td>Growth rate of labor augmenting technology</td>
<td>1.005</td>
<td>Set</td>
</tr>
<tr>
<td>$\delta^p$</td>
<td>Private capital quarterly depreciation rate</td>
<td>0.0070</td>
<td>Set</td>
</tr>
<tr>
<td>$\delta^g$</td>
<td>Public capital quarterly depreciation rate</td>
<td>0.0078</td>
<td>Set</td>
</tr>
<tr>
<td>$Z_0$</td>
<td>Initial level of technological process</td>
<td>1</td>
<td>Set</td>
</tr>
<tr>
<td>$\xi$</td>
<td>Capital adjustment cost parameter</td>
<td>10</td>
<td>Set</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Curvature parameter in the utility function</td>
<td>2</td>
<td>Set</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Consumption weight in utility function</td>
<td>0.3161</td>
<td>Calibrated from (19e)</td>
</tr>
<tr>
<td>$k / y$</td>
<td>Private Capital to output ratio</td>
<td>15.7364</td>
<td>Calibrated from (19a) and (19b)</td>
</tr>
<tr>
<td>$k^e / y$</td>
<td>Public Capital to output ratio</td>
<td>2.3995</td>
<td>Calibrated from (19f)</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Time discount factor</td>
<td>0.9901</td>
<td>Calibrated from (19a) and (19b)</td>
</tr>
<tr>
<td>$g$</td>
<td>Substitutability between private and public consumption in utility</td>
<td>0</td>
<td>Set</td>
</tr>
<tr>
<td>$g^e_0 / y$</td>
<td>Government consumption to output ratio</td>
<td>0.1469</td>
<td>Data</td>
</tr>
<tr>
<td>$g^i_0 / y$</td>
<td>Government investment to output ratio</td>
<td>0.0340</td>
<td>Data</td>
</tr>
<tr>
<td>$\tau^l_0$</td>
<td>Tax rate on labor income</td>
<td>0.30</td>
<td>Data</td>
</tr>
<tr>
<td>$\tau^k_0$</td>
<td>Tax rate on capital income</td>
<td>0.27</td>
<td>Data</td>
</tr>
<tr>
<td>$\tau^c_0$</td>
<td>Tax rate on consumption</td>
<td>0.20</td>
<td>Data</td>
</tr>
</tbody>
</table>
### Table 2: Data Averages and Long Run Solution

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Data Averages</th>
<th>Long Run Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c/y$</td>
<td>Consumption to output ratio</td>
<td>0.6472</td>
<td>0.6091</td>
</tr>
<tr>
<td>$i/y$</td>
<td>Private investment to output ratio</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>$h$</td>
<td>Hours at work</td>
<td>0.20</td>
<td>0.2099</td>
</tr>
<tr>
<td>$k/y$</td>
<td>Private capital to output ratio</td>
<td>15.7364</td>
<td>15.7364</td>
</tr>
<tr>
<td>$k^g/y$</td>
<td>Public capital to output ratio</td>
<td>2.3995</td>
<td>2.3995</td>
</tr>
<tr>
<td>$r^b$</td>
<td>Real return to government bonds</td>
<td>0.011</td>
<td>0.010</td>
</tr>
<tr>
<td>$b/y$</td>
<td>Public debt to output ratio</td>
<td>2.56</td>
<td>2.56</td>
</tr>
<tr>
<td>$g_0^H/y$</td>
<td>Government transfers to output ratio</td>
<td>0.1636</td>
<td>0.2196</td>
</tr>
<tr>
<td>$TR/y$</td>
<td>Tax Revenue to output ratio</td>
<td>0.2916</td>
<td>0.4098</td>
</tr>
</tbody>
</table>

Notes: (i) Quarterly data over the period 1960:1-2005:4 (ii) $b/y$ has been computed from annual series as $4 \times (b/y)$ over the period 1970-2005 (iii) Data average for $r^b$ is over the period 1998:1-2005:4 (iv) Quarterly series for private and public capital stocks were generated using a perpetual inventory method; see Appendix C for details.

### 3.3.2. 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 $x$. Tax rates, $\tau^l, \tau^k, \tau^g$, are kept constant over time at its data average, while the three categories of government spending instruments, $g^c, g^g, g^l$, remain fixed at its long-run levels implied by the model, $g^c_0, g^g_0, g^l_0$.

The linearized conditions constitute a second-order difference equation system in 6 unknowns, namely, $\hat{x}, \hat{c}^p, \hat{i}, \hat{h}, \hat{k}, \hat{k}^g$, of the form $E_t (A_t \hat{x}_{t+1} + A_0 \hat{x}_t) = 0$, where $\hat{x}_t = [\hat{y}_t, \hat{c}^p_t, \hat{i}_t, \hat{h}_t, \hat{k}_t, \hat{k}^g_t]^T$ and $A_t, A_0$ are constant matrices of dimension $6 \times 6$ and $6 \times 6$ respectively. To transform the system into an equivalent first order one, introduce an auxiliary variable $k: k = k_{t+1} \Rightarrow k_{t+1} = k_{t+2}$ and so increase the dimension of the system by adding the extra equation $k_2 - k_{t+1} = 0$. Thus, the system reduces to the following first-order difference equation system, in 7 unknowns, $E_t (A_t \hat{x}_{t+1} + A_0 \hat{x}_t) = 0$, where $\hat{x}_t = [\hat{y}_t, \hat{c}^p_t, \hat{i}_t, \hat{h}_t, \hat{k}_t, \hat{k}^g_t, \hat{k}_2_t]^T$, $k_2 \equiv k_{t+1}$ and $A_t, A_0$ are constant matrices of
dimension $7 \times 7$ and $7 \times 7$. The final system is a first-order difference equation system of the form $E_t \left( A_t \hat{x}_{t+1} + A_r \hat{x}_r \right) = 0$ in seven variables, where the two state variables are $(\hat{k}_t, \hat{k}_r)$ and the five control variables are $(\hat{y}_t, \hat{c}_t^p, \hat{i}_t, \hat{h}_t, \hat{k}_2)$. 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:

\[
\begin{align*}
\hat{d}_t^c &= M \hat{k}_t^s \\
\hat{k}_{t+1}^s &= P \hat{k}_t^s
\end{align*}
\]

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 $5 \times 2$ and $2 \times 2$ respectively.

Given the sequences of $(\hat{y}_t, \hat{c}_t^p, \hat{i}_t, \hat{h}_t, \hat{k}_2)$, 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.

### 3.3.3. 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, labor, 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 feasible). The three types of government spending instruments, $g^c, g^r, g^i$, remain fixed at its pre-tax reform equilibrium levels, $g^c_0, g^r_0, g^i_0$.

Combining the government’s budget constraint (18h) and the No-Ponzi condition, the government budget constraint can be written in present value terms as:
\[
\sum_{t=0}^{T} (\gamma_n^c \gamma_z)^t d_t \left[ \tau_0^c c_t^d + \tau_0^d a_t y_t + \tau_0^h (a_i + a_3) y_t \right] = \\
= \sum_{t=0}^{T} (\gamma_n^c \gamma_z)^t d_t \left( g_0^{a} + g_0^{d} + g_0^{h} \right) + \left( 1 + r_0^h \right) b_0
\]  
(22)

where,

\[
d_t = \prod_{j=1}^{t} \frac{1}{R_j} = \prod_{j=1}^{t} \frac{1}{1 + r_j^h}, \quad \text{and} \quad d_0 = 1
\]

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 feasible, 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 feasible. 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.
3.4. 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, labor 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

<table>
<thead>
<tr>
<th>Policy $i$</th>
<th>$\tau^l$</th>
<th>$\tau^c$</th>
<th>$\tau^e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark Economy</td>
<td>0.30</td>
<td>0.27</td>
<td>0.20</td>
</tr>
<tr>
<td>$P_1$: A 1 percentage point reduction in the capital income tax rate</td>
<td>0.3050</td>
<td>0.26</td>
<td>0.20</td>
</tr>
<tr>
<td>compensated by an increase in the labor income tax rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_2$: A 1 percentage point reduction in the capital income tax rate</td>
<td>0.30</td>
<td>0.26</td>
<td>0.2030</td>
</tr>
<tr>
<td>compensated by an increase in the consumption tax rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_3$: A 1 percentage point reduction in the labor income tax rate</td>
<td>0.29</td>
<td>0.2916</td>
<td>0.20</td>
</tr>
<tr>
<td>compensated by an increase in the capital income tax rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_4$: A 1 percentage point reduction in the labor income tax rate</td>
<td>0.29</td>
<td>0.27</td>
<td>0.2061</td>
</tr>
<tr>
<td>compensated by an increase in the consumption tax rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_5$: A 1 percentage point reduction in the consumption tax rate</td>
<td>0.30</td>
<td>0.3083</td>
<td>0.19</td>
</tr>
<tr>
<td>compensated by an increase in the capital income tax rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_6$: A 1 percentage point reduction in the consumption tax rate</td>
<td>0.3170</td>
<td>0.27</td>
<td>0.19</td>
</tr>
<tr>
<td>compensated by an increase in the labor income tax rate</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.4.1. 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.

3.4.1.1 Tax Reforms that Reduce the Tax Rate on Capital Income

This subsection examines the effects of tax reforms that reduce the capital income tax rate and increase: a) the labor 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 labor 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.

First, consider the case in which the decrease in the capital tax rate is met by an increase in the labor tax rate. There are two opposite effects on labor supply. The intratemporal and intertemporal substitution effects caused by the decrease in the after-tax return to labor lead households to decrease labor 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 labor supply on impact. As Figure 1 shows, labor 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 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 labor supply and the capital to labor ratio are unchanged.

Concerning the effects on public finances, the primary deficit-to-GDP 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 labor tax revenues cannot meet the decrease in capital and consumption tax revenues.

In the following periods of transition, even though work effort decrease along the dynamic path, the higher level of private capital stock leads to higher output. 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 declines along the transition path since the increase in consumption to output ratio allows for higher consumption tax revenues as share of output. However, the deterioration of the primary deficit-to-GDP 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 capital (private investment) increase by 0.5%, 0.17 and 1.87%, respectively. On the contrary, hours of work are 0.30% lower. There is an improvement in the primary deficit-to-GDP 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 labor tax rate

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71 There is also a wealth effect caused by the higher labor income tax rate that induces households to increase labor supply. On the other hand, there is a wealth effect produced by the lower tax rate on capital income that induces households to decrease labor supply.
72 A positive change in the primary deficit-to-GDP means that the primary balance deteriorates with respect to the pre-tax reform equilibrium.
73 Public capital remains unchanged both on impact and along the transition path since government investment remains fixed at its pre-tax reform equilibrium value.
increases output, private consumption and private capital, while it decreases labor 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 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 labor is now weaker. As a result, the negative effect on labor 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 labor supply.

As Figure 1 shows, the net effect on labor 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 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 continuous to increase since private capital increases. Also, note that along the transition path, output is higher relative to the case in which the decrease in the capital income tax rate is met by an increase in the labor income tax rate. The primary deficit-to-GDP 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 capital (private investment) increase by 0.78%, 0.54% and 2.16%, respectively. On the contrary, hours of work are 0.006% lower. There is also an improvement in the primary
deficit-to-GDP 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 labor tax rate. These results are in line with Cooley and Hansen (1992), as well as with the empirical evidence which suggests that labor tax rates are more harmful for the macroeconomy than consumption tax rates (see e.g. Daveri and Tabellini (2000).

3.4.1.2 Tax Reforms that Reduce the Tax Rate on Labor Income
This subsection examines the effects on the dynamic paths and the steady state levels of tax reforms that reduce the labor 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 labor income tax rate is met by an increase in the capital income tax rate and dashed line refers to the case in which the decrease in the labor income tax rate is met by an increase in the consumption tax rate.

In the case in which the decrease in labor 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 labor tend to increase labor supply. On the other hand, the intertemporal substitution effect caused by the decrease in the after-tax to investment tends to decrease labor supply. As Figure 2 shows, the net effect on impact period is a decrease in labor 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 labor supply. The primary deficit-to-GDP decreases because the higher consumption to output ratio allows higher consumption tax revenues as share of GDP.

In the subsequent periods of transition, labor supply increases. However, the low levels of future private capital stock lead to lower levels of output relative to the benchmark economy. The real interest rate adjusts upwards so as 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 capital (private investment) decrease by 1.17%, 0.50% and 4.1% respectively, while labor supply increases by 0.59%. The primary deficit-to-GDP 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 labor tax rate is met by an increase in the consumption tax rate. Both tax rates affect the same decision margin (consumption-labor choice), but in the opposite direction. As Figure 2 shows, labor 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 labor 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 deteriorates slightly in the early years of transition since the higher consumption tax revenue cannot meet the loss in labor tax revenue. Consequently, public debt-to-GDP increases in the following years of transition.

In the long run, output, labor 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 labor to output and capital to output ratios remain unchanged. The primary deficit-to-GDP 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 (even though quantitatively different) with the findings of Mendoza and Tezar (1998) for the U.S. economy. For instance, he finds that substituting the labor tax rate with a consumption tax rate increases output and private capital by about 8% in the long-run.

### 3.4.1.3 Tax Reforms that Reduce the Tax Rate on Consumption

This subsection examines 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 labor 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 labor income tax rate.

**Figure 3: Transitional Dynamics expressed as percentage deviations relative to the Benchmark Economy: a) \( P_5 (\tau_c \downarrow, \tau_k \uparrow) \), b) \( P_6 (\tau_c \downarrow, \tau_l \uparrow) \)**

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 labor 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 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 output to labor ratio, while the real interest rate adjusts upwards so as 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 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 with an increase in the labor income tax rate. As already explained, both tax rates affect the same decision margin, but in the opposite direction. Figure 3 shows that the distortions from the higher tax rate on labor 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 labor to output and capital to output ratios remain unchanged. Finally, there is deterioration in the primary deficit-to-GDP, which reflects the servicing of a lower debt-to-GDP ratio.

3.4.2. 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. 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 labor tax rate yields an output growth gain both on impact and along the dynamic path. Output growth is between 0.03% 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 \( (\ln\left(\frac{y_{t+1}}{y_t}\right) \times 100) \) Arising from Transitional Dynamics

Note: Impact Period is not shown in the subplots

Decreasing the labor 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 labor tax rate with a higher consumption tax rate, growth on impact period is about 0.41%. However, in the subsequent periods of transition the effects on growth are trivial. This is justified by the fact that both tax rates

\[ \text{Note: Impact Period is not shown in the subplots} \]

74 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.
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 labor 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 \( \left( \ln \left( \frac{y_{t+1}}{y_t} \right) \times 100 \right) \) Arising from Transitional Dynamics

<table>
<thead>
<tr>
<th>Policy ( i )</th>
<th>Growth Rate (%) on Impact Period</th>
<th>Average Annual Growth Rates (%) over the first four Five-Years Time Intervals*</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_1 (r^\downarrow, r^\uparrow) )</td>
<td>0.01%</td>
<td>0.025% 0.018% 0.0138% 0.0138%</td>
</tr>
<tr>
<td>( P_2 (r^\downarrow, r^\uparrow) )</td>
<td>0.22%</td>
<td>0.029% 0.023% 0.016% 0.012%</td>
</tr>
<tr>
<td>( P_3 (r^\downarrow, r^\uparrow) )</td>
<td>-0.07%</td>
<td>-0.06% -0.04% -0.032% -0.023%</td>
</tr>
<tr>
<td>( P_4 (r^\downarrow, r^\uparrow) )</td>
<td>0.41%</td>
<td>0.008% 0.006% 0.004% 0.003%</td>
</tr>
<tr>
<td>( P_5 (r^\downarrow, r^\uparrow) )</td>
<td>-0.87%</td>
<td>-0.114% -0.09% -0.065% -0.048%</td>
</tr>
<tr>
<td>( P_6 (r^\downarrow, r^\uparrow) )</td>
<td>-0.73%</td>
<td>-0.013% -0.01% -0.008% -0.006%</td>
</tr>
</tbody>
</table>

* 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 labor income tax rate.

3.4.3. Welfare Effects of Alternative Tax Structures

This subsection provides a quantitative comparison of the steady state and lifetime 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 D 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.
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 labor 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 labor. 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 labor 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 labor 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 labor 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 state. Table 5
illustrates that reducing the capital income tax rate and increasing the labor 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, where (1,1) refers to raw and column numbers
respectively). 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 labor 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 the
consumption and the decrease in labor supply in the early years of transition that
increase utility (see subplot (1,3)). The case in which the decrease in the labor 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 labor 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 labor 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 labor 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 labor 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 labor 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.

### 3.4.3.1. Sensitivity Analysis

This section provides a sensitivity analysis and examines how long-run welfare is affected when different combinations of tax rates on labor 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 long-run welfare gains/losses for different combination of tax ratios \((\tau^k / \tau^l), (\tau^k / \tau^c), (\tau^l / \tau^c)\) 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 shows the long-run 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.
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 \( \tau_k / \tau_l \) 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 \( \tau_k / \tau_c \) 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 \( \tau_c / \tau_l \) 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.
3.5. Concluding Remarks

This chapter has examined the quantitative implications of changes in the tax mix for transitional dynamics, transitional growth and welfare in the Greek economy from 1960-2005.

The results suggest that tax reforms in which a reduction in the capital income tax rate is met by an increase in the consumption or the labor income tax rate, increase output and private investment both in the short and long-run. Consumption is higher in the long-run relative to the pre-tax reform equilibrium, while labor supply is lower.

A permanent reduction in the labor 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 labor tax revenue. Cuts in the consumption tax rate that are compensated with increases in labor 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, while simultaneously increase the tax rates on consumption or labor income.

Finally, 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 labor 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.
Epilogue

This thesis has studied fiscal (tax-spending) policy in Greece from both a positive and normative perspective.

More specifically, the first chapter examined the evolution and the distribution of the tax burden in the Greek economy over the period 1970-2005 by constructing various effective tax rates. Then, the chapter followed the “stylized facts” methodology of Kydland and Prescott (1990) in order to analyze the cyclical features of the effective tax rates and to examine the relation between distortionary tax rates and economic activity from a business cycle perspective. For comparison reasons, results for other eight Euro-zone member countries are also reported.

The results suggest that the tax rates on labor and capital income in Greece are below the Euro-zone averages, while the consumption tax rate and the corporate income tax rate are close to the Euro-zone averages. The effective tax rates on personal income and on self-employment income are substantially lower than the Euro-zone averages.

Concerning the distribution of the tax burden between labor and capital income, Greece faced an increase in the tax burden on labor income relative to the tax burden on capital income from the mid 70s and until the mid 80s. The opposite is true during the mid 90s and until 2000. In addition, the results suggest that there is an unequal distribution of the tax burden between employees and self-employed in Greece.

In what concerns the volatility properties of the Greek effective tax rates, the tax rate on capital income exhibits higher volatility than the tax rate on consumption, which in turn, fluctuates more than the tax rate on labor income. Moreover, the tax rate on corporate income is the most volatile tax rate over the business cycle.

Concerning comovement properties, the tax rates on labor and capital income are countercyclical and synchronous with the output cycle, so that deviations of the effective tax rates from their trend are negatively associated with the output cycle. These findings indicate that tax rates are higher (lower) from their trend during recessions (expansions). On the other hand, the consumption tax rate is uncorrelated with the output cycle, while the personal income tax rate and the tax rates on self-employment and corporate income lag positively the cycle. In addition, the results show that the tax rates on labor and capital income are negatively associated with labor supply. The same is true for the tax rate related to social security contributions. On the other hand, the consumption tax rate is positively associated with labor supply.
The results for the individual Euro-zone countries suggest that a common feature across countries is that the tax rate on capital income fluctuates more than the tax rates on labor income and consumption. In addition, the effective tax rates on labor and self-employment income, as well as the tax rate related to social security contributions, are negatively associated with the output cycle. Moreover, the tax rate on corporate income lags positively the output cycle, while the capital income tax rate and the consumption tax rate display a variety of patterns. Another common feature is the negative association between the labor income tax rate and hours worked. The same is true for the personal income tax rate, as well as the tax rate related to social security contributions. On the other hand, the tax rate on capital income in most cases lags positively the cycle of hours worked.

The second chapter examined the importance of fluctuations in fiscal (tax-spending) policy for the Greek business cycle and presented an extensive analysis of the dynamic properties of an enriched Real Business Cycle Model using impulse response functions and variance decomposition. The results suggest that the model does quite well in reproducing the key stylized facts of the Greek business cycle in terms of volatility, persistence and comovement of the key macroeconomic variables.

Impulse response analysis shows that temporary increases in the labor income tax rate reduce output, labor supply and private capital more than similar increases in capital income or consumption tax rates. In addition, permanent increases in the tax rates on labor and capital income decrease long-run output, private consumption, private investment and hours worked more than permanent increases in the consumption tax rate.

Variance decomposition suggests that a significant portion of the variance of output, private consumption, private investment, hours worked, labor productivity and private capital can be explained by innovations in the tax rates on labor and capital income. Innovations in government consumption and government investment as shares of output and the tax rate on consumption have smaller contribution. Only 44.62% of the variance of output is due to technology shocks, while 30.80% is explained by innovations in the labor income tax rate and 19.78% by innovations in the labor income tax rate. However, for short time horizons, innovations in technology have a larger effect on output. The contribution of labor and capital tax rates is also found to be large concerning fluctuations in the rest of endogenous variables.
The third chapter has examined the quantitative implications of changes in the tax mix for transitional dynamics, transitional growth 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 or the labor income tax rate, increase output and private investment both in the short and long-run. Consumption is higher in the long-run relative to the pre-tax reform equilibrium, while labor supply is lower.

A permanent reduction in the labor 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 labor tax revenue. Cuts in the consumption tax rate that are compensated with increases in labor 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, while simultaneously increase the tax rates on consumption or labor income.

Finally, 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 labor 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.
References


Appendices

Appendix A: An Overview of the Greek Tax System

This appendix discusses the tax structure and the tax laws of the Greek tax system.

A.1. Personal Income Taxation

An individual in Greece is liable for tax on his income as an employee, employer and as a self-employed person. The income tax is levied on world-wide income of resident individuals. According to the Greek law, taxable income is classified in six categories: (a) Employment (b) Investment (c) Agricultural (d) Rental (e) Business (f) Professional. Income from each source is separately computed and individuals are subject to tax on the aggregate income from all categories.

In order to determine net taxable income, certain deductions are made from gross income, so that the taxable income is less than that which was actually declared. Both employees and self-employed persons pay the personal income taxation that applies to a progressive schedule to all earned income, net of social security contributions and of deductible expenses.\(^7^5\) Then, the “net income”, is taxed on the basis of a predetermined schedule. The schedule comprises income brackets with tax rates ranking from 0 to 40% (i.e. 15%, 30% and 40%). Tax reform packages came into effect within the last five years in order to decrease the tax burden on households. From 2005 the tax free threshold for employees and pensioners has increased to €12000 and for self-employed to €10.500. The thresholds are adjusted upwards according to the number of dependant children. Pensions are as a rule subject to taxation as employment income. It has to be mentioned that immovable property is subject to additional taxation beyond the normal progressive income at the rate of 1.5% (European Commission (2008a) and Ministry of Economy and Finance 2004).

\(^7^5\) Taxpayers are entitled to deduct a part of their expenses on goods and services, the amount of rent paid by the taxpayer, medical expenses etc. Moreover, tax credits are granted for each child.
A.1.1. Income from Dividends and Interest Earnings
Greece has a special regime for capital income taxation. Dividends distributed from after-tax profits of resident companies to resident individual and corporate shareholders are tax-exempt in the hands of the recipient. Investors are therefore exempted from any tax obligations. In fact, Greece is the only country in the European Union which exempts dividends at the personal level and has removed double taxation of dividends (dividends are taxed only at the corporate income level). Mutual funds profits are also tax exempt (European Commission (2008a) and Ministry of Economy and Finance 2004).

Tax rates on interest income have recently decreased in order to stimulate investment. There is a flat-rate regime at tax rates on interest earnings. All bonds and Treasury bills issued by the government or by public organizations are subject to a tax of 10%. Interest earnings from bonds issued by banks, corporations or insurance companies and interest on bank deposits are also subject to a tax rate of 10%. The tax rates of REPOS have increased from 7% to 10%. Interest on loans and interest received from abroad are taxed with a withholding tax at the rate of 20% if the payment is effected in Greece. A 15% withholding tax rate applies to fees paid by agents for supplies agreed with foreign entities; a 3% rate applies to construction constructors’ and 8% to service fees. Finally, reduction has been imposed on the tax rate on stock exchange transactions from 0.3% to 0.15% in order to enhance the stock exchange market’s prospects (European Commission (2008a) and Ministry of Economy and Finance (2004)).

It has to be mentioned that until recently, savings in private pension funds was not deductible from taxable income, in contrast to the practice in most EU countries. As a result of this tax anomaly, saving via private pension funds in Greece is very small. When dividends were paid through a private pension fund, the distribution was subject to a second round of taxation. This difference in rates created an incentive to invest in equities directly than via a private pension fund and did not encourage long-term savings (OECD (2005)).

A.1.2 Income from Capital Gains
A capital gain in Greece is added to regular income and is taxable at the same rate as regular income for an individual. However, capital gains from the sale of shares traded on the Athens Stock Exchange are tax exempt. Moreover, capital gains from mutual
funds located domestically or in another EU / European Economic Area are also tax exempt. There is a tax 5% from the transfer of unlisted shares, regardless of whether income arises from the transaction. A capital loss from the sale of an asset may in most cases be offset against regular taxable income and a capital gain from the sale of real estate is exempt from capital gains tax (European Commission (2008a)).

A.1.3 Social Security Contributions

In addition to the personal income taxes, labor income is subject to social security contributions. The insurance covers mainly pension, unemployment and care insurance. Social security payments are deductible from the personal income tax base.

An employer is obligated to deduct tax at source from an employee and to make additional contributions to social security. The employer's contribution is 28% of the salary and the employee's contribution is 15.9%. The taxable base is gross wage.

On the contrary, a self-employed individual makes lump-sum payments to social security himself and is obligated to make advance payments on income tax that will be offset on filing an annual report. It is worth noticing that a reduction was implemented for employers’ pension contributions for low-paid workers. Those earning the minimum wage were also exempted from paying employees’ social contributions (Ministry of Economy and Finance 2004).

While employees and employers together contribute approximately 44% of gross wages to the social security system, the self-employed (small entrepreneurs and trades and other professionals) contribute very little to the social security system since they make a monthly lump-sum payment. They tend to place themselves in low income classes to pay less, while being entitled to the same health service provision (Bronchi (2002)).

Finally, it has to be mentioned that until recently high social security contributions also were applied to low income levels and households with primary part-time earnings. As a result part-time work is actually low in Greece (Bronchi (2002)). In addition, numerous early retirement provisions depress incentives for older workers to participate in the labor force. Although the statutory retirement age in the main fund for private workers (IKA) is set at 65 for men, only 15% of those who retired in 1997 were in effect aged 65. All in all, only 32% of men and women retire under the normal provisions at the statutory age. The others do so under one of the various special provisions for arduous work (24%), disability (17%), seniority (4%), parents of school-
age children (3%) and other special cases (10%). The fundamental problem with these provisions is that they severely distort the system away from actuarial neutrality as they are not related to life expectancy at the time of retirement (OECD (2005)).

**A.2. Corporate Income Taxation**

Besides VAT and social security contributes for their employees, corporations in Greece are subject to corporate income taxes and real estate taxes. Corporations are taxed on their world wide profits. Foreign companies in Greece are taxed only on income that is generated in Greece. The following undertakings are subject to taxation:

(a) **Companies limited by shares** (with the suffix A.E.)
(b) **Companies limited by liability** (with the suffix E.P.E.)
(c) **Foreign companies** operating in any corporate form and foreign organizations whose objective is to acquire financial gain.
(d) **Public, municipal and community enterprises and undertakings**, irrespective of whether they constitute legal persons.
(e) **Co-operatives and their associations**. Also subject to taxation are the legal entities of public and private law (Greek and foreign) operating on a non-profit-making basis, including all types of institutions.

In 2006 the statutory tax rate on corporate income was 29%. The corporate income tax rate has been reduced to 25% in order to enhance the competitiveness of enterprises. The income of companies limited by shares (A.E.) is taxed before the distribution of profits at a single rate of 32% and no other charge is levied. It has to be mentioned that General and Limited partnerships paid a 22% corporate tax rate which has also been reduced to 20% since 2007. The corporate tax reform is expected to contribute up to 0.5% to GDP growth in the medium term (Ministry of Economic and Finance 2004).

The object of the income taxation is as follows:

(a) **Greek companies limited by shares (A.E.) and limited liability companies** (with the exception of banks and insurance companies): the total net income or profit earned in Greece or abroad. The profits distributed by Greek companies limited by shares and limited liability companies are taken from the balance of profits remaining after deduction of the income tax assessed.

(b) **Foreign companies operating in Greece (in any corporate form) and all foreign organizations**: the income or profit from a source in Greece, as well as the net profit arising from their permanent establishment and operation in Greece, irrespective of the way in which profits are appropriated. Different criteria apply however if there is an
agreement for the avoidance of double taxation between Greece and the country in which the foreign company is based.

(c) **Greek legal entities operating on a non-profit-making basis**: the income from the leasing of buildings, land and securities. Income acquired while in pursuit of their objectives is **not taxed**.

(d) **Foreign legal entities of a non-profit-making nature**: net income from all sources, with the exception of that acquired while in pursuit of their objectives.

(e) **Co-operatives and their associations**: the total income or profit acquired in Greece or abroad, before deduction of the relevant allowances and the profits which are distributed to their members.

Greek banks and insurance companies are taxed on their total income or profit acquired in Greece or abroad, after deduction of certain amounts corresponding to income which is taxed in a special way, until extinction of all tax liabilities.

### A.2.1. Tax Exemptions and Tax Incentives for Corporations

The deductibility of company expenses is subject to certain limits. Deductible business expenses from the net profits mainly include depreciation of physical capital, interest on liabilities, wages, social security contributions and provision of bad debts. Non-deductible expenses include corporate income tax, capital gains tax on the revaluation of immovable property, depreciation on fixed assets purchased from offshore company and fees paid to an offshore company (European Commission (2008a) and Ministry of Economy and Finance (2005)).

Tax incentives can be used to correct perceived market failures faced by specific sectors or disadvantaged regions. In Greece the major corporate tax incentives are provided on a regional and sectoral basis. They take the form of lower statutory rates and of partial or total exemption. Lower corporate taxes apply mainly to companies listed on the Athens Stock Exchange, to small-medium enterprises, while off-shore and shipping companies are tax exempt. In general, capital gains are treated as business income. However, a 20% capital gains rate applies to gains from sales of business, patents, rights etc. Capital gains from the sale of shares listed on the stock exchange are not taxed (under certain conditions).

In the lines of the Lisbon Strategy, new investment laws (2002, 2004) came into effect in order to attract private funds on R&D and innovation activities. They provide 50% relief of the scientific and technological research expenses that may be deducted
from the net profits in order to determine net taxable profits. Furthermore, there are
direct or indirect subsidies for investment on applied research labs, the provision of
innovating electronic and communication services and software development. From
year 2004 it is introduced a tax incentive for large investment which will provide for a
10-year freeze on the statutory corporate income tax rate if the investment is at least 30
million Euros (OECD (2005)).

The straight line method is the accepted method of depreciation in Greece. In
order to calculate the depreciation in the fixed assets, the enterprises may select and
utilize either the lower or higher depreciation factor or any other intermediate factor
lying between the lower and the higher factors, provided that the factor selected will
remain fixed until the complete depreciation of the above fixed assets (Ministry of
Economy and Finance (2004)).

As regards social security contributions, the firm’s taxable income was reduced
by 50% of the pension contributions paid for newly employed persons.

A.3. Taxes on Consumption

The Value Added Tax (VAT) was introduced in 1987 with an initial standard
rate of 16 per cent, and raised to 19 per cent in 2005, which is close to the EU average.
To contribute to the achievement of redistributive goals a reduced rate of 9% applies to
goods deemed to be necessities (fresh food products, pharmaceuticals, transportation,
electricity etc). A more reduced rate of 4.5% applies to books and magazines. In
addition to VAT an excise duty is levied on mineral oils, gasoline, tobacco, alcohol,
beer and wine (European Commission (2008a)).

Appendix B

The data source for the construction of the effective tax rates is the OECD Revenue
Statistics Vol. 2006 release 01, OECD Annual National Accounts - Volume 2: Detailed
Aggregates (2005 provision) and OECD Economic Outlook No 80. The data source for
hours worked is the OECD Employment and Labor Market Statistics. The data set
comprises annual data and covers the period 1970-2005. The capital stock for all

Data for hours worked in Greece is available since 1983. Prior to 1983 the series for hours worked are
taken from Christodoulakis et al. (1997). For Austria and Belgium series for total employment are used to
approximate labor supply.
countries was generated using a perpetual inventory method. Given an initial capital stock in 1970, real total fixed investment was accumulated using the law of motion of capital 

\[ k_{t+1} = k_t - \delta k_t + i_t, \]

where \( \delta k_t \) is real consumption of fixed capital (consumption of fixed capital at current prices was deflated using the GDP deflator. The initial stock of capital was chosen to be equal to \( 2.5 \times \text{Real GDP} \).

- \( W \) for Greece is available since 1995. For the previous years, \( W \) is approximated as \( WSSS - 2200 \), where \( WSSS \) denotes total compensation of employees.
- \( YOTH \) for Greece is available since 1995. Following Martinez-Mongay (2000), the net households’ self-employment and property income for the whole sample is approximated as the Net Operating Surplus of the total economy minus other direct taxes on capital: \( YOTH = NOS - 1200 - 4100 - 4300 - 4400 - 5212 \).\(^7\) For Belgium and Spain \( YOTH \) corresponds to the gross self-employment and property income received by households. Therefore, household consumption of fixed capital has been deducted from \( YOTH \).
- \( YSE \) is estimated residually as \( YSE = YOTH - YPE \), according to the OECD (2006) Economic Outlook Database Inventory.
- \( YPE \) is available since 1995 for Austria, Germany and Greece, since 1983 for Belgium, since 1975 for Finland, since 1979 for Italy, since 1980 for Netherlands and since 2000 for Spain. In order to recover data for previous years, it is assumed that \( YPE \) it has been throughout the periods a constant fraction of \( YOTH \) equal to the average value for the available years.
- \( NOSC \) is estimated as \( NOSC = GOSC - CFCC \), where \( GOSC \) is the gross operating surplus of corporations and \( CFCC \) is the consumption of fixed capital of corporations. Data for \( GOSC \) and \( CFCC \) is available since 1995 for Austria, Germany and Greece, since 1985 for Belgium, since 1975 for Finland, since 1980 for Italy and Netherlands and since 2000 for Spain. For previous years \( GOSC \) is approximated as \( NOS + CFC - YOTH \), while \( CFCC \) is assumed to follow the shape of \( CFC \).
- Germany and Netherlands provide data for tax revenues from the taxation of households’ labor income. For these countries category 1100 is further divided into

\(^7\) For a discussion of the advantages and the disadvantages of this approximation see Martinez-Mongay (2000).
the subcategory ‘wage tax’. Thus, total tax revenues from households’ labor income taxation are ‘wage tax’, while \((1100 - \text{wage tax})\) are tax revenues from households’ capital income taxation. The personal income tax rates for household’s labor and capital income can then be constructed as 

\[
\tau_h^l = \frac{\text{wage tax}}{W + WSE - 2100 - 2300}
\]

and

\[
\tau_h^k = \frac{1100 - \text{wage tax}}{\text{YOTH} - \text{WSE}}
\]

respectively, without assuming that all sources of households income are taxed at the same rate. In the main text, the results reported for the personal income tax rate correspond to \(\tau_h^l\).

- Unallocable tax revenues between 1100, 1200 have been allocated to 1100 and 1200 according to the relative weights of each in 1000 (the countries are Austria, Belgium, France and Greece).
- Unallocable social security contributions 2400 have been allocated to 2100, 2200 and 2300 according to the relative weights of each in 2000 (the countries are Greece and Italy).

### Appendix C

#### 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:

\[
h_{i,j} = h_i \frac{ET_{i,j}}{\sum_{j=1}^{4} ET_{i,j}}
\]

(A.1)

where \(i = 1960 - 2005\), \(j = 1, ... , 4\), \(h_{i,j}\) and \(ET_{i,j}\) are hours worked and total employment in year \(i\) and quarter \(j\) respectively.
B. Construction of Capital Stock Series
Quarterly series for the private capital stock are constructed via the perpetual inventory method using the law of motion of capital \( K_{t+1} = (1 - \delta_p) K_t + I_t \), where \( I_t \) is real fixed private investment. The value of the depreciation rate \( \delta_p \) is set equal to 0.007. The initial value for the private capital stock is set so that data average for the private capital to output ratio to be equal to the long-run private capital to output ratio implied by the model. Using data for real government investment, the same method used for the construction of public capital stock series. The value of the depreciation rate \( \delta_g \) is set equal to 0.0078, while the initial value for the public capital stock is set so that data average for the public capital to output ratio to be equal to long-run public capital to output ratio implied by the model.

C. Construction of Quarterly Effective Tax Rates
The approach of constructing quarterly effective tax rates on labor income, on capital income and consumption, closely follows Mendoza et al. (1994) and Martinez-Mongay (2000) and assumes that the self-employed earn both labor and capital income; see also Chapter 1. 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.

The effective tax rate on consumption is constructed as:

\[
\tau_c = \frac{TIND}{C + GC - TIND} \tag{C.2}
\]

where \( TIND \) denotes total indirect taxes, \( C \) denotes private final consumption expenditure at post-tax prices and \( GC \) denotes government final consumption expenditure. The personal income tax rate that applies both to labor and capital income of households is:

\[
\tau_h = \frac{TYH}{WSSS + WSE - SSRG + HCY} \tag{C.3}
\]

where

\[
WSE = \left[ \frac{(WSSS - 2200)}{EE} \right] \times (ES),
\]
where $TYH$ denotes direct taxes paid by households, $WSSS$ denotes total compensation of employees, $WSE$ denotes the imputed wage of the self-employed, $SSRG$ denotes social security contributions received by government, $2200$ denotes social security contributions paid by the employers, $EE$ denotes the number of employees, $ES$ denotes the number of self-employed, $HCY$ denotes total household capital income, $TYB$ denotes total direct taxes paid by business, $NOS$ denotes the net operating surplus of the economy, $NGDP$ denotes nominal gross domestic product, $TSUB$ denotes subsidies and $CFC$ denotes consumption of fixed capital. The effective tax rate on labor income is constructed as:

$$
\tau_{j} = \frac{\tau_{h}(WSSS+WSE-SSRG)+SSRG}{WSSS+WSE}
$$

The effective capital income tax rate is constructed as:

$$
\tau_{k} = \frac{\tau_{k}(HCY)+TYB}{NOS-WSE}
$$

Data for $TYH$ and $TYB$ is not available on quarterly basis. In order to obtain quarterly series it is assumed that in each quarter $TYB$ is a constant fraction of total direct taxes, $TY$. Hence, $TYB_{i,j} = R_{i} \times TY_{i,j}$ and $TYH_{i,j} = TY_{i,j} - TYB_{i,j}$, where $i = 1960 - 2005$, and $j = 1, \ldots, 4$. The fraction of total direct taxes paid by business, $R_{i}$, is computed from annual data as $R_{i} = \left(\frac{1200 + 5212}{1100 + 1200 + 5212}\right)_{i}$, where $1100$ are taxes on income, profits and capital gains of individuals, $1200$ are taxes on income, profits and capital gains of corporations and $5212$ are motor vehicle taxes paid by corporations. Annual data for $1100, 1200, 5212$ and $2200$ is available since 1965. In order to obtain series prior to 1965 it is assumed that $1100, 1200$ and $5212$ follow the shape of total direct taxes $TY$, while $2200$ follows the shape of $SSRG$. Series for $CFC$ are
available since 1970. Prior to 1970 the series are extrapolated from the series reported in
Christodoulakis et al. (1997).

Quarterly series for 2200 are obtained according to the interpolation rule:

\[ 2200_{i,j} = 2200_i \left( \frac{SSRG_{i,j}}{\sum_{j=1}^{4} SSRG_{i,j}} \right), \]

while quarterly series for CFC are obtained according to the interpolation rule:

\[ CFC_{i,j} = CFC_i \left( \frac{I_{i-1,j}}{\sum_{j=1}^{4} I_{i-1,j}} \right), \]

where \( i = 1960 - 2005 \), and \( j = 1, \ldots, 4 \). 78

**Appendix D**

Following among others Cooley and Hansen (1992) and Lucas (1990), I compute the permanent percentage change in private consumption that leaves households indifferent between steady state (lifetime) utility obtained by remaining in the pre-tax reform equilibrium and the steady state (lifetime) utility obtained by undertaking the tax reform.

**a) Lifetime welfare comparisons**

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

\[ u(c, 1-h) = \frac{M_i \left[ (c)^\gamma (1-h)^{1-\gamma} \right]^{\beta}}{1-\sigma} - 1 \]  

(D1)

where \( M_i = Z_0^{\gamma(1-\sigma)} Y_Z^{\gamma(1-\sigma)} \) are exogenous variables and \( c_i = c_i^c + \delta g_0^c \) denotes the composite consumption. The lifetime welfare under the base tax structure is:

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

(D2)

78 It is assumed that \( I_{1959,4} = I_{1960,1} \).
where \( c \) and \( h \) are constant along the balanced growth path and \( 0 < \tilde{\beta} = \beta^* \gamma \frac{1}{2} (1 - \sigma) < 1 \), \( Z_0 = 1 \). The lifetime welfare following a policy change is:

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

We find the value of \( x \) that satisfies the following equation:

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

Combining (D2) and (D4) and performing the calculations we get that:

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

or

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

where \( V^* \) and \( \bar{V} \) are given by (D3) and (D2) respectively.

In the simulations, the time horizon for the calculation of \( \bar{V} \) and \( V^* \) 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:

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

\( , 0 < \tilde{\beta} < 1 \) (D6)
where $c^*$ and $h^*$ are constant along the balanced growth path. We then find the value of $x$ that satisfies the following equation:

$$V^{ss} - (1 + x)^{(1 - \sigma)\bar{V}^{ss}} = 0$$

(D7)

where $\bar{V}^{ss} = \frac{1}{1 - \bar{\beta}} \left[ \frac{(c^* (1 - h^*))^{1 - \gamma}}{1 - \sigma} - 1 \right]$ is the steady state utility in the pre-tax reform equilibrium. Solving (D7) for $x$ we get that

$$x = \left[ \left( \frac{V^{ss}}{\bar{V}^{ss}} \right)^{\frac{1}{1 - \sigma}} - 1 \right] \times 100$$