Re-examining the Effects of Tax Policy on Economic Growth

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Abstract

Using a novel panel dataset of 65 countries for the period 1973-2000, this paper attempts to reconcile the conflicting evidence provided by the current literature on the effects of different tax categories on long-term economic growth. The effects of both top and average, personal and corporate income tax rates as well as the level of tax progressivity on growth are tested while controlling for other possible determinants of growth. The empirical results provide evidence for the distortionary effects of personal income taxes and tax progressivity on long run economic growth, but no robust evidence for any linear effect of corporate tax rates on long term economic growth is found. There is however, evidence for a non-linear effect of corporate taxation on economic performance. The sample splitting estimations also yield thresholds above which progressivity becomes harmful for growth but below which there is no significant effect. The thresholds associated with the respective decades seem to follow the average degree of progressivity rather closely and could be indicative of international tax competition.

Keywords: Tax Policy, Progressivity, Economic Growth, Threshold Estimation.

JEL Classification: E16, H30, O31, O40

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1. Introduction

“Senator McCain wants to add $300 billion more in tax breaks and loopholes for big corporations and the wealthiest Americans,"

Sen. Barack Obama (June 10, 2008)[1]

"Under Senator Obama's tax plan, Americans of every background would see their taxes rise—seniors, parents, small business owners, and just about everyone who has even a modest investment in the market,"

Sen. John McCain (June 10, 2008)[2]

Taxation has long been a topic that generates much discussion and debate among politicians and economists alike. In light of the current economic climate there has been a revived interest in the short-term and long-term effects of fiscal policy, and especially, tax policy on income growth. This issue is not only relevant because of the large, partially tax-based stimulus packages that were implemented by many governments to address the current recession, but also because of the necessity to finance these packages by increased tax revenues in the future which will require governments to raise future tax rates. Although the stimulus is directed at alleviating the short term effects of the recession, the long term costs of financing the stimulus packages should be minimised. This renders the absence of consensus in the empirical literature as to the effects of different tax structures on long-term economic performance (Arnold, 2008; Bleaney, Gemmell, & Kneller, 2001; Gemmell, Kneller, & Sanz, 2009; Kneller, Bleaney, & Gemmell, 1999; Lee & Gordon, 2005; Padovano & Galli, 2002) of considerable importance.

This study aims to re-examine current empirical results for the effects of various taxes on economic growth using a single dataset and testing the

[1] Business Week (2008), Retrieved June 11, 2008, http://www.businessweek.com

[2] Business Week (2008), Retrieved June 11, 2008, http://www.businessweek.com

effects of several measures of taxation employed by other authors. In using a single dataset to re-visit the various tax measures considered by the recent literature it is hoped that some of the apparent disagreement within the literature can be cleared up. Further to re-estimating the effects of various tax measures on growth in the linear regression framework, non-linear effects are considered for the effects of the top corporate income tax rate as well as personal income tax progressivity on growth.

The two main frameworks to predict the effects of taxation on growth are based on the neoclassical growth model (Solow, 1956; Swan, 1956) and various endogenous growth models (Barro, 1990; Lucas, 1990; Romer, 1986). Neoclassical models, representing one strand of the theoretical literature on long-run growth, predict that the effects of fiscal policy on growth are limited to transition periods. Tax policy has no effect on the long-term steady-state growth rate; growth is only temporarily affected (Cass, 1965; Koopmans, 1965; Solow, 1956, 1970; Swan, 1956). Endogenous growth models, in contrast, predict a permanent change in the growth rate of countries in response to fiscal policy changes (Barro, 1991; King & Rebelo, 1990; Lucas, 1988; Rebelo, 1991; Romer, 1986). However, in both types of models the effect of increased taxation on growth (if any) is predicted to be negative.

Empirical evidence on the effects of tax policy on long-term growth is mixed. While some studies report a statistically significant effect[3] of tax policy on long-term growth others do not[4]. This mixed evidence may be due to differences in the set of countries, sample periods, tax measures and empirical methodologies used in the literature. Kneller *et.al.* (1999), for instance, whose findings are based on a panel study of 22 OECD countries for the period 1970-1995, contend that distortionary taxation

[3] (Bleaney et al., 2001; Cashin, 1995; Engen & Skinner, 1992; Gemmell et al., 2009; Kneller et al., 1999; Kocherlakota & Yi, 1997; Widmalm, 2001).

[4] (Agell, Lindh, & Ohlsson, 1997; Katz, Mahler, & Franz, 1983; Koester & Kormendi, 1989; Mendoza, MilesiFerretti, & Asea, 1997).

(taxes on income) reduces the rate of economic growth and that non-distortionary taxation (indirect taxes) does not[5]. While Kneller *et.al.* (1999) disaggregate taxes into distortionary and non-distortionary taxes, Widmalm (2001), studying a sample of 23 OECD countries from 1965 to 1990, goes a step further by disaggregating distortionary taxes into taxes on corporate income and those on personal income. Staying within the linear regression framework, this study finds that only the average personal income tax rates and progressivity are negatively correlated with growth whereas average corporate taxes are not. Padovano and Galli (2002), using a sample of 23 OECD countries over the period 1951 to 1990, propose a new measure of effective marginal tax rates but do not disaggregate distortionary taxes into personal and corporate income taxes; they find that both the marginal income tax rate and tax progressivity have negative effects on growth. Lee and Gordon (2005) use a cross-section of 70 countries from 1970-1997 and find that the top marginal corporate tax rate has a significantly negative effect on economic growth but find no effect from personal income taxes or tax progressivity. Contrary to Lee and Gordon (2005), Arnold (2008) uses data for 21 OECD countries for 35 years and finds that taxes on income (and even more so taxes on corporate than those on personal income) have the largest negative correlation with growth while the effects of taxes on consumption as well as recurrent taxes on immovable property have the smallest effects. Income tax progressivity in that study is significantly negatively correlated with economic growth.

This study attempts to reconcile some of the conflicting evidence on the effects of tax structure on economic growth by analysing an unbalanced panel dataset for 65 countries for the period 1973 to 2000. The tax policy changes are identified by using the top marginal and average income tax rates for individuals and corporations. The effects of these different taxes on growth are investigated using a variety of econometric techniques

[5] They also find that productive government expenditure enhances growth, while non-productive expenditure does not.

including two-way fixed and random effects as well as dynamic panel regressions. Moreover, taking account of the recent empirical evidence for non-linear effects in the relationship between other fiscal policy measures and economic growth (Adam & Bevan, 2005; Papageorgiou, 2002), this author also investigates whether critical threshold values exist for both the top corporate income tax rate and tax progressivity. By testing for these thresholds this paper addresses the question: From which point onward does the tax in question become harmful for growth? The empirical results from the linear estimations provide evidence of a negative and significant relationship between personal income taxes and tax progressivity on growth. There is also evidence of a non-linear relationship between both corporate income taxation and personal income tax progressivity with economic performance.

The remainder of the thesis is structured as follows: a comprehensive literature survey is provided in Chapter 2. Chapter 3 discusses the data used in detail. Chapter 4 presents the empirical methodologies for the benchmark linear models, chapter 5 presents and discusses the empirical results of the benchmark models, chapter 6 deals with the issue of mutual causality, chapter 7 discusses the theory and empirics of progressivity, chapter 8 presents and discusses results for the Hansen (2000) data splitting analysis, and chapter 9 concludes.

2. Previous literature

As mentioned previously, mainstream long-run growth theory distinguishes between two types of models: neoclassical or exogenous growth models, as pioneered by Solow (1956) and Swan (1956), and the more recent endogenous growth models following the work of Romer (1986), Barro (1990), Lucas (1990), King and Rebelo (1990), and Rebelo (1991)[6]. In the neoclassical models fiscal policy can affect the steady state levels of output but not the long-run growth rate. In the case of endogenous growth theory the models predict a negative coefficient of taxation on long-run growth (not only on the level of output). This long term negative effect could occur via any one of a number of channels which include: entrepreneurship (Schumpeter, 1942), human capital (Lucas, 1990), investment (Poterba, 1989), and research and development (Hall, 1995). Although the data and methodology used in this paper cannot discern the specific channel by which changes in fiscal policy affect growth, the effects of tax policy on growth itself can be identified. Such identification is potentially useful for policy makers and researchers alike as it identifies what can be expected from specific changes in the tax structure of countries. In the following paragraphs some of the most influential endogenous growth models are discussed.

The first of the endogenous growth models is provided by Romer (1986) who, building on a standard neoclassical growth model, endogenizes the rate of technological change. A critical assumption of this model is that there are constant returns to scale to capital (knowledge) at the aggregate level and that capital (knowledge) is an input in production. This may at first seem strange, but when combined with decreasing returns to capital at the firm level it becomes clear that this system can still be solved for a steady state growth path.

[6] Although many of these general endogenous growth models do not deal explicitly with tax policy, comparative statistics with respect to tax changes may be derived to show how taxation affects long-run growth.

Barro (1990) is the first study that incorporates tax policy into an endogenous growth framework, and suggests that taxation is distortionary for long-term economic growth because it can affect the economic agent's incentives to invest in either physical or human capital. It is argued that taxation on income is distortionary as it clearly reduces the return to capital at the margin. Similarly, Rebelo (1991) developed a model demonstrating taxation on income (personal and corporate) to be distortionary.

Human capital (knowledge) is not only related to growth but is in fact a main driver of it with predicted welfare effects twice that of reducing inflation by 10 percentage points, and about 20 times that of eliminating post World War II sized business cycles (Lucas, 1990). Lucas' (1990) model is based on a closed economy where there is effectively only the choice of investing or consuming. The growth effect in that model is not only due to the direct effects of higher human capital in the current period but also the positive externalities generated by educated people in the next time period (Lucas, 1990). Since people learn from one another – even in informal settings (by observation etc.) – individuals with an above average allocation of human capital (education) are likely to increase the overall level of human capital by more than just their own capital's effect on the average level of education. Moreover, if human capital is mobile (people can migrate between countries), countries with lower tax rates (*ceteris paribus*) will attract more human capital than those with higher tax rates and will therefore exhibit higher growth rates.

Although theoretical predictions of the effects of taxation on growth are reasonably clear, the empirical results are not. Mendoza *et.al.* (1997) find that neither the tax structure nor the level of taxation is a significant determinant of economic growth. Their model is based on the Harberger superneutrality conjecture (Harberger, 1964a, 1964b) which suggests minimal effects of taxation on economic growth due to the 'superneutrality'

of taxation[7]. Superneutrality here refers to the idea that very large changes in the tax structure will have only infinitesimal effects on the rate of economic growth because the effects of taxation on investment are small and investment in turn has only small effects on growth. This argument rests on the assumption that taxes only affect growth through the investment channel when in fact there are numerous channels by which taxation may impact growth[8].

Kocherlakota and Yi (1997) find support for endogenous growth theories such as those of Barro (1990) and Lucas (1990) in a study of time series data for the United States (spanning 100 years) and the United Kingdom (spanning 160 years). They argue that even if long-run economic growth is constant whilst changes in tax rates have a trend (upward or downward) there may be evidence of endogenous growth when other fiscal policy variables such as government spending are considered. In particular, they discuss some of the criticisms directed at endogenous growth models, among these, that there exists a steady growth rate over time even though tax rates have decreased markedly. They reason that this is due to the growth enhancing effect of productive government spending offsetting the growth retarding effect of increased distortionary taxes and *vice versa*.

In an influential empirical study Kneller *et.al.* (1999) distinguish between distortionary and non-distortionary taxes[9] as well as between productive and non-productive government expenditures in a panel dataset of 22 OECD countries for the period 1970-1995. By making this distinction between productive and non-productive government expenditures the

[7] Harberger (1964a, 1964b) makes the argument that since the effect of investment on growth is small, and the effect of taxation on investment is also small, the effect of taxation on growth will be negligible.

[8] Other channels include: entrepreneurship(Schumpeter, 1942), human capital (Lucas, 1990), investment (Poterba, 1989) and research and development (Hall, 1995)

[9] Although not the first to do so it is an improvement on its predecessors (Helms, 1985; Miller & Russek, 1997; Mofidi & Stone, 1990) and it is one of the more influential papers to date.

authors address the points raised by Kocherlakota and Yi (1997). In this context distortionary taxes are those taxes that are hypothesised to affect individuals' investment decisions (mainly taxes on income and wealth), and productive government spending is spending that is likely to increase productivity (spending on health, education, defence, public services and infrastructure)[10]. They find that once the budget constraint is adequately controlled for, distortionary taxation does in fact lower the long-run growth rate and that non-distortionary taxation does not. Moreover productive government spending is found to be growth enhancing, while non-productive spending is not. The authors control for endogeneity by estimating the model in first differences and using lags of all the fiscal variables as instruments. In addition to the fiscal variables the level and first differences of the labour force growth rate and initial GDP are also used as instruments.

Widmalm (2001) is the first study which further disaggregated distortionary taxes, and investigated the effects of personal and corporate income taxes on growth. She finds that only the average personal income tax rate has a significant (negative) effect on growth and that the average corporate tax rate does not. She uses a panel of 23 OECD countries for the period 1965-1990 with the tax variables described in Table 1 below as well as a tax progressivity measure which is discussed in detail later in this thesis.

Table 1: Tax rates used by Widmalm (2001)

Overall average tax rate	$\frac{\text{total income tax revenue}_t}{\text{GDP}_t}$
Average personal income tax rate	$\frac{\text{total personal income tax revenue}_t}{\text{total tax revenue}_t}$
Average corporate income tax rate	$\frac{\text{total corporate income tax revenue}_t}{\text{total tax revenue}_t}$

[10] For a detailed classification of taxes and government spending see Kneller *et.al.* (1999) or Bleaney *et.al.* (2001).

It has been suggested that empirical studies on economic growth suffer from various model specification issues; most notably that the results are often highly sensitive to changes in model specification with some variables even changing direction based on the inclusion or omission of another (Levine & Renelt, 1992). For this reason Widmalm employs extreme bounds analysis, also known as EBA (Leamer, 1983), to apply strict selection criteria on the set of potential explanatory variables. This is done in an attempt to reduce the sensitivity of the model to changes in specification. The sensitivity analysis indicates that the lag of the log of initial GDP, investment, personal taxation and tax progressivity are significant and robust determinants of growth but that corporate taxation, trade openness, the population growth rate, government spending, inflation and inflation volatility are not[11].

Widmalm (2001) relies heavily on a number of assumptions regarding the tax structure of countries in her study. The assumptions are that the structure is assumed unchanged over the entire sample period (for the progressivity measure) and that the underlying composition of the tax revenues in all the countries in the study is the same. These assumptions are necessary in order to ensure that countries with the same tax rates, but different shares of personal and corporate income tax revenues in total tax revenue have the same progressivity measure. Widmalm (2001) acknowledges that if the underlying tax structures changed within the period of her study the progressivity measure would be biased, but argues that there were no significant changes in the tax structures. The second assumption is as important in many other studies employing the average income tax measure as it is in the Widmalm (2001) study.

Padovano and Galli (2002) criticise the calculated average tax rates used in most of the previous literature citing several biases that are likely when such measures are used. They explain in detail how and why the

[11] Government spending does not appear to be included in all the regressions and this may cause omitted variable bias.

assumption of similar tax revenue shares of personal and corporate income across countries and time is violated. They also argue against the use of statutory rates. This argument is based on the idea that the top statutory rate overestimates the real or effective marginal tax rate due to various tax exemptions and exclusions. To correct for this problem they regress tax revenues on GDP as well as an intercept and slope dummies for tax reforms throughout the period. They further argue that this method of estimating the effective marginal income tax rate is more accurate than using the top statutory income tax rates because it usually yields a value close to, but lower than, the statutory rate. This implies that this new estimate is likely to account for exemptions etc. whereas the top statutory rate does not. Furthermore, they use extreme bounds analysis to test the robustness of their model to changes in the set of control variables and find that their results are not sensitive to model specification. Using a sample of 23 OECD countries for the period 1960-2000 they find that marginal tax rates as well as tax progressivity are negatively related to economic growth.

Noting the arguments made by Padovano and Galli (2002), Lee and Gordon (2005) argue that the estimated effective tax rates may be biased because of tax evasion issues that many countries face. They agree that average tax rates are also unlikely to be a good measure for the same reasons cited by Padovano and Galli (2002). They therefore use the top statutory tax rate in their estimations. Lee and Gordon (2005) argue that the specific tax that is most likely to affect growth is the top statutory corporate tax rate. This argument rests mainly on theories of positive effects of entrepreneurship on growth (Schumpeter, 1942). In terms of Schumpeter's (1942) argument the recent evidence for negative effects of taxation on entrepreneurship (Cullen & Gordon, 2002; Gentry & Hubbard, 2000, 2004a, 2004b, 2005; Gordon, 1998) implies a negative effect of taxation on growth through reduced entrepreneurship (Lee & Gordon, 2005).

Lee and Gordon (2005) do not report any specific sensitivity analysis (such as EBA which is used by both Widmalm (2001) and Padovano and Galli (2002)) in their empirical analysis. They also differ from Kneller *et.al.* (1999) and Bleaney *et.al.* (2001) in controlling only for overall government spending instead of accounting for specific elements of government spending (productive and non-productive).

In a sample of 70 developed and developing countries from 1970-1997 Lee and Gordon (2005) use neighbouring countries' tax rates weighted by the inverse of the distance between the countries to instrument for the home country's tax rates, in order to solve the endogeneity problem associated with the tax rates. They further argue that the neighbouring countries' tax rates are not determined by the growth rate of the home country but that it is highly correlated with the home country's tax rate, making neighbouring countries' tax rates a good instrument. After controlling for endogeneity, Lee and Gordon (2005) find that the top corporate tax rate has a negative and significant affect in all their regressions but that the top personal income tax rate and their measure for progressivity does not.

The results of Lee and Gordon (2005) are supported by Arnold (2008) in a study of 21 OECD countries for the 35 year period of 1971-2004. The author finds that corporate and personal income taxation exhibit large negative effects on growth when compared with taxes on consumption and property that have smaller growth effects. Arnold (2008) controls for endogeneity between the income tax indicators and the business cycle by regressing the income tax variables on the output gap and using the residuals of these regressions rather than the actual income tax variables in the subsequent regressions[12].

The most recent empirical work (to my knowledge) is that of Gemmell *et.al.* (2009). They test for the effects of a country's tax structure on its

[12] They use a Two-Stage Least-Squares regression.

growth rate in a sample of 17 OECD countries over 35 Years[13] using Pooled Mean Group (PMG) estimation (Pesaran, 2003). The PMG estimation combines pooled panel techniques that capture the long-run effects and mean group techniques that capture short-run effects. By using the PMG technique the authors can explicitly control for international competition among countries for physical capital and allow for different long-run and contemporaneous effects of the control variables on growth. Their results indicate that there is significant competition among countries for companies' limited physical capital (investment). This is intuitively supported by the downward trend in corporate tax rates reported over the past three decades (Dreher, 2006; Gemmell, Kneller, & Sanz, 2008), and it may explain why there has not been an increase in growth rates over time (Kocherlakota and Yi, 1997; Duncan *et.al.*, 2008).

In conclusion, although theory largely predicts a negative effect of taxes on growth (either permanent or transitional) empirical studies are less cohesive. Kneller *et.al.* (1999) test for the effects of distortionary and non-distortionary taxes on growth and find evidence for a statistically significant negative effect of distortionary taxation on growth. Both Widmalm (2001) and Lee and Gordon (2005) disaggregate income taxes into taxes on personal and corporate income. Widmalm (2001) finds that only average personal income taxes affect growth, but that average corporate income taxes do not. Lee and Gordon (2005) on the other hand find that only the top corporate tax rate affects growth, and that top personal income taxes do not. Although the results of the studies by Widmalm (2001) and Lee and Gordon (2005) do not lend support to one another, they do not contradict each other either[14], and at the aggregate level both papers support Kneller *et.al.* (1999)[15].

[13] The sample used by Gemmell *et.al.* (2009) ranges in size from 12 to 17 countries because of data limitations.

[14] There is a slight contradiction where the progressivity measure is concerned; however, they use different progressivity measures so the results are not directly comparable.

[15] This is because Kneller et.al. (1999) do not distinguish between personal and corporate income taxes, instead they test the combined effect. Therefore if either corporate or

This thesis aims to help clarify the role alternative tax measures play in determining long-term economic growth. It does so by applying different econometric techniques to a panel dataset and testing for the effects of both the top and average personal and corporate income tax rates as well as tax progressivity within that dataset. When using that dataset to calculate and test the various different tax measures popular in recent empirical studies, one can not only compare the results of these studies more clearly but also relate the new findings in this study better to those of the previous literature.

Table 2: Summary of Widmalm (2001), Padovano and Galli (2002) and Lee and Gordon (2005)

	Widmalm (2001)	Padovano and Galli (2002)	Lee and Gordon (2005)
Top corporate income tax rate	-	-	Negative Significant
Top personal income tax rate	-	-	Negative Insignificant
Average corporate income tax rate	Insignificant Non-robust (Positive)	-	-
Average personal income tax rate	Negative Significant Robust	-	-
Marginal tax rate	-	Negative Significant Robust	-
Average income tax rate	Insignificant Non-robust (Positive)	-	Insignificant (Negative)
Progressivity	Negative Significant Robust	Negative Significant Robust	Insignificant (Nil)

personal income taxes are found to be negative and significant (while the other is insignificant or also negative) the results lend support to Kneller *et.al.* (1999).

3. Data

The panel dataset used for this paper consists of 65 countries over the period 1973-2000. Analogous to Kneller *et.al.* (1999), Widmalm (2001) and Lee and Gordon (2005) 5-year averages of all variables are used in order to remove the short-term fluctuations in the dataset[16]. There are thus five 5-year periods and one 3-year period[17] for each country in this dataset. The last period is a three year average of the last three years of the sample[18] (1998-2000). Out of a possible total of 380 observations the maximum sample size of this study is only 245 observations as there are observations missing for some countries in some periods.

For all OECD countries in the sample, the average tax rates (for personal, corporate and indirect taxes) are obtained from the Economic Outlook database of the OECD. Their top statutory tax rates are obtained from the World Tax Database (WTD) provided by the office for tax policy research (OTPR) at the University of Michigan. For all non-OECD countries, all tax variables are obtained from the WTD and the World Development Indicators (WDI) databases. The statutory rates are taken directly from the WTD, but the average rates are calculated by dividing the total personal or corporate tax revenues (in current local currency units) by GDP[19] (in current local currency units).

The share of government expenditures and investment as a percentage of GDP as well as the trade openness variable is obtained from the Penn World Tables version 6.2 (Hereafter PENN 6.2) (Heston, Summers, &

[16] Note that in a working paper Gemmell *et.al.* (2009) suggest that this is not the ideal way to deal with seasonality but that one should rather specifically model it. The main reason for this critique is that using 5-year averages drastically reduces the number of observations and thereby the quality of the data.

[17] Periods 1-6 are 1973-1977, 1978-1982, 1983-1987, 1988-1992, 1993-1997 and 1998-2000.

[18] Following Lee and Gordon (2005).

[19] GDP data is taken from the WDI.

Aten, 2006). All other control variables and their sources are as follows: Initial GDP per capita (real GDP per capita in 1970), total population, population growth rate, government debt to GDP ratio, foreign direct investment to GDP ratio (FDI) and inflation (calculated from the GDP deflator) are from the World Development Indicators (WDI). The data on tertiary and primary education completed were taken from the Barro-Lee education dataset (2000). The dependent variable – growth in per capita GDP – is obtained from the WDI database. Summary statistics for the tax variables are reported in Table 3 and summary statistics for all the other variables including the dependent variable (growth in per capita GDP) are presented in Table 4.

There is a large overlap between the countries used in this study and those of Lee and Gordon (2005) and Widmalm (2001). These interrelationships are presented in Table 6.

Table 3: Summary statistics for the tax variables

Variable	N	Mean	Min	Max	Source
Top marginal corporate tax rate	245	38.440	21 (Brazil, 1995)	62.4 (Iran, 1990)	WTD
Top marginal personal tax rate	245	50.116	7.25 (Ivory Coast, 1985)	90 (Iran,1985)	WTD
Average corporate tax rate	245	3.150	0.0192 (Costa Rica, 1980)	29.186 (Trinidad and Tobago, 1975)	WDI and WTD, SourceOECD
Average personal tax rate	245	6.605	0.104 (Kazakhstan, 2000)	28.604 (Denmark, 2000)	WDI and WTD, SourceOECD

Note: The Average tax rates for non-OECD countries are calculated from the tax revenues as a share of GDP. For OECD countries the average tax rates are taken directly from SourceOECD.

Table 4: Summary statistics for the dependent variable and the control variables.

Variable	n	Mean	Min	Max	Source
Growth rate of real GDP per capita (% change)	245	1.663	-25.001 (Liberia, 1990)	17.476 (Cyprus, 1990)	WDI
Trade openness	245	70.195	12.992 (Brazil, 1990)	223.386 (Malta, 1995)	PENN 6.2
Government spending (% of GDP)	245	20.196	7.436 (Zimbabwe, 1975)	42.493 (Azerbaijan, 1995)	PENN 6.2
Investment (% of GDP)	245	17.890	2.58 (Cote d'Ivoire, 1990)	62.918 (Zambia, 1970)	PENN 6.2
Primary education completed	222	16.768	2 (Liberia, 1980)	42.6 (Trinidad and Tobago, 1980)	Barro-Lee (1990)
Tertiary education completed	223	6.908	0.3 (Indonesia, 1980 and 1985; Zambia, 1980)	30.3 (United States of America, 2000)	Barro-Lee (1990)
Initial GDP per capita (1970)	218	6822.539	208.322 (India, 1975-2000)	18481.56 (United States of America, 1975-2000)	WDI
Inflation, GDP deflator (annual %)	245	34.859	-1.153 (Japan, 2000)	2117.262 (Peru, 1990)	WDI
Population growth rate (% change)	245	1.237	-4.481 (Cyprus, 1975)	4.751 (Cote d'Ivoire, 1980)	WDI
Total population (billion)	245	0.052	1.319 (10^{-4}) (St. Lucia, 1990)	0.999 (India, 2000)	WDI
Debt (% of GDP)	115	66.538	3.142 (Iran, 1980)	362.444 (Congo, Rep, 1995)	WDI
Foreign Direct Investment (FDI as % of GDP)	243	2.406	-1.447 (Indonesia, 2000)	52.595 (Belgium, 2000)	WDI
Lee Gordon tax progressivity measure	245	30.541	1.164 (Norway, 1995)	496.559 (Iran, 1980)	WDI, WTD and SourceOECD
Arnold tax progressivity measure	245	29.541	0.164 (Norway, 1995)	495.559 (Iran, 1980)	WDI, WTD and SourceOECD
Reversed Lee Gordon tax progressivity measure	245	2.122	1.022 (Norway, 1995)	9.982 (Iran, 1980)	WDI, WTD and SourceOECD
Reversed Arnold tax progressivity measure	245	1.122	0.022 (Norway, 1995)	8.982 (Iran, 1980)	WDI, WTD and SourceOECD
Reversed Lee Gordon tax progressivity measure*difference	245	105.215	1.974 (Norway, 1995)	896.560 (Iran, 1980)	WDI, WTD and SourceOECD
Reversed Arnold tax progressivity measure * difference	245	61.704	0.043 (Norway, 1995)	806.741 (Iran, 1980)	WDI, WTD and SourceOECD

As is evident from the tables presenting the OLS, two-way fixed-effects and Arellano-Bond (dynamic panel) regressions the sample size generally varies between 222 and 245 observations. This variation is due to the lack of data for some periods in the education variables (222 for primary education and 223 for tertiary education). Table 5 indicates the countries and periods which have been excluded for lack of data regarding primary and tertiary variables respectively.

Table 5: Data excluded for lack of data regarding primary and tertiary variables respectively.

Primary education		Tertiary education	
Country	Period	Country	Period
Cote d'Ivoire	2 – 6	Cote d'Ivoire	2 - 6
Morocco	2 – 5	Morocco	2 - 5
Gabon	4	Gabon	4
Namibia	4,5	Namibia	5
Azerbaijan	5,6	Azerbaijan	5,6
Estonia	5,6	Estonia	5,6
Latvia	5,6	Latvia	5,6
Lithuania	5,6	Lithuania	5,6
Kazakhstan	5,6	Kazakhstan	5,6
St. Lucia	4	St. Lucia	4

Table 6: Summary of the countries used in this study as well as the Lee and Gordon (2005) and the Widmalm (2001) studies.

Countries in this study	Bos	LG	Wid	Countries in this study	Bos	LG	Wid
Argentina	*	*		Egypt, Arab Rep.	*	*	
Australia	*****	*****	*****	Ecuador		*	
Austria	*****	*****	*****	El Salvador		*	
Azerbaijan	*			Estonia	*		
Barbados	*			**Finland**	*****	*****	*****
Belgium	*	*		**France**	*****	*****	*****
Bolivia		*		Gabon	*		
Botswana		*		Germany	*		*
Brazil	*	*		Ghana		*	
Bulgaria	*			Greece		*	*
Cameroon	*	*		Guatemala		*	
Canada	*****	*****	*****	Guyana		*	
Chile		*		Haiti	*	*	
China		*		Honduras	*	*	
Colombia	*	*		Hong Kong		*	
Congo, Dem. Rep.		*		Iceland	*		*
Congo, Rep.	*	*		India	*	*	
Costa Rica	*	*		Indonesia	*	*	
Cote d'Ivoire	*	*		Iran, Islamic Rep.	*		
Croatia	*			**Ireland**	*****	*****	*****
Cyprus	*			Israel	*	*	
Denmark	*****	*****	*****	**Italy**	*****	*****	*****
Dominican Republic	*	*					

The following abbreviations are used in Table 6: Bos refers to this study, LG refers to Lee and Gordon (2005) and Wid refers to Widmalm (2001).

In Table 6: A * indicates that the country to the left of the star in that row is included in the study presented in that column. Countries included in all three studies are in bold faced text.

Table 6 (Continued)

Countries in this study	Bos	LG	Wid	Countries in this study	Bos	LG	Wid
Jamaica	*	*		Peru	*	*	
Japan	*****	*****	*****	Philippines		*	
Kazakhstan	*			Poland	*		
Kenya		*		**Portugal**	*****	*****	*****
Korea, Rep.		*		Russia	*		
Latvia	*			Senegal	*	*	
Liberia	*			Sierra Leone		*	
Lithuania	*			Singapore		*	*
Luxembourg			*	South Africa	*	*	
Malaysia	*	*		**Spain**	*****	*****	*****
Malawi		*		Sri Lanka		*	
Malta	*			St. Lucia	*		
Mauritius	*			**Sweden**	*****	*****	*****
Mexico		*		Switzerland		*	*
Morocco	*	*		Thailand	*	*	
Namibia	*			Trinidad and Tobago	*	*	
Netherlands	*****	*****	*****	Turkey		*	
New Zealand	*****	*****	*****	**United Kingdom**	*****	*****	*****
Nigeria		*		**United States**	*****	*****	*****
Nicaragua		*		Uruguay		*	
Norway	*****	*****	*****	Venezuela	*	*	
Pakistan	*	*		Zambia	*	*	
Panama	*			Zimbabwe	*	*	
Paraguay		*		Totals	65	70	23

4. Methodology

The benchmark model used in this paper is:

$$Growth_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 X_{it} + \varepsilon_{it}$$

Where the subscript i represents the country (ranging from 1-64), t denotes the time period (ranging from 1 to 6), Growth is the growth rate of per capita GDP, T is a tax vector which represents either the top statutory tax rates on personal and corporate income or the average tax rates on personal and corporate income. X is a vector of control variables comprising of government spending (Kneller et al., 1999), inflation (Widmalm, 2001), investment (Kneller et al., 1999; Lee & Gordon, 2005), trade openness (Lee & Gordon, 2005), debt (Kneller et al., 1999), FDI (Gemmell et al., 2009), primary education and tertiary education.

Starting with the estimation of an OLS model with robust standard errors[20], one way fixed and random-effects as well as two-way fixed and random-effects models are estimated to identify the most appropriate methodology. If the inclusion of either fixed or random-effects significantly alters the results obtained from the OLS estimations, unobserved heterogeneity is very likely to be an issue ruling out pooled OLS on the basis of likely bias in the parameter estimates. To choose between fixed and random effects models the Hausman (1978) model specification test is used.

An additional reason for the use of the alternative methodologies is to allow for comparability with other studies. Specific reasoning for each of the latter four methodologies as well as a brief intuitive discussion of how they work is provided in the following paragraphs.

[20] White (1980) corrected

One way fixed effects regressions control for country specific effects that are not explicitly controlled for by other variables. This is done by generating and including (n-1) binary variables where n is the number of countries in the sample[21]. Just as there are unobserved and therefore uncontrolled differences between countries, there may be uncontrolled differences between time periods. This is referred to as unobserved heterogeneity at the time level and may be due to a global recession, among other factors. To control for this time level heterogeneity, a two-way fixed-effects model may be employed, where not only country dummies, but also time (in this case period) dummies are included in the regression[22]. This is illustrated in the following equation:

$$Growth_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 X_{it} + a_i + \delta \mathrm{D} + \varepsilon_{it}$$

Where a_i denotes the unobserved country effects, δ is a 1×4 coefficient vector and D is a matrix containing the time dummies. The usual reason for using the fixed-effect regression technique rather than random effects is that this may arguably be a well defined set of countries namely: All countries for which the required data is available. However, this argument is not very robust given that the dataset includes developed, developing and transitional economies. Reasons for using random effects models rather than fixed effects include: Only 65 out of the 288 countries in the world are represented here and therefore the sample may not be well defined. That is to say that there may be something inherently similar about all the countries for which this type of data is available. This dataset has a large cross-section component relative to its time series component. Both of these are valid reasons for considering random effects models.

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[21] Note that one cannot include an intercept dummy variable for each country in the regression (with a constant) because this will result in perfect multi-colinearity. Perfect multi-colinearity means that there will be infinitely many solutions for the system of equations from which the OLS estimates are computed.

[22] (t-1) time dummies are included in the regression, omitting one time dummy to avoid the aforementioned problems in solving the system.

The Random Effects estimator assumes that the term β_i is a sum of a common constant β, and a time invariant cross-section specific random variable which is uncorrelated with the explanatory variables. Since it is a generalized least squares estimator, and ensures homoskedastic errors, it is more efficient than the fixed-effects estimator. If however, unobserved heterogeneity at the country level and/or time level is important, the random-effects estimator might not be consistent[23] (Wooldridge, 2009).

Multicollinearity is only an issue if it is caused by a correlation between the tax variables and other explanatory variables because the focus of this study is the tax variables' effects on growth. The usual multicollinearity problems are mitigated by including the theoretically important variables one at a time, and in the order theory and existing empirics suggests, constantly checking for changes in the t-statistics as an indication of multicollinearity[24]. This in itself does not solve the multicollinearity issues but does mitigate them. If multicollinearity persists in the model it will ultimately only affect the t-statistics (downward bias) so that variables that may be significant appear to be insignificant. It does not systematically bias results in any direction although severe multicollinearity could result in an estimated coefficient that is far from the population coefficient. The likelihood of multicollinearity problems is further reduced by employing a reasonably large sample (more than 240 observations in most estimations).

[23] We test whether to use fixed or random effects by using the Hausman specification test.

[24] Although the results are not reported in this paper we also use the Hendry approach to check for multicollinearity with no significant changes in the preferred model.

5. Results from OLS and Panel Estimations

Before discussing the results from the various empirical estimations reported in this chapter it is useful to consider the expected sign of the coefficients of the variables used. Table 7 summarizes the expected coefficient signs not only for the tax measures on which this study focuses but also for the control variables. The hypothesized signs are consistent with the theoretical and empirical literature on long-run growth as outlined in section 2 and there is good economic consensus regarding the expected signs.

Table 7: Expected coefficient signs for the independent variables.

Variable	Expected coefficient	Variable	Expected coefficient
Top Statutory Corporate Income Tax Rate	Negative	Investment (% GDP)	Positive
Top Statutory Personal Income Tax Rate	Negative or insignificant	Foreign Direct Investment (FDI as % GDP)	Positive or insignificant
Average Corporate Income Tax Rate	Negative or insignificant	Primary Education Completed	Positive
Average Personal Income Tax Rate	Negative	Tertiary Education Completed	Positive
Inflation (annual %)	Negative	Trade Openness	Positive
Debt (% of GDP)	Negative	Total Population	Positive or insignificant
Population Growth Rate (%)	Negative	Government Spending (% of GDP)	Positive or insignificant
Log of Initial GDP Per Capita (1970)	Negative or insignificant	OECD Dummy Variable	Positive
Sub-Saharan Africa Dummy Variable	Negative	Period (Testing for a time trend)	Ambiguous

Note: Positive indicates positive and significant and negative indicates negative and significant.

In the remainder of this chapter the results from the OLS[25] (Table 8 to Table 11) and two-way fixed effects (Table 12 to Table 14) regressions are reported and discussed.

Table 8: OLS (robust) with average tax rates (Table 1 of 2)

	1	2	3	4	5	6	7
Average corporate tax rate	-0.038 (-0.38)	-0.07 (-0.73)	-0.039 (-0.64)	-0.01 (-0.15)	-0.045 (-0.78)	-0.046 (-0.79)	0.001 -0.02
Average personal tax rate	0.011 -0.38	-0.05 (-1.08)	-0.043 (-1.06)	-0.049 (-0.95)	-0.042 (-1.02)	-0.054 (-1.30)	0.015 -0.22
Total government spending	-0.037 (-0.78)	-0.019 (-0.37)	-0.029 (-0.63)	-0.02 (-0.42)	-0.035 (-0.75)	-0.025 (-0.54)	-0.054 (-0.99)
Investment	-	**0.121** -2.21**	**0.088* -1.77**	**0.114** -2.09**	**0.087* -1.68**	0.085 -1.63	**0.094* -1.79**
Primary education	-	-	**0.096*** -2.79**	-	**0.084** -2.38**	**0.084** -2.37**	**0.077** -2.31**
Tertiary education	-	-	-	0.05 -0.98	-	-	-
Trade openness	-	-	-	-	**0.014*** -3.46**	**0.012*** -3.02**	**0.009** -2.15**
Inflation	-	-	-	-	-	**-0.003*** (-3.59)**	**-0.002** (-2.57)**
Log on initial GDP 1970	-	-	-	-	-	-	-0.289 (-0.95)
Constant	**2.460** 2.18**	0.433 -0.28	-0.56 (-0.41)	-0.023 (-0.01)	-1.185 (-0.84)	-1.051 (-0.75)	1.233 -0.38
Number of observations	245	245	222	223	222	222	206
F-statistic	0.262	2.145	3.718	2.248	4.821	7.112	5.258
Adjusted R-squared	0.005	0.075	0.131	0.084	0.159	0.182	0.182

Note: t-statistics are reported in parentheses. Significance indicated as follows: *** significant at 1% level, ** significant at 5% level, * significant at 10% level.

[25] Note that all OLS estimations are adjusted for heteroskedasticity using White's (1980) Heteroskedastic Consistent Covariance Matrix (Whites (1980) HCCM).

Table 9: OLS (robust) with average tax rates (Table 2 of 2)

	1	2	3	4	5	6
Average corporate tax rate	-0.046 (-0.79)	-0.038 (-0.63)	-0.009 (-0.14)	-0.010 (-0.17)	-0.019 (-0.36)	-0.010 (-0.16)
Average personal tax rate	-0.054 (-1.30)	-0.055 (-1.35)	**-0.109** (-2.18)**	-0.073 (-1.22)	-0.049 (-0.96)	-0.069 (-1.09)
Total government spending	-0.025 (-0.54)	-0.023 (-0.51)	-0.020 (-0.46)	-0.078 (-1.65)	**-0.088** (-1.98)**	-0.067 (-1.41)
Investment	0.085 (1.63)	**0.087* (1.70)**	**0.089* (1.82)**	**0.086* (1.87)**	**0.093** (2.09)**	**0.063* (1.70)**
Primary education	**0.084** (2.37)**	**0.086** (2.42)**	0.042 (0.77)	0.060 (1.05)	0.063 (1.24)	0.045 (0.95)
Trade openness	**0.012*** (3.02)**	**0.012*** (2.77)**	**0.011*** (2.68)**	**0.019*** (3.77)**	**0.018** (2.59)**	**0.018*** (3.72)**
Inflation	**-0.003*** (-3.59)**	**-0.003*** (-3.82)**	**-0.003*** (-4.02)**	**-0.003*** (-2.95)**	**-0.003*** (-2.83)**	**-0.003*** (-3.74)**
Time dummy	-	0.113 (0.90)	-	-	-	-
Population growth rate	-	-	-0.733 (-1.12)	-0.608 (-0.88)	-0.657 (-0.80)	-0.415 (-0.52)
Total population (billions)	-	-	-	**6.008*** (3.47)**	**6.154*** (4.32)**	**4.773*** (3.54)**
OECD	-	-	-	-	-0.496 (-0.33)	-
Sub-Saharan Africa dummy	-	-	-	-	-	-2.046 (-1.47)
Constant	-1.051 (-0.75)	-1.667 (-1.20)	0.734 (0.30)	0.379 (0.15)	0.604 (0.20)	0.951 (0.46)
Number of observations	222	222	222	222	222	222
F-statistic	7.112	7.009	8.639	11.560	10.437	10.718
Adjusted R-squared	0.182	0.185	0.216	0.260	0.261	0.289

Note: t-statistics are reported in parentheses. Significance indicated as follows:

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

Due to concerns relating to unobserved heterogeneity, the discussion of the OLS results is brief yet informative because it allows for a better comparison of the results provided in this study with those in other studies. Considering Table 8 (columns 1-7) and Table 9 (columns 1-6) one can see that in the OLS regressions there is no robust evidence of any significant effect of the average personal and corporate income tax rates on long-term economic-growth. As anticipated, investment (Table 8 columns 2,3,4,5 and Table 9 columns 2,3,4,5 and 6), primary education (Table 8 columns 3,5,6,7 and Table 9 columns 1 and 2) and trade openness (Table 8 columns 5,6 and 7; and Table 9 columns 1-6) have positive effects on the growth rate and inflation (Table 8 columns 6 and 7; and Table 9 columns 1-6) has a negative effect. The insignificant effect of initial GDP indicates that there is no unconditional convergence but does not eliminate the possibility of conditional convergence[26]. Neither the Sub-Saharan Africa dummy variable nor the population growth rate has a significant effect on growth in these regressions[27]. The estimated coefficients of the tax variables as well as other control variables in Table 8 and Table 9 are of a similar magnitude and direction to those of Lee and Gordon (2005); in some cases the estimates are exactly the same. The sensitivity of these results to the inclusion of some control variables indicates that there may be issues with multicollinearity[28] and/or endogeneity and that one should interpret the results with care.

[26] Unconditional convergence refers to convergence among all countries whereas conditional convergence suggests that there is convergence among developed countries and among developing countries.

[27] Note that when one drops the total population variable, the population growth rate remains insignificant but the average personal income tax rate and the Sub-Saharan Africa dummy become significant.

[28] Note the change in the significance of the primary education completion ratio when the population growth rate is included; this indicates multicollinearity between the two variables (correlation -0.4955***).

Table 10: OLS (robust) with top tax rates (Table 1 of 2)

	1	2	3	4	5	6
Top corporate tax rate	**-0.097*** (-2.94)**	**-0.082*** (-2.65)**	**-0.053* (-1.94)**	**-0.074*** (-2.63)**	-0.044 (-1.63)	**-0.057** (-2.11)**
Top personal tax rate	0.001 -0.04	-0.017 (-1.23)	**-0.026* (-1.75)**	-0.02 (-1.53)	**-0.026* (-1.83)**	**-0.028** (-1.98)**
Total government spending	-0.042 (-0.90)	-0.025 (-0.51)	-0.014 (-0.33)	-0.017 (-0.40)	-0.02 (-0.48)	-0.006 (-0.15)
Investment	-	**0.114*** -2.81**	**0.085** -2.17**	**0.115** -2.55**	**0.084** -2.05**	**0.080** -1.97**
Primary education	-	-	**0.087*** -2.78**	-	**0.078** -2.4**	**0.076** -2.36**
Tertiary education	-	-	-	-0.02 (-0.56)	-	-
Trade openness	-	-	-	-	**0.013*** -3.09**	**0.010** -2.52**
Inflation	-	-	-	-	-	**-0.003*** (-6.40)**
Constant	**6.222*** -4.37**	**4.118** -2.39**	2.281 -1.5	**3.912** -2.22**	1.404 -0.87	2.128 -1.37
Number of observations	245	245	222	223	222	222
F-statistic	3.811	4.556	3.746	2.991	4.886	12.782
Adjusted R-squared	0.052	0.119	0.167	0.126	0.189	0.22

Note: t-statistics are reported in parentheses. Significance indicated as follows:

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 11: OLS (robust) with top tax rates (Table 2 of 2)

	1	2	3	4	5	6	7
Top corporate tax rate	**-0.057** (-2.11)**	**-0.063** (-2.41)**	**-0.070** (-2.27)**	**-0.065** (-2.20)**	-0.051 (-1.48)	**-0.069** (-2.52)**	**-0.060** (-2.34)**
Top personal tax rate	**-0.028** (-1.98)**	**-0.025* (-1.84)**	**-0.044** (-2.29)**	**-0.030** (-2.11)**	**-0.028* (-1.94)**	-0.02 (-1.52)	-0.017 (-1.32)
Total government spending	-0.006 (-0.15)	-0.026 (-0.63)	-0.003 (-0.07)	-0.007 (-0.18)	-0.008 (-0.20)	**-0.070* (-1.82)**	-0.061 (-1.58)
Investment	**0.080** -1.97**	**0.098** -2.05**	**0.080* -1.93**	**0.078** -2.03**	**0.077* -1.77**	**0.082** -2.13**	**0.058* -1.85**
Primary education	**0.076** -2.36**	**0.074** -2.35**	**0.070** -2.25**	**0.070** -2.27**	0.057 -1.18	**0.089*** -2.79**	**0.063** -2.24**
Trade openness	**0.010** -2.52**	**0.007* -1.77**	**0.011*** -2.69**	**0.017*** -2.79**	**0.010** -2.52**	**0.018*** -4.69**	**0.018*** -4.61**
Inflation	**-0.003*** (-6.40)**	**-0.003*** (-5.53)**	**-0.004*** (-6.92)**	**-0.004*** (-6.53)**	**-0.003*** (-5.99)**	**-0.003*** (-5.52)**	**-0.003*** (-5.97)**
Log on initial GDP 1970	-	-0.254 (-1.60)	-	-	-	-	-
Time trend	-	-	-0.291 (-1.48)	-	-	-	-
Foreign direct investment	-	-	-	-0.181 (-1.18)	-	-	-
Population growth rate	-	-	-	-	-0.326 (-0.55)	-	-
Total population	-	-	-	-	-	**6.810*** -5.42**	**5.582*** -4.94**
Sub-Saharan Africa dummy	-	-	-	-	-	-	**-1.936** (-2.40)**
Constant	2.128 -1.37	**4.435** -2.45**	**4.832** -2.17**	2.679 -1.58	2.687 -1.58	2.222 -1.5	**2.763** -1.99**
Number of observations	222	206	222	222	222	222	222
F-statistic	12.782	8.451	12.686	11.605	12.334	12.808	11.854
Adjusted R-squared	0.220	0.237	0.231	0.281	0.229	0.280	0.307

Note: t-statistics are reported in parentheses. Significance indicated as follows:
*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 10 and Table 11 present the results for OLS regressions using the top statutory tax rates rather than the average tax rates. These tables show that once the equation is specified with adequate control variables,

there is a consistently negative and significant effect of both top personal (Table 10 columns 3,5 and 6; and Table 11 columns 1-5) and top corporate (Table 10 columns 1-4 and 6; and Table 11 columns 1-4, 6 and 7) income tax rates on growth. The negative coefficient of the top corporate tax rate (Table 10 columns 1-6; and Table 11 columns 1-7) is in the range of -0.053 to -0.097 and therefore fairly close to the results reported by Lee and Gordon (2005) [the range in that study is 0.057 to -0.073 (Table 3, p1038)]. The coefficient of the top corporate tax rate indicates that a 10 percentage point decrease in the top corporate tax rate will lead to an increase in growth of between 0.57% and 0.73%, or alternatively it will take a decrease of between 13.70% and 17.54% percentage points in the top corporate income tax rate to effect a 1 percentage point increase in the growth rate of a country. Although this may seem like a rather small effect, compounded over several years or even decades, it will result in a significantly higher level of GDP per capita[29]. The control variables also correspond well across studies: inflation has a (statistically significant) coefficient of -0.003, which is of the same magnitude as the coefficient reported in the Lee and Gordon (2005) study; the Sub-Saharan Africa dummy has a statistically significant coefficient of -1.936 in this study and is equal to -2.283 in Lee and Gordon (2005)[30]. The fact that the coefficients of the various tax and control variables in the OLS regressions are closely related to those found in Lee and Gordon (2005) means that a solid basis for a comparison across studies is offered. There is also significant overlap in the countries studied in this thesis and those studied by Widmalm (2001) and Lee and Gordon (2005). Of the 70 countries studied by Lee and Gordon 43 are duplicated here and of the 23 studied by Widmalm 20 are duplicated in this thesis. Table 6 shows a detailed breakdown of the country coverage of the various studies discussed here.

[29] For example, a 5% decrease in the top corporate tax rate will result in an effective increase in GDP of 11.47% over a 50 year period.

[30] Both are statistically significant at the 5% level.

Table 12: Two-way fixed-effects with average tax rates (Table 1 of 2).

	1	2	3	4	5	6
Average corporate tax rate	-0.148 (-0.98)	-0.176 (-1.17)	-0.007 (-0.08)	-0.011 (-0.13)	-0.164 (-1.05)	-0.019 (-0.20)
Average personal tax rate	**-0.650*** (-2.64)**	**-0.680*** (-2.72)**	**-0.514** (-2.31)**	**-0.513** (-2.40)**	**-0.642*** (-2.72)**	**-0.572*** (-2.79)**
Total government spending	-0.046 (-0.34)	-0.076 (-0.56)	0.014 (0.10)	0.016 (0.11)	-0.075 (-0.61)	-0.031 (-0.25)
Investment	-	0.071* (1.90)	-	-	-	-
Primary education	-	-	0.001 (0.02)	-	-	-
Tertiary education	-	-	-	0.052 (0.36)	-	-
Trade openness	-	-	-	-	0.027 (1.48)	0.024 (1.36)
Inflation	-	-	-	-	-	**-0.023*** (-5.87)**
Constant	**7.275*** (2.89)**	**6.583*** (2.66)**	**5.071** (2.09)**	**4.851* (1.81)**	**6.167** (2.16)**	**5.450** (2.12)**
Number of observations	245	245	222	223	245	245
Number of groups	65	65	55	56	65	65
F-statistic	1.693	1.927	1.145	1.128	1.685	5.396
Adjusted R-squared	0.103	0.117	0.067	0.068	0.121	0.282
Overall R-squared	0.000	0.001	0.001	0.000	0.003	0.046
Hausman p-value	0.0265	0.0973	0.3460	0.0831	0.0493	0.0001

Note: t-statistics are reported in parentheses. Significance indicated as follows:
*** significant at 1% level, ** significant at 5% level, * significant at 10% level.
Hausman p-value tests the probability that the difference in coefficients is not systematic, thus a significant result indicates that the fixed-effects methodology is preferred.

Table 13: Two-way fixed-effects with average tax rates (Table 2 of 2).

	1	2	3
Average corporate tax rate	-0.019 (-0.20)	0.007 (0.07)	0.005 (0.05)
Average personal tax rate	**-0.572***** **(-2.79)**	**-0.624***** **(-3.06)**	**-0.619***** **(-3.02)**
Total government spending	-0.031 (-0.25)	-0.017 (-0.14)	-0.028 (-0.22)
Trade openness	0.024 (1.36)	**0.033**** **(2.11)**	**0.034**** **(2.13)**
Inflation	**-0.023***** **(-5.87)**	**-0.023***** **(-5.82)**	**-0.023***** **(-5.78)**
Population growth rate	-	-0.891 (-0.97)	-0.873 (-0.94)
Total population	-	-	5.548 (1.59)
Constant	**5.450**** **(2.12)**	**5.909**** **(2.11)**	**5.828**** **(2.09)**
Number of observations	245	245	245
Number of groups	65	65	65
F-Statistic	5.396	5.441	5.210
Adjusted R-squared	0.282	0.314	0.316
Overall R-squared	0.046	0.080	0.085
Hausman p-value	0.0001	0.1215	0.0406

Note: t-statistics are reported in parentheses. Significance indicated as follows:
*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 12 and Table 13 present the results for two-way fixed-effects regressions for the average personal and corporate tax rates. As anticipated the average personal income tax rate has a consistently negative and significant coefficient, as does inflation and the population

growth rate[31]. This negative and significant effect observed for the average personal income tax rate in all the regressions supports the findings of Widmalm (2001).

As expected, trade openness has a positive coefficient (Table 12 column 5 and 6; and Table 13 column 1-3) while total government expenditures (Table 12 column 1-6; and Table 13 column 1-3), investment (Table 12 column 2) and both of the education measures are insignificant (Table 12 column 3 and 4). These results are largely in line with those of Lee and Gordon (2005). The finding of no significant effect of investment on growth is in accordance with Kneller *et.al.* (1999) but contradicts Widmalm (2001) who finds a robust positive effect for OECD countries[32]. The positive effect hypothesised for education is not observed in these regressions but is not of any major significance for the interpretation of the tax variables' coefficients.

Table 14 presents the results of the two-way fixed-effects regression using top statutory tax rates. The results indicate a consistent and significantly negative effect of the top statutory personal income tax rate on growth (Table 14 columns 1-7), thus lending support to Widmalm (2001). As in the regressions using the average tax rates the trade openness variable has a positive and significant effect (Table 14 columns 5-7) and inflation has a negative effect on growth (Table 14 columns 6 and 7). All of these findings are consistent with current economic theory. The education variables (Table 14 columns 3 and 4), investment (Table 14 column 2) and government spending (Table 14 columns 1-7) again have no significant effect on growth.

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[31] The Sub-Saharan Africa dummy is insignificant, as is the OECD dummy, debt is sometimes significant but is very sensitive to model specification.

[32] Since this study covers not only OECD countries but also developing countries this difference in findings is perhaps not overly disturbing. Padovano and Galli (2002) warn against using OECD countries and developing countries in regressions where a single coefficient is assumed for both OECD and developing countries because there may be different effects between these sets of countries.

Table 14: Two-way fixed-effects with top tax rates (Table 1 of 1).

	1	2	3	4	5	6	7
Top corporate tax rate	0.003 (0.07)	0.007 (0.17)	-0.015 (-0.37)	-0.012 (-0.31)	0.011 (0.29)	0.001 (0.02)	0.006 (0.15)
Top personal tax rate	**-0.047** (-2.25)**	**-0.047** (-2.25)**	**-0.045** (-2.24)**	**-0.044** (-2.19)**	**-0.049** (-2.32)**	**-0.042** (-2.05)**	**-0.040* (-1.95)**
Total government spending	-0.032 (-0.22)	-0.050 (-0.34)	0.024 (0.15)	0.020 (0.13)	-0.062 (-0.48)	-0.025 (-0.19)	-0.038 (-0.28)
Investment	-	0.044 (1.07)	-	-	-	-	-
Primary education	-	-	0.024 (0.64)	-	-	-	-
Tertiary education	-	-	-	0.051 (0.35)	-	-	-
Trade openness	-	-	-	-	0.028 (1.38)	0.026 (1.32)	0.027 (1.37)
Inflation	-	-	-	-	-	**-0.024*** (-5.33)**	**-0.024*** (-5.29)**
Total population	-	-	-	-	-	-	**6.734* (1.71)**
Constant	**5.415** (2.21)**	**4.654* (1.86)**	**4.594* (1.69)**	4.774 (1.62)	4.042 (1.43)	4.340 (1.54)	3.982 (1.44)
Number of observations	245	245	222	223	245	245	245
Number of groups	65	65	55	56	65	65	65
F-statistic	1.211	1.597	0.922	0.773	1.270	4.077	3.994
Adjusted R-squared	0.047	0.052	0.039	0.038	0.065	0.247	0.250
Overall R-squared	0.027	0.069	0.077	0.047	0.070	0.084	0.093
Hausman p-value	0.0004	0.0312	0.9653	0.2153	0.0015	0.0000	0.2951

Note: t-statistics are reported in parentheses. Significance indicated as follows:

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 15 and Table 16 present the results for two-way random-effect regressions using the average personal and corporate income tax rates as tax vector. The main change when moving from the fixed to the random-effects models is that investment and primary education becomes statistically significant (Table 15 columns 2-7; and Table 16 columns 1-5). Inflation (Table 15 columns 6 and 7; and Table 16 columns 1-5), the population growth rate (Table 15 column 7; and Table 16 columns 1-5) and the Sub-Saharan Africa dummy (Table 15 columns 4 and 5) all still have a negative and significant effect on growth. Most important is the effect of the average personal income tax rate (Table 15 column 7; and Table 16 columns 1-5) on growth, it is between -0.05 and -0.178 while the average corporate income tax rate (Table 15 columns 1-7; and Table 16 columns 1-5) has no statistically significant effect on growth. This is again in accordance with Widmalm (2001) who also finds a negative and significant effect of average personal income taxation on growth and no effect of average corporate tax rates.

Table 15: Two-way random-effects with average tax rates (Table 1 of 2).

	1	2	3	4	5	6	7
Average corporate tax rate	-0.081 (-0.67)	-0.114 (-0.94)	-0.028 (-0.42)	-0.011 (-0.16)	-0.029 (-0.45)	-0.030 (-0.47)	-0.001 (-0.02)
Average personal tax rate	-0.055 (-0.88)	-0.100 (-1.28)	-0.055 (-0.77)	-0.073 (-0.83)	-0.050 (-0.72)	-0.070 (-1.02)	-0.139* (-1.91)
Total government spending	-0.041 (-0.56)	-0.041 (-0.57)	-0.031 (-0.46)	-0.030 (-0.44)	-0.039 (-0.61)	-0.029 (-0.45)	-0.025 (-0.42)
Investment	-	0.098 (1.62)	0.080 (1.41)	0.092 (1.53)	0.066 (1.14)	0.068 (1.15)	0.078 (1.44)
Primary education	-	-	**0.064* (1.76**)	-	**0.063* (1.74)**	**0.063* (1.72)**	0.029 (0.55)
Tertiary education	-	-	-	0.058 (0.86)	-	-	-
Trade openness	-	-	-	-	**0.020*** (3.43)**	**0.016*** (2.91)**	**0.015** (2.41)**
Inflation	-	-	-	-	-	**-0.003*** (-4.45)**	**-0.003*** (-4.73)**
Population growth rate	-	-	-	-	-	-	-0.822 (-1.02)
Constant	**2.903* (1.70)**	1.643 (0.86)	-0.029 (-0.02)	0.469 (0.23)	-0.989 (-0.52)	-0.666 (-0.36)	1.131 (0.36)
Number of observations	245	245	222	223	222	222	222
Number of groups	65	65	55	56	55	55	55
Degrees of freedom	3	4	5	5	6	7	8
Chi-Squared	1.192	3.698	10.473	6.313	16.886	50.747	63.341

Note: t-statistics are reported in parentheses. Significance indicated as follows:

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

If Hausman p-value is significant the fixed effects methodology is preferred.

Table 16: Two-way random-effects with average tax rates (Table 2 of 2).

	1	2	3	4	5
Average corporate tax rate	-0.001 (-0.02)	0.000 (0.00)	-0.053 (-0.57)	-0.059 (-0.61)	-0.065 (-0.66)
Average personal tax rate	**-0.139*** **(-1.91)**	-0.113 (-1.44)	**-0.167**** **(-2.52)**	**-0.164**** **(-2.42)**	**-0.178***** **(-2.65)**
Total government spending	-0.025 (-0.42)	-0.056 (-0.95)	-0.061 (-1.00)	-0.057 (-0.91)	-0.045 (-0.75)
Investment	0.078 (1.44)	0.076 (1.44)	0.087 (1.54)	0.063 (1.41)	0.063 (1.42)
Primary education	0.029 (0.55)	0.038 (0.68)	-	-	-
Trade openness	**0.015**** **(2.41)**	**0.019***** **(2.71)**	**0.019**** **(2.50)**	**0.019**** **(2.51)**	**0.016**** **(2.16)**
Inflation	**-0.003***** **(-4.73)**	**-0.003***** **(-4.19)**	**-0.005***** **(-3.18)**	**-0.006***** **(-3.39)**	**-0.006***** **(-3.46)**
Population growth rate	-0.822 (-1.02)	-0.767 (-0.93)	**-0.908*** **(-1.77)**	-0.679 (-0.97)	-0.668 (-0.95)
Total population	-	**5.513**** **(2.50)**	**4.610***** **(2.78)**	**3.630**** **(2.24)**	-
Sub-Saharan Africa Dummy variable	-	-	-	-2.294 (-1.02)	-2.503 (-1.12)
Constant	1.131 (0.36)	0.838 (0.27)	2.341 (0.97)	2.738 (1.35)	2.991 (1.45)
Number of observations	222	222	245	245	245
Number of groups	55	55	65	65	65
Degrees of freedom	8	9	8	9	8
Chi-Squared	63.341	96.094	53.160	58.301	49.339

Note: t-statistics are reported in parentheses. Significance indicated as follows:

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 17 and Table 18 present the results for the two-way random-effects models using the top statutory corporate and personal tax rates rather than the average tax rates as the tax vector. There is no statistically significant effect of the top corporate income tax rates on growth in either of the tables (Table 17 and Table 18 columns 1-6 respectively) while the significant effect of the top personal income tax rate are confined to estimations where the population growth rate is not controlled for. There is again no statistically significant effect of government spending on growth (Table 17 columns 1-6; and Table 18 columns 1-6). Investment (Table 17 columns 2-6; and Table 18 columns 1-6) and trade openness (Table 17 columns 5-6; and Table 18 columns 1-6) both have the expected positive coefficients. Primary education is the preferred education (or human capital) measure since it is statistically significant and tertiary education is not (Table 17 columns 3-6; and Table 18 columns 1, 3 and 4). Inflation (Table 17 column 7; and Table 18 columns 1-6) and the population growth rate (Table 18 columns 3-6) both have the expected negative effects on the growth rate of per capita GDP. An interesting result is the positive and significant effect of the total population variable on growth (Table 18 columns 3-6); the overall population is included to control for possible economies of scale (regressions 5 and 6). OECD countries do not appear to have a different intercept from non-OECD countries (Table 18 column 4) and Sub-Saharan African countries grow at between 1.933% and 2.162% slower than other countries (Table 18 columns 5 and 6).

Table 17: Two-way random-effects with top tax rates (Table 1 of 2).

	1	2	3	4	5	6
Top corporate tax rate	-0.037 (-1.19)	-0.034 (-1.13)	-0.025 (-0.91)	-0.030 (-1.10)	-0.016 (-0.59)	-0.032 (-1.15)
Top personal tax rate	-0.018 (-1.42)	**-0.026** (-2.04)**	**-0.025* (-1.90)**	**-0.022* (-1.79)**	**-0.023* (-1.77)**	**-0.025* (-1.87)**
Total government spending	-0.040 (-0.59)	-0.038 (-0.55)	-0.020 (-0.31)	-0.031 (-0.48)	-0.029 (-0.48)	-0.016 (-0.28)
Investment	-	**0.094** (1.96)**	**0.078* (1.69)**	**0.096* (1.83)**	0.067 (1.41)	0.069 (1.47)
Primary education	-	-	**0.074** (2.00)**	-	**0.072* (1.92)**	**0.072** (1.98)**
Tertiary education	-	-	-	-0.024 (-0.47)	-	-
Trade openness	-	-	-	-	**0.017*** (3.18)**	**0.012*** (2.58)**
Inflation	-	-	-	-	-	**-0.003*** (-5.69)**
Constant	**4.571*** (3.06)**	**3.249* (1.74)**	1.449 (0.77)	2.755 (1.28)	0.259 (0.13)	1.138 (0.62)
Number of observations	245	245	222	223	222	222
Number of groups	65	65	55	56	55	55
Degrees of freedom	3	4	5	5	6	7
Chi-Squared	6.232	11.067	11.644	9.146	18.685	71.601

Note: t-statistics are reported in parentheses. Significance indicated as follows:

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 18: Two-way random-effects with top tax rates (Table 2 of 2).

	1	2	3	4	5	6
Top corporate tax rate	-0.032 (-1.15)	-0.027 (-0.87)	-0.036 (-1.11)	-0.036 (-1.17)	-0.031 (-1.07)	-0.030 (-0.96)
Top personal tax rate	**-0.025*** **(-1.87)**	-0.021 (-1.41)	-0.017 (-1.24)	-0.016 (-1.08)	-0.015 (-1.17)	-0.019 (-1.60)
Total government spending	-0.016 (-0.28)	-0.017 (-0.32)	-0.060 (-1.26)	-0.066 (-1.35)	-0.056 (-1.15)	-0.057 (-0.99)
Investment	0.069 (1.47)	0.067 (1.46)	0.071 (1.57)	0.083* (1.74)	0.053 (1.56)	0.049 (1.48)
Primary education	**0.072**** **(1.98)**	0.048 (0.86)	0.059 (1.04)	0.059 (1.05)	0.043 (0.98)	-
Trade openness	**0.012*** **(2.58)**	**0.012**** **(2.52)**	**0.018*** **(3.59)**	**0.016**** **(2.20)**	**0.018*** **(3.60)**	**0.019*** **(3.24)**
Inflation	**-0.003*** **(-5.69)**	**-0.003*** **(-5.38)**	**-0.003*** **(-5.12)**	**-0.003*** **(-4.76)**	**-0.003*** **(-5.11)**	**-0.005*** **(-3.54)**
Population growth rate	-	-0.492 (-0.63)	-0.449 (-0.60)	-0.563 (-0.57)	-0.315 (-0.37)	-0.430 (-0.63)
Total population	-	-	**6.222*** **(3.88)**	**6.095*** **(3.41)**	**5.263*** **(4.00)**	**4.529*** **(3.19)**
OECD Dummy variable	-	-	-	-0.644 (-0.41)	-	-
Sub-Saharan Africa Dummy variable	-	-	-	-	-1.933 (-1.11)	-2.162 (-1.14)
Constant	1.138 (0.62)	1.840 (0.82)	1.874 (0.92)	2.295 (0.83)	2.238 (1.27)	3.515** (2.20)
Number of observations	222	222	222	222	222	245
Number of groups	55	55	55	55	55	65
Degrees of freedom	7	8	9	10	10	9
Chi-Squared	71.601	78.718	102.274	107.698	106.149	68.759

Note: t-statistics are reported in parentheses. Significance indicated as follows:

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

The Hausman test for fixed versus random effects for the most comprehensive specifications indicate that fixed-effects regressions are preferred to random effects regressions. The more complete specifications of the fixed and random-effects regressions are very similar in their findings with regard to all the important variables and therefore the choice of methodology is ultimately not vital to the results.

In summary, there is evidence of significant negative (linear) effects on growth for both top and average personal income tax rates in both OLS and two-way fixed-effects regressions and for a negative growth effect of only the average personal income tax rates in two-way random effects regressions. Recall that Widmalm (2001) finds a significant and negative effect on growth only for the average personal income tax rate and not for the average corporate tax rate, and that Lee and Gordon (2005) find a negative effect of the top corporate rate only and not for the top personal income tax rate. The results reported therefore support those of Widmalm (2001) as well as lending partial support to those of Lee and Gordon (2005). At this point in the paper evidence for a significant and negative effect of either top or average corporate tax rates is limited to OLS regressions. This suggests that the estimated effects of corporate taxation on growth might reflect uncontrolled heterogeneity at the country and time levels rather than the effect of corporate taxation on growth. Investment, openness, primary education and total population have positive and often significant effects on growth, whereas inflation, the population growth rate and the Sub-Saharan Africa dummy all have negative and often significant coefficients. Table 19 presents a summary of the results for top and average, personal and corporate tax rates in the three different methodologies reported so far.

Table 19: Summary of the results for OLS and two-way fixed and random-effect regressions.

	OLS	Two-way fixed-effects	Two-way random-effects
Average personal income tax rate	Insignificant unless population growth rate is controlled for and total population is not included. Coefficient ranges from -0.109** to 0.015	Significant at the 1% level throughout. Coefficient ranges from -0.650*** to -0.513***	Significant when correctly specified, that is, not significant in the first 6 regressions where population growth rate is omitted. Significant in the last 6, after population growth rate is included. Coefficient ranges from -0.178*** to -0.001
Average corporate income tax rate	Insignificant throughout	Insignificant throughout	Insignificant throughout
Top statutory personal income tax rate	Significant in most regressions (that are appropriately specified. Table 10 regressions 4, 6 and 7 Table 11 regressions 1-5) Coefficient ranges from -0.044** to 0.001	Significant throughout Coefficient ranges from -0.049** to -0.040*	Insignificant throughout
Top statutory corporate income tax rate	Significant in 12 of the 14 regressions. Coefficient ranges from -0.097*** to -0.044	Insignificant throughout	Insignificant throughout

Note: t-statistics are reported in parentheses. Significance indicated as follows:

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

6. Dealing with endogeneity

Empirical studies on growth often suffer from issues of endogeneity[33]. Therefore, if there is endogeneity, one cannot be sure that the coefficients and t-statistics are correct; that is, without addressing the endogeneity issue the coefficient estimates presented in the previous section may be biased. One way to deal with this issue is by using an instrumental variable regression technique. The Arellano-Bond panel estimator is a GMM estimator and is used to estimate dynamic panels with fixed effects. The advantage of the Arellano-Bond estimation is the fact that it not only allows the inclusion of the lagged dependent variable (lagged growth) in the specification, and therefore allows to investigate the dynamics of adjustment, but also allows one to control for the endogeneity between the tax variables and economic performance. The regression equation is specified in first differences and parameter estimates are chosen which satisfy the orthogonality (no endogeneity) condition as closely as possible. In this thesis only the variables that are consistently significant in the fixed and random effects estimations are included in the Arellano-Bond estimation. Total population is excluded from this estimation for comparability with other studies – the exclusion of total population does not significantly alter the results of the Arellano-Bond estimation.

The results reported in Table 20 are for regressions that instrument for the respective control variables using their lags. The results from the Arellano-Bond estimations with average corporate and personal tax rates are presented in Table 20[34] regressions (or columns) 1-3. The corresponding regressions using top corporate and personal income tax rates are

[33] Endogeneity (also known as reverse or mutual causality) is when the independent variable x can explain changes in the dependent variable y but y can also affect x. Endogeneity is of particular concern in empirical studies of growth because the growth rate of a country can plausibly affect its rate of taxation, openness and various other theoretical determinants of growth.

[34] Only the significant results are reported here but more complete tables are available upon request.

reported in Table 20 regressions 4-5. The sample size in these estimations is reduced to 115 observations, rather than 245 as before, due to the estimation technique's use of lags.

From Table 20 (regressions 1-3) it is clear that even when one controls for endogeneity using the Arellano-Bond estimator the average personal income tax rate is still significant and negatively related to economic-growth. However none of the other tax measures are significant (Table 20, regressions 1-6). Investment (Table 20, regressions 2, 3, 5 and 6) and trade openness (Table 20, regressions 3 and 6) both have positive and significant effects on growth regardless of the tax vector used[35].

Table 20: Arellano-Bond regressions.

	1	2	3	4	5	6
Lag of growth	-0.061 (-0.37)	-0.087 (-0.48)	-0.007 (-0.05)	-0.067 (-0.37)	-0.102 (-0.52)	-0.023 (-0.14)
Average corporate tax rate	-0.059 (-0.18)	-0.193 (-0.59)	-0.154 (-0.52)	-	-	-
Average personal tax rate	**-1.035** (-2.14)**	**-0.970** (-2.08)**	**-0.944** (-2.14)**	-	-	-
Top corporate tax rate	-	-	-	-0.019 (-0.45)	-0.012 (-0.31)	-0.007 (-0.18)
Top personal tax rate	-	-	-	-0.027 (-1.22)	-0.034 (-1.36)	-0.039 (-1.46)
Total government spending	-0.016 (-0.07)	-0.081 (-0.38)	-0.088 (-0.42)	-0.115 (-0.58)	-0.197 (-1.12)	-0.195 (-1.08)
Investment	-	**0.216** (2.33)**	**0.166** (2.05)**	-	**0.221** (2.43)**	**0.170** (2.26)**
Trade openness	-	-	**0.042** (1.78)**	-	-	**0.045** (1.72)**
Constant	**10.084*** (2.61)**	**7.369** (1.67)**	4.644 (1.01)	**6.898** (2.04)**	4.609 (1.08)	2.623 (0.54)
Number of observations	115	115	115	115	115	115
Number of groups	40	40	40	40	40	40
Chi-squared	22.330	49.107	55.041	7.464	58.709	47.935

Note: t-statistics are reported in parentheses. Significance indicated as follows:
*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

[35] Inflation, population growth rate and log of initial GDP are all insignificant.

7. Progressivity

7.1 Introduction

To understand the importance of progressivity in this study of the effects of taxation on growth it is vital that one defines progressivity. There is a general idea, broadly referred to as progressivity, but no single all encompassing definition. The concept of progressivity is multi-faceted: Bracewell-Milnes (1979) suggests in his comment on the Kakwani (1977)[36] paper that "Part of the trouble with the measurement of progressivity has been that there are more valid and relevant mathematical concepts than there are names for them in common usage at present" (p651). This statement highlights the fact that there is no single definition of progressivity that is robust to all points of view and that can be universally applied regardless of the specific question at hand.

One definition that is widely accepted as the core measure of progressivity[37] defines a tax schedule as being progressive at a point if the marginal rate exceeds the average rate at that point; in that case the (income) tax schedule is said to be progressive (point-wise progressive) (Liu, 1985; Musgrave & Thin, 1948). Furthermore, if there is point-wise progressivity at every point in the system the system is said to be globally progressive (Jakobsson, 1976; Liu, 1985; Musgrave & Thin, 1948). This paper applies the 'point-wise' progressivity notion to the average and top personal income tax rates to proxy for global progressivity. This is usually done because not enough data is available to test global progressivity in its purest form as this would require detailed information regarding the income distribution as well as the tax structure.

[36] Kakwani (1977) proposes a new measure for income tax progressivity. It is equivalent to twice the area between the Lorenz curve (the relationship between income distribution and the proportion of income received) and the concentration curve of taxes (the relationship between the income distribution and the proportion of taxes paid by individuals with income less than x) (Dorrington, 1979).

[37] Progressivity here refers to tax rate progression specifically.

There appears to be little disagreement among economic theorists that tax progressivity can hamper growth by changing the incentives of economic agents (Caucutt, Imrohoroglu, & Kumar, 2000). Empirical estimations of the effects of progressivity on economic performance have not enjoyed the same measure of consensus (Arnold, 2008; Lee & Gordon, 2005; Padovano & Galli, 2002; Widmalm, 2001). This may be due to the widely varying measures of progressivity used in the empirical literature as well as the difference in samples; both countries and time periods differ significantly across studies (Arnold, 2008; Lee & Gordon, 2005; Padovano & Galli, 2002; Widmalm, 2001). A likely reason for these varying measures of tax progressivity in use is that there is currently no single measure of progressivity available which captures the various effects of tax-progressivity[38] simultaneously. Li and Sarte (2004) predict that progressivity will have a negative effect on output growth[39]. They suggest that this is probably due to distortions in the incentives faced by investors, which lead to lower investment in both human and physical capital because of reduced returns to investment.

Some recent empirical studies on the effects of tax progressivity on growth include: Widmalm (2001), Padovano and Galli (2002), Lee and Gordon (2005) and Arnold (2008). Three of the four (Widmalm, 2001: Padovano and Galli, 2002; Arnold, 2008)) studies find a negative and significant effect of progressivity on growth, controlling for various other determinants thereof. Each of these studies use a different progressivity measure. This could be interpreted as an indication that the way in which progressivity is measured does not impact the direction of the effect of tax progressivity on long-run growth. Lee and Gordon (2005), however, find no evidence of any significant linear effect of tax progressivity on growth using a measure

[38] Both Kakwani (1977) and Suits (1979) make valiant efforts at producing a single useable measure but, although each of their measures has its virtues, they both fall short of achieving this ambitious goal.

[39] This result can also be extrapolated from Barro (1990) and Barro et.al. (1995) see Gemmell et.al. (2009)

that is very closely related to that of Arnold (2008). In fact, it can be shown that the Arnold (2008) and Lee Gordon (2005) progressivity measures are a linear transformation of one another:

$$Arnold = \frac{(Top - Average)}{Average} = \frac{Top}{Average} - \frac{Average}{Average} = \frac{Top}{Average} - 1$$

$$Arnold = Lee\ Gordon - 1$$

The different estimation results may be due to Lee and Gordon (2005) considering not only OECD countries (as the other three papers do) but a mixed sample consisting of 70 developing and developed countries. This may be seen as an indication that the effects of progressivity on growth are highly sensitive to sample selection, a point made by Padovano and Galli (2002) when they suggest that the various determinants of growth may have different effects in developing and developed countries[40] as illustrated for the effect of tax variables on output (Garrison & Lee, 1992) and also in the context of the discussion on conditional convergence (Grier & Tullock, 1989).

For the purpose of selecting an appropriate tax progressivity measure, the following paragraphs expand on the merits and flaws of the alternative measures employed. Widmalm (2001) uses a measure of progressivity that is effectively equal to the elasticity of tax revenues with respect to GDP (Snowbarger & Kirk, 1975).

[40] This variation is not captured by the inclusion of any sub-sample dummy variable (such as the OECD dummy) since it is not simply a different intercept but rather different effects of the various determinants of growth. Interaction terms between the country or 'regional' dummies may capture this but this will put further strain on the dataset by greatly reducing the degrees of freedom in the estimations.

More precisely stated, the Widmalm (2001) tax progressivity measure, (hereafter referred to as the Widmalm progressivity measure), is equal to α_1 from the regression:

$$\ln(Tax\ revenues_t) = \alpha_0 + \alpha_1 \ln(GDP_t) + \varepsilon_t$$

For the study at hand this measure may not be ideal. This follows since the underlying sample spans a 28 year period and the validity of α_1 as a good measure of progressivity assumes that the underlying tax structure does not change over time[41]. This assumption is unlikely to hold for the time period covered by this study. In fact, there is mounting evidence that tax structures have been changing over time continually. The data shows decreases in top corporate income tax rates (Gemmell et al, 2009) as well as in personal income tax rates and progressivity (Duncan & Sabirianova Peter, 2008). Although Snowbarger and Kirk (1975) specify a caveat, Widmalm (2001) uses the above tax progressivity measure stating that there weren't any significant changes in tax structures (tax reforms) in the countries studied over her sample period (23 OECD countries, 1965-1990). The advantage of this measure is that it can give some indication of the level of tax progressivity when data on top and average tax rates are not available.

A study that uses a variation of the Widmalm measure of progressivity is Padovano and Galli (2002) who suggest that calculated average tax rates and top statutory tax rates are inappropriate for the computation of progressivity measures. They argue that using these rates can lead to flawed results as the calculated average tax rates may be biased due to differences in the underlying tax structure[42]. Padovano and Galli (2002)

[41] It is simple enough to conjure some hypothetical examples where two fundamentally different tax structures would yield the exact same Widmalm progressivity measure or where the same tax rates would yield a very different progressivity measure, in both instances due to the tax revenue distribution.

[42] As discussed for the Widmalm (2002) example.

use a very similar technique to Widmalm (2001) but they correct for tax policy changes by including a level dummy for the intercept and a slope dummy for GDP. The dummy variables take the value 1 after a change in tax policy. The equation Padovano and Galli (2002) use to estimate the marginal tax rate α_1 is[43]:

$$REV_t = \alpha_0 + \alpha_1 GDP_t + \alpha_2 TAXREF_t + \alpha_3 (TAXREF_t \times GDP_t) + \varepsilon_t$$

Where REV denotes total tax revenues, GDP stands for gross domestic product, TAXREF is the tax reform dummy variable and the subscript t refers to the time period. The average tax rate is defined as the ratio of tax revenues to GDP. To measure the effect of progressivity on growth both average and marginal tax rates are included with the standard conditioning variables and the estimated parameter α_1 is used as the progressivity measure. However, Lee and Gordon (2005) note that this measure increases with all activity that increases tax revenues (*ceteris paribus*), therefore making it a poor measure of income tax progressivity.

The third measure discussed here is the measure used by Lee and Gordon (2005) (hereafter the Lee Gordon progressivity measure). The Lee Gordon progressivity measure is given by the ratio of the top personal income tax rate and the average personal income tax rate:

$$\left(\frac{Top\ personal\ \ income\ \ tax\ rate}{Average\ \ personal\ \ income\ \ tax\ rate}\right)$$

[43] For α_3 significantly different from zero, the marginal tax rate is calculated as a weighted average of α_1 and α_3, α_3 weighted by the percentage of years in the sample period for which the reform has been implemented.

This means that a long time period can be considered without the assumption of a stationary tax structure. This ratio may also be converted to a percentage change measure[44] for ease of interpretation.

The Lee Gordon progressivity measure also has shortcomings. The main possible cause for concern is that two completely different structures could again end up with the exact same value for progressivity (a concern similar to the Widmalm progressivity measure, but for slightly different reasons). The argument for the effect of progressivity on growth rests on the idea that the incentives facing an individual economic agent is affected by progressivity. Although the measure will only be identical in some select cases the same bias applies to all cases. There can be very similar values for the Lee Gordon progressivity measure even when there are substantial differences in the incentives faced by economic agents.

The fourth measure considered is that of Arnold (2008) (hereafter the Arnold progressivity measure). The same criticism can be levelled at the Arnold progressivity measure as at the Lee Gordon progressivity measure, namely that it could generate the exact same value for two very different tax structures. This result could be anticipated as it has already been shown that the Arnold and Lee Gordon progressivity measures differ only by a constant.

The problems referred to with regard to the Lee Gordon and Arnold progressivity measures are mitigated (as in the original studies) by the inclusion of either the top tax rates or the average tax rates in all regressions testing for the effects of progressivity on growth. By including these tax measures the authors control for the level of taxation and thereby the aforementioned problem is corrected because it is related to different levels of taxation rather than the specific rate of progression.

[44] If the average tax rate is 20% and the top rate is 40% the Lee Gordon progressivity measure is 2, that is, the top rate is at 200% the average rate.

Table 21: Summary of the progressivity measures

	Widmalm (2001)	Padovano and Galli (2002)	Lee and Gordon (2005)	Arnold (2008)
Measure	$\text{Ln}(REV) = \alpha_0 + \alpha_1 \ln(GDP) + \varepsilon$	$REV_t = \alpha_0 + \alpha_1 GDP_t + \alpha_2 TAXREF_t + \alpha_3 (TAXREF_t \times GDP_t) + \varepsilon_t$	$\frac{Top\ personal\ income\ tax\ rate}{Average\ personal\ income\ tax\ rate}$	$\frac{Top - Average}{Average}$
Advantages	Can be computed even without data on top and average tax rates	May take account of tax avoidance or evasion issues more accurately than other measures. It corrects the disadvantage of the Widmalm progressivity measure.	Easily computed Can be used even when there are changes in the tax structure	Easily computed Can be used even when there are changes in the tax structure
Disadvantages	Cannot be used if there are tax reforms during the period studied	Data requirements are stringent and calculation is more complex than for the other measures.	Relies heavily on the average tax rate which is shown to be less than ideal. Requires data on average tax rates as well as top statutory tax rates which are not always available.	Relies heavily on the average tax rate which is shown to be less than ideal. Requires data on average tax rates as well as top statutory tax rates which are not always available.

After commenting on the advantages and disadvantages of the various measures currently available, the question remains which measure of progressivity to use in this study. Due to concerns over the effects of tax policy changes over the observed sample period, the Widmalm measure seems inappropriate[45]. The measure used by Padovano and Galli (2002) cannot be calculated for the dataset used in this study[46] due to data restrictions and is thus omitted. Both the Lee and Gordon, and Arnold measures will be used in conjunction with the variables discussed in the following paragraphs[47].

One of the theories on progressivity that has not received much attention in the economic growth literature is the idea that one should measure progressivity from an after-tax perspective rather than a tax-paid perspective (Liu, 1985). This idea can be incorporated into both the Lee and Gordon and the Arnold progressivity measures. This so called 'reversed' Lee Gordon measure is calculated as follows:

$$Reversed\ Lee\ Gordon = \frac{100 - Average\ personal\ tax\ rate}{100 - Top\ personal\ tax\ rate}$$

and the 'reversed' Arnold measure is:

$$Reversed\ Arnold = \frac{(100 - Average) - (100 - Top)}{(100 - Top)}$$

[45] For evidence on changes in tax structure over the observed sample period, see (Duncan & Sabirianova Peter, 2008; Gemmell et al., 2009).

[46] This is because data on tax policy shocks are not available for all the countries in the sample.

[47] This is done for ease of comparison. Note that it is expected that the various regressions which differ only by the use of either one of these progressivity measures are expected to have different constants but that all of the other coefficients will be the same (ignoring rounding errors) because the progressivity measures differ only by a constant – see footnote 40.

Calculating the ‘reversed’ measures in this way rather than using the more standard formulas[48] makes the results more intuitive since increasing the top personal income tax rate will decrease the denominator and therefore increase the value of the progressivity measure and *vice versa*.

These ‘reversed’ measures should measure the incentives that individuals face more accurately if investment decisions are based on after tax income. It can be argued that the standard and reversed progressivity measures are two sides of the same coin, and to some extent that is true. There is however, an important transformation made when using the reversed progressivity measures in that these measures may measure incentives more linearly than the standard measures. It also yields results that are more comparable to the original progressivity measures since these can again be shown to differ only by a constant.

[48] $Reversed\ Lee\ Gordon = \frac{100 - Top\ personal\ \ tax\ rate}{100 - Average\ \ personal\ \ tax\ rate}$

and $Reversed\ Arnold = \frac{(100 - Top)}{(100 - Average\ ) - (100 - Top)}$

7.2 Empirical evaluation of the effects of tax progressivity

Due to concerns about endogeneity of the explanatory variables, this section reports only the results for the Arellano-Bond regressions. The results are presented in Table 22[49]. Table 22 contains only the results for the regressions using the various Arnold progressivity measures because it has been established that the Arnold, as well as the Lee and Gordon measures do not differ significantly and therefore the Arnold measures' results can be said to represent those of the Lee and Gordon measures (and *vice versa*). The results (Table 22 regressions 1-4) indicate that there is in fact a negative and highly significant effect of personal income tax rate progression on economic growth. This contradicts the results of Lee and Gordon (2005) who report no statistically significant effect of progressivity on growth, but supports the results of Widmalm (2001), Padovano and Galli (2002), as well as Arnold (2008). This support for the aforementioned studies using a sample of 65 developed and developing countries rather than the OECD samples used by the other 3 studies may be seen as a small step forward in achieving more coherent empirical results for the effects of tax progressivity on growth.

The inclusion of the various progressivity measures in the regressions does not affect the coefficients of the other variables significantly. For example trade openness had coefficients of 0.042 to 0.045 in Table 20 (regressions 3 and 6) and 0.039 to 0.049 in Table 22 (regressions1-4), and investment had coefficients of 0.166 to 0.170 in Table 20 (regressions 3 and 6) and 0.200 to 0.249 in Table 22 regressions 1-4). Although the magnitude of the effect of investment appears lower in Table 22, it is not statistically different from the results in Table 22. However, the inclusion of

[49] Results for one and two-way, fixed and random-effects are consistent with those presented for the Arellano-Bond regressions, indicating a negative and highly significant effect of all the progressivity measures in 34 of the 36 regressions. These results are available from the author upon request.

the reversed Arnold measure does cause the top personal income tax rate to become positive and significant, most likely due to multicollinearity (pair-wise correlation statistic indicates a correlation of 0.7887 with a p-value of 0.0000).

Table 22: Results for Arellano-Bond regressions with progressivity.

	1	2	3	4
Lag Growth	-0.118 (-0.84)	-0.146 (-0.97)	-0.111 (-0.68)	-0.147 (-0.85)
Average corporate tax rate	-0.028 (-0.10)	-0.176 (-0.55)	-	-
Average personal tax rate	**-0.951**** **(-2.21)**	**-0.862**** **(-2.04)**	-	-
Top corporate tax rate	-	-	-0.003 (-0.09)	-0.035 (-0.84)
Top personal tax rate	-	-	-0.010 (-0.62)	**0.055**** **(2.02)**
Total government spending	-0.024 (-0.13)	-0.050 (-0.27)	-0.136 (-0.78)	-0.074 (-0.39)
Investment	**0.249***** **(3.57)**	**0.216***** **(3.51)**	**0.216***** **(3.03)**	**0.200***** **(3.09)**
Trade openness	0.039 (1.63)	**0.043*** **(1.86)**	**0.042*** **(1.64)**	**0.049*** **(1.93)**
Arnold progressivity measure	**-0.044***** **(-3.01)**	-	**-0.035**** **(-2.31)**	-
Reversed Arnold progressivity measure	-	**-1.266***** **(-2.78)**	-	**-1.601***** **(-2.84)**
Constant	3.240 (0.97)	5.067 (1.63)	-0.039 (-0.01)	-2.152 (-0.45)
Number of observations	115	115	115	115
Number of groups	40	40	40	40
Chi-squared	51.813	76.910	65.736	68.987

Note: t-statistics are reported in parentheses. Significance indicated as follows:
*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

7.3 Discussion of some limitations and ideas

The results for the tax progressivity variable above are likely to depend critically on the underlying assumptions of the income and tax revenue distributions. Davies (1980) suggests that one cannot generate any single measure that controls for progressivity because the actual or effective progressivity depends on the income distribution, or on the tax revenue distribution. Consider a 1 percentage point increase in the top personal income tax rate that affects only 1% of total taxable income. Clearly, this will have a smaller effect on total output than a 1 percentage point change in the top personal income tax rate which affects 10% of total tax revenues.

There is some question with regards to whether one should use tax revenue distributions or income distributions. Both methods have their benefits but it appears likely that tax revenue distributions should be the preferred option since it is likely to account more accurately for the effects on individuals' behaviour (regardless of the number of individuals). Whether it is one wealthy investor or ten less wealthy investors who change their behaviour may not matter for the growth rate if the overall change in capital (both physical and human) is the same. Therefore if there is some parity between physical and human capital the tax revenue distribution is preferred over the income distribution because it will capture both effects. If however, there is no parity between physical and human capital distribution then both measures may be required depending on whether physical or human capital is more important for growth.

Another concern with the measures used in this paper is that they can at best capture progressivity between the average personal income tax rate and the top statutory personal income tax rate. It is likely that tax progressivity affects behaviour of not only the wealthiest individuals but also those that are significantly less well off. The measures employed, however, give no insight into the effects of progressivity at different levels

of income (relative to GDP per capita), a topic that may be addressed by future research.

Given that the income or tax revenue distribution may have implications for the effects of taxation on growth a brief discussion of the likely effects is required. If the income or tax revenue distribution impacts growth and is correlated with tax progressivity, the estimated coefficient of the progressivity variable will be biased unless the income or tax revenue distribution is controlled for. The size of this bias will depend on the correlation between income or tax revenue distribution and progressivity as well as on the partial effect of tax revenue or income distribution on growth. Alesina and Rodrik (1994) show that increasing income inequality decreases the growth rate of economies. Data considerations prevent the inclusion of income inequality measures in this study and any suggestions as to the effects of this omission on the results presented here are speculative. One possible outcome is that the inclusion of such a variable may increase the magnitude of the effect of progressivity on growth. This is because tax progressivity is intended to reduce income inequality by taxing the rich at a higher rate and redistributing the proceeds unevenly – *i.e.* favouring the poor. Thus income inequality is said to have a negative effect on growth and would be expected to be negatively correlated with progressivity. This means that the inclusion of the inequality variable is likely to increase the negative effect attributed to progressivity as some of the positive effects from equality will most likely currently be attributed to progressivity – thereby reducing its negative effect.

8. Testing for the presence of critical thresholds

8.1 Introduction

Although there is some theoretical consensus that the expected effect of corporate taxation on growth is negative (Barro, 1991; King & Rebelo, 1990; Lucas, 1988; Rebelo, 1991; Romer, 1986), the empirical analysis of this thesis finds little support for such an effect[50]. Given this counterintuitive result, this section considers the possibility of a non-linear effect of corporate taxation on growth. There are only a number of other empirical macroeconomic studies that have used non-linear methods previously. These include Adam and Bevan (2005) who find evidence for a threshold in the debt to GDP ratio (1.5% of GDP) above which debt becomes growth retarding but below which there is no effect of debt on the growth rate of GDP per capita, and Papageorgiou (2002) who finds evidence for thresholds in initial GDP, trade shares and the literacy rate. There is no real precedent testing for non-linearities in taxation but Adam and Bevan (2005) state that, *"In principle, of course, there may be non-linearities in the budget, particularly in revenue and expenditure items"* (2005, p. 580). This chapter focuses on these non-linearities in the revenue items (the top corporate tax rate and personal income tax progressivity). If progressivity or corporate taxation below a specific level has no effect (or a significantly different effect than above the threshold) on the growth rate of GDP per capita then policy makers may wish to design the tax structure accordingly.

[50] This is also in contrast to the findings of Arnold (2008) and Lee and Gordon (2005) who find significant effects of the top corporate tax rate on economic growth in linear estimations. It does support the findings of Widmalm (2001) who finds no effect of the average corporate tax rate on growth.

8.2 Critical threshold methodology

The Hansen (2000) data splitting methodology is employed to test for the likelihood of a split in the sample at each value of the selected variable (the threshold variable). Hansen (2000) suggests that if this likelihood is over 95% a split (threshold) is likely and that the threshold should be at the point with the highest likelihood. There are a multitude of possible causes of such splits in the data many of which may be rooted in social or psychological beliefs such as fairness. It is easy to conjure up a scenario where people (on average) are willing to pay tax up to a specific rate but once the tax rate goes above this level people start to change their behaviour. This is especially likely in the case of progressivity where people may consider their tax rate relative to that of other people. They may then ask the question: "Why should I have to pay that much more tax than them?" with an "I work hard for my money" attitude.

The following regression specification is used for the threshold estimations:

$$Growth_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 C_{it} + \beta_3 J_{it}[T - \tilde{T}]_{it} + \varepsilon_{it}$$

$$J_{it} = \begin{cases} 1 \; if \; T > \tilde{T} \\ 0 \; if \; T \leq \tilde{T} \end{cases}$$

Countries are indexed by i, time (in 5-year periods) by t, and ε is an error term. J is an indicator variable and β_0, β_1, β_2 and β_3 are parameters to be determined by the data. Growth is the growth rate of GDP per capita, C is a control vector as specified in Table 25 and T is the threshold variable (either top corporate income tax rate or tax progressivity). This allows the effects of the threshold variable to be different above and below the threshold $\tilde{T}$.

The assumptions when using the Hansen methodology include no-multicollinearity, stationarity, linearity, homoskedasticity and regressor independence or exogeneity. It is likely that the relationship may be sufficiently well explained by a linear approximation, especially when a structural break is included in the relationship, that the assumption of linearity should not be a concern. The other assumptions may be breached in this case and remedies are discussed in the following paragraph.

One way to mitigate the endogeneity issues is to include the lags of the top and average income tax rates in the respective regressions rather than the variables themselves. This reduces the effects of endogeneity because this period's growth rate should not affect last period's tax rates, but last period's tax rates could conceivably affect this period's growth rate. Unfortunately the lag of the tax rates may not be perfectly exogenous because of possible effects of rational expectations. If there are certain expectations regarding the future growth rate based on the current tax rates it could have some effect on current tax rates. This effect should be small (especially in a 5 year averaged sample) and it can therefore be argued that endogeneity is unlikely to be of any real concern.

The remaining concerns of no-multicollinearity, stationarity and homoskedasticity are noted, but do not justify ignoring the opportunities presented by the use of the sample splitting technique. Especially since one can do extensive robustness checks of the estimated thresholds by analysing the data using techniques such as two-way fixed-effects, random-effects and dynamic panel regressions that can mitigate these possible problems.

Given that Gemmell et.al. (2009) and Duncan et.al. (2009) among others suggest that there is a downward trend in the top corporate income tax rate and tax progressivity along with the evidence from this dataset (Table

24) it is likely that the estimated thresholds (if any) will shift over time[51]. To control for this, not only the overall sample is used but also three subsamples (by decade) to see if there is evidence of a similar downward trend in the estimated thresholds. Note that for the sake of simplicity the data is split into 'decades' as follows; periods 1 and 2 is referred to as decade one, periods 3 and 4 as decade two and periods 5 and 6 as decade three.

Table 23: Definition of the time periods used for the sample splitting analysis

Period	Time	Decade
1	1973-1977	1
2	1978-1982	
3	1983-1987	2
4	1988-1992	
5	1993-1997	3
6	1997-2000	

For these three subsamples the lags of the variables could not be used because the sample then becomes too small. The estimations using lags in the overall sample yield very similar results to the estimations without lags (threshold estimated at 38.7% as opposed to 38.5%). This result may indicate that endogeneity is not of particular importance for these estimations.

[51] This indicates that the threshold depends on a country's level of taxation relative to other countries rather than on absolute values.

Table 24: Summary of arithmetic means of the top corporate income tax rate and income growth by decade

Variable	Decade One	Decade Two	Decade Three	Apparent trend
Reversed Lee Gordon Progressivity measure	2.799	2.202	1.595	Downward
Top corporate tax rate	42.357	40.903	33.572	Downward
Growth	1.696	1.221	2.040	None

Table 25: Control vectors

Variable	Control vector 1 (Used for top corporate tax rate)	Control vector 2 (Used for progressivity)	Control vector 3 (Used for progressivity)
Top statutory personal income tax rate	*	*	
Top corporate income tax rate		*	
Average personal income tax rate			*
Average corporate income tax rate			*
Total government spending	*	*	*
Trade openness	*	*	*
Investment	*	*	*
Population growth rate	*	*	*
Reversed Lee Gordon progressivity measure	*		

A * indicates that the variable is included in the specified control vector,

Table 27, 30 and 31 present summarised results for the sample splitting regressions testing for a split in either the top corporate income tax rate or the reversed Lee and Gordon progressivity measure. The control vectors

used in the regressions are chosen for their significance in earlier regressions and these vectors are indicated in Table 25.

8.3 Results of regressions testing for the non-linearities in the top corporate income tax rate

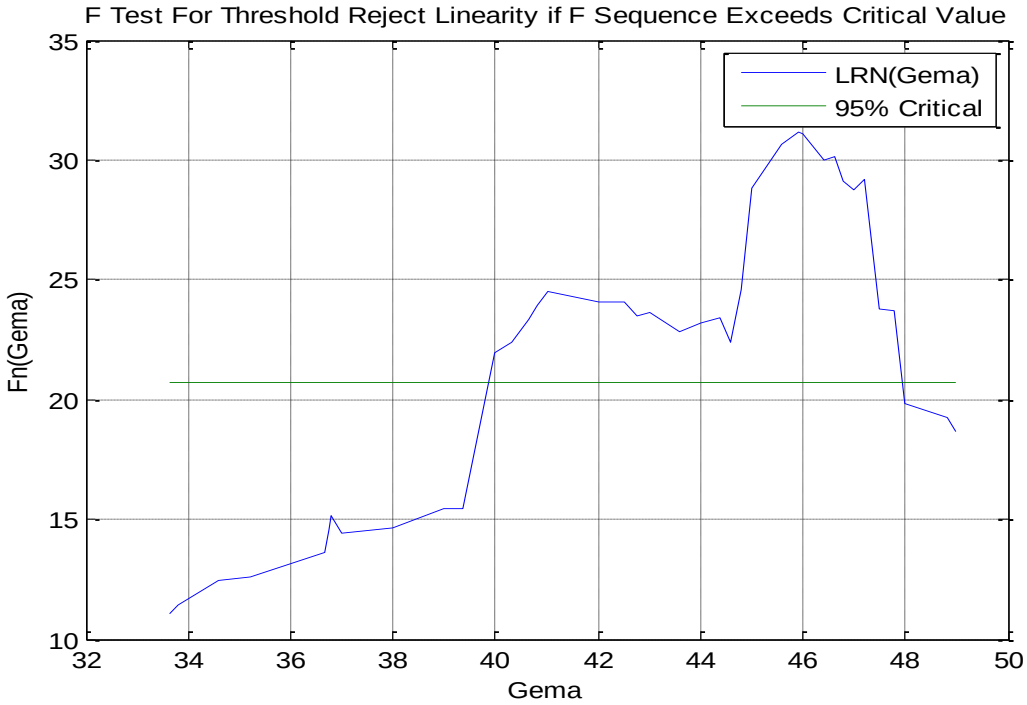

Figure 1: Top corporate income tax rate using decade one and control vector 1

Threshold, 45.9000***

Figure 1 depicts the results for the sample splitting estimation of the top corporate income tax rate for the first (decade one) subsample. The highest probability of a split in corporate taxation occurs at a value of 45.9% and this is the estimated threshold. There is, however, a range of values for which the test statistic exceeds the critical value in Figure 1, these range from 39.8% to 48%.

Figure 2: Top corporate income tax rate using decade two sample and control vector 1

Threshold, 42.5000***

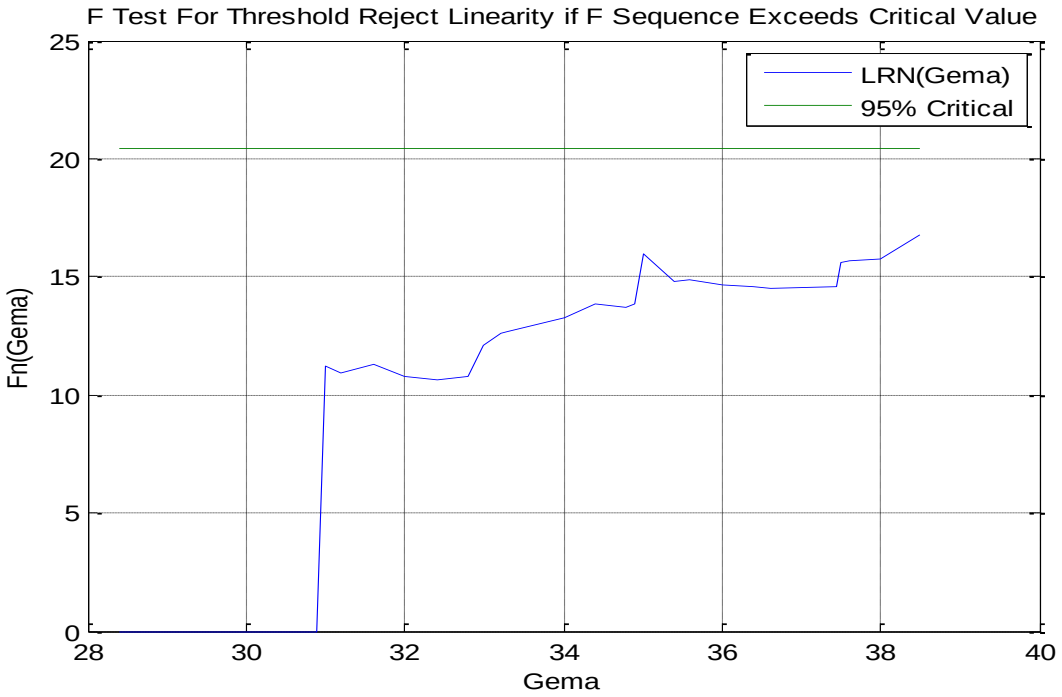

Figure 3: Top corporate income tax rate using decade three sample and control vector 1

Threshold, 38.5000

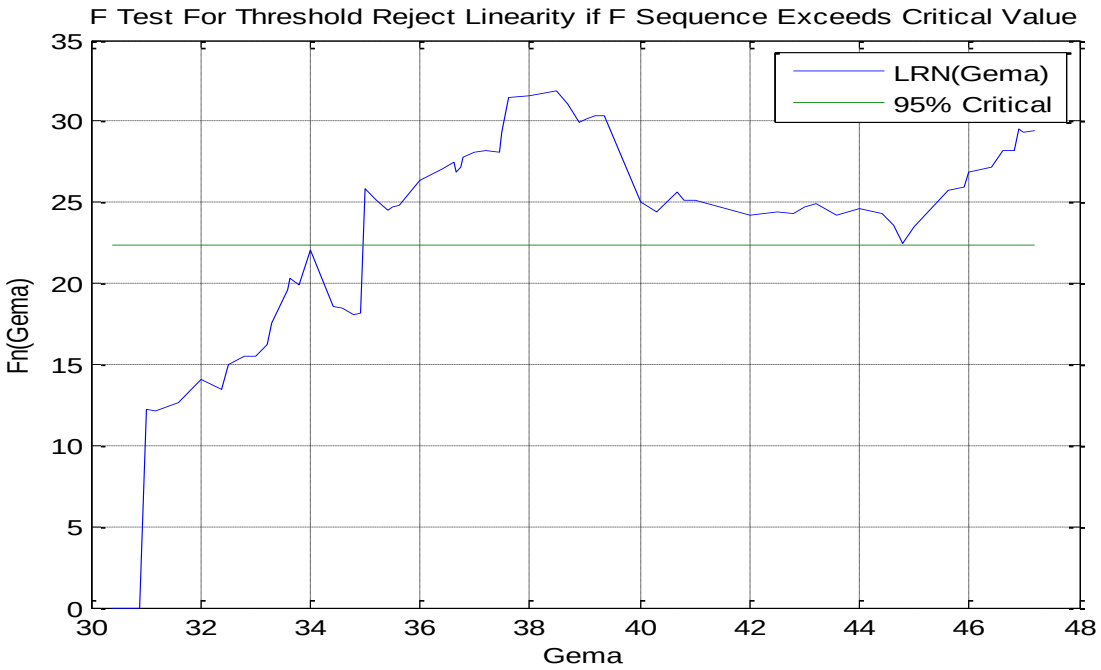

Figure 4: Top corporate income tax rate using overall sample and control vector 1

Threshold, 38.5000***

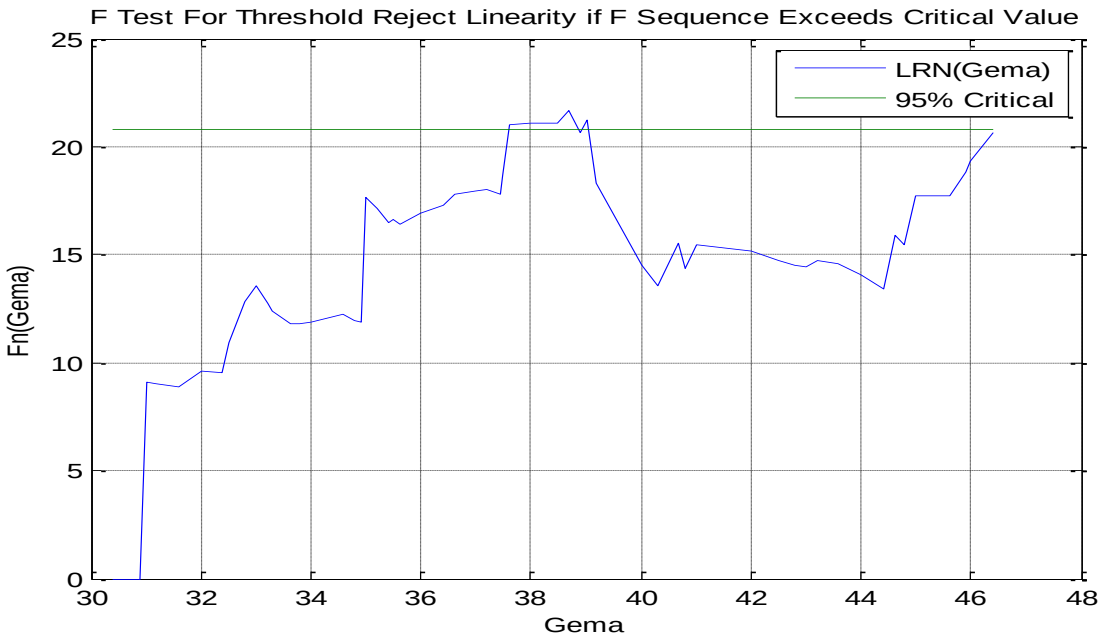

Figure 5: Top corporate income tax rate using lag of overall sample and control vector 1

Threshold, 38.7000

Table 26: Sample splitting results, testing for a split in the top corporate income tax rate using control vector 1.

Threshold Variable	Sub-Sample	n	Control Vector	Threshold Estimate	p-value	Figure
Top corporate tax rate	Decade one	64	1	45.9000	0.0000	1
Top corporate tax rate	Decade two	86	1	42.5000	0.0090	2
Top corporate tax rate	Decade three	95	1	38.5000	0.2810	3
Top corporate tax rate	Overall	245	1	38.5000	0.000	4
Top corporate tax rate	Lag Overall	183	1	38.7000	0.0330	5

Note: n is the number of observations.

From Figure 5: Top corporate income tax rate using lag of overall sample and control vector 1

Threshold, 38.7000

Table 26 one can see that there is an apparent downward trend in the thresholds following the downward trend in the average top corporate income tax rates (Table 24). The threshold is slightly higher than the arithmetic mean in each case. This result confirms a priory beliefs about the data. It can also be seen as supporting the idea that there is international tax competition (Gemmell et al., 2009) in that if a country's tax rate is too far above the average its economic growth rate is adversely affected. Although there is not enough data to accurately make any deductions, one possible reason for the threshold being somewhat higher than the average may be attributed to the costs of relocating to a country with a more favourable tax system. If relocating is costly (as it usually is) the cost of relocation must be less than increased earnings after tax for the relocation to be attractive.

Table 27 below summarizes the results for the overall sample, the lag of the overall sample and the three subsamples (by decade). The results of the OLS analysis (with the exception of the decade one and two subsamples) indicates a negative and significant effect of low levels of corporate taxation (below the respective thresholds), but no significant effect of higher levels of corporate taxation (above the respective thresholds). Decade one is the only instance where there is (as hypothesised) a larger negative effect of taxes above the threshold. Decade two finds no significant effect either above or below the threshold. The two-way fixed effects analysis indicates no significant effect either above or below the respective thresholds in any of the available results.

Table 27: Summary of the coefficients from regressions testing the estimated split in top corporate tax rate using control vector 1[52].

	OLS			Two-Way Fixed-Effects		
	Full sample	Below threshold	Above threshold	Full sample	Below threshold	Above threshold
Decade one	**neg****	**neg***	**neg****	neg	neg	neg
Decade two	neg	neg	neg	pos	pos	ins obs
Decade three	neg	**neg*****	neg	neg	neg	ins obs
Overall	neg	**neg***	neg	neg	neg	neg
Lag of Overall	**neg***	**neg****	neg	neg	neg	neg

Note: neg indicates a negative coefficient, pos indicates a positive coefficient and ins obs indicates that there were insufficient observations. Significance as before; * significant at 10%, ** significant at 5%, *** significant at 1%.

[52] Control vector 1 is: Top statutory personal income tax rate, Total government spending, Trade openness, Investment, Population growth rate and the Reversed Lee Gordon progressivity measure.

Table 28 and Table 29 present the results from the OLS and two-way fixed-effects regressions for the overall sample and the lagged overall sample. Although some control variables change or lose significance there are no unexpected signs in any of the control variables. There are also no particularly interesting changes in magnitude or direction of any of the variables' effects between the overall sample and the lagged sample. The largest changes are in the top corporate rate itself which changes from being insignificant in the complete overall sample to significant in the lag of the complete overall sample. However, the difference in size of the corporate tax rate between the overall and lagged overall samples was not very notable. In the regressions of the values below the threshold the magnitude and significance again changes slightly between the overall sample and its lag. In this case it changes from -0.132* (Table 28, column 4, row 3) to -0.076** (Table 29, column 4, row 3) which is a reasonably large change in magnitude. However for the purposes of this analysis the direction of the change is more important than the magnitude of the change because the quality of the available data is such that a qualitative rather than quantitative emphasis should be placed on the result.

Table 28: Comparison of OLS and Two-Way Fixed-Effects regressions of the overall dataset and the two subsets for a split in the top corporate tax rate.

	Overall		Less than		Greater than	
	1 (OLS)	2 (2FE)	3 (OLS)	4 (2FE)	5 (OLS)	6 (2FE)
Top corporate tax rate	-0.064 (-1.44)	-0.042 (-1.46)	**-0.132* (-1.87)**	-0.123 (-1.20)	-0.067 (-0.89)	-0.001 (-0.01)
Top personal income tax rate	0.014 (-0.64)	0.019 (-0.69)	-0.008 (-0.17)	0.045 (-0.53)	0.017 (-0.49)	0.003 (-0.05)
Total government spending	-0.034 (-0.86)	0.041 (-0.34)	-0.04 (-0.62)	-0.007 (-0.05)	-0.006 (-0.14)	0.163 (-0.76)
Trade openness	**0.011*** (-2.78)**	**0.036** (-1.99)**	**0.019*** (-4.13)**	0.004 (-0.17)	-0.003 (-0.48)	0.062 (-1.36)
Inflation	**-0.005*** (-3.90)**	**-0.025*** (-5.43)**	**-0.005*** (-4.13)**	**-0.026*** (-4.66)**	**-0.017** (-2.14)**	0.05 (-1.16)
Population growth rate	**-0.647* (-1.75)**	-0.669 (-0.65)	-0.191 (-0.66)	1.421 (-1.67)	-0.961 (-1.65)	-0.678 (-0.51)
Reversed Lee Gordon progressivity measure	-0.455 (-1.63)	**-1.096** (-2.27)**	0.092 (-0.09)	-1.171 (-0.74)	-0.502 (-1.41)	**-1.133* (-1.69)**
Constant	**5.273*** (-3.93)**	4.322 (-1.28)	**6.494*** (-2.78)**	6.407 (-1.23)	**6.315* (-1.97)**	-2.037 (-0.30)
Number of observations	245	245	126	126	119	119
Number of groups	-	65	-	56	-	45
F-statistic	11.585	4.66	8.731	2.85	3.712	0.97
Adjusted R-squared	0.209	0.308	0.291	0.559	0.176	0.241
Overall R-squared	-	0.133	-	0.159	-	0.04
Threshold	-	-	<38.5	<38.5	≥38.5	≥38.5

Note: t-statistics are reported in parentheses. Significance indicated as follows:

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 29: Table for the comparison of OLS and Two-Way Fixed-Effects regressions of the lagged overall dataset and the two subsets for a split in the top corporate tax rate.

	Overall		Less than		Greater than	
	1 (OLS)	2 (2FE)	3 (OLS)	4 (2FE)	5 (OLS)	6 (2FE)
Lag of top corporate tax rate	**-0.078* (-1.67)**	-0.022 (-0.69)	**-0.076** (-2.05)**	-0.067 (-1.04)	-0.055 (-1.04)	-0.034 (-0.31)
Lag of top personal income tax rate	**0.029* -1.8**	0.000 (0.00)	0.027 -1.22	0.005 -0.11	0.042 -1.44	-0.042 (-0.69)
Total government spending	0.023 -0.62	-0.137 (-1.38)	0.067 -1.51	-0.083 (-0.65)	-0.053 (-0.93)	-0.115 (-0.45)
Trade openness	**0.015*** -3.5**	**0.043** -2.39**	**0.020*** -3.71**	0.026 -0.74	0.005 -0.38	**0.120* -1.92**
Inflation	-0.001 (-0.53)	**-0.023*** (-2.91)**	0.001 -0.72	-0.015 (-0.14)	**-0.015* (-1.91)**	0.044 -0.9
Population growth rate	-0.221 (-0.49)	1.117 -0.8	-0.425* (-1.71)	1.903 -1.58	-0.051 (-0.06)	2.265 -0.92
Reversed Lee Gordon progressivity measure	**-0.597*** (-2.70)**	**-0.828** (-2.21)**	-0.500 (-0.78)	1.490 -0.89	-0.529* (-1.75)	**-1.194* (-1.82)**
Constant	**3.408** -2.48**	5.346 -1.46	2.429 -1.44	-1.420 (-0.22)	3.363 -1.29	1.329 -0.13
Number of observations	183	183	102	102	81	81
Number of groups	-	59	-	51	-	35
F-statistic	9.26	3.566	6.828	0.951	3.863	1.092
Adjusted R-squared	0.137	0.209	0.293	0.17	0.063	0.373
Overall R-squared	-	0.015	-	0.001	-	0.002
Threshold	-	-	<38.7	<38.7	≥38.7	≥38.7

Note: t-statistics are reported in parentheses. Significance indicated as follows:

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

8.4 Results for the non-linearities in personal income tax progressivity

This section presents the results for the sample splitting regressions testing for thresholds in personal income tax progressivity. Figures 6-10 present the graphs for the sample splitting estimation, showing the likelihood of a threshold at the value (x-axis). Table 31 summarizes the results of the sample splitting estimations, and the results from the subsequent regressions on the split sample are reported in tables 32 and 33.

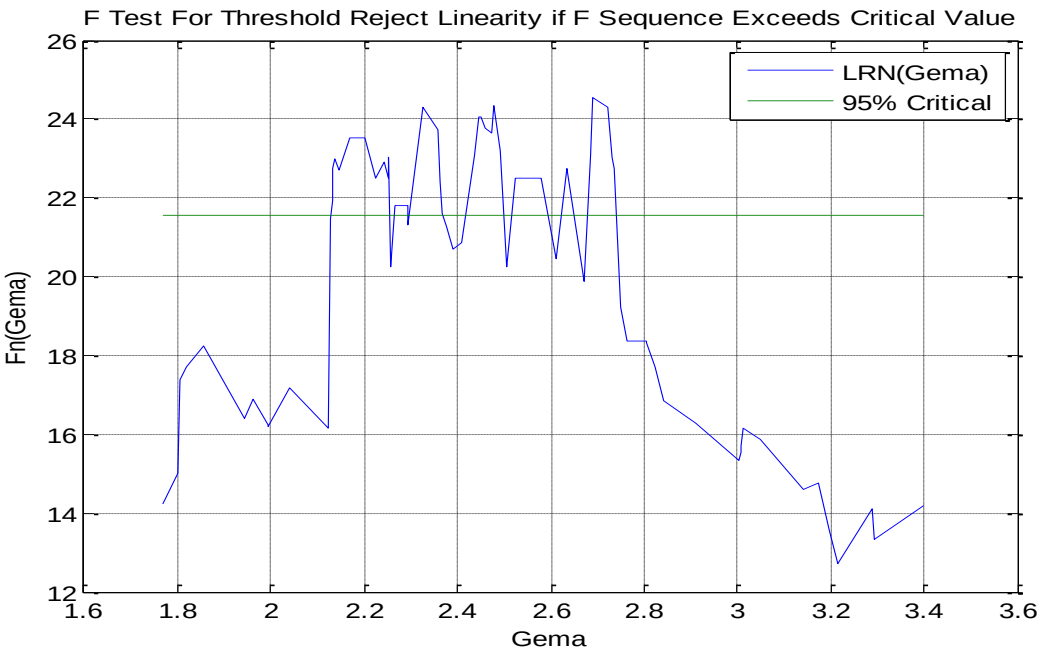

Figure 6: Reversed Lee Gordon Progressivity measure using decade one sample and control vector 3
Threshold, 2.6880***

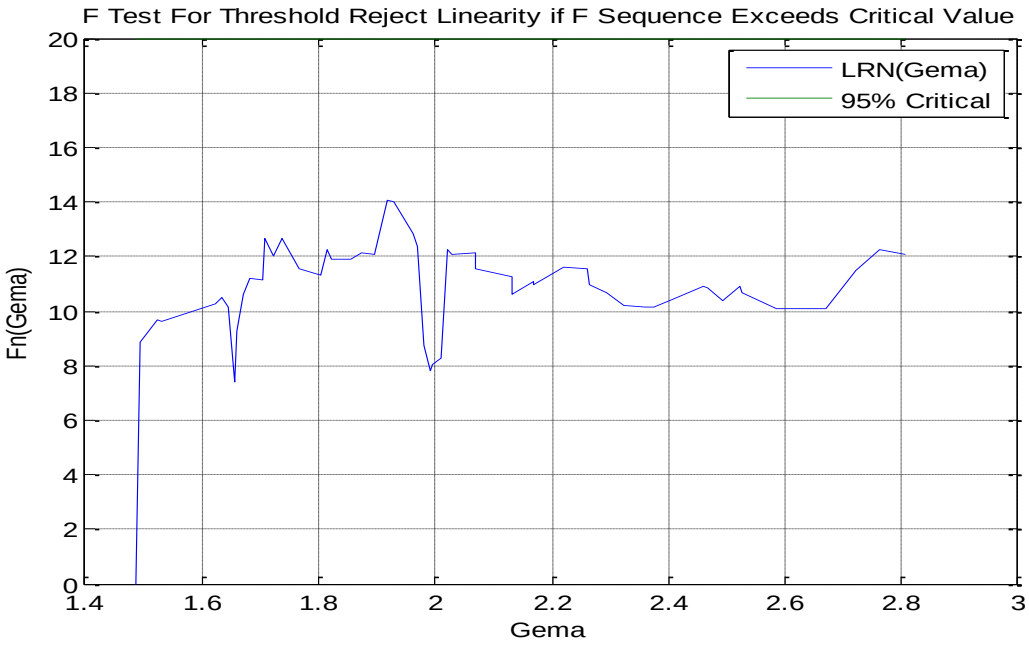

Figure 7: Reversed Lee Gordon Progressivity measure using decade two sample and control vector 3
Threshold, 1.9178

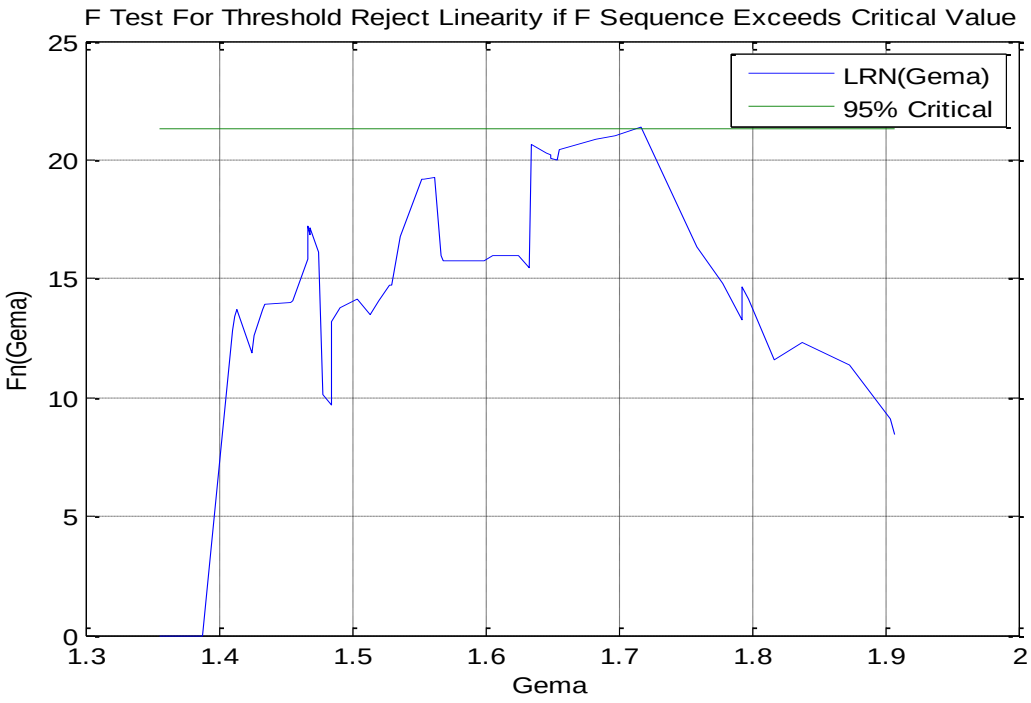

Figure 8: Reversed Lee Gordon Progressivity measure using decade three sample and control vector 3
Threshold, 1.7174**

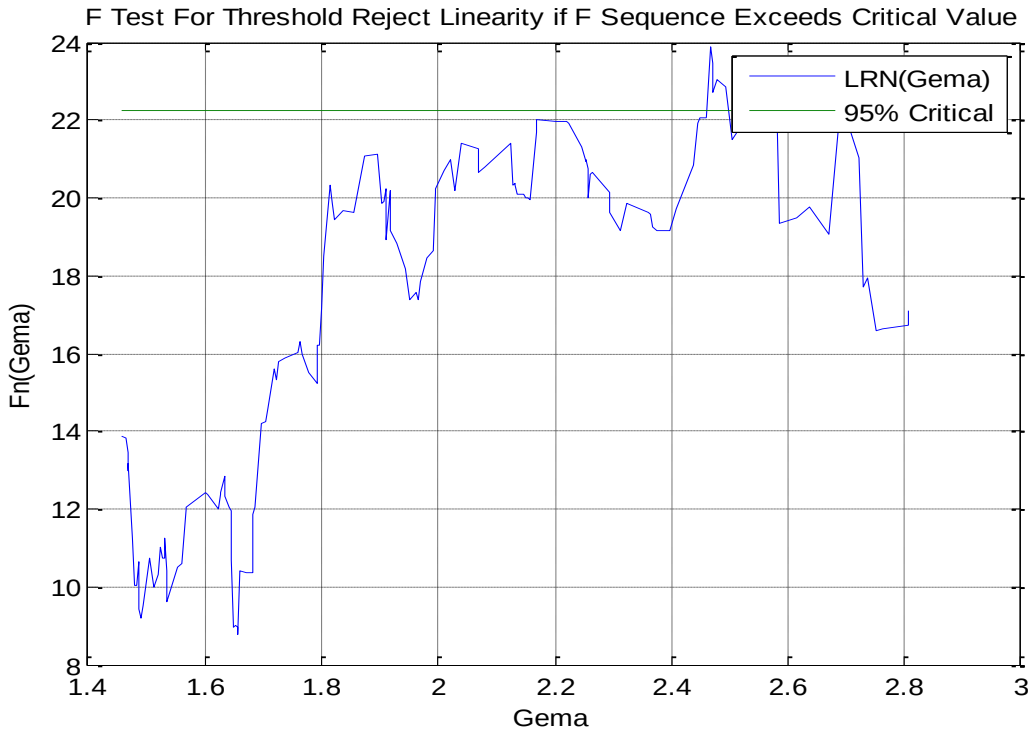

Figure 9: Reversed Lee Gordon Progressivity measure using overall sample and control vector 3
Threshold, 2.4672**

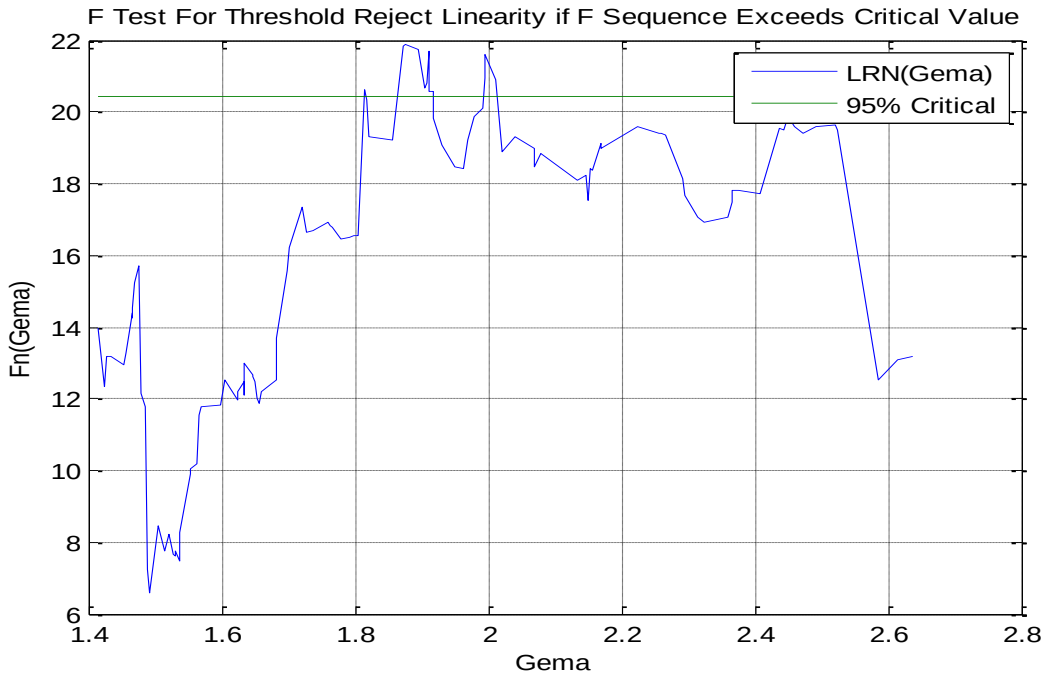

Figure 10: Reversed Lee Gordon Progressivity measure using lagged overall sample and control vector 3
Threshold, 1.8753**

Table 30: Sample splitting results summary, Reversed Lee Gordon Progressivity measure with control vector 2

Threshold Variable	Sub-Sample	n	Control vector	Threshold Estimate	p-value	Figure
Reversed Lee Gordon Progressivity Measure	Decade one	64	3	2.6880	0.0090	6
Reversed Lee Gordon Progressivity Measure	Decade two	86	3	1.9178	0.6410	7
Reversed Lee Gordon Progressivity Measure	Decade three	95	3	1.7174	0.0470	8
Reversed Lee Gordon Progressivity Measure	Overall	245	3	2.4672	0.0180	9
Reversed Lee Gordon Progressivity Measure	Lag Overall	183	3	1.8753	0.0270	10

Note: n is the number of observations.

Figure 10: Reversed Lee Gordon Progressivity measure using lagged overall sample and control vector 3
Threshold, 1.8753**

Table 30 presents summary results for the non-linear analysis conducted for a split in the reversed Lee Gordon Progressivity measure using control vector 2. There is again an apparent downward trend in the thresholds over time (by decade) which follows the downward trend in the average progressivity over time (Table 24) and is consistent with other empirical research (Duncan et.al, 2008). Although the threshold for decade two is not significant it follows the downward trend observed in the data. These results also support the idea of international tax competition, not only in corporate income taxation but also in personal income tax progression.

Table 31 summarizes the results from the analysis of the tax progressivity measure using the various subsamples of data and both OLS and two-way fixed-effects methodologies to test the estimated splits in the sample.

From Table 31 it is clear that the two-way fixed-effects regressions show the expected increased negative effect of progressivity above the threshold, Tables 32 and 33 show the magnitude of these effects. Note the pattern in the coefficients of the reversed Lee Gordon progressivity measure in the overall estimation, insignificant (and often positive) below the threshold and very significant and even more negative above the threshold in Tables 32 and 33.

There are significant similarities between this result and that of Adam and Bevan (2005) in that Adam and Bevan (2005) find that there is a negative correlation between debt and growth in a standard linear model and that levels of debt below a threshold value have no significant effect on the growth rate but that debt above the threshold has got significant negative effects on growth. Table 31 shows that in all three fixed effects estimations for the sample below the threshold value (for which coefficients could be estimated) there is a positive but insignificant effect of progressivity on growth. Although this result is not in any way robust or significant it is interesting as it relates to the income redistribution ability of a tax structure, the more progressive the structure the greater the opportunity for redistribution[53]. Limited progressivity is shown not to be harmful to economic growth and may be used to reduce income inequality which in turn may be beneficial.

[53] Note however, that a flat tax can still be used in a way that will result in greater income equality, this will depend on the way in which the taxes are distributed by the government.

Table 31: Summary of the coefficient from regressions testing the estimated split in the Reversed Lee Gordon Progressivity measure with control vector 3

	OLS			Two-Way Fixed-Effects		
	Full sample	<	≥	Full sample	<	≥
Decade one	Neg	**pos*** **	pos	pos	ins obs	Neg
Decade two	Neg	pos	pos	**neg** **	ins obs	**neg** **
Decade three	Neg	neg	pos	pos	pos	ins obs
Overall	**neg*** **	neg	**neg*** **	**neg** **	pos	**neg*** **
Lag of Overall	**neg*** **	neg	**neg*** **	**neg** **	pos	**neg*** **

Note: neg indicates a negative coefficient, pos indicates a positive coefficient and ins obs indicates that there were insufficient observations. Significance as before; * significant at 10%, ** significant at 5%, *** significant at 1%.

Table 32: Table for the comparison of OLS and Two-Way Fixed-Effects regressions of the overall dataset and the two subsets.

	Overall		Less than		Greater than	
	1 (OLS)	2 (2FE)	3 (OLS)	4 (2FE)	5 (OLS)	6 (2FE)
Average corporate tax rate	-0.005 (-0.07)	-0.012 (-0.11)	-0.015 (-0.17)	0.069 (0.89)	0.033 (0.25)	**-1.385* (-1.90)**
Average personal tax rate	**-0.089** (-2.45)**	**-0.573*** (-3.05)**	**-0.085** (-2.31)**	**-0.393** (-2.22)**	0.173 (0.62)	-0.604 (-1.43)
Total government spending	-0.040 (-1.06)	0.021 (0.18)	-0.026 (-0.59)	-0.105 (-1.08)	-0.292 (-1.51)	-0.077 (-0.50)
Trade openness	**0.012*** (2.62)**	**0.036** (2.26)**	**0.015*** (2.99)**	**0.028** (2.24)**	0.008 (0.47)	0.013 (0.53)
Inflation	**-0.005*** (-3.81)**	**-0.023*** (-5.95)**	**-0.005*** (-3.53)**	**-0.024*** (-5.38)**	**-0.047*** (-2.74)**	-0.042 (-1.61)
Population growth rate	**-0.927*** (-2.64)**	-0.767 (-0.82)	**-1.107*** (-4.06)**	**-1.842*** (-5.01)**	1.188 (0.58)	**4.161*** (3.65)**
Reversed Lee Gordon Measure	**-0.474*** (-2.69)**	**-0.820** (-2.47)**	0.204 (0.43)	0.358 (0.57)	-0.323 (-1.16)	**-2.105*** (-5.30)**
Constant	**4.561*** (3.78)**	**6.790*** (2.74)**	**3.203* (1.96)**	**7.685** (2.55)**	**4.708* (1.76)**	**8.873* (1.99)**
Number of observations	245	245	189	189	56	56
Number of groups	-	65	-	63	-	27
F-statistic	10.007	5.438	7.754	5.581	2.949	96.654
Adjusted R-squared	0.215	0.353	0.335	0.551	0.128	0.833
Overall R-squared	-	0.096	-	0.240	-	0.002
Threshold	-	-	<2.4672	<2.4672	≥2.4672	≥2.4672

Note: t-statistics are reported in parentheses. Significance indicated as follows:

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 33: Table for the comparison of OLS and Two-Way Fixed-Effects regressions of the lagged overall dataset and the two subsets.

	Overall		Less than		Greater than	
	1 (OLS)	2 (2FE)	3 (OLS)	4 (2FE)	6 (OLS)	6 (2FE)
Lag of average corporate tax rate	0.068 (1.10)	0.165 (0.82)	0.071 (0.76)	0.606** (2.30)	0.045 (0.54)	0.161 (0.20)
Lag of average personal tax rate	-0.042 (-0.89)	-0.071 (-0.53)	-0.030 (-0.79)	-0.008 (-0.02)	0.041 (0.28)	-0.173 (-0.60)
Total government spending	0.031 (0.92)	-0.104 (-0.98)	0.024 (0.55)	**-0.287*** (-3.19)**	-0.042 (-0.50)	-0.159 (-0.52)
Trade openness	**0.016*** (3.18)**	**0.042** (2.36)**	**0.024*** (4.15)**	0.008 (0.39)	0.005 (0.58)	**0.083* (1.80)**
Inflation	0.000 (0.06)	0.008 (0.31)	0.001 (1.58)	0.002 (0.06)	**-0.044** (-2.61)**	0.006 (0.15)
Population growth rate	-0.568 (-1.15)	1.108 (0.77)	**-1.073*** (-5.15)**	**-2.074*** (-3.34)**	0.638 (0.46)	**4.023* (2.03)**
Reversed Lee Gordon Measure	**-0.466** (-2.40)**	**-0.767** (-2.01)**	0.533 (0.58)	-0.730 (-0.50)	**-0.634** (-2.43)**	**-1.810*** (-3.07)**
Constant	1.872 (1.41)	2.645 (0.74)	0.415 (0.21)	**8.035** (2.47)**	2.961 (1.59)	3.117 (0.48)
Number of observations	181	181	98	98	83	83
Number of groups	-	59	-	48	-	37
F-statistic	8.976	1.603	10.567	4.274	3.150	16.905
Adjusted R-squared	0.125	0.186	0.414	0.501	0.069	0.548
Overall R-squared	-	0.011	-	0.106	-	0.019
Threshold	-	-	<1.8753	<1.8753	≥1.8753	≥1.8753
Lag of average corporate tax rate	0.068 (1.10)	0.165 (0.82)	0.071 (0.76)	0.606** (2.30)	0.045 (0.54)	0.161 (0.20)

Note: t-statistics are reported in parentheses. Significance indicated as follows:

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

8.5 Discussion of results for the sample splitting regressions

The results from the sample splitting analysis of the top statutory corporate income tax rate indicate that there are thresholds, not only in the pooled dataset but also in two of the three subsets. The threshold in the overall or pooled sample is at 38.5% and for the lagged values of the overall sample it is at 38.7%. This suggests that endogeneity may not be a large concern in this case. The apparent downward trend in the thresholds over time could be interpreted as being indicative of international tax competition as suggested by Gemmell *et.al* (2009). The logic for this deduction is as follows: If there is competition between countries for the limited human and physical capital available at a point in time, it makes sense that any country with a tax rate that is too far above the mean or that of its main competitors will lose capital. This country will be forced to lower its tax rate to stem the flow and perhaps regain 'market share'. The competitors may subsequently respond by lowering their rates even further and the cycle continues. This means that the tax rate threshold of a country may depend on a dynamic international level of taxation (taxation relative to other countries' rates) rather than simply a specific level of taxation that is constant over time. When the OLS and two-way fixed-effect regressions are performed after the dataset is split at the proposed level the results are somewhat surprising. There is evidence of a negative and significant effect in the overall sample below the tax threshold of 38.5% but no effect above the threshold. This effect is also observed around the 38.7% threshold estimated for the dataset using the lags of the policy variables. This result is counterintuitive as one would expect high rates to have a more negative effect on growth in order to conform to the hypothesised inverse U shape curve (Barro, 1990).

Splits were also found in both sets of regressions for the reversed Lee Gordon progressivity measure[54]. These tax rate thresholds follow the downward trend in the average level of progressivity over time. This lends further support for the theory of international tax competition not only in corporate taxation but also in personal income tax progressivity. The OLS and two-way fixed-effect regressions performed on the sample, once split at the estimated tax threshold level, indicate that progressivity has no effect below the estimated threshold but that there is a negative and significant effect above the threshold. This could be interpreted as indicating a level of tax progression that could be employed to increase redistribution potential without harming economic-growth similar to the threshold in the debt to GDP ratio estimated by Adam and Bevan (2005).

[54] Although only the results for the regressions using control vector 3 are discussed in detail since there is less co linearity between the progressivity measure and the average income tax rates than between the progressivity measure and the top income tax rates.

9. Conclusion

Using a panel of 65 countries for the period 1973-2000 this analysis finds support for the hypothesis that distortionary taxation (taxes on income) affects growth negatively and that personal income tax progressivity is also a significant (negative) determinant of long-term economic growth. The effects of progressivity and personal income taxes are evident in linear models, such as OLS, two-way fixed and random-effects and dynamic panel regressions but the effects (if any) of the top corporate income tax rate are less clear and limited to OLS regressions. Evidence is however, presented for a non-linear (negative) effect of the top statutory corporate income tax rate as well as for personal income tax progressivity on growth.

It is important to note that the threshold estimates (by decade) for both the effects of progressivity and corporate income taxation on growth follow the downward trend in both personal income tax progression and corporate income taxation noted by recent work (and observed in the data), with the threshold for each decade lower than the one before. This result may be indicative of some competition between countries in their rates of taxation for physical and human capital.

The estimated threshold (for the overall sample) for tax progressivity (using the reversed Lee Gordon progressivity measure) ranges from 1.7[55] to 2.5[56], and for the top corporate income tax rate it is 38.5% in the pooled dataset. Further analysis of these findings indicate that if progressivity is

[55] This is the value obtained from top and average personal income tax rates of approximately 48% and 12% respectively – in the dataset used, the United Kingdom's tax structure for the period 1988-1992 featured top and average personal income tax rates of 48% and 12.5% respectively.

[56] This value is obtained from top and average personal income tax rates of approximately 63% and 6% respectively – in the dataset used, Jamaica (1973-1977) had a structure close to this with a top personal income tax rate of 62.25% and an average personal income tax rate of 5.41%.

kept below this threshold it has no significant effect on growth but that once it rises above this level there is a significant negative correlation between progressivity and growth. The findings for progressivity are as expected. For the top corporate income tax rate however, the effect below the threshold is negative, and above it, there is no significant effect. It seems that the evidence of the top statutory corporate income tax rate's effect on growth is counterintuitive, since it predicts that levels of corporate taxation below the threshold are distortionary while taxation above the threshold is not. That is to say that low levels of corporate taxation is bad for growth and high levels of corporate taxation have no effect on growth – this is the opposite to what most empirical papers on the topic find (Arnold, 2008; Lee and Gordon, 2005) and is also not in accordance with theory.

Given the relatively short time frame covered by this study, no inference could be made with respect to whether the endogenous growth or neoclassical models are supported by the data. However, it is clear that one cannot reject the endogenous growth models even with 28 years of data.

Future research may consider the impact of including income inequality in the regressions that investigate the effects of taxation on growth as well as exploring the counterintuitive result for the effect of corporate taxation on growth.

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