A theoretical and empirical analysis of the impact of dual income taxation on economic growth

Sebastian Ellingsen

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Department of Economics

University of Oslo

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Preface

This thesis is written as a completion of the Master of Philosophy in Economics at the University of Oslo. Approaching the end of my time at the University of Oslo, I would like to use this opportunity to thank all the people of who I am indebted to for their encouragement and support throughout; fellow students, family and Caroline (who has had to endure her share of economics-talk over the years). In particular I wish to thank my supervisor Thor Olav Thoresen, for the time and effort he has spent providing excellent supervision and inspiration through the work with the thesis. His guidance in navigating the literature on which this thesis is based has been invaluable. I would also like to thank Victoria Sparrman for providing me with part of the data set used in this thesis and Alessia Russo for helping me out with insights on economic modeling. In addition I would also like to thank Oslo Fiscal Studies for granting me their scholarship, for which I am very grateful. Any remaining mistakes or inaccuracies are mine, and mine alone.

Summary

Tax systems distort economic behavior in ways that matter for economic growth. It has been argued that a dual income tax reform can alleviate some of these distortions. The dual income tax potentially has influence on output growth through increased allocative efficiency of capital and increased saving and investment. The long run impact of a dual income tax reform is studied in a neoclassical growth model with endogenous labor supply. In this framework, changes in tax rates in line with dual income taxation causes growth in excess of the equilibrium growth rate. The effect of dual income tax systems on economic growth is analyzed empirically by estimating a reduced form macroeconometric relation using aggregate data for a number of OECD-countries. The results are consistent with previous studies in the field. The findings suggest that the dual income tax has had a small positive effect on economic growth. When correcting for data on corporate income taxes this effect is reduced, suggesting a substantial amount of the effect of dual income income taxation on growth is driven by reductions in corporate income taxes.

Contents

1 Introduction

Raising revenue from taxes distorts economic behavior by changing the relative prices of various forms of market activities. In general, this has an impact on how resources are allocated by the market. On the other hand, generating enough revenue is necessary for a government to finance many of the preconditions of a functioning market economy. Thus, raising a given amount of revenue in the least distortionary manner is the main tension in designing tax systems. The extent to which this endeavour is successful, has potentially large implications for welfare, see for example the recent Mirlees review, (Mirlees et al. (2011)). The nordic system of dual income taxation (henceforth DIT) is a particular approach of dealing with this issue. It is a tax system that divides the total income in earned income and capital income, taxing these sources of income at different schedules. It implements a low and flat tax schedule on capital income in combination with progressive taxation of labor income. The DIT can be interpreted as a compromise between incorporating theoretical insights from optimal tax design, calling for zero taxation of capital, as analyzed by Judd(1988) and Chamley(1986), and practical concerns such as raising enough revenue and distributional concerns, as highlighted for instance by the OECD (2006) and Piketty and Saez (2012). A key argument for the DIT is it's alleged positive effect on economic growth through increased allocative efficiency capital. However, even though there have been evaluations of the effects of the DIT; examples in the nordic countries are Thoresen and Alstadsæter (2008), Lambert and Thoresen (2009) and Thoresen et al. (2012), there have been no studies to my knowledge investigating the influence of DIT on economic growth empirically. Addressing this issue constitutes the aim of this master thesis.

A DIT system comprises of several features according to Sørensen (2005)a. It has a flat uniform tax rate on all forms of capital income, equal to the corporate income tax. There is full relief of double taxation of corporate income.[1] The tax base on capital and corporate income is broad. It also has a basic tax rate on personal income, equal to the corporate tax rate, combined with a progressive surtax. In sum, the essence of the DIT is to tax all types of capital at the same low and flat rate, while keeping the labor income tax schedule progressive. There is a growing theoretical literature on the properties of such a tax system, see Boadway (2005), Sørensen and Nielsen (1997) and Sørensen (1998), highlighting both economic efficiency and equity considerations. Less has been written about the relation to economic growth. However, Keuschnigg and Dietz (2007) and Radulescu and Stimmelmayr (2005) suggest DIT reforms for Switzerland and Germany respectively, and argue that an implementation of a pure form DIT system would have a positive impact on economic growth in these countries. In section 2 I discuss the effects that are likely to be the most important factors in explaining the impact of the DIT theoretically in neoclassical growth model. The aim is to make qualitative predictions. Depending on initial conditions, the model predicts the DIT to increase capital intensity. The impact on labor supply is vulnerable to changes in the exogenous parameter values.

Several countries, in particular the nordic countries, modernized their income tax systems in line with the DIT in the early 1990's. They went from comprehensive income tax systems that were regarded as highly distortionary, to implementing features with key characteristics of the DIT. These tax reforms had many common elements. They lowered the tax rates on personal capital income and corporate income. In addition, these reforms all went far in attempting to remove double taxation of equity and

[1] The manner in which this is done may vary. In Norway after 1992 this was done by the so called imputation system. There was full deduction of the tax allready paid at the corporate level. Since the rates on personal capital income and corporate income were the same this amounted to the same rate on dividends as on other personal capital income.

taxing different types of capital at the same rates. In recent years, many other countries have made moves towards DIT systems, (Eggert and Genser, (2005)). Several countries have introduced low flat rates on some types of capital income, resulting in tax systems that may be termed semi-dual income tax systems, (OECD, (2006)). The fact that different countries have implemented different aspects of the DIT highlights that the distinction between comprehensive and DIT systems are not easily determined.

There is a large empirical literature on the relationship between tax design and economic growth, with contributions applying both aggregated and disaggregated data, see Myles (2009)a. The literature using aggregate data is part of a larger literature conducting cross-country comparisons to estimate the importance of various determinants of economic growth, see for example Barro (1996) and Mankiw, Romer and Weil (1992). Recent contributions relating economic growth to tax design are Lee and Gordon (2005), Arnold et al. (2011), OECD(2010), Acosta-Ormaechea et al. (2012) and Arnold (2008). These studies use cross-country panel regressions to analyze the relationship between various taxes and economic growth. They estimate the impact of different tax variables controlling for various determinants of growth that have been established by previous studies. In this master thesis I will to a large extent follow this approach, using macroeconomic data in a panel data setting. However, my approach differs in taking explicit account of the DIT systems.

This master thesis is organized as follows. In section 2 I use a growth model to illustrate and discuss several of the properties DIT systems potentially have on economic growth. The model is an infinite horizon neoclassical growth model with endogenous labor supply. In section 2 I derive the model and look at the effects different taxes have on the long run equilibrium. The model shows that taxing capital income and firm profits reduce the long run steady state capital stock, thus reducing growth. In this framework, taxing capital and corporate income in line with the DIT will cause positive growth rates. Changes in labor supply will also occur, however, this effect depends on the numerical values of the parameters chosen in the model and the initial state of the economy, thus the prediction on labor supply is less clear. In section 3 I test the predictions of the model empirically using a panel of aggregate data from a subsample of OECD countries. Controlling for variables often cited to explain growth performance, I use the countries that according to the OECD (2006) implemented dual income taxes in the early 1990's to investigate wether correlations in the data are in line with the predictions of the theoretical model of section two. Using well established methods in the literature on empirical growth I find some suggestive evidence for the predictions of the theoretical model. The data shows a positive and significant impact of the DIT systems that were implemented in the Nordic countries in the early 1990's on growth in GDP per capita. Section 4 concludes.

2 Theoretical analysis

The theoretical literature on economic growth is large. When studying different determinants of economic growth, it is well established that the causation runs in several directions. My aim is to study the causation from taxation to economic growth. Myles (2009)b illustrates this particular interaction in the following manner,

$$g = f(a_1(\mathbf{t}), ..., a_n(\mathbf{t})). \tag{1}$$

The growth rate g of the economy is a function of all the determinants of growth, the vector $\mathbf{a}$. Some of these determinants cause only transitory changes in growth rates, typically changes in the accumulation of different productive assets. Others however, cause changes in long-run productivity growth. All these determinants in **a** are in turn a function of the tax system, the vector of all feasible tax instruments **t**. The functional form of f potentially varies among different economies and over time.[2] Thus, in order to assess the effects of a particular tax system on economic growth, the most important determinants must be identified along with the most important effects the various tax changes have on these.

Theories of economic growth offer a range of explanations on the determinants of economic growth and their relative importance. While there is more controversy in the determinants of an economy's equilibrium growth path, there is a wide acceptance in economics that accumulation of productive assets has a positive impact, at least on transitory growth rates. This will remain the main focus of my analysis, however, other theories of growth are also important when finding control variables for the empirical specification. I therefore survey the main insights of economic growth theory below.

2.1 Theories of economic growth

The main insight in early growth theory is that the ultimate determinant of economic growth is increased productivity. Accumulation of resources must reach a steady state intensity due to depreciation and the law of diminishing returns.[3] Changes in investment and saving behavior may thus influ-

[2]This issue makes pooling of the data an overly restricitve assumption. Including a fixed effects formulation may to some extent alleviate this, as is done in the empirical section.

[3]This is the main contribution of the Solow model, (Solow (1956)). A constant saving rate will increase output per capita as long as the contribution of the saved capital exceeds the constant share of depreciation. As the output grows, diminishing returns kicks in and

ence transitory growth rates of the economy, Solow (1956). This approach was later combined with theories on how optimizing consumers adjust their investment behavior intertemporally, as modeled in Ramsey (1928). Neoclassical growth theory is the study of how an economy grows when it is organized in competitive markets. The level of output is then determined by individual's incentives to accumulate productive assets. With this frame of reference, taxation can be interpreted as distorting relative prices and therefore changing the market equilibrium. Thus, taxation might cause changes in an economy's long-run equilibrium output caused by changes in capital intensity and labor supply. Immediate examples are saving and investment decisions and therefore accumulation of physical and human capital. Taxation not only affects the stock of productive assets in steady state, but also the composition of these. It is therefore a possibility that taxation leads to lower productivity due to an inefficient composition of inputs in production. For example, perfectly competitive markets would align the after tax rate of return to physical and human capital. If one of the factors is taxed disproportionally, the market aligns the after tax returns, possibly giving another human capital and physical capital ratio in equilibrium. This will decrease the level of production possible at a given endowment of resources.

These models all assume an exogenous growth in productivity. As in the simple Solow model, the law of diminishing returns eventually kicks in, (Solow (1956)). There are a number of models that have endogenised productivity growth. Some models explain long run growth as a consequence of positive externalities in the growth process, see for example Romer (1986). Other theories attempt to explain the determinants of the growth rate in productivity as a consequence of individuals and firms incentives. Firms,

a steady state intensity of capital per capita is reached in which the depreciation in each period equals the contribution of capital on increased output. This intuition is also key in the model applied in the next section.

entrepreneurs and individuals have incentives to invest in sectors of the economy that have important productivity spill-overs into the overall economy. The general idea is that private agents do this because it lets them extract rents from these activities and innovations, (Acemoglu (2009)). In addition, competition among firms is viewed as a driver of the incentives to innovate. These ideas stem from the Schumpeterian growth literature, surveyed in Aghion and Howitt (1998). There is an influential literature simulating tax reforms using endogenous growth models, see for example Barro (1990). This literature concludes that tax reforms can have permanent effects on the growth rate of an economy. However, these models are highly sensitive to changes in parameter values, a problem when considering the uncertainty in the estimation of these, (Engen and Skinner (1996)).

A different approach is to address the influence of growth on policy, i.e turn the relationship around. The political economy of economic growth addresses these issues, ways in which a society aggregates individual preferences into policy. Some institutional arreangements thus lead to policies that favor economic growth. Alesina and Tabellini (1990) and Persson and Svensson (1989) are examples of this approach. In this view, the determinants of economic growth are the characteristics of societies that choose policies that favor growth.[4] Making policies and institutions endogenous poses problems for the empirical study of taxation and growth, there are few remaining exogenous factors that can be applied for empirical analysis, (Easterly and Rebelo (1993)).

All these issues have implications for the interpretation and formulation of the empirical model. However, including these issues in a theoretical

[4]I think this is an important aspect of the DIT. There might be gains from commitment when the principle of equal taxation of various sources of capital is adhered to.

model quickly makes it vulnerable to changes in the parameters. The theoretical approach chosen here is the neoclassical growth model. This model highlights issues I believe, based on the Nordic experiences, are most prevalent when it comes to a shift towards the DIT and those that are able to explain effects that can be carried over to an empirical investigation.

2.2 The model

In this section I use a growth model to illustrate the long-run effect on equilibrium capital intensity and labor supply of introducing various taxes. The aim is to set up a general framework to study the impact of taxes on economic growth and use this to analyze how changes in tax rates in line with dual income tax reform changes the market equilibrium and long-run steady state of the model. The model is a neoclassical growth model with endogenous labor supply. It is a model of a homogenous population with inhabitants, organized in households, that consume and supply labor in perfectly competitive markets. Having a homogenous population is a simplifying assumption that is chosen because the aim is to conduct a positive analysis of the qualitative implications of the DIT on economic growth. The consumers' incentive to smooth consumption over time, gives them an incentive to save by investing part of their wage in the production process of the economy, thereby increasing output. In this model the focus is on tax distortions. Therefore, what the government does with it's revenue is held exogenous. This type of model is widely used in the literature on economic growth. The standard neoclassical growth model of the type used here is presented in Barro and Sala-i-Martin (2004), Acemoglu (2009) and Romer (2012) in great detail. However, I expand the model with government consumption and different types of taxes in order to use it to study the impact of DIT on economic growth.

2.2.1 Households

The economy is inhabited by households that receive utility over consumption today and over an infinite horizon. There is an exogenous rate x, of labor augmenting productivity growth. Productivity at time t is thus $A(t) = A_0 e^{xt}$. The household also discounts the future at a rate $0 < \rho < 1$ and therefore cares less about future consumption. In this theory of consumer behavior, a concave utility function creates an intertemporal trade-off that induces households to save, forego consumption today to consume it in the future. At the same time, the household chooses its labor supply at each period t. This is modeled as a trade-off between consumption and leisure. Only by foregoing leisure is it possible for the consumer to produce in a labor market at a given wage.

The behavioral assumption on the household is that it chooses consumption and labor supply at each time t to maximize its utility. U is regarded as a continuous and discounted sum of utility that is increased by consumption c, and reduced by work effort, l. The utility of the consumer at $t = 0$ is given below.[5]

$$U = \int_0^\infty u(c, l) e^{-\rho t} dt \tag{2}$$

A widely used functional form in macroeconomics and growth literature is the log utility function which is separable in labor. In line with Barro and Sala-i-Martin (2004) I assume the following functional form of the instantaneous utility function,[6]

[5] It follows from this framework that the household's problem is the same for all times t.

[6] This function is the asymptotic case of a more general class of utility function, the constant elasticity of substitution utility function. A maximum of the consumers problem is achieved if the following assumptions on the instantaneous utility functions are introduced, $u'(c) > 0, u''(c) < 0, u'(l) < 0, u''(l) > 0$.

$$u = ln(c) - \varphi l^{1+\sigma}. \tag{3}$$

The household's choices are constrained by the prices in the market. The household may buy assets b to smooth consumption between periods. It can do this at the interest rate, r. Also the return to labor is given by the wage rate, w, whereas p is the price on a unit of consumption. Various taxes change the prices in this economy and thus further constrain the household's choices in the market. The budget constraint below must hold at all times.

$$\dot{b} = rb + wl - pc \tag{4}$$

The household's problem is to maximize the utility subject to their budget constraint over the infinite horizon. In each period it must choose the amount of labor supplied and how to allocate the income between different consumption goods and periods.[7] The problem can be stated in the following manner,

$$\max_{c,l} \int_0^\infty u(c,l)e^{-\rho t}dt \quad s.t \quad \dot{b} = rb + wl - pc. \tag{5}$$

This is a problem of optimal control over an infinite horizon. The problem is solved by the maximum principle for infinite horizons[8]. This gives the Hamilton function below.

$$\hat{H}(t,c,l,r,w) = u(c,l)e^{-\rho t} + \mu(t)(rb + wl - pc) \tag{6}$$

[7] The intertemporal nature of the households problem opens up for violating the budget constraint over the infinite horizon. By using the market for assets it is a possibility that the present value of the households consumption to exceed the present value of its income in equilibrium by borrowing and rolling over the debt forever. The no-Ponzi condition rules out this kind of behavior by exogenously stating that the market has mechanisms of preventing this type of behavior. The following condition thus also constrains the agents behavior. The condition is $\lim_{t\to\infty} b(t)e^{-\int_0^t r(s)ds} \geq 0$.

[8] An exposition of this theory can be found in Sydsæter et al. (2008).

The problem has the following first order conditions.

$$(i)\ \ u'(c)e^{-\rho t} - \mu(t)p(t) = 0$$

$$(ii)\ \ u'(l)e^{-\rho t} + \mu(t)w(t) = 0$$

$$(iii)\ \ \mu'(t) = -\mu(t)r$$

Using (i) and (ii) the condition for optimal labor supply of the household directly.

$$-\frac{u'(l)}{u'(c)} = \frac{w}{p}. \tag{7}$$

In each period the household will supply labor in the market up to an amount such that the marginal disutility of working is exactly offset by the marginal return measured in utility of supplying another hour in the labor market. In this situation there are no further gains from trade between the household and the firm in the labor market.

Taking the derivative with respect to time of (i) and combining it with (iii) gives the optimal path of consumption. The first order conditions of the problem will result in the following differential equation that describes the optimal path.

$$r = \rho - c\frac{u''(c)}{u'(c)}\frac{\dot{c}}{c} - \frac{\partial u^2}{\partial c \partial l}\frac{l}{u'(c)}\frac{\dot{l}}{l} + \frac{\dot{p}}{1+p}. \tag{8}$$

The second expression on the right hand side equals the elasticity of marginal utility with respect to consumption.

$$\varepsilon = -\frac{u''(c)}{u'(c)}c. \tag{9}$$

This gives the following optimal path[9],

$$r = \rho + \varepsilon\frac{\dot{c}}{c} - \frac{\partial u^2}{\partial c \partial l}\frac{l}{u'(c)}\frac{\dot{l}}{l} + \frac{\dot{p}}{1+p}. \tag{10}$$

The condition states that along the optimal path the marginal gain in postponing a unit of consumption equals the marginal discounted realized return in the market. ε is the elasticity of marginal utility and therefore measures the concavity of the utility function.[10] The concavity measures the strength of the households' incentive to smooth consumption in the market. Therefore the more concave the utility function is, the smaller is his incentive to adjust to changes in the rate of return, thus the smaller the change in consumption growth. If the marginal utility of consumption is linear, the incentive to smooth consumption is weak, resulting in a household that reacts extensively to changes in the market return. In the presence of a positive exogenous growth rate in prices, the real return of foregoing consumption today is reduced. In isolation this will discourage saving and investment of the household in the same way as a reduced interest rate.

The cross derivative of labor and consumption measures the extent to which consumption and leisure are complements or substitutes.[11] If the cross derivative of consumption and work effort is negative, the household gets less utility from a marginal increase in consumption the higher the work effort is. In the case with growth in labor intensity the household has even less incentive to save since future marginal utility of consumption decreases as the work effort then will be higher. If the cross derivative is positive, the

[9]Mangassarian's theorem states that satisfying the conditions for the maximum principle is sufficient for the path to be a maximum as long as the Hamilton function is concave in the controll variables, as is the case of this problem, Sydsæter et al. (2008).

[10]The more concave the utility function is in c the higher is ε.

[11]Intuitively, this derivative measures the extent to which the household enjoys consumption in the time off work.

marginal utility of consumption increases with labor supply. In this case the household has an additional incentive to forego present consumption. If it is zero, only market return and the incentive to smooth consumption matters for the saving decision. These are interesting properties that describe how investment and saving decisions might be influenced by decisions in the labor market. If the instantaneous utility function takes the form above consumption and leisure are two isolated sources of utility and the cross-derivative equals zero. The differential equation for consumption growth is then given by the expression below.

$$\frac{\dot{c}}{c} = \frac{r - \rho}{\varepsilon}, \tag{11}$$

In the model there is an exogenous labor augmenting growth rate in productivity and an endogenous growth in labor supply. To study the long run equilibrium in such a model it is usual to rewrite the stocks in per efficient capita terms.[12] The growth rate in consumption per efficiency unit of labor is therefore given by the following equation,

$$\frac{\dot{\hat{c}}}{\hat{c}} = \frac{r - \rho}{\varepsilon} - \left[x + \frac{\dot{l}}{l} \right] \tag{12}$$

With the functional form above the condition for optimal labor supply is given by the expression below.

$$\varphi(1 + \sigma) c l^{\sigma} = \frac{w}{p} \tag{13}$$

This expression can be written in per capita form in the same manner, this is shown in the appendix and yields the following expression,

$$\varphi(1 + \sigma) l^{\sigma + 1} = \frac{(1 - \alpha)\hat{k}^{\alpha}}{\hat{c}} \tag{14}$$

[12] As is usual in models of growth the variables denoted with a hat are measured in per efficient unit of labor.

This expression is needed to find the labor supply in long run equilibrium. Labor supply is determined endogenously in the model. This means that knowing the real wage and consumption, the labor supply of the maximizing household must follow. Knowing the growth in consumption and the real wage it is possible to deduce the growth rate in labor supply in the model, this is shown in the appendix. With the functional form chosen there is zero growth in labor supply in long-run equilibrium. The growth in the real wage is exactly offset by the growth in consumption.

2.2.2 Firms

It is necessary to know how production takes place in order to study the market equilibrium of the economy. The model consists of many firms producing the consumption good, acting in a perfectly competetive manner. The firms can therefore be aggregated in a production function which will be analyzed in the model. The firms choose between the different input factors and level of production given market prices in order to maximize the profits. As with the consumers, the firms have to take the market environment as given and then decide how to behave optimally constrained by market prices and technology. The representative firm's problem can be stated in the following manner,

$$\max_{I,L} \pi = \int_0^\infty [pf(K,L) - qI - wL]e^{-rt}dt \quad s.t \;\; \dot{K} = I - \delta K, \;\; K(0) = K_0 \tag{15}$$

The firm maximizes the present value of profits over an infinite horizon by choosing inputs optimally to given prices. I solve the problem using optimal control theory as shown in the appendix. The solution to the profit maximization problem is given by the usual first order conditions. The value of the marginal product equals the factor price for all t. The cost of investing for the firm is denoted by q. In the following I will assume that investment is costless for the firm.[13]

$$w(t) = pf'(L), \quad r(t) = pf'(K) - \delta. \tag{16}$$

The aggregate production function takes the Cobb-Douglas form, shown below,

$$y = K^{\alpha}(AL)^{1-\alpha}. \tag{17}$$

In per efficient capita terms the production function is given by the following expression,

$$\hat{y} = \hat{k}^{\alpha}. \tag{18}$$

This gives the following expressions for the market return to labor and capital,

$$w(t) = pA(t)(1-\alpha)\hat{k}^{\alpha}, \quad r(t) = p\alpha\hat{k}^{\alpha-1}. \tag{19}$$

From this we see that the real return to labor and capital is increasing due to the exogenous technical rate of change that is present in the model. At all times the rate of return to different factors of production is governed by the marginal product. This is a consequence of perfect competition; there can never be any remaining gains from trade in equilibrium. This will be elaborated upon in the next subsection.

2.2.3 Equilibrium

There are three markets in the model, a market for the consumption good, a labor market and a market for capital.[14] All these markets are assumed to

[13] In the sense that q=1. $q > 1$ could denote the reduced form of some tax distortion that increases the cost of capital for the firm.

[14] Actually there is a continum of markets in the model, but three markets for each time t.

clear at all times t. Thus, in equilibrium the wage makes the labor supply of households equal the labor demand of firms, $l^s(w) = l^d(w)$. The interest rate r in equilibrium makes the supply of capital of households equal the demand of firms, $K(r) = b(r)$. The price of the consumption good is the numeraire,[15] thus all other prices are measured in terms of units of the consumption good. Put differently, an equilibrium in this model is thus a feasible time path of allocations $[k(t), b(t), l(t), c]$ and prices $[p, r(t), w(t), \bar{\tau}]$, such that the firms maximize their profits, consumers maximize their utility, resource constraints hold and that the governments budget constraint holds. $\bar{\tau}$ is a vector of the governments tax instruments. Having defined the equilibrium of the model there now are sufficient conditions to determine the value on all the endogenous variables. This insight can be used to study the long run evolution of these static equilibria to changes in tax policy as will be done in the next sections.

2.2.4 The government

The government is modeled in the simplest possible manner. It finances its activities by taxing different forms of income. The only fiscal instruments the government has at its disposal are distortionary taxes. Government spending is held exogenous in the model. The budget constraint must hold for all times t, I ignore the governments ability to trade in capital markets. The budget constraint is given below, where τ_b is a tax levied on the return of the households investment and τ_w is a labor income tax.

$$G(t) = \tau_b r + \tau_w lw + \tau_c pc + \tau_f \pi'. \tag{20}$$

In addition there is a tax rate on private consumption denoted τ_c. This tax will play the role of a uniform tax on all different consumption goods.

[15] $p(t) = 1$ for all t.

τ_f is a tax on the firms profits,[16] levied on a share of the firms profits to make it non-neutral in the model. In the following I will find the reduced form equations of the model without any taxation of distortionary taxes to act as a benchmark case for comparison.

2.2.5 Steady state

In each period capital is invested by the household. Capital evolves in accordance with the law of motion for capital.

$$\dot{K} = I - \delta K \tag{21}$$

Investment in this economy is given by the following equation,

$$I = rK + wl - c. \tag{22}$$

Thus the growth in the capital stock is the difference of the invested capital and the depreciation. Using the equilibrium conditions and various resource constraints I find expressions for the growth rates of the endogenous variables of interest.[17] These expressions are given below.

$$\frac{\dot{\hat{c}}}{\hat{c}} = (\alpha \hat{k}^{\alpha-1} - \delta) - \left[\rho + x + \frac{\dot{l}}{l}\right] \tag{23}$$

$$\frac{\dot{\hat{k}}}{\hat{k}} = \hat{k}^{\alpha-1} - \left[\delta + x + \frac{\dot{l}}{l}\right] - \frac{\hat{c}}{\hat{k}} \tag{24}$$

$$\frac{\dot{l}}{l} = \frac{\alpha}{1+\sigma}\frac{\dot{\hat{k}}}{\hat{k}} - \frac{1}{1+\sigma}\frac{\dot{\hat{c}}}{\hat{c}} \tag{25}$$

[16] This is formulated as a tax on corporate profits. However, the C-D production function has constant returns to scale, thus the only possible equilibrium profit is zero. This problem is alleviated by the fact that I assume the government lacks perfect information on the firms profit and therefore calculates the tax using a different tax base than true profits.

[17] I show this in the appendix.

$$\varphi(1+\sigma)l^{\sigma+1} = \frac{(1-\alpha)\hat{k}^{\alpha}}{\hat{c}} \tag{26}$$

The growth rate in consumption per efficient capita is determined by the real return to capital because of the households incentive to save. This incentive is reduced by the strength at which the agent discounts the future. The exogenous growth in productivity and increases in labor supply are factors that dilute the per efficient capita expressions. The net increase in capital per efficient capita equals the total production minus the part consumed by the household and the government.[18] The same factors dilute capital per efficient capita. The labor supply is determined by the ratio of consumption and the real wage. Growth in labor supply is thus governed by the growth in these factors.

Usually in growth models equations such as these define a system with a saddle point equilibrium. Many of the paths rely on initial conditions that do not make economic sense. The system can be reduced further to find the constraints on the parameters that would ensure existence of this equilibrium.[19] Since I am not going to introduce parameter values, I just assume they have appropriate values for the system to have a unique solution and then find the closed form solution directly. Combining the equations determines the steady state values of capital and consumption per efficient capita, in addition to the labor supply in steady state. The steady state variables of the system are shown below.[20]

[18]In this benchmark case $G(t) = 0$ for all times t.

[19]The necessary constraints on the parameters are that the eigenvalues of the linearized reduced form matrix needs to be less than one in absolute value and have opposite signs, Sydsæter et al. (2008).

[20]ss denotes the variable value in steady state.

$$\hat{k}^{ss} = \left[\frac{\alpha}{x+\delta+\rho}\right]^{\frac{1}{1-\alpha}} \tag{27}$$

$$\hat{c} = \hat{k}^{ss^{\alpha}} - (\delta + x)\hat{k}^{ss} \tag{28}$$

$$l^{ss} = \left[\frac{(1-\alpha)(\rho+\delta+x)}{(1+\sigma)\varphi(\rho+(\delta+x)(1-\alpha))}\right]^{\frac{1}{1+\sigma}} \tag{29}$$

The steady state of capital per efficient capita is the same as it would have been with inelastic labor supply. It increases in the capital share of the production function, the marginal product of capital in efficiency units. It decreases in x and δ. These factors dilute the amount of capital, alternatively increases the amount required to keep the capital measured in efficiency units at a constant value. ρ measures the extent to which the households are patient. The higher ρ is, the more they discount future consumption, decreasing the incentive to forego present consumption. In each period, the household adjusts its labor supply such that the marginal disutility of labor is just offset by the marginal utility of the real wage. Therefore, the factors that decide the wage rate in steady state are important parameters to decide the steady state labor supply. In addition, the parameters describing the disutility of labor reduces the steady state labor effort.

In the following I will use the model of the previous section to look at what happens when different features of a DIT is introduced. Such a reform increases the overall tax burden on capital by tightening rate of return allowance, broadening the tax base on capital and making capital taxation increasingly neutral. It uses this increase in revenue to finance a rate reduction on the tax rate on personal capital in addition to alleviating double taxation of capital in all forms. The tax rate on consumption and labor might need to be changed to make the tax reform revenue neutral, therefore the long run effect of changing these tax rates is also of interest. The analysis is in a sense partial, I regard different aspects of the dual income tax in isolation. Although somewhat stylized, this makes the effect of each particular tax rate clearer.

2.3 Taxation of capital income

In this section I consider a reduction the tax rate on personal capital income. This changes the household's and government's budget constraint. In this section I assume that the government finances all of its activity with distortionary taxation of capital income. The budget constraints in this case are shown below.

$$\dot{b} = (1-\tau_b)rb + wl - pc \tag{30}$$

$$g = \tau_b r K \tag{31}$$

A fraction τ_b of the income from investing in capital is payed to the government at each time t. This changes the equation of the system in the following manner.

$$\frac{\dot{\hat{c}}}{\hat{c}} = (1-\tau_b)(\alpha \hat{k}^{\alpha-1} - \delta) - \left[\rho + x + \frac{\dot{l}}{l}\right] \tag{32}$$

$$\frac{\dot{\hat{k}}}{\hat{k}} = \hat{k}^{\alpha-1} - \left[\delta + x + \frac{\dot{l}}{l}\right] - \frac{\hat{c}}{\hat{k}} - \frac{\hat{g}}{\hat{k}} \tag{33}$$

$$\frac{\dot{l}}{l} = \frac{\alpha}{1+\sigma}\frac{\dot{\hat{k}}}{\hat{k}} - \frac{1}{1+\sigma}\frac{\dot{\hat{c}}}{\hat{c}} \tag{34}$$

$$\varphi(1+\sigma)cl^{\sigma} = w \tag{35}$$

The steady state values of the system are then given by the following equations.

$$\hat{k}^{ss} = \left[\frac{(1-\tau_b)\alpha}{x+\rho+(1-\tau_b)\delta}\right]^{\frac{1}{1-\alpha}} \tag{36}$$

$$\hat{c} = \hat{k}^{ss^{\alpha}}(1-\alpha\tau) - (\delta + x)\hat{k}^{ss} \tag{37}$$

$$l^{ss} = \left[\frac{(1-\alpha)\hat{k}^{\alpha}}{\varphi(1+\sigma)\hat{c}}\right]^{\frac{1}{1+\sigma}} \tag{38}$$

From these equations it becomes clear that the usual factors that determine the steady state capital stock are important in determining the impact of taxing personal capital income. Capital taxation decreases the long-run steady state capital intensity. In addition, capital income taxation affects all the endogenous variables in steady state.

Tax rates on capital will have a direct influence on growth through distorting the return to capital, and thus the incentive to save. When the taxation of capital is increased people change their behavior in response the increase. Lower return of capital induces an immediate increase in consumption. When consumption increases, fewer resources are diverted to maintaining the capital stock at its current value and hence more depreciates than is invested. In the long run this decreases the capital stock, thus reducing the productive capacity of the economy. By the same mechanism, a reduction in the tax rate on capital will increase economic growth. Moreover, in the new steady state the level of consumption is also lower as can be seen by comparing equation (36) with the corresponding equation without taxation.

Since taxation of capital changes the values of both $\hat{k}$ and $\hat{c}$ it might also change the steady state value of labor supply even though labor and leisure is separable in the utility function. The reason is that labor supply is determined endogenously in the model, given when the real wage and consumption is given. If consumption changes relatively more than the real wage the labor supply will decrease, while the labor supply will increase in the opposite case. The qualitative effect of capital income taxation on labor supply is ambiguous, depending on the parameterisation of the model.

2.4 Double taxation of capital

In addition to a tax on capital, all firms pay a share of their profits to the government. If only pure rents are taxed, the maximization problem of the firms is not affected and the tax is said to be neutral. It induces no behavioral change in this case. In this section I consider a non-neutral corporate income tax, similar to the cases studied by Sandmo (1974). This distorts the choice of inputs for the firm. Tax rates on inputs will cause substitution away from the relatively more expensive inputs. In this model this can be incorporated by not deducting all the costs from the firms profits. The firms problem is then given by the following problem.

$$\max_{I,L} \pi = \int_0^\infty [(1-\tau_f')(f(K,L) - sI - wL) - (1-s)I]e^{-rt}dt \quad s.t \quad \dot{K} = I - \delta K \quad (39)$$

The firm pays the share τ_f of the tax base to the government. However, only a share s of the investment costs are deducted from the tax base. In general this could stem from the governments inability to estimate the true economic values internalized by the firm.[21] The tax paid by the firm can thus be influenced by choosing the level of investment and will distort the

[21] An example could be to tight depreciation allowances.

economic decision. As shown in the appendix, this increases the cost of capital for the firm. The firms first order condition is given by the following equations, where τ_f denotes the effective tax rate of capital.[22]

$$(i)\ \ pf'(K)(1-\tau_f) = \delta + r$$

$$(ii)\quad pf'(L) = w$$

Taxing firm profits in this manner decreases the rate of return of investing in the firm. The system now evolves in accordance with the following equations.

$$\frac{\dot{\hat{c}}}{\hat{c}} = (1-\tau_b)(\alpha\hat{k}^{\alpha-1}(1-\tau_f)-\delta) - \left[\rho + x + \frac{\dot{l}}{l}\right] \tag{40}$$

$$\frac{\dot{\hat{k}}}{\hat{k}} = \hat{k}^{\alpha-1} - \left[\delta + x + \frac{\dot{l}}{l}\right] - \frac{\hat{c}}{\hat{k}} - \frac{\hat{g}}{\hat{k}} \tag{41}$$

$$\varphi(1+\sigma)cl^{\sigma} = w \tag{42}$$

Corporate taxation thus leads to double taxation of capital, further decreasing the rate of return of investing in the production process for the consumers. This further increases the tax wedge in the market for productive capital. There is a wedge between the real value of investing an additional unit of capital and the return at the corporate level. When this return is eventually paid out to the investor, for instance as dividends, there is an additional wedge caused by taxation on the personal level. The long-run values of the endogenous variables in per efficient capita units is found in the usual manner and are given by the expressions below,

$$\hat{k}^{ss} = \left[\frac{(1-\tau_f)(1-\tau_b)\alpha}{x+\rho+(1-\tau_b)\delta}\right]^{\frac{1}{1-\alpha}} \tag{43}$$

[22] As shown in the appendix, $\tau_f = \frac{\tau_f'(1-s)}{1-s\tau_f'}$.

$$\hat{c} = \hat{k}^{ss^{\alpha}} - \hat{k}^{ss}(x+\delta) - \hat{g} \tag{44}$$

$$l^{ss} = \left[\frac{(1-\alpha)\hat{k}^{\alpha}}{\varphi(1+\sigma)\hat{c}}\right]^{\frac{1}{1+\sigma}} \tag{45}$$

Double taxation further decreases the rate of return to investments. Again, this affects the tradeoff between consumption in the different periods. Increased present consumption causes less saving and therefore less investment. When less capital is invested and the replacement ratio kept constant, the capital stock in per efficiency units decreases. All deviations from a corporate income tax on pure rents will have this effect in the long run. The other equations show that it has the same effect on consumption and the same ambiguous effect on labor supply.

2.5 Taxation of labor income

In this section I introduce a labor income tax. This changes the household's and the government's budget constraint. I assume that the government finances all of its activity with distortionary labor income taxation. The budget constraints of the household and the government given by the expressions below,

$$\dot{b} = rb + (1-\tau_w)wl - pc \tag{46}$$

$$g = \tau_w lw. \tag{47}$$

The tax rate on labor is denoted by τ_w. Taxation of labor income will change the labor supply by altering the return to supplying labor in the market. The system of equations with labor income taxation is given below,

$$\frac{\dot{\hat{c}}}{\hat{c}} = (\alpha \hat{k}^{\alpha-1} - \delta) - \left[\rho + x + \frac{\dot{l}}{l}\right] \tag{48}$$

$$\frac{\dot{\hat{k}}}{\hat{k}} = \hat{k}^{\alpha-1} - \left[\delta + x + \frac{\dot{l}}{l}\right] - \frac{\hat{c}}{\hat{k}} - \frac{\hat{g}}{\hat{k}} \tag{49}$$

$$\varphi(1+\sigma)cl^{\sigma} = (1-\tau_w)w \tag{50}$$

Using the system I find the following steady state values,

$$\hat{k}^{ss} = \left[\frac{\alpha}{x+\delta+\rho}\right]^{\frac{1}{1-\alpha}} \tag{51}$$

$$\hat{c} = \hat{k}^{ss^{\alpha}}(1-(1-\alpha)\tau) - (\delta+x)\hat{k}^{ss} \tag{52}$$

$$l^{ss} = \left[\frac{(1-\alpha)(\rho+\delta+x)(1-\tau_w)}{(1+\sigma)\varphi((x+\rho+\delta)(1-\tau_w(1-\alpha)-\alpha(x+\delta))}\right]^{\frac{1}{1+\sigma}} \tag{53}$$

Taxation of labor income has an ambiguous effect on labor supply in the long run. Taxing labor directly reduces the real wage. However, increased government consumption crowds out private consumption in the new long run equilibrium. The first order condition of the intertemporal optimum is not affected, thus the capital intensity is the same as before. Taxation of labor income therefore does not affect investment behavior. This is a consequence of strict separability of the utility function in consumption and leisure.

2.6 Taxation of consumption

Taxation of consumption goods is also considered in the model due to it's potential role in making the change to the DIT system revenue neutral, as in Keuschnigg and Dietz (2007). Taxing consumption goods changes the budget constraint of the consumer and government in the following manner,

$$\dot{b} = rb + wl - (1 + \tau_b)c \tag{54}$$

$$g = \tau_c c \tag{55}$$

A well known result from optimal tax theory is that a uniform tax on all goods consumed by the individual is equivalent to a lump sum tax. However, as usual the government can only tax transactions that occur in the market, in this sense a uniform tax on all goods is impossible in practice.[23] It will distort the tradeoff between market and non-market activities. In this model, I abstract from household production. However, leisure can not be taxed and a uniform tax on consumption will have an influence through the labor supply decision. In addition, increasing the consumption tax may cause distortions in the intertemporal decision of the household, since in the reform period, changes in consumption taxation affect the relative prices of consumption in the different periods. To show this I solve households maximization problem again and find the optimal path of consumption below.

$$\frac{\dot{\hat{c}}}{\hat{c}} = (\alpha \hat{k}^{\alpha-1} - \delta) - \left[\rho + x + \frac{\dot{l}}{l}\right] + \frac{\dot{\tau}_c}{1 + \tau_c} \tag{56}$$

If the consumption tax evolves over time it will affect the households tradeoff by changing the relative prices of consumption in the different periods. Growth in the consumption tax will have the same effect as a lower real return to saving. It will induce the household to save less, by making future consumption less attractive. Consumption will then evolve along a lower

[23] In addition, non-uniform optimal taxation of consumption goods would require large administration costs, requiering updating the tax schedules with changes in preferences and technology. This is likely to be highly unfavorable to economic growth because it would hamper investment.

path, more is consumed resulting in a lower steady state with the usual mechanism of dilution and depreciation. However, assuming no growth in the consumption tax, the reform is simply a discontinuous jump that is not anticipated by the household, in this case the derivative of the tax is alway zero and the term therefore vanishes. In this case there is no effect of consumption tax on saving, the expression then becomes the familiar one below.

$$\frac{\dot{\hat{c}}}{\hat{c}} = (\alpha \hat{k}^{\alpha-1} - \delta) - \left[\rho + x + \frac{\dot{l}}{l}\right] \tag{57}$$

$$\frac{\dot{\hat{k}}}{\hat{k}} = \hat{k}^{\alpha-1} - \left[\delta + x + \frac{\dot{l}}{l}\right] - \frac{\hat{c}}{\hat{k}} - \frac{\hat{g}}{\hat{k}} \tag{58}$$

$$\varphi(1+\sigma) c l^{\sigma} = \frac{w}{1+\tau_c} \tag{59}$$

As with labor taxation, taxation of consumption goods does not alter the tradeoff between periods, unless it varies over time. The steady state values of the endogenous variables are now given by the following expressions,

$$\hat{k}^{ss} = \left[\frac{\alpha}{x+\rho+\delta}\right]^{\frac{1}{1-\alpha}} \tag{60}$$

$$\hat{c} = \frac{\hat{k}^{ss^{\alpha}} - (\delta + x)\hat{k}^{ss}}{1+\tau_c} \tag{61}$$

$$l^{ss} = \left[\frac{\alpha(\rho+\delta+x)}{(1+\sigma)\varphi(\rho+(\delta+x)(1-\alpha))}\right]^{\frac{1}{1+\sigma}}. \tag{62}$$

With this specification of the utility function there is no effect on the steady state capital intensity or labor supply from taxing the consumption goods. The only effect is through lower consumption and is thus equivalent to a lump sum tax in the model. However, the reason follows from the fact that the real wage is reduced by the exact same amount as the consumption in long-run equilibrium. If the change in consumption did not reduce with this amount, taxation of consumption would induce changes in labor supply.

2.7 The dual income tax in the neoclassical growth model

The introduction of a DIT system in this modeling framework implies lowering the tax rate on capital below that of labor. In addition, the corporate income tax is lowered, set equal to the personal income tax on capital. Double taxation is fully alleviated. The capital income tax base is broadened, aiming at equalizing tax rates on various forms of capital income and assets. Reduction of tax rates of capital income and corporate profits increases the household's incentive to save. Removing double taxation of capital further decreases the wedge between the real and private return of capital. In line with the above reasoning, this implies that more capital is accumulated than is diluted by productivity growth and depreciation each period, hence driving the growth rate to a positive level in excess of the exogenous rate of productivity growth. In addition, lower taxation of corporate profits and equalizing tax rates on different types of capital will also have an effect on the production efficiency of the economy.

In order to assess the quantitative implications of these effects and the transitional dynamics of the model specific parameter values would have to be introduced. However, the aim of this section has only been to derive qualitative implications of changing tax rates in line with a DIT reform. In sum, a DIT might cause growth through increasing equilibrium investment. In the model this will cause a transitory effect on growth that is higher than the equilibrium growth rate. I therefore expect to find a positive influence on DIT and economic growth in the data. In the next section I will investigate data from 23 OECD-countries evaluate this effect.

2.7.1 Extensions

To highlight some of the shortcuts and loose ends I will discuss some possible extensions of the model. An immediate extension of the model could be to include heterogenous agents, as is done in Caselli and Ventura (2000). Differences in skill would yield different returns in the labor market. This would allow for introducing a progressive income tax schedule and studying the effects on growth of changing this schedule in a DIT reform. In addition, a very natural extension would be to allow for a larger role of the government. This could be done by letting government consumption enter into the production function of firms or the utility of the households. In this case, economic growth would also be influenced by changes in government consumption and the revenue requirement of the government would be needed to be taken more account of.[24] Moreover, it would open up for using the model to do welfare analysis. Another interesting extension could also be to introduce different sectors of the economy. These could grow at different exogenously given rates, inducing structural change. This model could then be used to study tax policies in countries with large differences in productivity growth in different sectors, such as the Norwegian economy. Finally, open economy issues matter for growth, in a more rigorous model, these issues would need to be taken into account.

[24] An interesting effect could be to look at the effect when government consumption is a complement to private consumption, this could then induce changes changes in saving. A way to motivate this could be that government spending on legal institutions is necessary for complicated transactions such as saving to take place.

3 Empirical analysis

Although the model of the previous section is simple, it produces many testable hypotheses regarding the relationship between taxation and economic growth. In this section I attempt to test some of the implications of the theoretical model in a panel of aggregate data for OECD-countries. I will investigate if the features of the DIT system mentioned above are positively related to growth in real data. The approach taken is to investigate the impact of tax reforms in the nordic countries that came close to a DIT reforms, and compare these experiences with the rest of the sample. If the effects modeled in the theoretical section are of any significance, the subset of countries with DIT should have a higher growth rate than the others in the period following the shift towards DIT. These tax reforms are shown in table 1.

3.1 Empirical background

The empirical approach chosen follows a large strand of the established literature on taxation and economic growth. In this literature cross-country panels of macroeconomic data are used to estimate the relationship between tax rates and economic growth. Arnold et al. (2011) is an example of this approach. They use aggregate data to investigate the relationship between economic growth and various forms of taxes in a panel of OECD countries. They find that tax design influences economic growth. More specifically they find that taxation of immovable property is the least harmful, followed by consumption taxes, personal income taxes and corporate income taxes. They estimate that shifting 1% of the tax revenue towards the less harmful taxes would increase growth between 0.25% to 1%. Lee and Gordon (2005) use a fixed effects regression model to estimate the effect of different tax rates on economic growth in a sample of 70 developed and developing countries. They estimate a negative effect of corporate income taxes of economic growth; a 10% reduction in the corporate income tax will increase the growth rate with approximately 1%. Arnold (2008) also finds a negative impact from the personal and corporate income taxes on economic growth and concludes that taxes on immovable property and consumption are the ones with the least negative impact on growth. Kneller et al. (1999) find that some personal income taxes reduce growth, while for example taxation of consumption does not seem to affect growth. Widmalm (2001) also estimates the effects of various forms of taxation on GDP in the OECD. She finds a negative relationship between personal income taxation and economic growth. However, capital taxation on the personal level is not explicitly accounted for. She also concludes that taxation of consumption has the least negative impact on economic growth.

The findings of this literature suggests that taxation and in particular corporate and personal income taxation has an effect on economic growth. However, due to the large technical difficulties in comparing tax rates on various forms of capital in system with very different tax rules, this literature has to a large extent ignored including more detailed information on the composition of the capital tax base. They mainly include information on corporate income and taxes on housing. The literature represented by these authors thus to a large extent ignores tax designs of capital income. In this master thesis I attempt to take explicit account of this by including information on one particular tax system, that of the DIT, into the empirical analysis of taxation and economic growth.

3.2 Data description

The countries analyzed are a subset of the member countries of the OECD, excluding the countries from Latin America, eastern-European countries and Turkey. The data used in this analysis are available from the online data

Table 1: DIT reforms. The table is an extension of the table found in Sørensen (1994).

Country	Personal	Capital	Corporate	Integration
Finland				
Before 1993	25-57	25-57	37	Double taxation
After 1993	25-57	25	25	Full relief
After 2005	25-57	28	26	Partial relief
Norway				
Before 1993	26.5-50	26.5-40.5	50.8	Partial relief
After 1993	28-41.7	28	28	Full relief
After 2006	28-48	28	28	Partial relief
Sweden				
Before 1993	36-72	36-72	52	Double taxation
After 1993	31-51	30	30	Full relief

bases of the OECD. The data on GDP,[25] saving rate and net investment is obtained from the online data base of the national accounts that are measured annually. The data on GDP is filtered using the Hodrick-Prescott filter with a parameter of 80.[26] I have applied the Hodrick-Prescott filter on the GDP data to smooth away parts of the business cycle. The dependent variable of the analysis is the annual change in the logarithm of the gross domestic product. I apply control variables to account for business cycles and growth enhancing features that are not tax related.

The explanatory variable of interest is a dummy variable which takes the value 1 for time periods under a DIT in selected countries, see table 1. Some of the nordic countries have implemented DIT, OECD (2010), OECD (2006) and Sørensen (1994). This includes Norway from 1993 to the present,

[25]The GDP data are the purchasing-power adjusted values.

[26]The Hodrick-Prescott filter is a widely used method in macroeconomics to filter out cyclical components in time-series data. The method is a minimization problem, trading off deviations from trend with a loss in correcting the time series.

Sweden from 1993 and onwards and Finland from 1993 to 2005. In these countries the tax rates on capital were lowered, broadened and set equal to the corporate income tax. This was combined with progressive taxation of labor income. However, a number of countries in the sample have implemented tax systems that share some characteristics with that of DIT countries, Genser and Reutter (2007). This highlights that the distinction between countries having implemented the DIT and those who have is not sharp. Therefore largely ignoring more detailed differences in these countries tax systems is a weakness of this analysis. The countries of the full sample are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States.

Several of the control variables are obtained from the statistics data base of the OECD. The saving rate is measured as the net saving divided by the gross domestic product of the country, net saving is measured as the difference between disposable income and final consumption taken from the national accounts. Net capital stock is the total capital, measured with 2005 as a base year and deducted for estimated capital depreciation. Inflation is measured as yearly averages of the core inflation, provided by national statistics agencies to the OECD. FDI is the inflow of foreign direct investment as measured in thousands of American dollars. As a measure of human capital I use a variable defined as the Barro-Lee skill ratio, (Rossvoll and Sparrman, (2013)). It measures the ratio of the population over 15 with some level of tertiary education. The data are taken from Barro and Lee (2010).[27] Labor participation is a the percentage of the total population

[27] The data set only includes 5 year averages. Rossvoll and Sparrman (2013) extend this using a linear approximation. The data can be found at: `http://www.barrolee.com`. They are also available in Barro and Lee (2010).

employed. The terms of trade measures the change in the import prices relative to export prices relative to its 2005 value.[28] Long-run unemployment is the share of the unemployed who have stayed unemployed for more than 12 months. The R&D intensity is measured by the R&D cost over value added in the manufacturing sector, obtained from Rossvoll and Sparrman, (2013). Data on corporate income taxes come from the World Tax Database of the Office of Tax Policy Research.[29] In addition the average tax wedge is included in the data set. The tax wedge measures the sum of the direct tax rate, employment tax rate and the indirect tax rate for a worker with average income. The Summary statistics of all the included data is provided in table 2.

Table 2: Summary statistics

Variable	**Obs.**	**Mean**	**Std.dev**	**Min.**	**Max.**
Log GDP per capita	985	-6.88	1.88	-11.35	-1.7
Capital stock	223	75.89	21.61	27.05	117.37
Population growth	1177	0.707	0.5855	-2.74	4.48
Human capital	820	22.9	0.19	0.014	1.07
R&D	649	0.047	0.034	0.002	0.159
Inflation	978	4.47	3.98	-4.4	26.4
Saving rate	925	8.74	5.84	-14.82	29.99
FDI	505	22613	42570	-36602	321276
Terms of trade	924	98.66	14.1	60	191.6
Corporate income tax	667	0.365	0.1	0.125	0.61
Average tax wedge	299	36.4	10.4	15.86	57.1
DIT	58	0.039	0.194	0	1

[28] This variable is of particular importance when it comes to Norway which has experienced high growth rates due to a large improvement in the terms of trade in the period it has had a DIT.

[29] `http://www.bus.umich.edu/otpr/otpr/default.asp`

3.3 Econometric specification

The regression model I will apply can be interpreted in line with the type of model of the previous section. As is usually the case when regressing policies on growth, I apply control variables that are widely believed to explain part of the variations in growth rates. The formulation and included variables follows follows the specifications in the influential papers on the empirics of growth by Barro (1996) and Mankiw, Romer and Weil (1992). The equation estimated takes the following functional form, given that countries are represented by subscript i and time by subscript t,

$$log\ y_{i,t} = \phi_0 + \phi_1 DIT_{i,t} + \beta_{\mathbf{1}}' \mathbf{X_{i,t}} + \beta_{\mathbf{2}}' \mathbf{v_{i,t}} + \gamma_i + \phi_2' tax_{i,t} + \varepsilon_{i,t} \tag{63}$$

The dependent variable $log\ y_{i,t}$ is the logarithm of GDP per capita for country i at time t. $\beta_{\mathbf{1}}'\mathbf{X}$ contains the baseline model of economic growth, in line with the model in the previous section. The coefficients of the explanatory variables denote the change in ratio of the output of the economy for a unit change in the variable. Growth in output is understood as the sum of the growth rates in the stocks of the economy. It therefore includes the capital stock and the growth rate of the population. Changes in the human capital is also included. Increases in human capital cause changes in the productivity of each worker. In addition to increases in the economy's stocks of productive assets various other factors increase economic growth, through for example productivity growth.[30] $\mathbf{v_{i,t}}$ is a vector of other control variables. It contains inflation and unemployment to further adjust for the business cycle, in addition to controlling for the negative effects these variables may have on growth. Unemployment might influence growth through depreciation of human capital, and inflation through allocation inefficiencies. R&D intensity will explain some differences in productivity growth. In addition

[30] x, in line with the model in section 2.

it contains variables meant to control for open economy issues, the inflow of FDI and the change in the terms of trade. It also contains the average saving rate in year t which is given by the first lag. $tax_{i,t}$ includes data on corporate income taxation and the average tax wedge. I include this to control for other tax related issues and for robustness. The unemployment rate is differenced because I find evidence non-stationarity in this time series. The data are summarized in table 2. To control for unobserved differences among countries I include country specific fixed effects, these effects are given in the vector γ. This variable will capture some of the effects from omitted variables that differ between countries. $DIT_{i,t}$ is the dummy variable for the subset of the sample that is a DIT regime.

In a panel of countries, that potentially vary greatly along many dimensions it is necessary to take account of unobserved country heterogeneity. Pooling the data in a cross-country comparison is a strict assumption and in the presence of country specific effects this will cause an omitted variable bias of the estimates. How this country heterogeneity is modeled empirically potentially has a large influence on the outcome. In the econometric analysis of panel data, panel specific effects are often dealt with in two different ways, see Greene (2008). The country specific effects can be modeled either as fixed or random effects. The random effects approach assumes that the country specific effects are orthogonal with all the other regressors. This amounts to assuming that all the country specific effects have no systematic influence on any of the explanatory variables included in the empirical model. This seems to be unlikely when comparing countries using aggregate data. The second approach is the fixed effects model. This approach amounts to including a constant term for each country that is hypothesized to absorb the country specific effect.[31] It is also worth noting that estima-

[31] Using the Hausman test I find that there is not sufficient evidence in the data to reject

tion using fixed effects are the most widely used approach in the literature on applied economic growth.

In the next sections I estimate the fixed effects model by OLS. Since the the available data resulted in an unbalanced panel I can not specify a structure on the correlation between panels, which would be relevant for countries with integrated markets as many of the countries in the sample have. The estimated models are reported in the next sections.

3.4 Results

I estimate the coefficients of the baseline model in (1). I then include the various control variables to see to what extent the estimates of the baseline model are stable. This is done in (2). In (3) I add the variables on tax policy to see if I can replicate results previously established in the literature by adding the average tax wedge in addition to the corporate income taxes. (4) Measures the influence of the dual income tax. In (5) I estimate the influence of DIT again, but this time controlling for the corporate income tax. The various estimates of the models are reported in table 3.

the random effects specification. However, since this specification seems unreasonable I estimate both versions. Estimating the model with random effects has no effect on the sign of the estimated parameter on the DIT dummy variable.

Table 3: Estimation with OLS

Dependent variable: Log GDP per capita	(1)	(2)	(3)	(4)	(5)
Baseline model					
Capital stock	.022	.013	.012	.013	.013
	(.000)	(.000)	(.000)	(.000)	(.000)
Human capital	.193	.147	.103	.157	.115
	(.130)	(.061)	(.055)	(.061)	(.069)
Population growth	-.058	.058	0.107	.061	.048
	(.032)	(.020)	(.022)	(.020)	(.022)
Control variables					
ΔLogUnemployment rate		-.007	-.001	-.003	.007
		(.027)	(.024)	(.027)	(.028)
R&D intensity		1.971	.086	2.03	1.925
		(.280)	(.24)	(.279)	(.291)
Inflation		-0.112	-.010	-.009	-.009
		(.002)	(.003)	(.002)	(.002)
Saving rate		.012	.002	.012	.012
		(.001)	(.001)	(.001)	(.001)
FDI		-2.5e-7	-1.8e-7	-2.64e-7	-2.38e-7
		(.000)	(.000)	(.000)	(.000)
Terms of trade		-.004	-0.0	-.004	-.004
		(.000)	(.000)	(.000)	(.000)
Tax variables					
Average tax wedge			-.005		
			(.003)		
Corporate income tax			-.159		-.161
			(.114)		(.126)
DIT				**.025**	**.013**
				(.014)	(.017)
Number of observations:	208	103	56	103	103
R^2 overall:	0.221	0.046	0.223	0.047	0.089
F statistic:	0.000	0.000	0.000	0.000	0.000

Note: All the coefficients are estimated using country fixed effects. Standard errors are in brackets.

The DIT dummy is estimated to be positive. The estimated coefficient in the various specifications of the model is between 0.025 and 0.013. This implies that, according to the model, an introduction of a DIT regime increases annual growth in GDP per capita in a country by a factor of 1 to 2.5 percent. The sign, size of the estimate and the significance is robust to different estimation methods and the inclusion of different explanatory variables. The estimates of the baseline model and the control variables also are stable to the inclusion of the DIT dummy. As expected, the estimated coefficient on the dual income tax dummy is reduced by the inclusion of the corporate income tax variable. This suggests that part of the impact of the DIT on economic growth is through lower corporate taxes. The estimated result of the various coefficients are consistent with the predictions of the 'neoclassical view' taken in the theoretical section. The result of the estimation is that there is an effect on economic growth in the countries with implemented pure DIT systems that is not accounted for by any of the other included parameters or country specific effects. I interpret this that it to some extent captures the causal effect of introducing a dual income tax system in an economy on growth.

The estimated coefficients of the baseline model are largely as expected and robust over different specifications. They are in line with the conclusions of the theoretical model and to some extent in line with previous empirical studies studies on the determinants of economic growth, Barro (1996). Increases in the capital stock and human capital has a positive effect on output growth. Increases in the population growth also has this effect. The saving rate increases factor accumulation and has a significant and positive impact on growth.

The estimated effects of the other control variables are also in general as expected. Some of the variables are likely to explain differences in productivity growth between countries. The change in unemployment rate has a negative effect on growth. As already mentioned, this is likely to be a consequence of reduced overall production in the economy in addition to reduced productivity stemming from depreciation in the skill set of unemployed workers. The estimated coefficient on the R&D intensity is positive. This is likely to be explained both by the effect from R&D spending, but also from the reverse causality, that high growth may influence the incentives to conduct R&D spending. Inflation and unemployment enters negatively on growth as expected from economic theory. Moreover, the corporate income tax and average tax wedge enters negatively in all the regressions. This is in line with previous studies empirical studies on taxation and economic growth, (Lee and Gordon (2005)).

Several issues arise that matter for the estimated result. There are methodological problems in using a panel of countries when analyzing growth in general and the interconnectedness of growth and taxation in particular. Acknowledging these issues I argue that the sample of countries used in this analysis makes these problems less severe, although the estimate is likely to be biased upwards due to endogeneity. In addition, as in many growth regressions, unobserved country heterogeinity remains an important problem.

3.4.1 Econometric challenges

As the model above is formulated the impact of a DIT reform is interpreted as having a positive impact on the annual growth rate of the economy. To interpret this effect causally one has to believe that all the determinants of economic growth are taken account of in the model and that the only remaining differences between countries can be summarized by changing the intercept of the panel. In addition, the likelihood that a country changes it's tax system in the direction of a DIT system can not be related to any of the factors related causing growth. These issues raise a problem when interpreting the estimates. Different empirical phenomena such as simultaneity, selection-bias and omitted variable bias are all likely to be present and causes the estimators to lack consistency.[32]

The main problem with the empirical specification is likely to be an omitted variable bias. An example of this is in the analysis is data on how the government uses its tax revenue. To account for the total effect of a given tax structure on economic growth, the expenditure side needs to be included. For example, some expenditure characteristics of the selected DIT countries might be picked up by the DIT variable. The impact of government spending on economic growth is documented by Angelopoulus, Economides and Kammas (2006). If there are systematic differences in how countries use revenue and the tax structure, the parameters estimated will be biased. However, such systematic differences are less likely in the subsample of countries used to estimate the model than in the full sample of OECD-countries, even though such differences remain a possibility. An additional problem is that the above analysis takes a quite simple view on the properties of different tax systems. The effective tax rate is not necessarily perfectly reflected in the data on tax rates and the specification of the dual income tax dummy variable. To amend this would be a challenging task, digging into details in the tax systems of all the countries in the sample to determine the effective tax rate in capital within these countries. Another problem is the limited samples of countries who implemented DIT reforms and the limited time frame in which these were implemented, all in the early 1990's. Making the estimation vulnerable to the macroeconomic circumstances of the time.

[32]These phenomena are often termed together as endogeneity in the applied economic literature since all these issues all have that in common that they cause some systematic pattern in the error term of a regression.

Another problem of cross country comparisons on economic growth is simultaneity of the various determinants of growth. High growth is likely to cause increases in investment in different factors of production as well. Spurious relationships are to some extent avoided by including the right control variables. Moreover, when investigating the impact of taxation on growth is the endogeneity of tax policies. As already mentioned, there is a growing literature highlighting this interaction, (Alesina and Tabellini (1990)) . If this is a good description of reality, as many studies suggest it is, this will result in biasing the estimated effect of DIT on growth. In general, economic theory suggests that the estimated coefficient is likely to be biased upwards. The reason is related to Wagner's law, (Hindricks and Myles (2006)). It states that high growth increases the demand for government spending and therefore taxation. High growth will therefore also increase equilibrium tax rates, causing a spurious relationship between growth and taxation. When it comes to the DIT reforms in the nordic countries it is relevant to point out that the introduction of DIT systems in essence were a response to changing international economic circumstances, such as EU ascension for some nordic countries. In addition, in the years prior to the tax reforms, there was widespread liberalization of the nordic economies. The DIT reforms can also be a response to forces related to this. This again causes endogeneity, there may be some effects captured by the DIT dummy that is in essence related to other omitted variables, caused by the same things that caused the DIT reform.

However, again these shocks are not unique to the nordic countries, and is likely to reflected in the GDP of more of the countries in the sample. This will limit the potential bias. In addition, many of the countries in the sample are highly integrated in this time period, this makes the problem smaller since many of the countries to some extent follow the same business cycles over the period. In addition, the robustness of the results when changing the functional form and the inclusion of other explanatory variables makes the estimated coefficient plausible, even if the effect is somewhat overestimated due to the endogeneity of tax policies. In addition, the finding is in line with the results of the theoretical model. I therefore think it is likely that the DIT reforms of the early 1990's in the nordic countries had a moderate and positive impact on economic growth. At least this can not be ruled out by this empirical analysis.

3.4.2 Additional explanations

The empirical specification does not reveal much on the sources of the positive estimate, some additional explanations might therefore be in order. A dual income tax reform is likely not only to influence transitory effects on economic growth, but also on changes in productivity growth and allocation efficiency and through other dimensions than the ones modeled in section two.

In the absence of productive efficiency, resources in the economy will not be fully utilized and it is possible to increase the production of some goods without reducing the production of others by reallocating inputs. A dual income tax reform aims at removing differential tax treatment of various types of capital, inputs and returns from the corporate sector. This could move the economy closer to productive efficiency. If successful, this would induce an efficiency gain, directing scarce resources to parts of the economy where they are of highest value by aligning the pre tax rates of return to different assets. Even if not completely successful in aligning the real and private return to capital in different production processes, an in general lower tax on capital income could decrease the overall tax wedges of different projects and still yield an efficiency gain. If there is differential tax treatments of different types of capital, this would imply different after tax returns of capital in different sectors of the economy. There have been indications that the dispersion of interest rates among sectors in the Norwegian economy narrowed after the 1992 tax reforms, Christiansen (2004), showing that this tax reform improved the allocation of capital, reducing the relative tax wedges on various forms of capital. This could have an effect on the transitory growth rates of the economies that implemented the DIT system.

The corporate income tax is also believed to distort allocative efficiency of capital among incorporated firms. Since in a classical system of corporate taxation, debt is deductible, this could result in a so called debt bias.[33] Such a tax system creates distortions in the allocation of resources between firms that are reliant on debt over equity, again reducing the overall factor productivity. Also the fact that high technology firms also are particularly reliant on equity capital makes the debt bias unfortunate for productivity growth. Due to credit market frictions, new firms may have more trouble in obtaining enough capital. This therefore harms newly established firms disproportionately, since the are more are reliant on debt to finance investments, Sinn (1991).[34] Again, this causes firms to face different costs of capital, distorting productive efficiency.

In sum, there are several additional interesting properties with DIT in relation with economic growth. Some of the effects mentioned above are

[33]There are other adverse consequences of the debt bias. The idea is that if firms can deduct interest payments from their tax bill, they will favor debt over equity, worsening their balance sheets. This may have adverse consequences for factor utilization and productivity over the course of the business cycle.

[34]Financing investment through retained earnings is obviously also more difficult for new firms.

likely to have an impact on productivity growth, while with others it can be anticipated to have an effect on transitory growth rates. However, the nature of the empirical problem and available data makes it difficult disentangle effects going through increased accumulation and through growth in productivity.

3.4.3 Extensions

Important extensions and improvement of this the empirical analysis above could be done along a number of lines. As already denoted, it is crucial to improve the data, in particular a richer representation of capital taxation. In addition, the data set should be extended with more variables and longer time series for some of the countries that lack data. This would allow putting more structure on the empirical model and add various assumptions on country interdependencies. In addition, more variables on tax rates would improve the analysis substantially, allowing the analysis to account for detailed differences in tax structures. This would allow for an analysis of different degrees of dual income tax system by creating a measure of this property. It is also likely that some aspects of the DIT reform are lost in the aggregation of the data. Another analysis with more disaggregated data is likely to be able to reveal more of the impact of DIT on economic growth.

4 Conclusion

In this master thesis I have analyzed the effect of a DIT on economic growth. There are several theoretical arguments that suggest that a dual income tax reform will have a positive impact on economic growth. These have been highlighted in the theoretical model. In particular, reducing tax rates on capital, the corporate income tax and double taxation of capital will cause transitory growth rates in excess of equilibrium productivity growth. In addition there are likely to be gains from increased allocative efficiency of capital between different firms. In the empirical part of the analysis I find some support of the hypotheses of the theoretical model. I estimate a positive impact of the DIT reforms of the nordic countries and preceding economic growth in these countries. This result is robust to different specifications, in line with the theoretical model and previous studies on economic growth and taxation, for example Barro (1996), Gordon and Lee(2005).[35] However, the empirical analysis suffer from many of the same deficiencies that other analyses of this type do, thus the aggregate data used in this thesis are insufficient in establishing a causal link between DIT and economic growth. Future work should apply improved data sets, which opens up for a closer examination of the problems raised in this study. However, so far I am inclined to believe that the DIT is beneficial for economic growth. At least this study has not proven otherwise.

[35] In the appendix I show that the conclusion remains the same using a random effects model.

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A

Theoretical appendix

A.1 A solution to the household's problem with taxation of capital and labor income

I use the Hamilton function in the text. The current value Hamiltonian can not be applied since in a general equilibrium setting, all the endogenous variables potentially vary over time. Using the maximum principle for infinite horizons I get the following necessary conditions for a maximum.

$$(i) \quad u'(c)e^{-\rho t} - \mu(t)p(t) = 0$$

$$(ii) \quad u'(l)e^{-\rho t} + \mu(t)w(t) = 0$$

$$(iii) \quad \mu'(t) = -\mu(t)r$$

The condition for optimal labor supply follows directly. The condition for the optimal path of consumption follows from (i) and (iii). Since

$$u'(c)e^{-\rho t} - \mu(t)p(t) = 0 \tag{64}$$

The derivative with respect to time is given by

$$p'(t) = \left(\dot{c}u''(c) + l'(t)\frac{\partial u^2}{\partial c \partial l}\right) e^{-\rho t} - \rho e^{-\rho t} u'(c) \tag{65}$$

Combining with (iii) gives the following equality.

$$\frac{u'(l)e^{-\rho t}}{(1 - t_w)w(t)} = \left(\dot{c}u''(c) + l'(t)\frac{\partial u^2}{\partial c \partial l}\right) e^{-\rho t} - \rho e^{-\rho t} u'(c) \tag{66}$$

Using the condition for optimal labor supply gives

$$u'(c)e{-}\rho t = \left(\dot{c}u''(c) + l'(t)\frac{\partial u^2}{\partial c \partial l}\right) e^{-\rho t} - \rho e^{-\rho t} u'(c) \tag{67}$$

Using the elasticity of marginal utility with respect to consumption and ignoring exogenous growth in prices and taxes the Euler equation from section 2 is found by rearranging this expression.

$$r = \rho + \varepsilon \frac{\dot{c}}{c} - \frac{\partial u^2}{\partial c \partial l} \frac{l}{u'(c)} \frac{\dot{l}}{l} \tag{68}$$

The necessary conditions of the maximum principle yields the maximum utility for the household by Mangassarian's theorem.

A.2 Growth in labor supply

Labor supply is determined endogenously in the model. It is therefore a function of the growth in the real wage and growth in optimal consumption. Using the specified functional form and that the price of consumption is defined as the numeraire I get,

$$\varphi(1+\sigma)l^{\sigma}c = w \tag{69}$$

Using that

$$\hat{c} = \frac{c}{Al} \tag{70}$$

Using this and the equilibrium condition I find the following equality

$$\varphi(1+\sigma)l^{\sigma+1} = \frac{(1-\alpha)\hat{k}^{\alpha}}{\hat{c}} \tag{71}$$

Taking the total derivative of this expression with respect to time gives the expression below.

$$\varphi(1+\sigma)^2 l^{\sigma} l'(t) = \frac{(1-\alpha)\alpha\hat{k}^{\alpha-1}\hat{c}\hat{k}'(t) - (1-\alpha)k^{\alpha}\hat{c}'(t)}{\hat{c}^2} \tag{72}$$

Rearranging this expression gives the following expression

$$\varphi(1+\sigma)^2 l^{\sigma} l'(t) = \frac{(1-\alpha)\alpha\hat{k}^{\alpha-1}}{\hat{c}} \left[\frac{\hat{k}'(t)}{\hat{k}(t)} - \frac{\hat{c}'(t)}{\hat{c}(t)} \right] \tag{73}$$

Using that,

$$\varphi(1+\sigma)l^{\sigma+1} = \frac{(1-\alpha)\hat{k}^{\alpha}}{\hat{c}} \tag{74}$$

I find the expression below by rearranging

$$\frac{\dot{l}}{l} = \frac{\alpha}{1+\sigma}\frac{\dot{\hat{k}}}{\hat{k}} - \frac{1}{1+\sigma}\frac{\dot{\hat{c}}}{\hat{c}} \tag{75}$$

A.3 A solution to the firm's problem

The Hamilton function of the problem is given by the following expression,

$$\hat{H}(t, K, \mu, r, w) = f(K, L) - I - wL]e^{-rt} + \mu(t)(I - \delta K) \tag{76}$$

Maximizing with respect to I yields,

$$\mu(t) = e^{-rt}. \tag{77}$$

Further,

$$\mu'(t) = -\hat{H}'(K) = -e^{-rt}f'(K) + \mu(t)\delta \tag{78}$$

Taking the derivative of the first expression and inserting yields,

$$-re^{-rt} = -e^{-rt}f'(K) + \delta e^{-rt} \tag{79}$$

This condition gives the optimal capital function $K^{*}(t)$ that maximizes the problem for a given function of labor demand. Finding the labor demand is then like a static problem an amounts to maximizing the profit for each time t.

A.4 The growth rate of capital per efficient capita

The aggregate resource constraint is found by combining the equilibrium conditions with the consumers budget constraint.

$$\dot{k} = rk + wl - pc \tag{80}$$

Again using the definition of the per efficient capita formulation of capital

$$\hat{k} = \frac{k}{Al} \tag{81}$$

Taking the derivative of this expression gives,

$$\dot{\hat{k}} = \frac{\dot{k}Al - [k\dot{A}l + kA\dot{l}]}{(Al)^2} \tag{82}$$

Inserting for $\dot{k}$ gives the following expression

$$\dot{\hat{k}} = \frac{rk + wl - c}{Al} - \hat{k}\left[x + \frac{\dot{l}}{l}\right] \tag{83}$$

Using the equilibrium conditions and rearranging I get the equation for the growth rate of capital in the text.

$$\frac{\dot{\hat{k}}}{\hat{k}} = \hat{k}^{\alpha-1} - \left[\delta + x + \frac{\dot{l}}{l}\right] - \frac{\hat{c}}{\hat{k}} \tag{84}$$

Using the expression for the growth rate of labor the above expression can be reduced further. I will however abstain for this because I do not need the reduced form equation for the growth in capital for my applications.

A.5 The firm's problem with non-neutral taxation of profits

For simplicity I rewrite

$$(1-\tau)(f(K,L) - sI - wL) - (1-s)I \tag{85}$$

to

$$(1-\tau)(f(K,L) - wL) - (1-s\tau)I. \tag{86}$$

As already noted, the present value hamiltonian can not be used in a general equilibrium setting. I therefore formulate the problem as in the firm's problem above. Maximizing the hamilton function with respect to the control yields the following equation,

$$\mu(t) = e^{-rt}(1 - s\tau), \tag{87}$$

where $\mu(t)$ is the costate function of the problem. Then I use the following first order condition,

$$\mu'(t) = \mu(t)\delta - e^{-rt}(1 - \tau)f'(k). \tag{88}$$

Taking the derivative of the first first order condition with respect to time yields the following equation,

$$\mu'(t) = -re^{-rt}(1 - s\tau). \tag{89}$$

Inserting and rearranging yields the following expression,

$$-re^{-rt}(1 - s\tau) = \delta e^{-rt}(1 - s\tau) - e^{-rt}(1 - \tau)f'(k). \tag{90}$$

Solving this for the marginal product of k yields the following expression,

$$f'(k) = \frac{(1 - s\tau)}{(1 - \tau)}(\delta + r). \tag{91}$$

In the body of the text I denote,

$$\frac{(1 - s\tau)}{(1 - \tau)} = \frac{1}{(1 - \tau_f)}, \tag{92}$$

where τ_f can be interpreted as the effective tax rate on capital on the firm. Thus,

$$\tau_f = \frac{\tau(1 - s)}{1 - st}. \tag{93}$$

When s=1 it is clear that the effective tax rate is zero. In this case all costs are deducted from the profits and this case therefore amounts to the well known property that taxation of pure rents is neutral. Decreases in s drives a wedge between the real and private return of capital from the viewpoint of the firm.

A.6 Growth rates in consumption and capital

By combining the equations on growth rate in capital, consumption and labor supply it is possible to find the growth rate in consumption and capital expressed only by exogenous variables. The three equations are given by the following expressions as elaborated upon above.

$$\frac{\dot{\hat{k}}}{\hat{k}} = \hat{k}^{\alpha-1} - \left[\delta + x + \frac{\dot{l}}{l}\right] - \frac{\hat{c}}{\hat{k}} \tag{94}$$

$$\frac{\dot{\hat{c}}}{\hat{c}} = \alpha\hat{k}^{\alpha-1} - (\delta + \rho + x) - \frac{\dot{l}}{l} \tag{95}$$

$$\frac{\dot{l}}{l} = \frac{\alpha}{1+\sigma}\frac{\dot{\hat{k}}}{\hat{k}} - \frac{1}{1+\sigma}\frac{\dot{\hat{c}}}{\hat{c}} \tag{96}$$

By inserting the growth rate of labor supply into the growth rate of capital and consumption and then combining these two expressions.

A.7 Steady state

The steady state values of the system are found by solving the system below.

$$0 = \hat{k}^{\alpha-1} - [\delta + x] - \frac{\hat{c}}{\hat{k}} \tag{97}$$

$$0 = \alpha\hat{k}^{\alpha-1} - (\delta + \rho + x) \tag{98}$$

$$\varphi(1+\sigma)l^{\sigma+1} = \frac{(1-\alpha)\hat{k}^{\alpha}}{\hat{c}} \tag{99}$$

This is a well defined system of three equations and three unknowns. This gives the steady state value of all the endogenous variables that are displayed in the body of the text in section two.

A.8 Production efficiency

Equalizing tax rates on capital is done to impact the production efficiency of the economy. Having mentioned this several times, this will be elaborated upon in this subsection in a more general setting that in the model of section 2.

Taxation of firms' profits distorts the demand for capital, inducing the overall level of investment, and therefore the capital intensity to become inefficiently low. However, taxing capital differently for different firms also causes static distortions in the market for capital. This could happen if a lower tax rate is levied on firms that are not incorporated. This could change the cost of the various inputs for different firms, if the corporate income tax is not neutral. This can be illustrated using the model by levying two different tax rates on profits for firms that in some way differ. The first order conditions of these firms are given below.

$$p_1 f_1'(K) = \frac{r}{1-\tau_1} \qquad p_1 f_1'(L) = w$$

$$p_2 f_2'(K) = \frac{r}{1-\tau_2} \qquad p_2 f_2'(L) = w$$

These equations can be combined to yield the condition for production efficiency.

$$\frac{\frac{f_1'(K)}{f_1'(l)}}{\frac{f_2'(K)}{f_2'(l)}} = \frac{1-\tau_2}{1-\tau_1} \tag{100}$$

The first best allocation is characterized by the following equality.

$$\frac{\frac{f_1'(K)}{f_1'(l)}}{\frac{f_2'(K)}{f_2'(l)}} = 1 \tag{101}$$

This results in a tax induced wedge on the productive efficiency in the case of corporate taxation that is proportional to the difference in the tax rates on the two firms. The right hand side of this expression is the ratio of the marginal willingness to pay labor for an additional unit of capital in the corporated and unincorporated sector. Since the ratio is less than one, the corporate sector values an additional unit of capital more than the unincorporated sector. Thus, pareto-improving trades between the sectors are possible, but the corporate tax rate prevents these trades from taking place. This shows that corporate taxation has an additional harmful effect on the equilibrium allocation of capital also within each period. Taxing all types of capital equal to the corporate tax rate may alleviate this distortion. Thus taxing different organizational forms of firms more equal will realize production efficiency. As can be seen above, this will remove all the intratemporal distortions in the capital markets of the model. This is taking the economy back to the first best allocation of capital and labor in the intratemporal equilibrium. The productive capacity of the economy could then be increased by using resources more efficiently.

B

Empirical appendix

B.1 Testing for robustness of the results

In this section I estimate the same relationship using a random effects model. The estimates are reported in table 4. The estimates on the control coefficients are less stable over the different specifications and less as expected from economic theory. However, the DIT variable remains positive and significant. The effect of including data on corporate income taxation remains the same as in the fixed effects approach.

B.2 Testing for unit roots in a panel data setting

It is well known that many time series on aggregate macroeconomic data are not stationary, they thus follow a random walk, (Davidson and Mackinnon (2009)). This has consequences for the interpretation of the estimated parameters of the econometric model. If there is a presence os a unit root in some of the variables of the panel this might result in spurious regressions, estimating a positive and significant result that is completely a result of the random walk of the time series. In addition the estimates of coefficients do not follow the standard t-distribution. Rather it follows the Dickey-Fuller distribution. This has potential consequences for the inference that can be done with the estimated model and needs to be taken account of. I find strong evidence that all the series are either integrated to order one or zero using the Dickey-Fuller test for panel data. The logarithm of unemployment show strong signs of unit roots. Conducting the same test for this variable with the first difference I find that there is a strong indication that the series is integrated of the first order. This is taken account for in the specification of the model by using the differenced series.

Table 4: Estimation with OLS

Dependent variable: Log GDP per capita	(1)	(2)	(3)	(4)	(5)
Baseline model					
Capital stock	.023	.04	.049	.039	
	(.001)	(.004)	(.008)	(.003)	(.003)
Human capital	.07	-3.64	-2.87	-3.50	-3.28
	(.130)	(.27)	(.37)	(.249)	(.207)
Population growth	-.069	-.56	-.27	-.531	-.515
	(.035)	(.18)	(.262)	(.163)	(.133)
Control variables					
ΔLogUnemployment rate		-.033	.075	.0151	.47
		(.32)	(.24)	(.29)	(.243)
R&D intensity		1.7	-.185	-.683	-2.76
		(1.69)	(2.33)	(1.57)	(.291)
Inflation		.02	.0001	.054	.040
		(.030)	(.003)	(.027)	(.022)
Saving rate		.001	.023	.002	..004
		(.012)	(.018)	(.011)	(.009)
FDI		-2.00 e-6	-1.8e-7	-1.54e-6	-6.23e-7
		(.000)	(.000)	(.000)	(.000)
Terms of trade		-.02	-0.18	-.025	-.020
		(.004)	(.006)	(.004)	(.003)
Tax variables					
Average tax wedge			.009		
			(.008)		
Corporate income tax			-4.64		-4.72
			(1.32)		(.697)
DIT				**.508**	**.24**
				(.09)	(.017)
Number of observations:	208	103	56	103	103
R^2 overall:	0.26	0.96	0.98	0.95	0.97

Note: All the coefficients are estimated using country random effects. Standard errors are in brackets.