Session Number: 8A

Session Title: Contributed Macro Papers: Topics in National and Historical Accounting and Productivity Comparisons

Paper Number 15

Session Organizer: Edward Wolff

Paper Prepared for the 28th General Conference of

The International Association for Research in Income and Wealth

Cork, Ireland, August 22-28, 2004

TWENTY WAYS TO AGGREGATE CAPITAL:
DOES IT REALLY MATTER FOR A STUDY OF ECONOMIC GROWTH?

ABDUL AZEEZ ERUMBAN

For additional information please contact**:**

Abdul Azeez Erumban
Faculty of Economics
University of Groningen
Post Bus 800
9700 AV GRONINGEN
The Netherlands
Tel: +31 (0) 50 363 3762
Fax: +31 (0) 50 363 7337
E-mail: a.azeez.erumban@eco.rug.nl

Twenty Ways to Aggregate Capital

Does it really Matter for a Study of Economic Growth?

Abdul Azeez Erumban[#]

Abstract

With the increasing importance of investment in Information Technology, methods for measuring the contribution of capital to growth have assumed center- stage again in growth accounting literature. The importance of using growth of capital services rather than capital stocks has long been advocated, and has become mainstream practice. However, the choice for a particular rate of return in the derivation of capital service prices is not straightforward and has barely been researched.

Using four alternative rental price models – based on both external and internal rates of return models–this paper quantifies differences in capital service growth rates under different model assumptions. These differences are examined on two grounds: firstly, the differences when different rental price models are used; and secondly, the differences when allowances are made for the effect of taxes and subsidies in the calculation of rate of return and rental prices.

We have carried out empirical analysis for four European Union countries, in 26 industries, across 6 asset types from 1982 to 2001. The results show that the inclusion of taxes in the rental price formulation has little impact in most industries. Hence, from the empirical point of view, given the dataset, the use of pretax rental prices may not produce significantly different results in most industries. In contrast, considerable differences are observed between growth rates generated by external rate of return models versus internal rate of return models. Hence, considering the fact that the internal model assures a complete consistency of national income and production accounts, one may prefer the internal rate of return models in calculating capital input rates in a productivity analysis.

[#] *Faculty of Economics, University of Groningen, Post Bus 800, 9700 AV Groningen, The Netherlands,* ***E-mail:*** *a.azeez.erumban@eco.rug.nl*

I am thankful to Bart van Ark, Marcel Timmer and Robert Inklaar for their comments on this paper. I also received useful comments from Gerard Kuper.

Twenty Ways to Aggregate Capital

Does it really Matter for a Study of Economic Growth?

Abdul Azeez Erumban

I. Introduction

Capital is undeniably a major source of growth; it has made an important contribution to differences in growth rates between countries and times (Denison, 1980). With the increasing importance of investment in Information and Communication Technology (ICT), methods for measuring the contribution of capital to aggregate growth have reassumed centre-stage in growth accounting literature. Many recent studies have shown that ICT-capital has contributed significantly to productivity growth (Jorgenson, 2001; Van Ark et al., 2002) though the extent of contribution varies across countries. Dividing the total capital into ICT capital and non-ICT capital, studies have attempted to delineate the contribution of these two different components to total growth using the growth accounting framework.[1] One major issue in the quantification of capital's contribution to growth using this framework is related with the measurement of capital input. Though the concept is well defined in theory, empirical measurement has been a longstanding subject of debate.[2] Nevertheless, it has long been advocated and has become mainstream practice that the capital services from an asset, rather than the capital stock, is appropriate for production and productivity analysis. Jorgenson (2001) has argued that the difference between growth in capital services and capital stock represents the improvement in capital quality.[3] The introduction of ICT into a production process is expected to improve the quality of capital significantly, which might enhance labour productivity. The

[1] Growth accounting allows the decomposition of total growth into the contribution of the growth of inputs and to a residual factor. This residual is considered to be a depiction of multi factor productivity (MFP) and is often called *Solow residual*, as the theoretical premise of this framework is largely derived from Solow (1957).
[2] See the literature on the well-known Cambridge controversy (for example, Harcourt, 1972 and Harcourt and Laing, 1971 and the papers therein).
[3] The premise of this view is that the difference between growth of capital services and capital stock represents the substitution toward assets with higher marginal products. For instance, a shift toward ICT capital increases the quality of capital, as these equipments have relatively high marginal products.

observed improvement in labour productivity in ICT using sectors (van Ark et al., 2002) may be considered to indicate such quality changes, and therefore signifies the importance of reliably estimating capital service flows.

The challenge in measuring capital input for growth accounting is associated with the implicit nature of capital services; the quantity of capital services is not usually directly observable (Harper et al.). Therefore, the empirical researcher has to rely on theoretical yardsticks to approximate the capital services. Following the theoretical arguments of Jorgenson (1963)**,** Hall and Jorgenson (1967), and Jorgenson and Grilliches (1967) capital services are usually derived using the estimated capital stock for the individual assets and the relevant user cost or rental price of capital, assuming that flows are in proportion to the stock of assets. However, there are different ways of measuring rental price of capital and thereby of obtaining capital service growth rates. And the selection of any particular measure will significantly influence the calculated growth rates and contributions. The study by Harper et al. (1989) utilizes 5 alternative rental price models to evaluate the capital aggregation for US manufacturing industries over the 1948-81 period. Their results show significant differences between different models. After examining different performance measures, though empathetic to the approaches based on income identity, they draw no strong conclusions on the matter.

The aim of this paper, in line with Harper et al. (1989), is to understand whether different rental price models produce significantly different capital service growth rates in the EU countries. This is important in the face of the recent surge in growth accounting literature that examines the contribution of ICT capital. While Harper et al. limits their study to the US only, we compare our results across 26 industry groups in four EU countries, over the 1982-2001 period. Also an attempt is made to empirically understand the impact of including tax in the cost of capital equation on the growth rates of capital. It has been argued that tax plays a major role in altering investment behavior (Hall and Jorgenson, 1967), and therefore, taxation has to be incorporated in the measurement of capital service prices. However, most studies in the context of the EU have considered pretax rental prices in order to arrive at capital service growth rates. Thus this study examines the sensitivity of final growth estimates for capital services, with respect to different measures of capital service aggregation.

This paper is organized into seven sections. In Section 2 we present a brief discussion on the analytical literature concerning growth accounting and capital aggregation. In Section 3 we discuss rental price formulation in brief, and in Section 4 we discuss different rates of return models used in deriving rental prices. Section 5 briefly discusses the data used in the study. Empirical results are discussed in Section 6, and finally Section 7 concludes the paper.

II. Growth Accounting and Capital Aggregation[4]

Growth accounting framework assumes total growth as a sum of weighted input growth and productivity. Assuming a competitive market and constant returns to scale, one may write the aggregate production function, with value-added as output (Q) and labor (L) and capital (K) as inputs, as

$$Q_t = A_t \, f_t \, (L_t, K_t) \qquad (1)$$

where A denotes the technical progress or the MFP. Then assuming a translog approximation, the growth accounting equation may be written as,

$$\ln(Q_t/Q_{t-1}) = \alpha(_{t,\, t-1})\ln(L_t/L_{t-1}) + (1-\alpha(_{t,\, t-1}))\ln(K_t/K_{t-1}) + \ln(A_t/A_{t-1}) \qquad (2)$$

where $\alpha(_{t,\, t-1})$ is the share of labor in value-added averaged over the two time periods, t and t-1. Equation (2) clearly shows that output growth is measured as a weighted sum of growth of labor and capital flows, where the weights are the share of each input in the value added. Similarly, growth in aggregate inputs may be calculated as the cost share weighted sum of growth of inputs (Jorgenson et al., 1987). In the case of labor such weights may be derived from the wage rates. The absence of an observable service price, however, makes it difficult to directly measure aggregate capital growth rates.

Capital stock consists of different types of heterogeneous assets, associated with specific capital service flows, making it essential that some kind of aggregation exists in order to employ equation (2). Assuming a strict proportionality between capital services and capital stocks at the level of individual assets, Jorgenson (1963) and Jorgenson and Grilliches (1967) have developed aggregate capital service measures that take into

[4] See OECD (2001 a and b)-both capital and productivity manuals- for detailed discussion on both these issues. Also see Hulten (2000) for detailed discussion on issues regarding productivity measurement.

account the heterogeneity of assets. In accordance with their aggregation procedure, the growth rate of aggregate capital may be measured as

$$\ln(K_t / K_{t-1}) = \sum_{i=1}^{n} \alpha_{i(t,t-1)} \ln(K_{it} / K_{it-1}) \qquad (3)$$

$$where \quad \alpha_{i(t,t-1)} = (\alpha_{it} + \alpha_{it-1})/2$$

$$and \quad \alpha_{it} = P_{it} K_{it} / \sum_{i=1}^{n} P_{it} K_{it}$$

where n is the total number of assets, P_{it} is the rental price of i^{th} capital asset in year t , and K_{it} is the capital stock of i^{th} asset in year t. It is evident from (3) that the two important components of capital service measure are capital stock and the service prices (rental price) of capital. Hence, though the relevant measure of capital input in the productivity analysis is the flow of capital services, it is essential to have consistent measures of capital stock in productivity analyses, as they offer a practical tool for estimating capital service flows. The usual practice of measuring capital stock is based on a perpetual inventory method, i.e.

$$K_{it}=(1-\delta_i)\, K_{it-1}+I_{i\,t} \qquad (4)$$

where δ_i is the rate of depreciation for the i^{th} capital asset. K_{it} is the beginning of year constant capital stock, and I_{it} is the constant investment in asset i installed in the beginning of period t. Thus using (3) and (4) the change in aggregate capital service flow may be measured as a weighted sum of the changes in the n asset specific capital stocks, where the weights are the relative cost shares.[5] The remaining task, therefore, is to construct appropriate measures of capital service prices (P_{it}) - rental prices or user cost of capital-, in order to derive the relative cost shares.[6]

[5] Note that the growth rate of capital may also be calculated using aggregate capital stock. That is ln (K_t/K_{t-1}) where $K_t=\sum K_{it}$ and represents the stock growth. However, such growth rate may differ significantly from the calculated share weighted growth rate using (2), as the latter may exhibit quality improvement in capital services.

[6] The economic rationale of using the rental prices to calculate a reliable service growth is that the investor expects to get more services in short time from an asset whose price is relatively high (or service life is relatively small).

III. Rental Prices: Concept and Measurement

As in the case of the wage rate for labor, the rental price for capital represents the unit cost of using a capital good for a specified period of time (Jorgenson and Yun, 1991). Services from capital goods are delivered to their owner, with no recorded market transaction, over the course of several years. This absence of a complete market for capital services and their durability makes it virtually impossible to figure the appropriate service price from market transactions (Harper, Berndt and Wood, 1989). A challenge in measuring capital input for growth accounting analysis is therefore associated with this implicit nature of capital services. One requires imputing the implicit rent that the owners of capital pay themselves, and therefore, it is often called *user cost of capital*. This makes researchers depend on theoretical benchmarks to derive an appropriate formula for rental prices.

We will examine a few formulas of rental prices that have appeared in the literature in detail, to help us understand the treatment of these variables in their formulations.

Hall and Jorgenson (1967) formulates the rental price equation as

$$P = qr + q\delta - \dot{q} \qquad (5)$$

where P is the rental price, q is the asset price ($\dot{q}$ denotes the change in asset prices), r is the discount rate (rate of return) and δ is the depreciation rate. However, there exists different ways of calculating (5) empirically, depending on how one treats the different components (r, δ and $\dot{q}$) of this formula.[7] For instance, the last component, i.e. the capital gains may, *inter alia*, be incorporated in two ways. In the first case, which is generally known as Neo-classical I, capital gains are perfectly anticipated. With the subscript t representing time period, (5) may be re-written as (see Appendix 1 for derivation),

[7] For example, while in Diewert's formulation capital gain is the difference between current and future prices, in Jorgenson's formulations it is the difference between current and last year prices (See Harper et al., 1989).

$$P_t = r_t q_{t-1} + \delta q_t - [q_t - q_{t-1}] \qquad (6)$$

where the capital gain is perfectly anticipated, represented by the difference between current year and previous year prices (see, Christensen and Jorgenson, 1969 and Jorgenson and Yun, 1991). And in the second case, the Neo-classical II;

$$P_t = r_t q_{t-1} + \delta q_t \qquad (7)$$

where capital gain is assumed to be zero. Jorgenson and Siebert (1968) have observed that the Neoclassical I models are relatively preferable to Neoclassical II models.

The general formulation of rental price, thus, comprises the nominal interest cost (or opportunity cost) plus the nominal cost of depreciation (the loss in the value of the asset as it ages) minus the nominal gain from holding the asset for each accounting period. A positive capital gain reduces the user cost of holding the asset, and therefore is subtracted, while a negative gain (or a loss) increases the user cost and therefore must be added, hence it has a negative sign.

III.1 The role of Taxes

The above derivation of rental prices, based on the assumed correspondence between asset prices and service prices[8] abstracts from any type of taxes. It is important to note here that the asset price-service price correspondence depends on the tax structure for property income generated by the asset. This is because taxes are assumed to play a major role in altering investment behavior, the premise being that entrepreneurs in pursuit of gain will be more attracted to purchasing capital goods if prices are low (Hall and Jorgenson, 1967). Therefore, the derivation of rental prices of capital, which assumes strong correspondence with asset prices, should account for the impact of taxes. In this

[8] See Christensen and Jorgenson (1969) for a detailed discussion on asset/service price correspondence. Also see Appendix 1.

regard, the effect of tax policy on cost of capital has been subjected to empirical scrutiny (see, for instance, Hall and Jorgenson, 1967).[9] Furthermore, some believe that the gap between economic depreciation and capital consumption allowances for tax purposes may be a reason for capital stagnation (Auerbach and Jorgenson, 1980). Therefore, it is important to incorporate taxation and the depreciation allowances for tax purposes in rental price equation, as they will definitely impact the user cost of capital and thereby capital services. In line with Hall and Jorgenson (1967) and Harper et al. (1989), incorporating tax factors into the formula, we may re write equation (7) for ith asset as[10]

$$P_{it} = T_{it}\left[r_t q_{i\,t-1} + \delta_{it} q_{it} - [q_{i\,t} - q_{i\,t-1}] \right] + b_{it} \qquad (8)$$

And with Neo-classical 2 assumptions,

$$P_{it} = T_{it}\left\lfloor r_t q_{i\,t-1} + \delta_{it} q_{it} \right\rfloor + b_{it} \qquad (9)$$

where the subscript i stands for asset, b_{it} is the rate of taxes on production, and T_{it} is the effective rate of taxation on capital income in asset i in period t. T_{it} is calculated as[11]

$$T_{it} = \frac{1 - u_t z_{it} - k_{it}}{1 - u_t} \qquad (10)$$

where u_t is the statutory corporate income tax in year t; z_{it} is the present value of depreciation deduction for tax purpose on a unit investment on asset i over life time of investment; k_{it} is the effective rate of investment tax credit.[12]

---

[9] Hall and Jorgenson conclude that tax policy highly influences levels and timing of investment expenditures. They also note the crucial role of tax policy in changing the composition of investment; liberalization of depreciation rules has caused a shift away from equipment structures in the US, while the investment tax credit and depreciation guidelines have caused a shift towards equipment.

[10] See Jorgenson and Sulliven (1981) for a detailed discussion on the derivation of the tax incorporated rental price formula.

[11] Further discussions on effective tax rate measurement may be found in Bradford and Fullerton (1981) and Fullerton (1999)

The expressions (8) and (9) reflects the shadow price of capital (Jorgenson, 1963). These equations vividly show that it accounts for the rate of return, depreciation, (capital gain) and taxation. As we mentioned earlier, the measurement of these components may be accomplished in different ways. The first component in (5), i.e. the rate of return, represents the opportunity cost of holding an asset. It may be considered either as a nominal rate of interest payment, if a loan was taken to acquire the asset or as the opportunity cost of employing capital elsewhere than in production. The issues associated with measurement of this component will be discussed further in the next section of the paper. Measurement of the second component, i.e. the depreciation, is a well-discussed issue in economics (see Hulten and Wykoff, 1981 and other papers in Hulten, 1981). Depreciation measures the loss of the market value of a capital asset over time. It may vary over time and depend on vintage (Shreyer 2003). However, considering the computational simplicity, the general practice in empirical literature is to assume a geometric depreciation rate. The last term in (5) measures capital gain or losses, or revaluation of an asset - the change in value that corresponds to a rise or fall in the price of that asset, independent of the effects of ageing. It compares the price of new capital assets in two periods, hence is independent of ageing. Despite its crucial role in the rental price specification, the way capital gain is incorporated in the measurement of rental prices is still a matter of dispute. As equation (8) clearly shows one way of incorporating this variable into the measurement of rental prices is to assume a perfectly anticipated capital gain. Another way is to drop out this term from the user cost equation, as in the case of (9). The third possibility is to employ a smoothed capital gain series, in order to reduce the volatility of user cost terms.

IV. Measuring Rates of Return

The rate of return may be considered as the annual rate of return on an investment, expressed as a percentage of total amount invested, or as the opportunity cost of holding a capital good rather than a financial asset. It may therefore be measured either as an external rate of return (like a bond rate) or an internal rate of return. The external uses the

[12] One major approach economies follow to encourage investment was to offset tax liability through subsides or investment grants. In the US the investment tax credit was the popular one, i.e. a credit against tax liabilities in proportion to investment expenditure (Jorgenson and Yun 1991)

opportunity, or ex-ante, approach, with some exogenous value for the rate of return, like interest rates on government bonds. The internal is the residual, or ex-post approach, with which one may calculate the internal rate of return as a residual, given the value of capital compensation, depreciation and capital gains.[13]

From the productivity measurement point of view the internal approach is considered to be preferable as it ensures complete consistency between income and production accounts. This approach, advocated by Hall and Jorgenson (1967), estimates the internal rate of return with the help of an accounting identity. Defining M_t as the total rent received from the various assets in each time period t (or the property income in time t), i.e.

$$M_t = \sum_{i=1}^{n} p_{it} K_{it} = p_{Kt} K_t = V_t - W_t \qquad (11)$$

where p_{it} is the price of each asset in time t, K_{it} is the capital stock in each asset, V is the value added, and W is the labor compensation. The total capital income or property compensation is thus calculated as value added minus labor compensation, assuming a constant returns to scale.[14] It consists of pretax profits, capital consumption allowances, net interest, transfer payments, business subsidies, indirect taxes and the portion of proprietors' income attributable to capital. Therefore, while calculating the rates of return we need to adjust capital compensation for corporate taxes and indirect taxes and the internal rate of return may be measured as a residual after adjusting for measures of capital stock, depreciation, capital gain and taxes. It is also essential to assume that a) markets are perfectly competitive, b) the nominal rate of return is the same for all assets in an industry, and c) the sum of rental payments for all assets is equal to total property compensation (see 11). Nevertheless, the measurement of internal rate of return could be accomplished through different approaches, depending on the assumptions regarding capital gain. We discuss three such methods that will be used in our empirical analysis.

---

[13] See OECD (2001) for a discussion of these alternatives.
[14] Note that the sum of labor and capital compensation is identically equal to gross value added at factor cost under all the typical neo classical assumptions concerning a production function, (Berndt and Hesse, 1986).

IV.1 Internal Nominal Rate of return (INR)

The internal nominal rate of return (INR) developed by Christensen and Jorgenson (1969), incorporating tax, may be defined as

$$INR_t = \left[M_t + \sum_{i=1}^{n} \left[-\delta_{it} T_{it} q_{it} K_{it} + T_{it} \dot{q}_{it} K_{it} - b_{it} K_{it} \right] \right] / \sum_{i=1}^{n} q_{i\,t-1} T_{it} K_{it} \quad (12)$$

An important point is that in (12) the expected capital gain is represented by realized capital gain or perfectly anticipated capital gain (that is $\dot{q}_{it} = (q_t - q_{t-1})$) and thus it follows the Neoclassical 1 model.

IV.2 Internal Own of Return (IOR)

Excluding the capital gain term from internal nominal rate of return equation (12), we have

$$IOR_t = \left[M_t - \sum_{i=1}^{n} \left[\delta_{it} T_{it} q_{it} K_{it} - b_{it} K_{it} \right] \right] / \sum_{i=1}^{n} q_{i\,t-1} T_{it} K_{it} \quad (13)$$

The above specification seems to belong to the Neo-classical II, where the capital gain expectations are myopic. However, Harper, Berndt and Wood (1989) have shown that if average capital gains instead of asset-specific capital gains are employed in (12), they produce the same results as that of (13) and therefore (13) accommodates certain amount of capital gain.[15] Therefore, this model may be considered to incorporate capital gain somewhat.

In summary, the nominal rate of return is defined as the return to capital divided by the value of assets, where the return to capital is property compensation before taxes, less corporate taxes and depreciation plus asset revaluation or capital gain; the own rate of return is the return to capital, (excluding capital gain), divided by the value of assets. Hence, the INR reflects returns resulting from earnings on assets and gains accruing

---

[15] See Haper et al. (1989, p 350) for the derivation of this relationship.

through capital gain, while the IOR reflects only earnings on assets (Fraumeni and Jorgenson, 1980) and the average capital gain (Harper et al., 1989).

IV.3 Internal nominal rate of return using smoothed capital gain (MOV)

Apart from the above two assumptions regarding capital gain, another possibility is to use smoothed capital gain series. This is useful if price changes are highly volatile. The use of smoothed series reduces volatility of user cost terms (Shreyer, 2003). In accordance with Harper et al. (1989), we propose using a smoothed capital gain series by employing a three-year moving average. These figures are then substituted for the perfectly anticipated capital gain term in (12).

IV.4 Constant External Rate of Return (Const)

The above-discussed approaches are theoretically consistent under the assumptions of constant returns to scale, competitive markets and the expected rate of return equal to the ex-post, realized rate of return. However, a practical problem arises when capital income in national accounts (gross operating surplus) becomes negative.[16] In such cases, the measured rental prices using internal rate of return may also become negative, which is theoretically inconsistent.[17] One way of eliminating such negative rental prices is to employ an external rate of return. Following Harper, Berndt and Wood we take a constant rate at 3.5 per cent, which is the difference between nominal discount rate and inflation rates in the US as calculated by Fraumeni and Jorgenson (1980) (see Harper et al. 1989). Thus we substitute internal own rate of return in rental price formula (13) with a 3.5. Note that the 3.5 rate of return is assumed to be a real rate of return (net of capital gains).

We measure rates of return using the above four formulations, i.e. the internal nominal rate of return (with capital gains – Neo-classical I), the internal own rate of return (with seemingly no capital gains – Neo-classical II), internal nominal rate of return with smoothed capital gains, and constant external rate of return. Then we derive the rental prices using equations (8) and (9), substituting r by relevant rates of return measures.

[16] In cases where there are high amount of net subsidies, or losses, value added may become less than labour compensation resulting in negative property compensation.

[17] Negative user costs of capital can also arise even if the rate of return is positive, when there are large capital gains in the user cost formula

V. Discussion of Data

The data used in this study are based primarily on Inklaar, O'Mahony and Timmer (2003).[18] The study was carried out for four EU countries for the period 1982-2001. The four EU countries are the Netherlands, France, Germany and the UK.[19] Though the study by Inklaar et al. covers the period 1979-2001, our analysis only covers the period 1982-2001, as the tax data used in this study have only been available since 1982. The study was conducted for 26 industries as listed in appendix 2.

The variables used in our study are the following. *Value added:* the current price gross value added obtained from national accounts statistics. *Labor compensation:* current price costs incurred on labor by the employer. *Capital:* capital stock is estimated using a perpetual inventory method for six types of assets using equation (4). The assets considered for this purpose are listed in Table 1.[20]

Table 1 Types of assets considered

	Asset
1	Non IT machinery
2	Non Residential structure
3	Transport Equipment
4	IT Equipment
5	Communication Equipment
6	Software

Depreciation: A geometric rate of depreciation is assumed. The rates are based on Fraumeni (1997) and Jorgenson and Stiroh (2000) and are industry-specific.[21] *Asset prices*: Investment price deflators with base year 1995 are used.

Apart from the input, output and price variables, we also use tax variables in our study, for which we rely on a different source. As noted by Jorgenson and Yun (1991), appropriate tax rate to analyze the impact of tax incentives for investment is corporate income tax. Following Harper et al. (1989) we use the effective marginal rate of corporate tax, since our interest is in calculating the rental price. The marginal rate of effective taxation mirrors the incentive to invest. We derived the marginal rate of taxation

[18] For a detailed discussion on the data see chapter 7 of Inklaar, O'Mahony and Timmer (2003).
[19] Note that in the case of the UK the end year is 2000.
[20] Following Inklarr et al we have excluded residential buildings from our capital stock estimation.
[21] See Inklaar et al (2003) for more discussion.

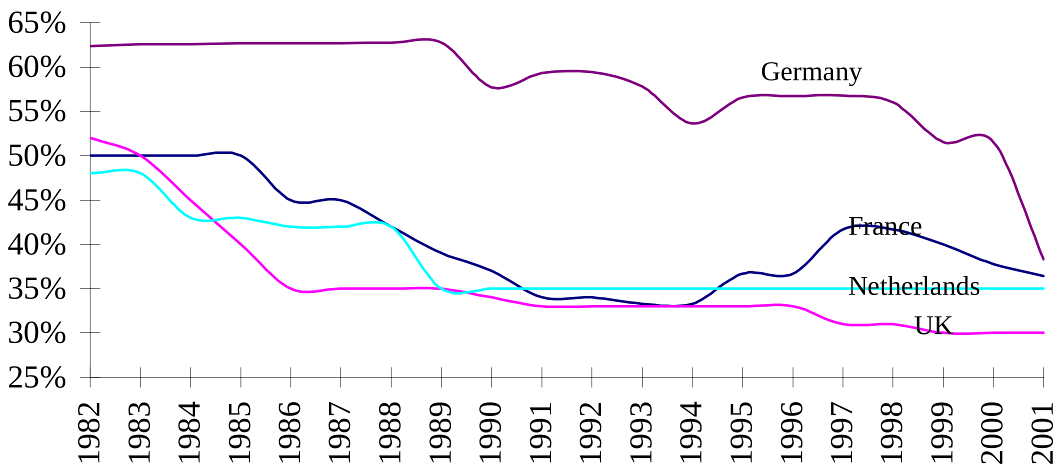
applying equation (10), using the data provided by Institute of Fiscal Studies (IFS), available from http://www.ifs.org.uk/corptax/ internationaltaxdata.zip. A detailed description of the sources, definition and construction of these data is provided in Devereux, Griffith and Klemm (2002), and Devereux, and Griffith (2003). Devereux, Griffith and Klemm (2002), provide statutory tax rates on corporate income and the present discounted value of depreciation allowances. Time series data is available for 16 countries of European Union and the G7 for 1982-2001 period, of which we use the rates for the countries Netherlands, France, UK and the Germany. These figures (see Graph 1) show a declining tendency in statutory tax rates particularly in recent years. The depreciation allowances are provided for two types of assets, i.e. the plant & machinery and industrial buildings. We have calculated the effective tax rate (T_{it}) using these two rates, in such a way that the rate for industrial buildings has been applied for non residential structures in our investment data base, and the depreciation allowances for plant and machinery are used in all other assets, including software that comes under the category of machinery. However, in the case of plant & machinery, we used the rates calculated using country specific inflation rates. Since such rates are not available for industrial buildings, we used the rates with common inflation rates.

The value added figures in our data consists of operating surplus, compensation to employees, and the taxes on production. Therefore, as we mentioned earlier, while we derive capital compensation as value added minus labor compensation, we also need to subtract taxes while deriving return. The calculation of indirect taxes ($\sum_{i=1}^{n}[b_{it}K_{it}]$) is made directly from National Accounts of selected countries. The data on taxes on production[22] was gathered from the Source OECD National Accounts Database under components of value added. These values are divided by calculated aggregate capital stock in order to arrive at the tax rate (b_{it}). However, these rates are not derived for

[22] These data consist of taxes payable on goods and services when they are produced, delivered, sold, transferred or otherwise disposed of by their producers plus taxes and duties on imports that become payable when goods enter economic territory by crossing frontiers or when services are delivered to resident units by non-resident units. They also include other taxes on production, consisting mainly of taxes on the ownership or use of land, building or other assets used in production, or on the labor employed or on compensation paid to employees.

individual assets. Instead, for deriving individual tax payments (in rate of return equations), a common rate is applied to individual capital stock estimates. Note that in our empirical calculations, we have also measured rates of return and rental prices without including this measure of indirect tax, as this data includes taxes not only on capital but also on employees' compensation. However, since the results are found to remain the same, they are not reported.

Figure 1: Statutory corporate tax rates



VI. Empirical Results

We have calculated the rental prices using the above-discussed four alternate rates of return models. As a forerunner to the general discussion on our cross-country, aggregate results, we first look at the results for a single industry, single asset in a selected country. We have plotted the measured rental prices and rates of returns using the four different approaches for the asset transport equipment in industry transport services in Netherlands in Figures 2 and 3 below. The results are provided for models with and without tax.

Figure 2: Rates of return: Transport Services, Netherlands

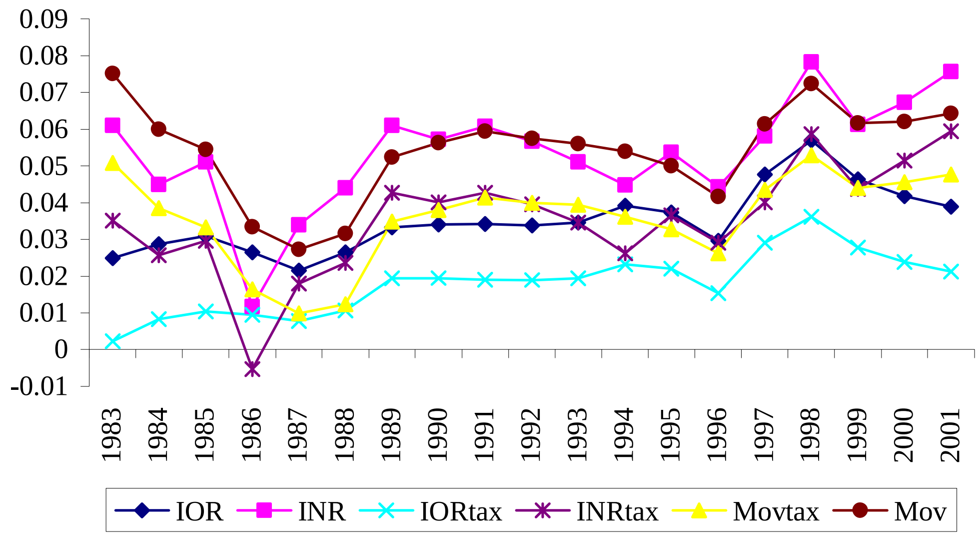
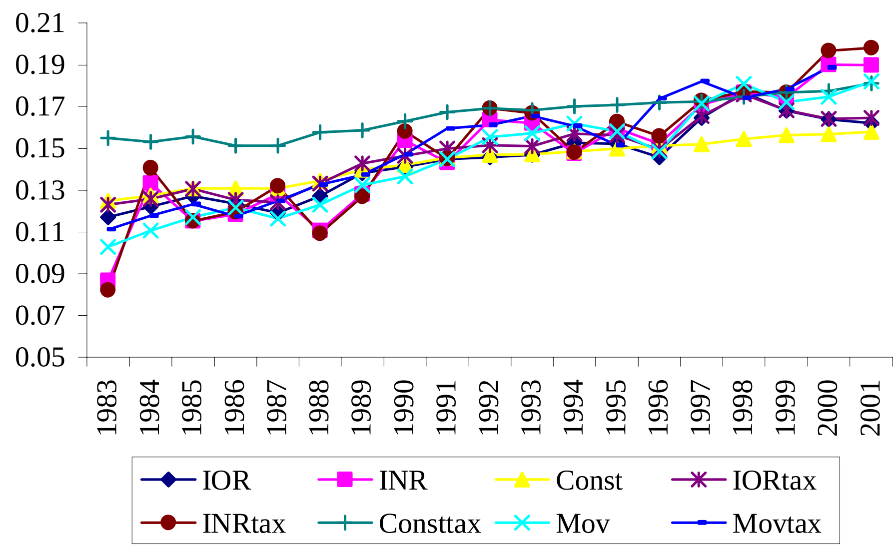


Figure 3: Rental Prices, Transport Services, Transport eqpt., Netherlands



Note: INR represents the rental prices measured using internal nominal rate of return; IOR for internal own rate of return; Mov for internal nominal rate of return with three-year moving averages of capital gains and Const for constant rate of return (3.5 per cent). All variables with tax represent the respective models, incorporating tax variables into the measurement.

An interesting feature observed in the figures is that while the rates of return show a notable decline when the tax is incorporated in the model, the rental prices show only a small increase. Thus it may be argued that though the introduction of tax variable does affect the rate of return, it only marginally affects the rental prices of the asset transport equipment in this industry. The rates of returns have shown notable fluctuations over the period. The same is the case with the rental prices also, except in constant rate of return models, which have shown almost a stable increasing tendency. However, the extent of variation in rental prices is relatively low compared to that of rates of return (see Table 2). The highest fluctuation in rental prices is witnessed by internal nominal rate of return model. The intensity of fluctuation has declined, however, while the capital gain series is smoothed using the moving averages. Therefore, the fluctuating tendency observed in the internal rates of return models may be attributed to the fluctuations in the capital gain component. For the same reason (in the presence of positive capital gains) the quantitative magnitudes of the rate of return measured using IOR is generally found to be smaller than that of INR. In comparing the internal rates of return models with those of external constant return model, one observes that the external model has produced a rental price higher than that of internal models, particularly in the first half of the period under consideration. Also, it has shown an increasing trend, which is true in the internal models too, but with more fluctuations compared to the constant returns models. Differences are also observed among the rental prices produced by internal models, though the extent of divergence is small.

Table 2: Variation in Rental Prices

Model	Mean	Standard Deviation
IOR	0.144	0.018
INR	0.148	0.028
Const	0.144	0.011
Mov	0.146	0.025
IORtax	0.148	0.017
INRtax	0.150	0.031
Consttax	0.166	0.010
Movtax	0.148	0.026

In the example of a single industry single asset case in the Netherlands data, we have observed differences between various measures of rental prices. Though the differences in the rental prices are quite marginal while the tax variable is introduced in the model, they may not be dispensed with, as they might have serious implications for the measured growth rates. There may also be considerable variations across countries, industries and asset types and therefore a generalization may not be valid. We have calculated the rental price weighted capital service growth rates using (3) for all 26 industry groups in each country separately, over the period 1982-2001. The calculated growth rates are given in Tables 1 to 2 in appendix 3. A comparison of these growth rates will tell us how much the end growth rates are affected by these different measures of rental prices.

Firstly, we look at how capital service growth rates respond when the tax variable has been incorporated in the measurement of rates of return and rental prices. Figures 4 to 7 provide the annual average growth rates of capital services produced by internal nominal rate of return model with and without tax for different countries.

Figure 4: Average Growth rates of Capital: Internal Nominal Rate of Return, Netherlands

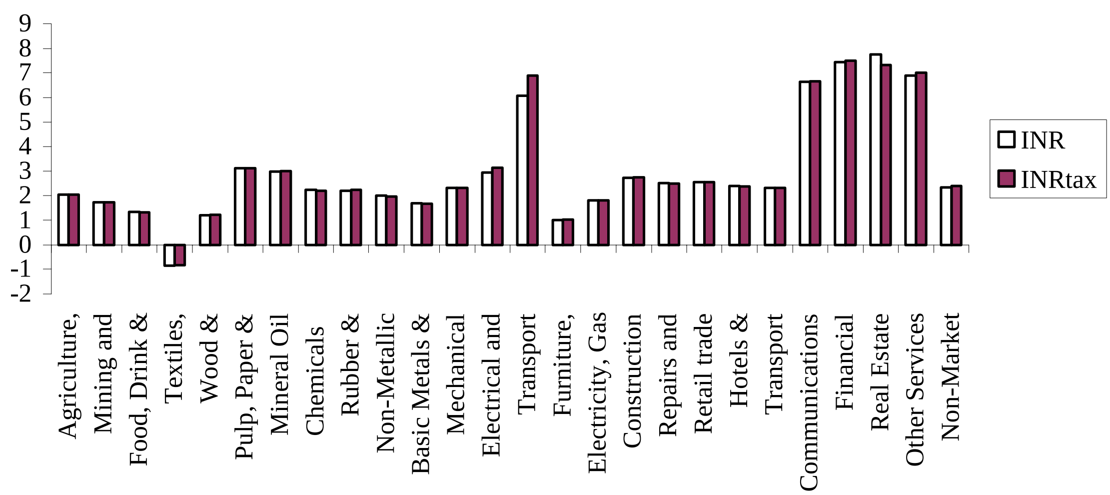


Figure 5: Average Growth rates of Capital: Internal Nominal Rate of Return, France

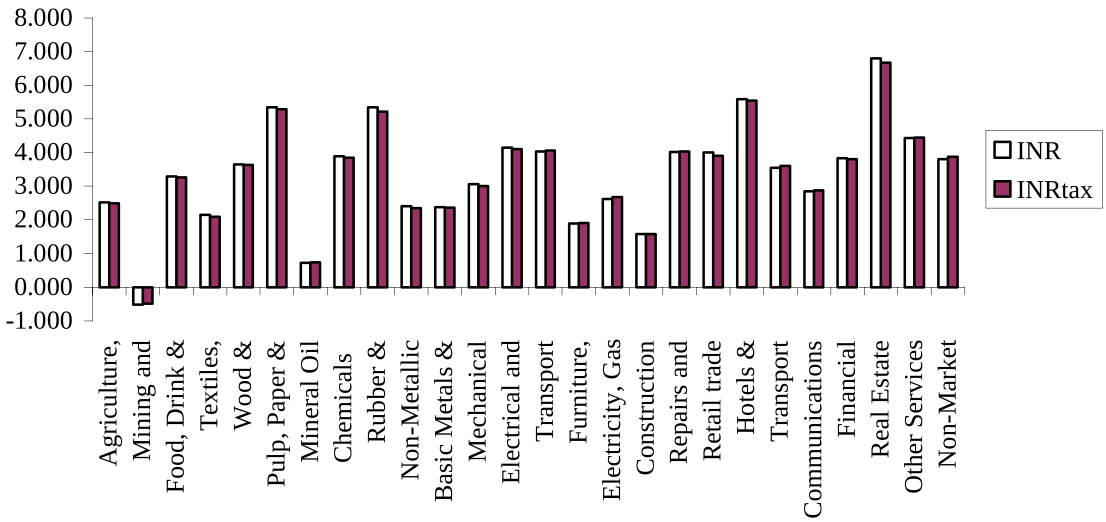


Figure 6: Average Growth rates of Capital: Internal Nominal Rate of Return, UK

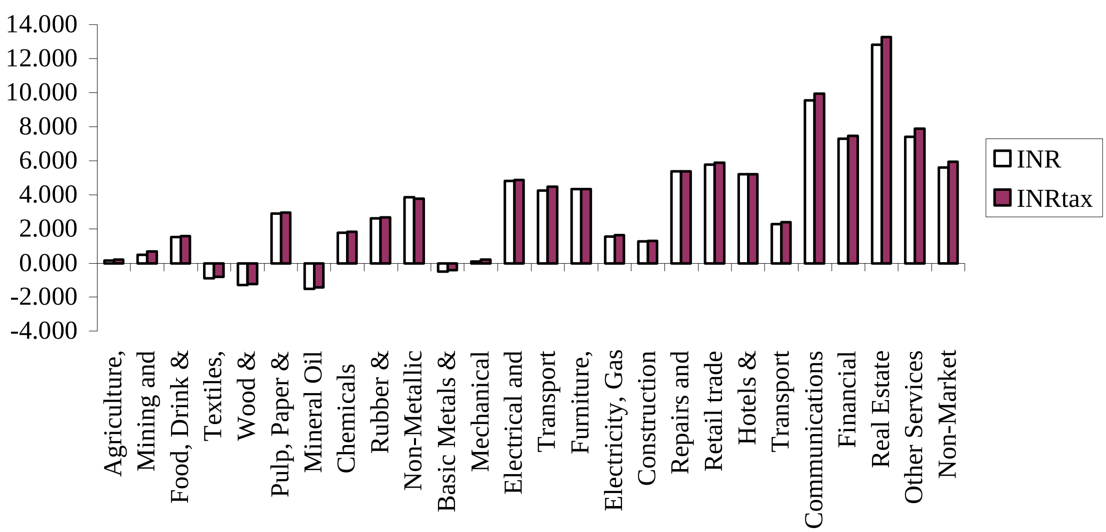
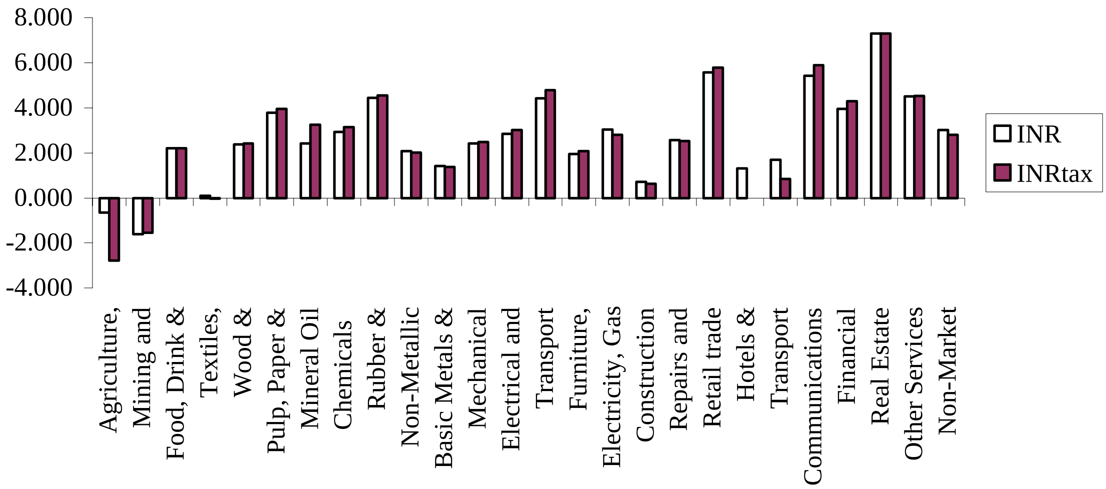


Figure 7: Average Growth rates of Capital: Internal Nominal Rate of Return, Germany



We observe, at the outset, that the impact of incorporating tax variable in the model is important in some industries, in most countries, while it is only marginal in some others. More importantly, the impact varies considerably across countries. However, the extent of visible differences is generally quite marginal (see Table 3), with few exceptions in some countries (for example Agriculture and Hotels & Catering sector in Germany). The industry real estate shows a relatively high difference in all the countries. Other industries that have shown relatively notable differences are transport equipment, electrical and electronic equipments & instruments, other services and non-market services in the Netherlands; other services, communications, non-market services, and transport equipment in the UK; rubber & plastics, retail trade, non-market service and pulp, paper & paper products in France; and agriculture, forestry & fishing, hotels and catering, transport service, mineral oil refining and communications in Germany. These differences, in most cases, are less than half a percentage point. Therefore, the extent of the tax influence on capital service growth rates may be trivial, at least in some industries.

Table 3: Difference between growth rates of capital services: the impact of taxes.

Industry	Netherlands	France	UK	Germany
Agriculture, Forestry and Fishing	0.0092	0.0223	-0.0444	2.1284
Mining and Quarrying	-0.0075	-0.0332	-0.1977	-0.0594
Food, Drink & Tobacco	0.0094	0.0243	-0.0586	-0.0103
Textiles, Leather, Footwear & Clothing	-0.0225	0.0487	-0.0810	0.1360
Wood & Products of Wood and Cork	-0.0214	0.0102	-0.0542	-0.0359
Pulp, Paper & Paper Products; Printing & Publishing	0.0046	0.0647	-0.0524	-0.1723
Mineral Oil Refining, Coke & Nuclear Fuel	-0.0241	-0.0157	-0.0636	-0.8272
Chemicals	0.0302	0.0502	-0.0820	-0.2064
Rubber & Plastics	-0.0286	0.1237	-0.0683	-0.0943
Non-Metallic Mineral Products	0.0352	0.0606	0.0775	0.0638
Basic Metals & Fabricated Metal Products	0.0120	0.0169	-0.0720	0.0520
Mechanical Engineering	-0.0102	0.0526	-0.1282	-0.0747
Electrical and Electronic Equipment; Instruments	-0.1909	0.0336	-0.0679	-0.1650
Transport Equipment	-0.8321	-0.0150	-0.2042	-0.3664
Furniture, Miscellaneous Manufacturing; recycling	-0.0213	-0.0265	-0.0013	-0.1420
Electricity, Gas and Water Supply	-0.0154	-0.0612	-0.0672	0.2372
Construction	-0.0224	-0.0051	-0.0452	0.0890
Repairs and wholesale trade	0.0251	-0.0113	0.0003	0.0396
Retail trade	-0.0003	0.1006	-0.1392	-0.1944
Hotels & Catering	0.0108	0.0406	-0.0160	1.3017
Transport	0.0091	-0.0540	-0.1283	0.8567
Communications	-0.0155	-	-	-0.4791

		0.0227	0.3980	
Financial Intermediation	-0.0501	0.0274	-0.1699	-0.3459
Real Estate Activities and Business Services	0.4437	0.1198	-0.4340	0.0099
Other Services	-0.1381	-0.0241	-0.4586	-0.0326
Non-Market Services	-0.0545	-0.0768	-0.3323	0.2210

Note: Differences are calculated as average capital service growth rate (without tax) – average growth rate (with tax), both using internal nominal rate of return (INR) models; a positive difference implies the growth rate decreases when the tax is incorporated.

The above observations are based on the internal nominal return models. A similar picture is observed in the case of the smoothed capital gains model, internal own rates of return models and constant return models (see Tables 4 to 6 in appendix 4). Divergence exists among different models in some industries in some countries when tax is introduced. As observed above, the differences are not very high. In most cases the divergence is less than half a percentage point with a few possible exceptions. For instance in the external rate of return model for France, Financial Intermediation and Real Estate have registered a slight decline in growth rates when tax is introduced into the estimation. If we look at the tax structure, we observe that both these two industries are highly taxed industries in France. On the other hand Mining and Quarrying in Germany, which enjoys huge amounts of subsidies, has witnessed a surge in growth. In the IOR model Transport Equipment and Real Estate in the Netherlands has registered a notable difference. While the former witnessed an increase, the latter registered a dip in the growth rate. In all the internal models, the sectors of Agriculture, Mineral Oil & Refinery, Hotels & Catering, and Transport in Germany have shown differences in growth rates. While hotels & caterings have shown a decline in their growth rates, mineral oil and refining have shown an increase. Interestingly, the agricultural sector has shown an increase in IOR model, while it has shown a decline in INR and Mov models, probably due to the presence of capital gain term. In general the differences in all countries and in all models are observed to be relatively higher in service sector industries. Most service sector industries have shown a decline, though marginal, in their growth rates, probably owing to the relatively high rates of taxes in these industries. Thus it seems that the tax variable has an indispensable effect, though it varies significantly across industries, on capital growth rates (aggregated using rental price shares) in all the countries considered.

Figure 8: Average Growth rates of Capital: Alternative rental prices, Netherlands

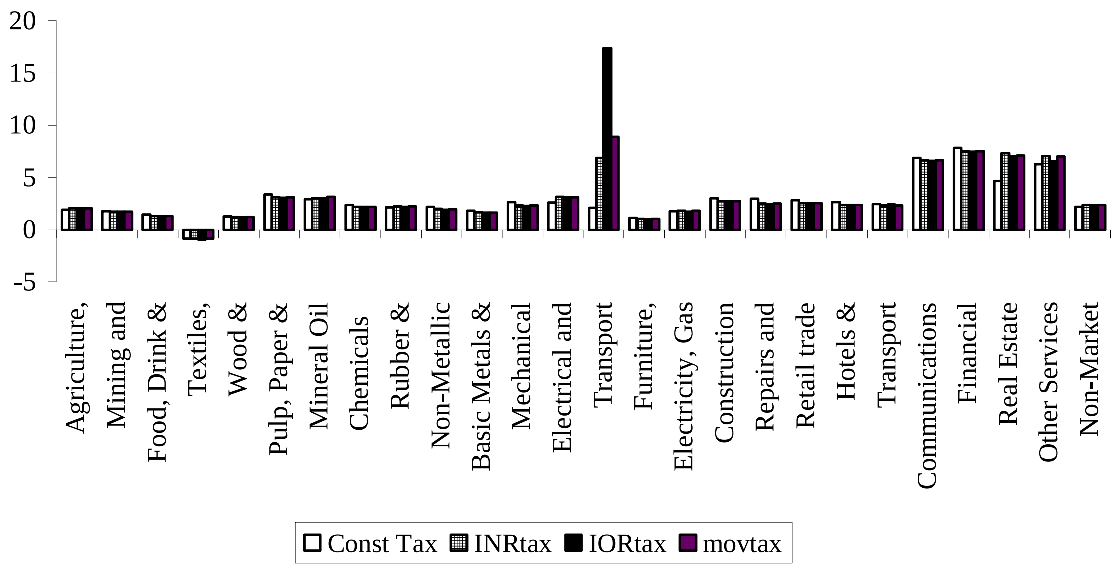


Figure 9: Average Growth rates of Capital: Alternative rental prices, France

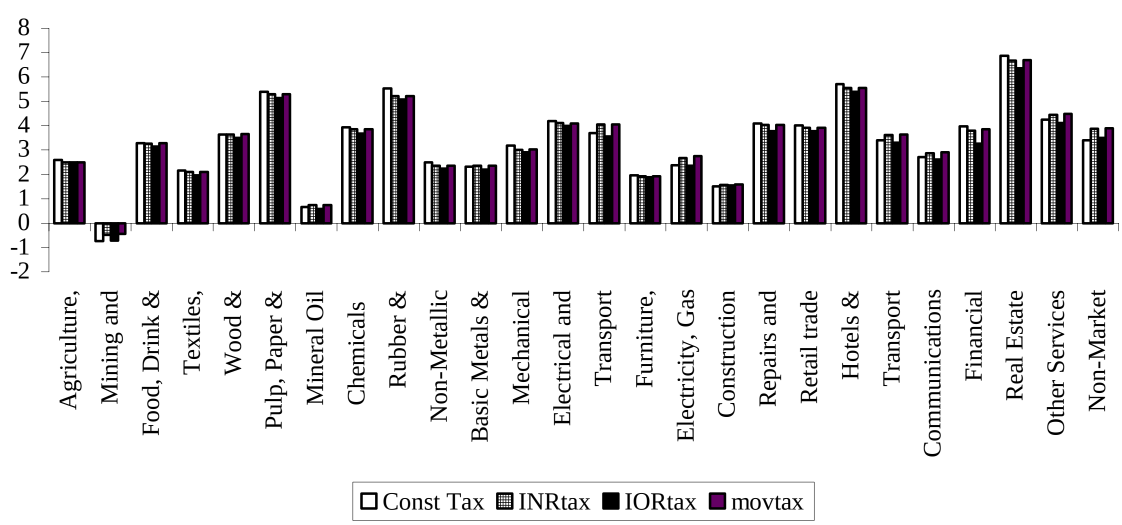


Figure 10: Average Growth rates of Capital: Alternative rental prices, UK

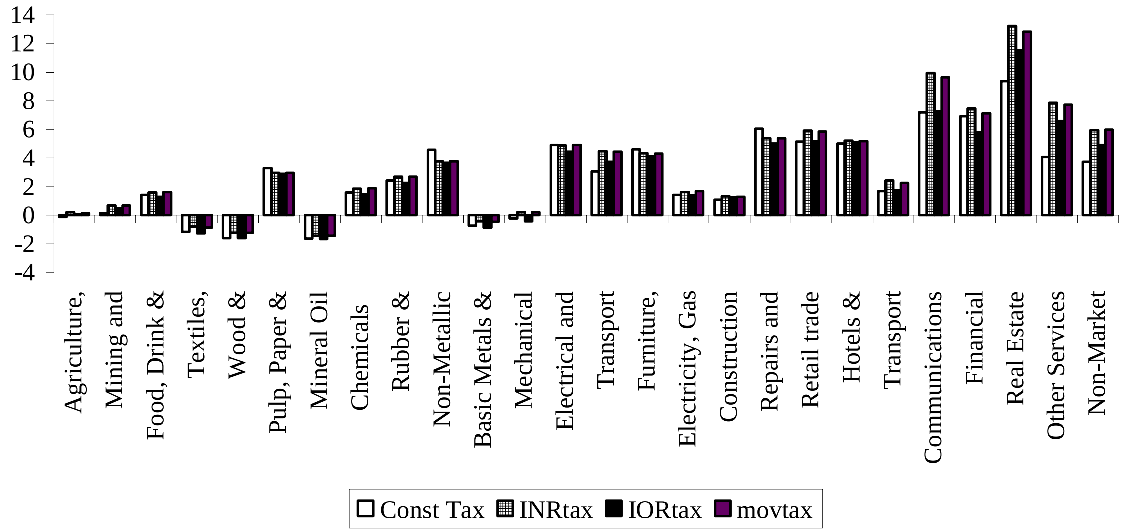
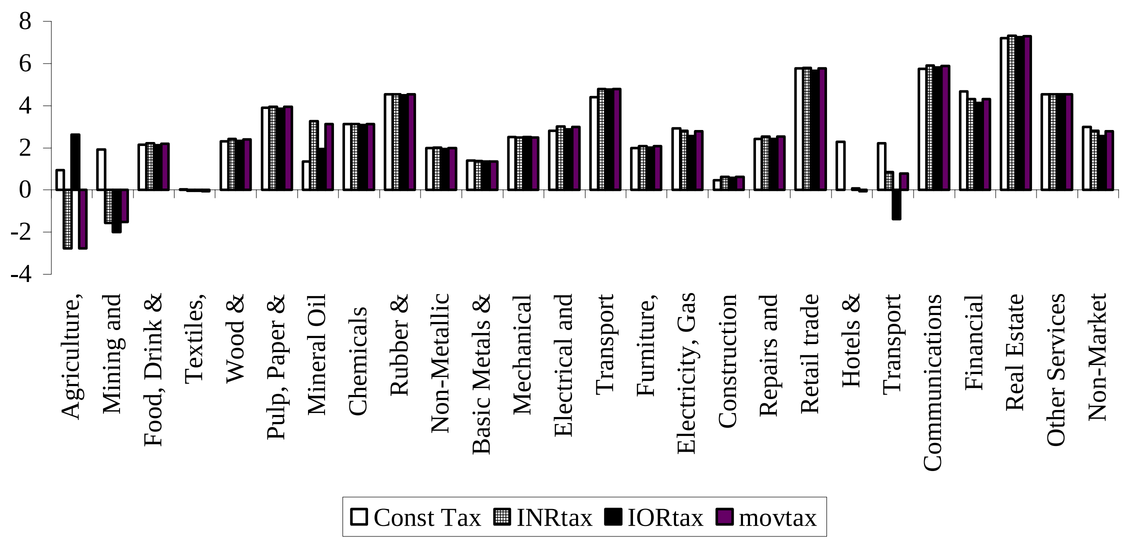


Figure 11: Average Growth rates of Capital: Alternative rental prices, Germany



With regard to the three different models we have considered, the evidences emerging from figures 8 to 11 are that there are differences between the growth rates generated by different measures. Despite the lower quantitative magnitudes, we note that the discrepancies between these measures may not be taken trivial. The divergence is more between constant rates of return models and internal rates of return models, while it is relatively less between the internal models. This pattern holds across countries. Thus it seems that there is considerable differences in the growth rates produced by internal and external rates of return models, though such differences varies across industries and countries.

Moreover, within the internal rates of return models, they too produce different results in few industries, though the degree of difference may be debatable. The differences are observed to be relatively small between internal nominal return models and smoothed capital gain models. There are exceptional cases however. The Transport Service sector in Germany, for instance, has shown a notable divergence between INR and smoothed capital gain model; the growth rate just been reversed! Similarly the Transport Equipment sector in Netherlands has shown a significant hike in the growth rate while IOR model is used. Note that these observations are based on the model with tax incorporated, as we have already seen that the incorporation of tax affects the results though not across the board. However, the models without tax also produce similar results.

It may be noted here, as we mentioned earlier, that in situations where capital compensation becomes negative, or there are high capital gains, it is possible to have negative rental prices. Such negative rental prices are not theoretically consistent, as the theoretical assumption underlying the derivation of growth accounting framework requires input service prices to be positive. One way of empirically eliminating such negative values is to assume a minimum positive value arbitrarily. However, since our aim is to understand the sensitivity of growth rates to different measures, we have not opted to make such an empirical assumption. In addition, since we are interested in understanding which model paints a better picture for growth accounting purpose, it is essential to know which models produce more sensible results. Therefore, in addition to the above observations, it is important and interesting to look at the number of negative values produced by different models.

Table 4: Percentage of negative values in Rates of Return

Model	NLD	FRA	UK	GER
INR	4.4	1.5	5.2	10.8
IOR	9.6	3.5	11.9	15.4
MOV	4.4	1.3	3.3	9.6

INRT	7.3	3.3	6.3	22.7
IORT	12.5	3.8	13.8	31.9
MOVT	6.3	2.9	4.4	21.3

Table 4 provides the percentage of negative values that appeared for each models of rates of returns. The Table shows that the largest number of negative values appeared in the internal own rate of return models, irrespective of the country we consider. This is true with both tax and non-tax models, though the models with tax have registered in general more number of negative values. The least number of negative values are in the moving average model. Among countries, Germany has witnessed more numbers of negative values, followed by the UK and the Netherlands. We also look at the negative values that appeared in the rental prices.

Table 5: Percentage of negative values in Rental prices

Model	NLD	FRA	UK	GER
INR	0.45	0.29	1.51	1.38
IOR	0.19	0.16	0.29	1.21
Const	0.00	0.00	0.00	0.00
MOV	0.26	0.29	0.35	1.38
INRTAX	0.54	0.29	1.83	2.79
IORTAX	0.48	0.09	0.32	4.26
CONSTTAX	0.00	0.00	0.00	0.35
MOVTAX	0.35	0.29	0.51	2.92

Though the percentage of negative values that appeared in rates of returns are relatively high, the same is not true of rental prices, which has shown only very few negative observations in most models. Table 5 shows that the largest numbers of negative values appeared in INR and INRtax models compared to all other internal rate of return models. The IOR model has produced the least number. This might be due to the incorporation of capital gain component in the internal nominal rate of return models. In the presence of large capital gains, it is possible to obtain negative rental prices in these models. Surprisingly, in the case of constant rates of return models, Germany has shown a positive number of negative values tax incorporated mode. This is seen in industry mining and quarrying, during the years 1996-2001, and may be attributed to the high subsidies given to this industry during this period. If we look at the taxes on production in this industry during this period, it is amazingly high as (-) 103 per cent of value added in 1996. These taxes have shown a declining trend in later years, though they trickled down only to (-) 66 per cent in 2001. As a percentage of capital stock, taxes have been as high as 30 percent in 1996 and 25 percent in 2001. Furthermore, in general Germany has witnessed the largest number of negative rental prices.

Table 6: Differences in Growth rates of Capital

Negative rental prices excluded - negative rental prices included						
Industries with differences	INR	INRtax	IOR	IORtax	mov	movtax
Netherlands						
Miner. Oil Refing, Coke & Nuclear Fuel	-0.02	-0.06	-0.02	-0.05	0.00	-0.03
Electrical and Electronic Equipment	-0.01	-0.05	-0.02	-0.06	-0.03	-0.05
Transport Equipment	-2.99	-3.69	-2.40	-12.80	-3.45	-4.43
Real Est. Activities & Business Services	-0.05	-0.07	0.00	0.00	0.00	0.00
France						
Mining and Quarrying	0.00	-0.01	0.00	0.01	0.00	-0.01
Wood & Products of Wood and Cork	0.00	0.00	0.00	0.00	0.00	-0.01
Transport Equipment	-0.05	-0.08	-0.01	0.00	-0.04	-0.07
Germany						
Agriculture, Forestry and Fishing	1.18	3.15	1.28	-2.50	1.15	3.12
Mining and Quarrying	0.02	0.03	0.10	1.35	0.03	0.00
Miner. Oil Refng., Coke & Nuclear Fuel	-0.69	-1.52	-0.50	-0.12	-0.64	-1.41
Transport Equipment	-0.09	-0.20	-0.10	-0.23	-0.08	-0.19
Hotels & Catering	0.28	1.44	0.34	1.30	0.32	1.52
Transport	0.15	0.85	0.14	2.62	0.18	0.87
Non-Market Services	0.00	0.00	0.00	-0.01	0.00	0.00
UK						
Mining and Quarrying	-0.02	-0.02	0.00	0.00	0.00	0.00
Pulp, Paper, Printing & Publishing	0.08	0.12	0.00	0.00	0.00	0.00
Miner. Oil Refing, Coke & Nuclear Fuel	0.00	0.01	0.00	0.00	0.00	0.01
Transport Equipment	-0.04	-0.12	-0.13	-0.16	-0.02	-0.02
Transport	0.00	0.00	0.00	0.00	0.00	0.00
Communications	-0.03	-0.18	0.00	0.00	-0.02	-0.06
Financial Intermediation	-0.36	-0.51	0.00	0.00	0.00	-0.03
Real Est Activities & Business Services	-0.37	-0.81	0.00	0.00	0.00	0.00
Other Services	-0.29	-0.45	-0.07	-0.07	-0.11	-0.16
Non-Market Services	0.00	-0.01	0.00	0.00	0.00	0.00

Note: The differences are calculated as capital growth rates calculated using rental prices adjusted for negative values *minus* growth rates not adjusted for negative rental prices

In order to unearth the sensitivity of calculated growth rates to negative rental values, we have calculated growth rates of capital services adjusting for negative rental prices. This is accomplished by assuming a minimum rental price of 0.0005, replacing the negative rental prices. The results brings notably different picture in some industries (see figures 1 to 4 in Appendix 5). The difference between the growth rates adjusted for negative rental prices and unadjusted growth rates are provided in Table 6. It seems that that though the differences are generally smaller in most industries, it is not the case across the board. The highest difference is observed in transport equipment sector in the Netherlands; this sector has shown a difference in growth rates in all other countries as well. It may also be noted that the model that has registered less number of industries with relatively high difference is the IOR model, as the negative rental prices appeared in this model are relatively low. In addition, the magnitude of observed differences are relatively small in IOR and smoothed capital gain series models, compared to INR models.

In view of the fact that incorporation of tax into the rental price model influences the measured growth rates of capital services at least in some industries, it may be deciphered from Table 5 that the model that has produced least number of negative values is the internal own rate of return model (with tax) in almost all countries considered. The same is true even if we consider models without tax: the internal own return models have produced the least number of negative values. Nevertheless the difference between least and most is quite small and indeed, in most cases the produced negative values are quite small say less than 5 percent of total observations. Therefore, it is quite difficult to judge that one model is better than the other, from an empirical viewpoint. Additional information from Table 6 that the magnitude of differences in growth rates generated by these models, while adjusted for negative rental prices, is relatively low in IOR and smoothed capital gain models worth mention. Hence, considering the empirical fact that the IOR models has across countries produced the least number of negative values, as these models accommodate in some way the capital gain component (Harper et al., 1989), and assures a complete consistency between national income accounts, we may argue that the internal own rate of return model is preferable, given this data set. On the other hand, if one prefers to use the INR models, it may be ideal to use smoothed capital gain series, as it reduces the volatility and the number of negative observations.

VII. To Sum Up

In this paper we attempted to understand the effect of alternative rental prices in capital aggregation on the measured growth rates of capital input. The measurement of capital is a disputable issue, at least at the empirical level. In order to arrive at some generally accepted measure of capital service growth, one requires reliable estimates of capital service prices or rental prices. The theoretical literature on rental prices has defined the concept well, though its measurement is still an empirical issue, as the researcher is left with many formulae. This paper has used four alternative rental price models, measured using internal nominal rate of return, internal nominal rate of return with smoothed capital gain, internal own rate of return and a constant rate of return, in calculating capital service growth rates. Moreover, we attempted to understand the effect of incorporating taxes into the model, on the growth rates of capital input.

The empirical results support the arguments that the exclusion of tax variable in the calculation of rental prices may have a bearing on the measured capital growth at least in some industries. This may depend on the volume of tax rates in each industry. In general, the growth rates were found to be decreasing in the presence of tax. This is because if the effective tax rate is high, the cost of capital will shoot up, and thus the incentive to invest will be low. Nevertheless, the observed differences between growth rates produced by two types of models are quite negligible in most cases. Therefore, from an empirical point of view, it may not be possible to make a strong argument that the potential peril in using pretax rental prices in aggregating capital services for growth accounting analysis is very high, given this dataset.

The growth rates generated by internal rate of return models and external rate of return models are found to differ considerably. It may be noted that the internal models are more theoretically consistent from the growth accounting point of view, as they provide complete consistency with national income and production accounting. This is because these measures are derived from capital income (see equations 11, 12 and 13), in such a way that capital income estimates are equated with payment to specific assets. In the productivity measurement, consequently, these measures leave the aggregate capital shares unaffected, while the aggregate growth rates calculated using shares may differ, owing to the differences in asset specific rental value shares. Such conditions, and the observed difference between external and more relevant internal measures may favor using the internal rates of return models in calculating capital service growth rates. However, between the three internal rates of return models also we observed differences in the resultant capital service growth rates, though they were marginal in terms of quantitative magnitudes. The observed differences between different measures, however, may not be ignored because the productivity differences across countries are, sometimes, evaluated on a marginal scale. Thus the answer to the question 'whether the use of alternative ways of capital aggregation matters for a study on economic growth' posed in our title may be 'yes'. Which way one chooses to aggregate capital inevitably does play a role in studies of economic growth, particularly while analyzing the contribution of capital to growth. After examining the growth rates produced by different models within internal rate of return models and the number of negative rental prices produced by these models, we may conclude that the internal own rate of return models is a preferred model for this data set. This model has produced the least number of negative rental prices, and as argued by Harper et al. (1989), it accounts for some amount of capital gain in calculation of rental prices.

Bibliography:

Auerbach A.J and Jorgenson, D.W (1980), Inflation-proof depreciation of assets, *Harvard Business Review*, October, 113-118.

Berndt ER and Hesse (1986), Measuring and assessing capacity utilization in the manufacturing sectors of nine OECD countries, *European Economic Review*, 30, 961-89

Berndt R.E (1976), Reconciling alternative estimates of elasticity of substitution, *Review of Economics and Statistics*, 58(1), 59-68.

Berndt, E R and D M Hesse (1986), Measuring and Assessing Capacity Utilization in the Manufacturing Sectors of Nine OECD Countries, *European Economic Review*, 30, pp. 961-89.

Chennells, L. and R. Griffith (1987), Taxing Profits in a Changing World, IFS: London

Christenson L.R and Jorgenson D.W (1969), The measurement of US real capital input, 1929-1967, *Review of Income and Wealth*, 15(4), 293-320.

Denison E.F (1969), Some major issues in productivity analysis: An examination of estimates of Jorgenson and Grilliches, *Survey of Current Business*. 52(5), 37-63.

Denison E.F (1980), The contribution of capital to economic growth, *The American Economic Review*, 70(2), 220-224.

Devereux, M.P. and R. Griffith (2003), Evaluating tax policy for location decisions, *International Tax and Public Finance*, 10, 107-126.

Devereux, M.P., R. Griffith and A. Klemm (2002), Corporate income tax reforms and international tax competition, *Economic Policy*, 17(35), 450-95.

Diewert W E(1980), Aggregation problems in the measuremnt of capital, in Usher D (eds) *The Measruement of Capital*, Chicago, The University of Chicago Press. Fraumeni B.M (1997), The measurement of depreciation in the US national income and product accounts, *Survey of Current Business*,

Fraumeni B.M and Jorgenson D.W (1980), The role of capital in US economic Growth, in Furstenberg V (eds) *Capital, Efficiency and Growth*, Cambridge MA.

Fullerton, D (1999), Marginal effective tax rate, in Cordes, J.J Ebel, R.D and Gravelle, J.G (eds), *The Encyclopaedia of Taxation and Tax Policy*, Urban Institute Press.

Hall R and Jorgenson D.W (1967), Tax policy and investment behavior, *American Economic Review*, 57(3), 391-414. Bradford D.F and Fullerton D (1981), Pitfalls in the construction and use of effective tax rates, *NBER working paper 688*

Hall R.E (1968), Technical change and capital from the point of view of the dual, *Review of Economic Studies*, 35(6), 35-46.

Harcourt G.C (1969), Some Cambridge controversies n the theory of capital, *Journal of Economic Literature*, 7(2), 369-405.

Harcourt, G C and N F Laing (1971), *Capital & Growth: Selected Readings*, Penguin.

Harper M.J, Berndt E.R and Wood D.O, (1989) Rates of return and capital aggregation using alternative rental prices.

http://www.ifs.org.uk/corptax/internationaltaxdata.zip.

Hulten C. R (1981) (eds), *Depreciation, Inflation, and the Taxation of Income from Capital*, Washington, the Urban Institute Press.

Hulten C.R (2000), Total factor productivity: A short biography, *NBER working paper* 7471.

Inklaar, R, O'Mahony M, and Timmer M.P (2003), ICT and Europe's productivity performance: Industry-level growth account comparisons with the United States, *Research Memorandum*, Groningen Growth and Development Centre, GD 68.

Inklaar,R, O'Mahony, M Robinson C and Timmer, M, (2003) Productivity and Competitiveness in the EU and the U.S, in O'Mahony and Bart van Ark (eds.) *EU Productivity and Competitiveness: A Sectoral Perspective; Can Europe Resume the Catching-Up Process?* European Commission, Brussels

Jorgenson D.W and Siebert C.D (1968), A comparison of alternative theories of corporate investment behaviour, *American Economic Review*, 58 (4), 681-712.

Jorgenson D.W and Stiroh (2000), Raising the Speed Limit: U.S. Economic Growth in the Information Age, *Brookings papers on economic activity*, 1.126-235

Jorgenson, D.W, F. Gollop and B. Fraumeni (1987*) Productivity and U.S. Economic Growth*, Cambridge, MA: Harvard University Press

Jorgenson, D.W. and Zvi Griliches (1967), The Explanation of Productivity Change, *Review of Economic Studies*, Vol. 34, pp. 249-83.

Jorgenson.D.W (1963). Capital Theory and Investment Behavior. *American Economic Review*, 53 (2), 247-259

O'Mahony and Bart van Ark (2003)(eds.) EU Productivity and Competitiveness: A Sectoral Perspective; Can Europe Resume the Catching-Up Process?, *European Commission*, Brussels.

OECD(2001), Measuring Capital: A Manual on the Measurement of Capital Stocks, Consuppitojn of Fixed Capital and Capital Services., OECD

OECD(2001), OECD Productivity Manual: A Guide to the Measurement of Industry-level and Aggregate Productivity Growth, Paris, OECD

Solow, R (1957), Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, vol. 39, pp. 312-320.

Stauffer, T. R (1971) The measurement of corporate rates of return: a generalized formulation, *The Bell Journal of Economics and Management Science*, 2, 434-467.

Tinbergen J (1942) On the theory of trend movements, in LH Klassen, et al. (eds) *Jan Tinbergen, Selected Papers*, Amsterdam, North Holland

Appendix 1

Derivation of rental price from the assumed correspondence between rental price and acquisition price

Equation (4) in the text shows capital stock as a weighted sum of past investments, i.e.

$$K_t = (1-\delta)K_{t-1} + I_t$$

$$= \sum_{\tau=0}^{\infty} (1-\delta)^{\tau} I_{t-\tau} \qquad (1)$$

where the weights are given by relative efficiencies $(1-\delta)^{\tau}$ assuming a geometric rate of depreciation. The price counter part of this capital stock equation is the acquisition price of investment goods. In neoclassical theory of optimal capital accumulation, the acquisition price of investment goods is the sum of future rental prices of capital services, weighted by the relative efficiencies of capital goods in each future period (Jorgenson and Yun 1991). Hence, the rental price can be calculated from this basic relationship between the price of a new capital good and the discounted value of all the future services derived from this capital good (Hall and Jorgenson, 1967). The rental prices of capital goods of different ages are proportional to the rental prices of a new capital good. The constants of proportionality are the relative efficiencies $(1-\delta)^{\tau}$. Thus, the acquisition price of investment goods q_t is expressed as the sum of future rental prices of capital service P_t, weighted by the relative efficiencies of capital goods in each future period, i.e.,

$$q_t = \sum_{\tau=0}^{\infty} (1-\delta)^{\tau} \prod_{s=1}^{\tau+1} \frac{1}{1+r_{s+t}} P_{t+\tau+1} \qquad (2)$$

where r_{s+t} is the rate of return in period s+t. Note that t represents the time of acquisition, and s denotes the time at which the capital services are supplied. The future rental prices are discounted in order to express prices for different time periods in terms of present values at time t. This expression can be compared with the corresponding expression PIM giving capital stock as a weighted sum of past investments.
Equation (1) can be expanded as

$$q_t = \frac{P_{t+1}}{1+r_{t+1}} + \frac{(1-\delta)P_{t+2}}{(1+r_{t+1})(1+r_{t+2})} + \frac{(1-\delta)^2 P_{t+3}}{(1+r_{t+1})(1+r_{t+2})(1+r_{t+3})}$$

$$+ \frac{(1-\delta)^3 P_{t+4}}{(1+r_{t+1})(1+r_{t+2})(1+r_{t+3})(1+r_{t+4})} + \ldots \qquad (3)$$

Then

$$q_t - q_{t-1} = -\frac{P_t}{1+r_t} + \left[1 - \frac{(1-\delta)}{(1+r_t)}\right]\left(\frac{P_{t+1}}{1+r_{t+1}} + \frac{(1-\delta)P_{t+2}}{(1+r_{t+1})(1+r_{t+2})} + \frac{(1-\delta)^2 P_{t+3}}{(1+r_{t+1})(1+r_{t+2})(1+r_{t+3})} + \ldots\right) \quad (4)$$

The last term in (4) is q_t, hence replacing it with (2), (4) becomes

$$q_t - q_{t-1} = -\frac{1}{1+r_t}P_t + \frac{r_t+\delta}{1+r_t}\sum_{\tau=0}^{\infty}(1-\delta)^{\tau}\prod_{s=1}^{\tau+1}\frac{1}{1+r_{s+t}}P_{t+\tau+1} \quad (5)$$

From (5), the rental price of capital service can be derived as;

$$P_t = q_{t-1}r_t + \delta q_t - (q_t - q_{t-1})$$

Appendix 2

Industries considered

	Industries
1	Agriculture, Forestry and Fishing
2	Mining and Quarrying
3	Food, Drink & Tobacco
4	Textiles, Leather, Footwear & Clothing
5	Wood & Products of Wood and Cork
6	Pulp, Paper & Paper Products; Printing & Publishing
7	Mineral Oil Refining, Coke & Nuclear Fuel
8	Chemicals
9	Rubber & Plastics
10	Non-Metallic Mineral Products
11	Basic Metals & Fabricated Metal Products
12	Mechanical Engineering
13	Electrical and Electronic Equipment; Instruments
14	Transport Equipment
15	Furniture, Miscellaneous Manufacturing; recycling
16	Electricity, Gas and Water Supply
17	Construction
18	Repairs and wholesale trade

19	Retail trade
20	Hotels & Catering
21	Transport
22	Communications
23	Financial Intermediation
24	Real Estate Activities and Business Services
25	Other Services
26	Non-Market Services

Appendix 3

Table 1: Growth rates of capital services using alternative rental price models

Industry	Netherlands				France			
	Const	**INR**	**IOR**	**mov**	**Const**	**INR**	**IOR**	**mov**
Agriculture, Forestry and Fishing	1.91	2.04	2.06	2.05	2.58	2.50	2.49	2.50
Mining and Quarrying	1.77	1.74	1.74	1.74	-0.74	-0.48	-0.72	-0.45
Food, Drink & Tobacco	1.46	1.33	1.29	1.32	3.29	3.27	3.15	3.28
Textiles, Leather, Footwear & Clothing	-0.82	-0.83	-0.91	-0.84	2.16	2.10	1.97	2.10
Wood & Products of Wood and Cork	1.29	1.23	1.16	1.23	3.64	3.64	3.49	3.64
Pulp, Paper & Paper Products; Printing & Publishing	3.41	3.12	3.05	3.11	5.38	5.29	5.13	5.30
Mineral Oil Refining, Coke & Nuclear Fuel	2.90	3.01	3.03	3.14	0.67	0.73	0.60	0.74
Chemicals	2.39	2.20	2.18	2.20	3.94	3.84	3.68	3.85
Rubber & Plastics	2.14	2.24	2.20	2.24	5.53	5.21	5.08	5.22
Non-Metallic Mineral Products	2.21	1.97	1.93	1.96	2.50	2.36	2.24	2.37
Basic Metals & Fabricated Metal Products	1.84	1.68	1.61	1.65	2.32	2.36	2.19	2.36
Mechanical Engineering	2.66	2.33	2.28	2.32	3.18	3.01	2.90	3.01
Electrical and Electronic Equipment; Instruments	2.60	3.14	3.12	3.13	4.19	4.11	3.99	4.10
Transport Equipment	2.10	6.90	17.39	8.88	3.70	4.05	3.55	4.05
Furniture, Miscellaneous Manufacturing; recycling	1.13	1.02	0.98	1.02	1.97	1.91	1.88	1.92
Electricity, Gas and Water Supply	1.76	1.82	1.74	1.82	2.37	2.68	2.34	2.75
Construction	2.98	2.76	2.72	2.75	1.51	1.58	1.54	1.58
Repairs and wholesale trade	2.98	2.49	2.47	2.49	4.09	4.03	3.76	4.03
Retail trade	2.81	2.56	2.54	2.56	4.00	3.91	3.77	3.91
Hotels & Catering	2.63	2.38	2.34	2.39	5.72	5.55	5.39	5.55
Transport	2.45	2.32	2.41	2.34	3.40	3.61	3.31	3.63
Communications	6.86	6.66	6.62	6.65	2.71	2.87	2.61	2.90
Financial Intermediation	7.85	7.50	7.48	7.51	3.98	3.80	3.28	3.85
Real Estate Activities and Business Services	4.64	7.32	7.03	7.11	6.87	6.67	6.36	6.68
Other Services	6.29	7.03	6.54	7.00	4.24	4.45	4.11	4.49
Non-Market Services	2.18	2.39	2.33	2.40	3.39	3.87	3.50	3.89

Note: all growth rates are calculated using models with tax

Table 2: Growth rates of capital services using alternative rental price models

Industry	UK				Germany			
	Const	**INR**	**IOR**	**mov**	**Const**	**INR**	**IOR**	**Mov**
Agriculture, Forestry and Fishing	-0.14	0.20	0.09	0.17	0.93	-2.79	2.63	-2.77
Mining and Quarrying	0.14	0.69	0.49	0.70	1.92	-1.56	-1.99	-1.52
Food, Drink & Tobacco	1.43	1.58	1.28	1.61	2.14	2.20	2.13	2.19
Textiles, Leather, Footwear & Clothing	-1.15	-0.80	-1.25	-0.84	0.02	-0.04	-0.03	-0.06
Wood & Products of Wood and Cork	-1.59	-1.23	-1.59	-1.23	2.31	2.42	2.32	2.40
Pulp, Paper & Paper Products; Printing & Publishing	3.30	2.97	2.90	2.96	3.91	3.95	3.85	3.94
Mineral Oil Refining, Coke & Nuclear Fuel	-1.63	-1.43	-1.68	-1.43	1.35	3.25	1.94	3.14
Chemicals	1.60	1.86	1.45	1.89	3.11	3.13	3.07	3.12
Rubber & Plastics	2.44	2.69	2.26	2.70	4.53	4.55	4.49	4.54
Non-Metallic Mineral Products	4.58	3.77	3.66	3.76	1.98	2.01	1.95	2.00
Basic Metals & Fabricated Metal Products	-0.72	-0.42	-0.85	-0.43	1.38	1.37	1.34	1.36
Mechanical Engineering	-0.22	0.23	-0.42	0.22	2.52	2.49	2.50	2.48
Electrical and Electronic Equipment; Instruments	4.93	4.88	4.42	4.89	2.81	3.02	2.88	3.00
Transport Equipment	3.07	4.48	3.74	4.44	4.39	4.78	4.75	4.79
Furniture, Miscellaneous Manufacturing; recycling	4.60	4.34	4.13	4.31	1.99	2.08	2.00	2.07
Electricity, Gas and Water Supply	1.41	1.64	1.39	1.70	2.91	2.79	2.56	2.78
Construction	1.07	1.31	1.25	1.29	0.45	0.63	0.56	0.61
Repairs and wholesale trade	6.05	5.40	5.01	5.38	2.42	2.53	2.42	2.52
Retail trade	5.14	5.90	5.20	5.87	5.75	5.78	5.65	5.76
Hotels & Catering	5.01	5.22	5.11	5.20	2.28	0.00	0.07	-0.07
Transport	1.68	2.42	1.74	2.26	2.20	0.84	-1.37	0.78
Communications	7.17	9.94	7.26	9.66	5.74	5.90	5.81	5.88
Financial Intermediation	6.92	7.46	5.81	7.12	4.67	4.30	4.11	4.29
Real Estate Activities and Business Services	9.40	13.25	11.54	12.83	7.20	7.30	7.24	7.29
Other Services	4.07	7.88	6.59	7.74	4.54	4.53	4.53	4.53
Non-Market Services	3.74	5.96	4.89	5.99	2.99	2.81	2.55	2.78

Table 3: Indirect taxes as a percentage of capital stock

Industry (26)	France		Germany		Netherands	
	1995	**1999**	**1995**	**1999**	**1995**	**1999**
Agriculture, Forestry and Fishing	-0.15	-0.08	-2.96	-2.19	0.46	0.12
Mining and Quarrying	2.30	2.46	-7.00	-27.83	0.09	0.10
Food, Drink & Tobacco	1.61	2.85	1.09	1.12	0.63	0.25
Textiles, Leather, Footwear & Clothing	6.20	5.63	0.95	1.21	0.27	0.16
Wood & Products of Wood and Cork	5.78	5.69	1.25	1.11	0.19	-0.26
Pulp, Paper & Paper Products; Printing & Publishing	3.58	3.29	1.19	1.64	0.30	0.24
Mineral Oil Refining, Coke & Nuclear Fuel	3.09	2.05	1.78	2.57	2.65	1.60
Chemicals	3.10	3.12	1.82	1.37	0.44	0.19
Rubber & Plastics	7.16	6.48	1.32	1.47	0.06	-0.26
Non-Metallic Mineral Products	4.06	4.04	1.59	1.15	0.67	0.45
Basic Metals & Fabricated Metal Products	3.07	3.23	0.96	1.15	0.18	-0.46
Mechanical Engineering	5.06	5.39	1.25	1.59	-0.36	-1.94
Electrical and Electronic Equipment; Instruments	2.91	3.38	0.51	0.68	-0.06	-0.36
Transport Equipment	2.59	3.13	0.13	-0.09	-0.46	-2.07
Furniture, Miscellaneous Manufacturing; recycling	4.11	4.33	1.23	1.03	0.15	-0.33
Electricity, Gas and Water Supply	1.33	1.24	-1.15	0.56	0.08	0.15
Construction	3.95	3.25	1.59	1.34	0.27	-0.88
Repairs and wholesale trade	3.45	3.05	4.17	4.65	0.51	0.03
Retail trade	3.45	3.05	4.17	4.65	0.51	0.03
Hotels & Catering	1.13	1.15	0.25	0.12	1.12	0.71
Transport	0.50	1.25	-0.75	-0.08	0.11	-0.03
Communications	0.50	1.25	-0.75	-0.08	0.11	-0.03
Financial Intermediation	6.11	6.54	2.53	2.84	0.41	0.33
Real Estate Activities and Business Services	10.09	10.83	1.28	1.66	1.63	1.23
Other Services	0.68	0.62	-0.69	-0.42	0.52	0.27
Non-Market Services	0.91	0.88	-0.81	-0.75	0.07	-0.15

Appendix 4

Table 4: Differences between growth rates: the Impact of taxes in IOR model.

IOR-IORtax	Netherlands	France	UK	Germany
Agriculture, Forestry and Fishing	0.0010	0.0123	-0.0342	-3.4793
Mining and Quarrying	-0.0078	0.0517	-0.1677	0.1855
Food, Drink & Tobacco	0.0092	0.0571	-0.0184	0.0173
Textiles, Leather, Footwear & Clothing	-0.0034	0.1089	-0.0281	0.1135
Wood & Products of Wood and Cork	-0.0054	0.0618	-0.0101	0.0073
Pulp, Paper & Paper Products; Printing & Publishing	0.0226	0.1236	-0.0543	-0.1242
Mineral Oil Refining, Coke & Nuclear Fuel	-0.0184	0.0462	-0.0264	0.4797
Chemicals	0.0357	0.1104	-0.0333	-0.1815
Rubber & Plastics	-0.0231	0.1828	-0.0206	-0.0682
Non-Metallic Mineral Products	0.0496	0.0907	0.0895	0.0776
Basic Metals & Fabricated Metal Products	0.0112	0.0674	-0.0206	0.0606
Mechanical Engineering	-0.0520	0.1019	-0.0518	-0.1028
Electrical and Electronic Equipment; Instruments	-0.2095	0.0668	-0.0139	-0.0906
Transport Equipment	-10.7909	0.1948	-0.1052	-0.3555
Furniture, Miscellaneous Manufacturing; recycling	-0.0136	-0.0219	0.0252	-0.1041
Electricity, Gas and Water Supply	-0.0001	0.0055	-0.0433	0.4134
Construction	-0.0281	-0.0131	-0.0335	0.1154
Repairs and wholesale trade	0.0329	0.1446	0.0453	0.0857
Retail trade	0.0021	0.1038	-0.0566	-0.1397
Hotels & Catering	0.0263	0.0750	-0.0018	1.1077
Transport	-0.0164	0.0184	-	2.6396

			0.0455	
Communications	-0.0076	0.0086	-0.0929	-0.4417
Financial Intermediation	-0.0449	0.1952	0.0278	-0.2376
Real Estate Activities and Business Services	0.6856	0.2819	-0.1420	0.0464
Other Services	0.0388	0.0671	-0.2936	-0.0390
Non-Market Services	-0.0499	0.0905	-0.1892	0.3787

Table 5: Differences between growth rates: the Impact of taxes in Mov model

Mov-Movtax	**Netherlands**	**France**	**UK**	**Germany**
Agriculture, Forestry and Fishing	0.0086	0.0226	-0.0410	2.1147
Mining and Quarrying	-0.0074	-0.0359	-0.1966	-0.0796
Food, Drink & Tobacco	0.0107	0.0238	-0.0605	-0.0034
Textiles, Leather, Footwear & Clothing	-0.0203	0.0480	-0.0731	0.1480
Wood & Products of Wood and Cork	-0.0213	0.0100	-0.0538	-0.0237
Pulp, Paper & Paper Products; Printing & Publishing	0.0063	0.0641	-0.0459	-0.1696
Mineral Oil Refining, Coke & Nuclear Fuel	-0.0513	-0.0153	-0.0638	-0.7772
Chemicals	0.0318	0.0504	-0.0885	-0.2000
Rubber & Plastics	-0.0278	0.1239	-0.0690	-0.0900
Non-Metallic Mineral Products	0.0371	0.0596	0.0810	0.0702
Basic Metals & Fabricated Metal Products	0.0169	0.0171	-0.0713	0.0582
Mechanical Engineering	-0.0090	0.0529	-0.1272	-0.0683
Electrical and Electronic Equipment; Instruments	-0.1871	0.0354	-0.0646	-0.1576
Transport Equipment	-1.1014	-0.0131	-0.1904	-0.3698
Furniture, Miscellaneous Manufacturing; recycling	-0.0209	-0.0269	0.0056	-0.1373
Electricity, Gas and Water Supply	-0.0165	-0.0678	-0.0798	0.2445
Construction	-0.0215	-0.0057	-0.0409	0.0957
Repairs and wholesale trade	0.0251	-0.0119	0.0038	0.0456
Retail trade	-0.0003	0.1006	-0.1336	-0.1861
Hotels & Catering	0.0108	0.0400	-0.0128	1.3370
Transport	0.0069	-0.0587	-0.1107	0.8797

Communications	-0.0137	-0.0235	-0.3574	-0.4692
Financial Intermediation	-0.0546	0.0230	-0.1312	-0.3428
Real Estate Activities and Business Services	0.4773	0.1196	-0.1190	0.0139
Other Services	-0.1335	-0.0281	-0.4390	-0.0323
Non-Market Services	-0.0550	-0.0789	-0.3340	0.2342

Table 6: Differences between growth rates: the Impact of taxes in Const model

Const-const tax	**Netherlands**	**France**	**UK**	**Germany**
Agriculture, Forestry and Fishing	-0.0889	0.0303	-0.0742	0.0796
Mining and Quarrying	-0.0037	0.0610	-0.2855	-3.7530
Food, Drink & Tobacco	0.0605	0.1031	0.0246	-0.0062
Textiles, Leather, Footwear & Clothing	0.0718	0.2120	0.0033	-0.0109
Wood & Products of Wood and Cork	0.0933	0.1108	-0.0198	-0.0049
Pulp, Paper & Paper Products; Printing & Publishing	0.1201	0.2134	0.0285	0.0064
Mineral Oil Refining, Coke & Nuclear Fuel	0.0243	0.0848	-0.0685	-0.0019
Chemicals	0.0729	0.1907	0.0093	-0.0019
Rubber & Plastics	0.0402	0.3742	0.0263	0.0010
Non-Metallic Mineral Products	0.1075	0.1940	0.1150	-0.0110
Basic Metals & Fabricated Metal Products	0.1377	0.1113	0.0136	-0.0031
Mechanical Engineering	0.1346	0.2186	0.0155	-0.0100
Electrical and Electronic Equipment; Instruments	0.1459	0.1217	0.0423	0.0039
Transport Equipment	0.1683	0.2116	0.0508	-0.0006
Furniture, Miscellaneous Manufacturing; recycling	0.0730	0.0234	0.0485	0.0014
Electricity, Gas and Water Supply	0.0981	0.0562	-0.0366	0.0166
Construction	-0.0117	-0.0346	-0.0209	-0.0140
Repairs and wholesale trade	0.1453	0.2457	0.0957	-0.0091
Retail trade	0.1189	0.3396	-0.0494	-0.0018
Hotels & Catering	0.1334	0.2229	-0.0307	-0.0072
Transport	-0.0576	-0.0318	-0.0969	0.0053
Communications	0.0641	0.0753	0.0539	-0.0029
Financial Intermediation	0.0986	0.7741	0.3151	0.0779
Real Estate Activities and Business Services	0.4315	0.5427	0.2594	0.0097
Other Services	0.2505	0.3057	0.1568	-0.0049
Non-Market Services	0.0492	0.1833	0.0907	0.0071

Appendix 5

Figure 1

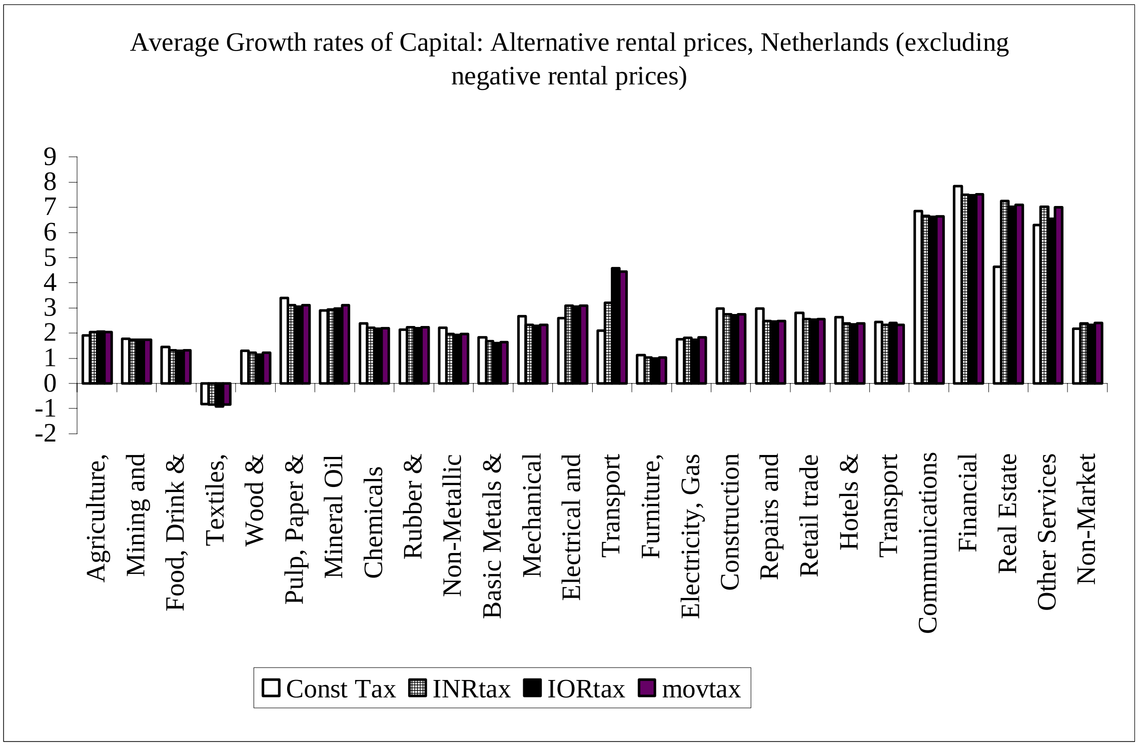


Figure 2

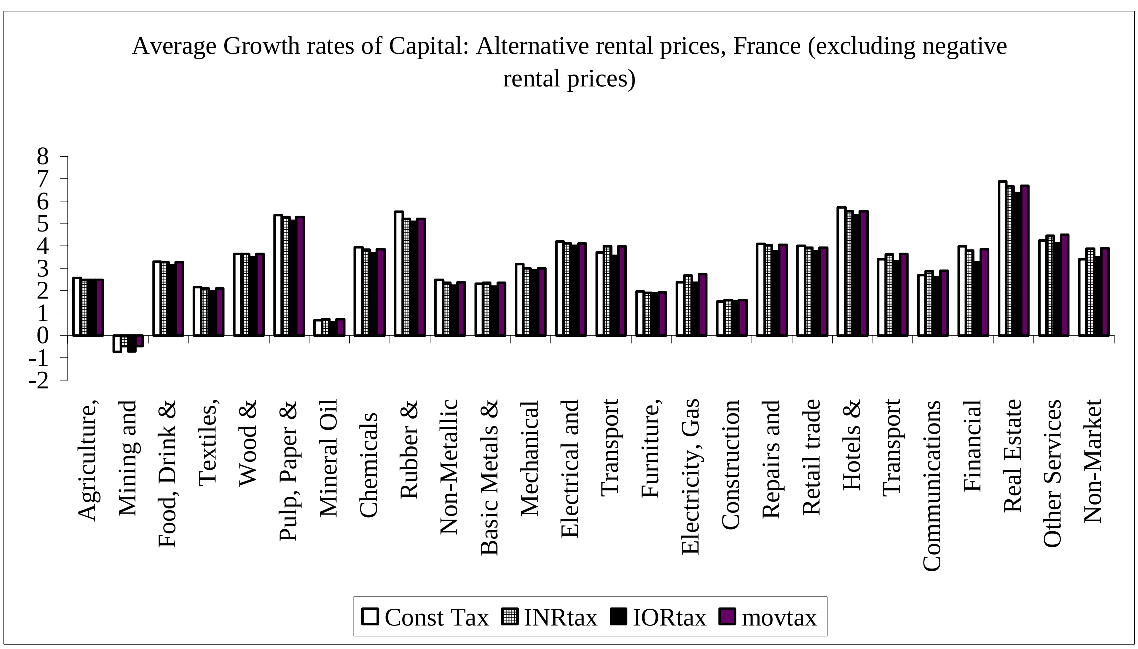


Figure 3

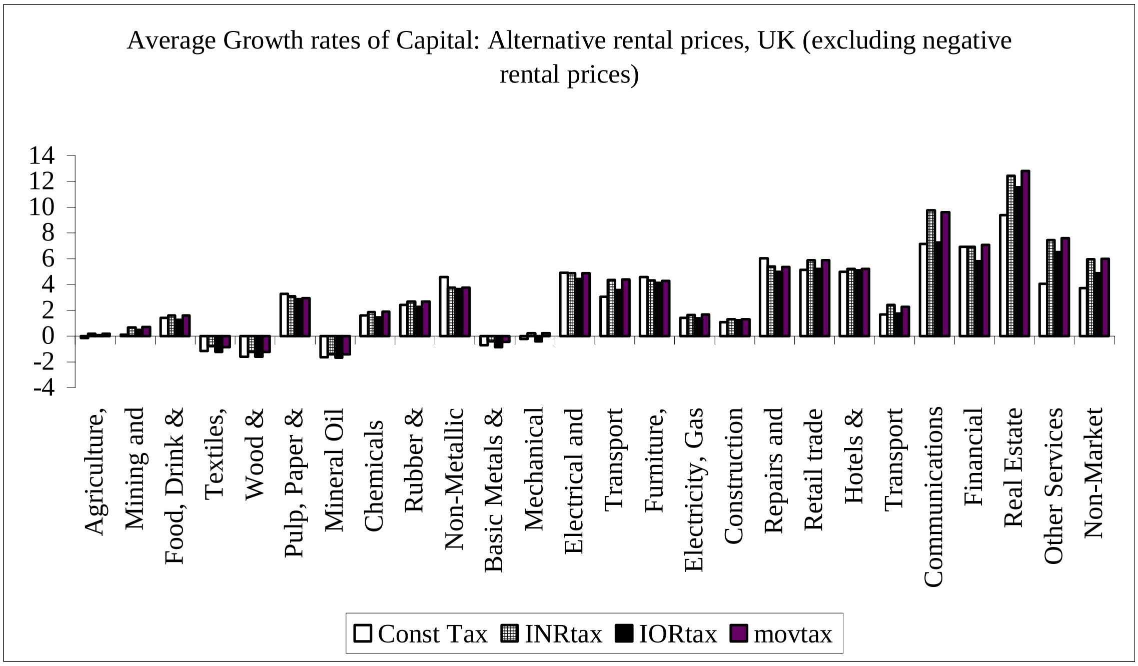


Figure 4