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Capital Aggregation and Growth Accounting: A Sensitivity Analysis

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Abstract

With the increasing importance of investment in Information Technology, methods for measuring the contribution of capital to growth have re-assumed centre-stage in recent growth accounting literature. The importance of using capital service growth rates rather than capital stock growth rates 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 the differences in multifactor productivity growth rates (MFPG) under different model assumptions. The differences in MFPG are also examined in terms of the inclusion of taxes and subsidies in the calculation of rental prices. Empirical analysis, carried out for four EU countries and the US in 26 industries during 1979-2003 shows that the use of capital stock overestimates MFPG in most industries. Incorporation of taxes seems to have only modest effect. The magnitude of divergence generated by alternative rental price models-particularly between internal models- is quite low. The difference is seen to be relatively high between external rate of return models and internal rate of return models.

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1. Introduction

The measurement of capital and its contribution to economic growth has been an important issue of attention in economics for long time. With the increasing importance of investment in Information and Communication Technologies (ICT), methods for measuring the contribution of capital to aggregate growth have reassumed centre-stage in growth accounting literature (Jorgenson, 2001; van Ark et al., 2008; Jorgenson and Vu, 2005; Inklaar et al, 2008). Dividing the total capital into ICT capital and non-ICT capital, studies have attempted to delineate the contribution of these two components to total growth using the growth accounting framework.[1] One major issue in the quantification of capital's contribution to economic growth using this framework is related with the measurement of capital input. Though many studies still use aggregate capital stock as a measure of capital input (e.g. Jones and Olken, 2005; Caselli, 2004), it has long been advocated that the flow of capital services, rather than the capital stock, is appropriate for production and productivity analysis (Jorgenson, 1963; Jorgenson and Griliches, 1967; Hall and Jorgenson, 1967).

The challenge in measuring capital services for growth accounting is associated with the implicit nature of the capital services; the quantity of capital services is not usually directly observable (Harper et al., 1989). 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 Griliches (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 stocks at *individual asset level*. However, there are different ways of measuring rental price of capital and thereby of obtaining capital service growth rates. The selection of any particular measure may significantly influence the calculated growth rates of capital and its contributions to output growth.

The aim of this paper is to examine whether the use of different rental price models in capital service aggregation produce significantly different capital services growths. Harper et al. (1989) have conducted a study by utilizing five alternative rental price models to evaluate the capital aggregation for the US manufacturing industries over the period 1948-81. Their results show significant differences between various models. While Harper et al. (1989) limits their study to the US manufacturing sector only, we do this exercise across 26 industry groups (see Table 3) in four EU countries along with the US, over a more recent time period, 1979-2003. Furthermore, we specifically examine the effect of alternative capital aggregation procedures on the measured multifactor productivity growth (MFPG). This is important because the choice of a particular rate of return will have consequences on the measured MFPG as it will affect the cost share of capital and thereby the growth rate of capital services (see discussion in next section). An attempt is also made to empirically understand the impact of including tax in the rental price equation on the growth rates of capital and thereby MFPG. It has been argued that tax plays a major role in altering investment behaviour (e.g. Hall and Jorgenson, 1967). However, most studies in the context of the EU have considered pre-tax rental prices in order to arrive at capital service growth rates. Therefore, taxation has to be incorporated in the measurement of capital service prices (see section 3.1 for a detailed discussion).

[1] There are also studies that tried to examine the US-EU productivity gap in terms of differences in ICT use, by classifying industries according to their ICT intensity. See for instance van Ark et al (2003) and Daveri (2004).

The 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 and the measurement of its components. Section 4 discusses the data used in the empirical analysis. Empirical results are discussed in Section 5, and finally Section 6 concludes the paper.

2. Growth Accounting and Capital Aggregation

Assuming a competitive market and constant returns to scale (CRS), the standard growth accounting equation with value-added as output (Y) and labour (L) and capital (K) as inputs can be written as[2]:

$$\Delta \ln Y_t = \Delta \ln A_t + \bar{a}_t \Delta \ln L_t + (1 - \bar{a}_t) \Delta \ln K_t \quad (1)$$

where the subscript t stands for time, and A denotes the technical progress, often called as the multifactor productivity (MFP).[3] $\bar{a}_t$ is the share of labour in the value-added averaged over the two time periods, t and t-1 (i.e. $\bar{a}_t = (a_t + a_{t-1})/2$), and Δ denotes the change in the relevant variable over the previous year. Equation (1) clearly shows that output growth is measured as a weighted sum of growth of labour and capital flows, where the weights are the shares of each input in the value added. This implies that in order to implement equation (1) it is essential to calculate the growth rate of aggregate inputs and output.[4] Ideally, one should be able to derive the growth in aggregate inputs as the cost share weighted sum of growth of inputs (Jorgenson et al., 1987). In the case of labour 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 service growth rates.

Capital stock consists of different types of heterogeneous assets with specific capital service levels. Therefore, this heterogeneity has to be taken into account while aggregating capital services across various asset types. Assuming a strict proportionality between capital services and capital stocks at the *level of individual assets*[5], Jorgenson (1963) and Jorgenson and Griliches (1967) have developed aggregate capital service measures that take into account the heterogeneity of assets. In accordance with their aggregation procedure, the growth rate of aggregate capital services may be measured as

$$\Delta \ln K_t^{sr} = \sum_{i=1}^{n} \bar{\gamma}_{i,t} \Delta \ln K_{i,t}^{st} \quad (2)$$

where $\bar{\gamma}_{i,t} = (\gamma_{i,t} + \gamma_{i,t-1})/2$ and $\gamma_{i,t} = c_{i,t} K_{i,t}^{st} / \sum_{i=1}^{n} c_{i,t} K_{i,t}^{st}$

[2] For a detailed discussion on growth accounting, see, among others, Jorgenson and Griliches (1967), Barro (1999) and Hulten (2000).
[3] Inklaar et al (2008) provides a useful summary of the concept of MFP (see Box 1, Inklaar et al 2008).
[4] See OECD (2001 a and b)-the so-called capital and productivity manuals- and EUKLEMS (2007) for discussions on the measurement of output and input for productivity analysis.
[5] Note that even though one would assume proportionality between capital stock and capital service at *individual asset level*, the factor of proportionality would vary across asset types and over time depending upon the marginal productivity of each asset type. At the aggregate level, the capital services should take account of the differences in the service delivered by different asset types.

where K^{sr}_t is the aggregate capital services in year t, n is the number of assets, $K^{st}_{i,t}$ is the capital stock of asset i in year t, $c_{i,t}$ is the rental price of asset i in year t, and $\gamma_{i,t}$ is the share of i^{th} asset in total capital compensation in year t. γ_{it} effectively incorporates the qualitative differences in the contribution of various asset types, as the capital composition changes.

It is evident from (2) that the two important components of the capital service measure are capital stock (K^{st}) and the service prices (rental price) of capital (c). 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 in order to practically estimate capital service flows. The usual practice of measuring capital stock is based on a perpetual inventory method, i.e.

$$K^{st}_{i,t} = (1-\delta_i)K^{st}_{i,t-1} + I_{i,t} \tag{3}$$

where δ_i is the rate of depreciation for the i^{th} capital asset and $I_{i,t}$ is the real investment in asset i installed in the beginning of period t. Using (2) and (3) the change in aggregate capital service growth rates may be measured as a weighted sum of the growth rates of asset specific capital stocks, with the weights being the relative compensation share of each asset.[6] The remaining task, therefore, is to construct appropriate measures of capital service prices for each asset type ($c_{i,t}$) - rental prices or user cost of capital-, in order to derive the relative compensation shares.

3. Measurement of Rental Prices (c)

As in the case of the wage rate for labour, the rental price for capital represents the unit cost of using a capital good for a specified period of time (Jorgenson and Yun, 1991). If there is an active rental market for capital assets it would have been possible to obtain the capital service prices directly as the rental price of using a capital asset, from which one can calculate the capital service flow. However, the rental prices of the capital service are unobservable, as capital services are delivered by capital goods over the course of their lifetime to their owners, without any recorded market transaction. Therefore, it is essential for the researcher to impute the implicit rental price that the owners of capital assets pay themselves as users, which is therefore often called as the user cost of capital (Harper et al., 1989; Balk, 2007).

While imputing rental prices one has to take into account that capital goods deliver their service (to their owner) over the length of several years. Hall and Jorgenson (1967) have developed a methodology within the boundaries of neoclassical theory. In this framework the rental price of capital is imputed from the relationship between the price of a new asset and the discounted value of all future services derived from that asset (also see Christensen and Jorgenson, 1969; Jorgenson 1967). In the absence of corporate taxes, they derive this relationship as,

[6] The economic rationale of using the rental share weights to aggregate capital services is that the investors expect to get more services in short time from an asset whose price is relatively high (or service life is relatively small). As one of the referees have pointed out, one could also account for the asset heterogeneity while calculating the contribution of capital to output growth, by entering each type of capital as a separate argument in the production function. This, however, will not be an appropriate solution in growth accounting, as it requires imposing the factor shares. Also note that the growth rate of aggregate capital stock may be calculated ln (K^{st}_t/K^{st}_{t-1}) where $K^{st}_t=\sum K^{st}_{i,t.}$ Such growth rate may differ significantly from the calculated share weighted growth rate using (2), as the latter accounts for the asset heterogeneity. The difference between these two is often considered as a measure of capital quality or composition effect.

$$P^{I}(s) = \int_{s}^{\infty} e^{-(r+\delta)(t-s)} c(t)dt \quad (4)$$

where P^I is the price of capital assets, r is the discount rate (or rate of return) and s and t are respectively the time of acquisition of capital goods and the time at which their services are supplied. Differentiating with respect to time Christensen and Jorgenson (1969) have provided a discrete time derivation of this equation:[7]

$$c_{i,t} = r_t P^{I}_{i,t-1} + \delta_i P^{I}_{i,t} - \dot{P}^{I}_{i,t} \quad (5)$$

where $\dot{P}^{I}_{t}$ is the expected capital gain term, i.e. the expected gain or loss from holding an asset over time. In the above formulation, Christensen and Jorgenson (1969) assumes the capital gain to be perfectly anticipated (so that all expectations are realized), i.e. the difference between current and previous period investment prices $\dot{P}^{I}_{t} = (P^{I}_{t} - P^{I}_{t-1})$.

3.1 The Role of Taxes

The above derivation of rental prices, based on the assumed correspondence between asset prices and service prices 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 behaviour, 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). For instance, investment decisions of firms can be highly responsive to corporate tax reforms as it may affect the return to investment (see Cummins et al, 1996). Therefore, the derivation of rental prices of capital, which assumes correspondence with asset prices, should account for the impact of taxes. In this regard, the effect of corporate taxes on the cost of capital has been subjected to discussion in the literature (see for instance, Hall and Jorgenson, 1967).[8] In line with Hall and Jorgenson (1967) and Harper et al. (1989), incorporating tax factors equation (5) can be rewritten for i^{th} asset as:[9]

$$c_{i,t} = T_{i,t}\left[r_t P^{I}_{i,t-1} + \delta_i P^{I}_{i,t} - \dot{P}^{I}_{i,t} \right] + b_{i,t} \quad (6)$$

where b_{it} is the effective rate of property taxes (nominal valued taxes assessed on the real stock of capital, see Harper et al, 1989), T_{it} is the marginal rate of effective taxation on capital income in asset i in period t, defined as (see Jorgenson and Yun 1991):

[7] We avoid the details of this derivation. Interested readers may refer to Christensen and Jorgenson (1969).

[8] Hall and Jorgenson (1967) examine the effect of tax policy on the cost of capital and 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 in the US, while the investment tax credit and depreciation guidelines have caused a shift towards equipment.

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

$$T_{i,t} = \frac{1 - u_t z_{i,t} - k_{i,t}}{1 - u_t} \quad (7)$$

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 the lifetime of the investment and k_{it} is the effective rate of investment tax credit.[10]

The user cost formulation in equation (6) is assumed to be equivalent to the marginal product of capital (under perfect competition). It reflects the shadow price of capital (Jorgenson, 1963) in that it can be considered as the market price of an asset if rented to a user (in the presence of a well developed rental market).

3.2 The components of Rental prices

Equation (6) shows that the general formulation of rental price comprises the nominal rate of return, the nominal cost of depreciation, corporate taxation and the nominal gain from holding the asset for each accounting period, i.e. capital gain. The empirical part of this paper is concerned with the measurement of (6) and therefore the major components of rental prices. The measurement of these components may be accomplished in different ways. In what follows, we discuss the alternative ways of measuring these components followed in the present Paper.

3.2.1 Depreciation (δ)

Depreciation measures the loss of the market value of a capital asset over time. Its importance in rental prices stems from the fact that the investor expects to get more services in a short time from an asset with relatively shorter service life. Therefore, while calculating capital service growth rates, higher weight should be attributed to assets that are rapidly depreciating. For instance, if investment in ICT capital, which is a short-living asset, is growing faster than that in non-ICT capital, the composition of capital stock will change in favour of ICT assets. Naturally, since the lifetime of the ICT equipment is shorter it will have a high depreciation rate compared to non-ICT capital. Consequently, from (6) it is evident that the rental price of ICT equipment, *ceteris paribus*, will be higher than that of non-ICT capital so that the growth rate of ICT equipment in total capital services gets a higher weight than that of non-ICT capital. In other words, a unit worth of investment in ICT capital has higher service flow than a unit worth investment in non-ICT capital.

The issues associated with the measurement of the depreciation are well-discussed in the economic literature (see Hulten and Wykoff, 1981 and other papers in Hulten, 1981).[11] Depreciation rates may vary over time and across countries and industries. However, considering the computational simplicity and the empirical support provided by Hulten and Wykoff (1981) the general practice in empirical literature is to assume a constant geometric depreciation rate. We do not delve much into this issue in this Paper. Rather, we opt to follow general practice. We assume a geometric depreciation pattern. Therefore, we concentrate below on the other two components- the rate of return and the capital gain.

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[10] Investment tax credit is a credit against tax liabilities in proportion to investment expenditure (Jorgenson and Yun 1991) aimed to encourage investment. It is equivalent to subsidies or investment grants aimed to offset tax liability.

[11] Also see Diewert (2001) who provides a discussion on the distinction between time-series and cross-section depreciations. Time-series depreciation captures the effect of changes in asset prices between two time periods and the effect of changes in the age of the asset. Thus it includes both the effect of depreciation as well as inflation.

3.2.2 Rates of Return (r)

The rate of return may be considered to represent the annual return on an investment as a percentage of the total amount of money invested, or as the opportunity cost of holding an asset (OECD, 2001a). It may be measured either as an external (also called exogenous or *ex ante*) rate of return or an internal (also called endogenous or *ex post*) rate of return.[12] In the external approach the rate of return is represented by some exogenous rate such as interest rates on government bonds. In the internal approach, on the other hand, rates of return are derived as residual, given the value of capital compensation, depreciation and capital gains. Clearly there is a problem of choice between *external* and *internal* measures of rates of return in the productivity analysis, and consequently this issue has been widely discussed in the literature (Berndt and Fuss, 1986; Harper et al, 1989; Diewert, 2001; Hulten, 1990). Though there is no consensus on the matter, Berndt (1990) has shown that the internal rates which reflect realized marginal products are theoretically more consistent for productivity analysis. The point here is that in growth accounting one is interested to understand the realized contribution of capital rather than the expected contributions (Berndt and Fuss, 1986; Oulton, 2007). The implied assumption here is that the ability of internal return to approximate the realized marginal product is higher than that of external rate of return (Berndt, 1990). Recently, this position has been questioned (see Schreyer et al, 2003). Schreyer et al (2003) argues that the internal measures need not be necessarily the correct measures of realized marginal productivity if for instance the capital is rented by a producer at a given pre-agreed rental price to be paid at the end of the period. A recent study by Oulton (2007) proposes an hybrid approach, where the rate of return in capital services are derived using external rate of return but the capital weights in growth accounting are derived using internal (i.e. share of gross operating surplus in value added) assumptions. He concludes that the internal rate is a better measure to use in a growth accounting exercise from a theoretical perspective, as suggested by Berndt (1990).

Table 1: Internal Vs. External Rate of Return

	Internal (*ex post*)	**External (*ex ante*)**
Defin-ition	Residual, given the values of capital compensation, depreciation and capital gains.	Derived from some exogenous information, such as financial market information.
Rationale	Equality of property income and the current value of capital services	Prior to making an investment decision, firms will have some idea of the required rate of return in deciding how much to invest which need not be equal to the realized (or ex post) rate (Oulton, 2007).
The-ory	Consistent with neoclassical theory, and hence the neoclassical growth accounting framework	No neoclassical assumptions
Advant ages	Assumes that sum of rental payments for all assets equal to total property compensation (M) that can be derived from value added	Do not impose the condition that the gross operating surplus is exhausted by factor payments.

[12] See Table 1 for a snapshot of these two approaches. Also see EUKLEMS (2007) and OECD (2001a) for a discussion of these alternatives.

	as a residual after labour compensation, which implies	
	(i) if an asset is excluded rate of return will be overestimated (e.g intangibles)13	Independent of the number of assets, and therefore do not have the problem of over estimation caused by the exclusion of certain assets or the presence of labour compensation for self-employed
	(ii)rate of return will be overestimated if appropriate adjustment is not made for labour compensation for self-employed, which is part of the mixed income component of operating surplus.	
	(iii)Neoclassical CRS and perfect competition assumptions-in parity with growth accounting assumptions.	Relaxes perfect competition and CRS assumptions.
	Since the rate is derived as a residual from national accounts, there is no choice problem	Choice of an appropriate rate is required.

Since there is no consensus on which rate should be used, the choice is left to the empirical researcher. Hence it is imperative to know how sensitive the final growth rates of capital and MFPG are to such empirical choices. We use both these measures in our empirical analysis in order to examine the sensitivity of MFPG and capital services to these choices. In what follows we explain the procedure adopted in this paper to derive the rates of return under these two assumptions.

The Internal Rate of Return (IR): The internal rate of return is defined as a residual obtained after adjusting capital compensation for depreciation and capital gain. This approach, advocated by Hall and Jorgenson (1967), estimates the internal rate of return with the help of an accounting identity that assumes that the sum of rental payments to all assets is equal to the total capital compensation, i.e.

$$M_t = \sum_{i=1}^{n} c_{i,t} K_{i,t}^{st} \tag{8}$$

where M_t is the total rent received from the various assets in each time period t (or the property income in time t), which can be empirically measured as:

$$M_t = P_t^y Y_t - w_t L_t \tag{9}$$

where P_t^y is the value added price, w is the wage rate and L is the labour input. The total capital income or property compensation is thus calculated as the nominal value added minus labour compensation, assuming a competitive market and CRS.[14] It consists of pre-tax profits, capital consumption allowances, net interest, transfer payments, business subsidies, indirect taxes and the portion of firms' income attributable to capital. Therefore, the internal rate of return may be measured as a residual after adjusting M_t for measures of depreciation, capital gain and taxes. Following Christensen and Jorgenson (1969), the internal rate of return can be measured as:

[13] However, it is noted by Baldwin et al (2005) that if the growth rate of omitted asset is the same as the average growth of included assets, there will be no bias in internal rate due to asset omission.
[14] Note that the sum of labour and capital compensation equals gross value added at factor cost under all the typical neo classical assumptions concerning a production function (Berndt and Hesse, 1986).

$$IR_t = \frac{\left[M_t - \sum_{i=1}^{n} \left[\delta_{i,t} T_{i,t} P_{i,t}^I K_{i,t}^{st} - T_{i,t} \dot{P}_{i,t}^I K_{i,t}^{st} + b_{i,t} K_{i,t}^{st} \right] \right]}{\sum_{i=1}^{n} P_{i,t-1}^I T_{i,t} K_{i,t}^{st}} \quad (10)$$

where IR is the internal rate of return, which is assumed to be constant across all assets in an industry, but varies across industries. As is clear from equations (9) and (10) one advantage of using an internal rate is that the surplus is taken directly from national accounts from which the required data for productivity analysis is also derived. Thus it ensures full consistency between income and production. We measure the IR using equation (10).

The External Rate of Return (ER): The internal approach discussed above is theoretically consistent under the assumptions of CRS, competitive markets, zero profits and an expected rate of return which equals the ex-post, realized rate of return. A number of studies have suggested an external or *ex ante* rate of return instead of this internal rate of return that should overcome some of the limitations of the latter (Diewert, 1980, Diewert, 2001; Schreyer et al, 2003, Schreyer, 2004; Balk, 2007). In the external approach the rate of return is taken from some exogenous information, such as financial market information. For instance, the rate of return could be considered as an external rate of interest if a loan is taken (OECD, 2001a). The rationale here is that prior to making an investment decision, firms will have some idea of the required rate of return in deciding how much to invest (Oulton, 2007). This expected rate need not be equal to the realized (or internal) rate.

The choice of an external rate helps to relax the strict neoclassical assumptions of CRS and perfect competition, as it does not impose the condition that the gross operating surplus is exhausted by factor payments (see e.g. Balk, 2007).[15]Balk (2007) argues that the internal rate of return measure is more prone to measurement error, as it closes the gap between the input and output side of the production unit, by assuming a zero profit. He provides an approach where the value added is assumed to be the sum of capital and labour costs and profits, thus waiving the neo-classical zero profit and marginal cost pricing assumptions. However, the choice of an appropriate external rate is problematic as there is no well-defined guidelines on which rate should be used. Diewert (1980) has suggested a wide range of different rates. Diewert (2001) has suggested a 4 per cent rate of return for OECD countries, under the assumption that producers face a real interest rate of around 4 per cent. He suggests that this rate is consistent with long-run economy-wide observed real rate of return for OECD countries that ranges 3 to 5 per cent. [16] In the present study, we use this 4 per cent constant external rate of return (hereafter CER).

[15] The profits in external measure can be above the normal profit. Therefore, the difference between *ex post* gross operating surplus and *ex ante* capital services may be considered as indication of monopoly profits, or presence of economies of scale (Baldwin et al 2005; Schreyer et al, 2004; Schreyer, 2004). The premise is that the gross operating surplus could be a sum of capital compensation and a measure of monopoly power. The latter could arise due to the presence of mark-up over marginal cost, or due to Schumpeterian entrepreneurial incentives or increasing returns to scale, all of which are assumed to be nonexistent in *ex post* rate, under strict neoclassical assumptions (see Schreyer et al. 2004). It could also be due to measurement error caused by the omission of certain factors (See Box 1; also see Diewert, 2001; Balk, 2007).

[16] Also see Oulton (2007) who makes a similar assumption.

3.2.3 Capital Gain

The third component of rental prices is the capital gain component. It measures the change in value of an asset that corresponds to a rise or fall in the price of that asset, independent of the effects of ageing. It measures the difference in the price of new capital assets in two periods, and is therefore independent of ageing. A positive capital gain reduces the user cost of holding the asset, and is therefore subtracted, while a negative gain (or a loss) increases the user cost and therefore must be added. Despite its crucial role in the rental price specification, there is more than one way by which the capital gain can be incorporated in the measurement of rental prices. We include capital gain in our measures of rates of return and rental prices using three alternative models.

1-Perfectly anticipated capital gain: As shown in equation (5) one way of incorporating capital gain into the measurement of rental prices is to assume a perfectly anticipated capital gain (Christensen and Jorgenson, 1969; Jorgenson and Yun, 1991; Harper et al, 1989). Both in (5) and in (10) the expected capital gain is represented by annual realized capital gain, that is that is the difference between current and last year prices i.e. $\dot{P}_{i,t}^{I} = (P_{i,t}^{I} - P_{i,t-1}^{I})$. Following Harper et al (1989), we call this rate of return model as internal 'nominal' rate of return (INR) model.

2-Zero capital gain: A second possibility is to drop this term from the user cost and rate of return equation. This implies that the producers expect current prices to prevail in the following period, so that the expectations are static (Woodland, 1975). This rate of return measure, which does not include capital gain term, is called the internal 'own' rate of return (IOR). After comparing this approach with the perfectly anticipated capital gain approach, Jorgenson and Siebert (1968) have shown a relative preference for the latter. However, we measure rate of return without capital gain since our objective is to understand the sensitivity of measured MFPG to alternative model assumptions.

3-Smoothed capital gain: While the role of capital gain and its inclusion in the rental prices is widely acknowledged, the use of annual capital gain and perfect anticipation assumptions are subject to criticism (Denison, 1969; Diewert, 1980). Denison (1969) argued that long-term averages of capital gain would be more appropriate as capital gains are highly volatile. The use of a long-term average capital gain term might help to reduce the volatility in rental prices. In accordance with Harper et al. (1989), we use a smoothed capital gain series by employing a three-year moving average. These smoothed capital gain measures are then substituted for the perfectly anticipated capital gain term in (10), thus providing a third internal rate of return model which we call the INR with smoothed capital gain (INRS).

Note that in all the models we assume that the nominal rate of return is the same for all assets within an industry, while the constant external rate of return is the same for all assets and industries. Also, the 4 per cent external rate of return is assumed to be a real rate of return (net of capital gains), and therefore will be used in the rental price models that do not incorporate capital gain (i.e. equation 6 excluding capital gain). All the three internal rates of returns are estimated with and without tax, thus providing 6 measures of rate of internal rate of return. Thus ultimately we have 8 different rental price models and corresponding capital service and productivity growth rates. Table 2 lists these 8 rental price models.

Table 2: Alternative Rental Price Models

	Model Abbreviation	Rate of Return	Capital Gain	Tax
1	CER	Constant External	No	No
2	CERTX	Constant External	No	Yes
3	INR	Internal Nominal	Annual	No
4	INRS	Internal Nominal	Smoothed	No
5	INRTX	Internal Nominal	Annual	Yes
6	INRSTX	Internal Nominal	Smoothed	Yes
7	IOR	Internal Own	No	No
8	IORTX	Internal Own	No	Yes

4. Data and Variables

The data used in this study are based primarily on O'Mahony and van Ark (2003), and its updates available through Groningen Growth and Development Centre (GGDC) website.[17] The study is conducted for four EU countries- Netherlands, France, Germany and UK- and the US using annual data for the period 1979-2003 for 26 industry groups listed in Table 3.

The empirical implementation in this paper consists of the measurement of the MFPG, using alternative measures of capital service growth rates. Hence the major variables that enter into our analysis are factor inputs (labour and capital) and output. For the *output* data, the current price gross value added obtained from national accounts statistics is deflated using value added deflators with base 1995. *Labour input* is measured as the product of total hours worked and a measure of labour composition. In order to calculate MFPG, we also needed the share of labour and capital in the value added (see equation 1). The *labour share* is calculated as labour compensation divided by value added, both in current prices and the former adjusted for income of self employed labours. Assuming perfect competition and CRS, the capital share is derived as a residual, i.e. value added minus labour compensation as a percentage of total value added.[18]

Capital stock is estimated using the perpetual inventory method for six asset types, using equation (3). The assets considered for this purpose are non-IT machinery, non-residential structures, transport equipment, IT equipment, communication equipment and software. The aggregate capital stock is arrived at by summing capital stocks across these six assets. And the aggregate capital service growth rates are derived using equation (2) applying alternative rental prices calculated using different rates of return models listed in Table 2. For this we required data on depreciation rates and asset prices. A geometric rate of depreciation is assumed. These rates are based on Fraumeni (1997) and Jorgenson and Stiroh (2000) and are industry-specific.[19] Investment price deflators with base year 1995 are used to represent the asset prices.

[17] For a detailed discussion on the data see Inklaar et al (2005).
[18] It may be noted here that if one use an *ex ante* measure in deriving output share of capital, it will produce an output elasticity of capital which is different from the one we use. However, in our empirical analysis, though we employ alternative rates of returns (*ex post* and *ex ante)*, following the recent theoretical conjecture (see Oulton, 2007), the output share of capital is measured by *ex post* in all cases.
[19] See Inklaar et al (2005).

Table 3: Industries and ISIC Codes

Number	Industry	ISIC rev3 code
1	Agriculture, forestry and fishing	01-05
2	Mining and quarrying	10-14
3	Food products	15-16
4	Textiles, clothing and leather	17-19
5	Wood products	20
6	Paper, printing and publishing	21-22
7	Petroleum and coal products	23
8	Chemical products	24
9	Rubber and plastics	25
10	Non-metalic mineral products	26
11	Metal products	27-28
12	Machinery	29
13	Electrical and electronic equipment & instruments	30-33
14	Transport equipment	34-35
15	Furniture and miscellaneous manufacturing	36-37
16	Electricity, gas and water	40-41
17	Construction	45
18	Wholesale trade	50-51
19	Retail trade	52
20	Hotels and restaurants	55
21	Transport & storage	60-63
22	Communications	64
23	Financial intermediation	65-67
24	Business services	71-74
25	Social and personal services	90-99
26	Non-market services	75-85

Apart from the input, the output and the price data, we also require tax data in order to derive rates of return and rental prices. As noted by Jorgenson and Yun (1991), the 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 we want to calculate the rental price. The marginal rate of effective taxation mirrors the incentive to invest. We measure the marginal rate of taxation by equation (7), using the data on statutory tax rates on corporate income and the present discounted value of depreciation allowances provided by Devereux, et al (2002).[20] The statutory tax rates in the countries in our sample have shown a declining tendency over time, particularly during the recent years (also see Sørensen, 2007). The depreciation allowances in Devereux, et al (2002) are available for two types of assets, i.e. plant & machinery and industrial buildings. We have calculated the

[20] This data is available from Institute of Fiscal Studies website http://www.ifs.org.uk/corptax /internationaltaxdata.zip. A detailed description of the sources, definition and construction of these data is provided in Devereux, et al (2002), and Devereux, and Griffith (2003). Note that Giannini and Maggiulli (2002) have estimated effective tax rates for EU countries. We, however, opt to use the IFS data as it provides time series for the entire period of analysis. The statutory tax rates in Giannini and Maggiulli (2002) for the countries in our sample are comparable with the IFS rates. For instance, in 1999 the statutory tax rates in IFS database are respectively 35, 40, 52 and 30 per cents for Netherlands, France, Germany and the UK, which are approximately the same in Giannini and Maggiulli (2002) also, as evident from their Figure 4.

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, and the depreciation allowances for plant and machinery are used for all other assets including software that comes under the category of machinery. Since we had no information on investment tax credit, it is assumed to be zero in our calculations.

The value added in our data consists of operating surplus, compensation to employees, and the taxes on production. Therefore, while deriving the internal rate of return as a residual of capital compensation (measured as value added minus labour compensation), we also need to subtract these taxes (see equation 10). The calculation of indirect taxes ($\sum_{i=1}^{n}[b_{it}K_{it}]$) is made directly from the National Accounts of selected countries. The data on taxes on production[21] was gathered from the Source OECD National Accounts Database under components of value added. These values are divided over calculated aggregate capital stock in order to arrive at the tax rate (b_{it}). However, these rates are not available for individual assets. Therefore, a common rate is derived by dividing, across all assets, total tax values by total capital stock, and this rate is applied to all assets. Note that in our empirical implementation, we have also measured rates of return and rental prices without 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.

5. Empirical Results

We have measured the rates of return and the rental prices using the four model assumptions, with and without corporate taxes (see Table 2). Thus we have 8 different measures of rental prices, rates of returns and the corresponding capital service and MFP growth rates. In this section we discuss the sensitivity of estimated MFPG to these 8 alternative model assumptions.

5.1 Negative Rental Prices

Since the internal rates of returns are measured as a residual, a practical problem arises when capital income in national accounts (gross operating surplus measured by M in equation 9) becomes negative.[22] This may result in negative rates of return.[23] In such cases, the measured rental prices using internal rate of return may also become negative. Negative rental prices can also arise even if the rate of return is positive, when there are large capital gains in the user cost formula. Such negative rental prices are theoretically inconsistent, as the theoretical assumption underlying the derivation of growth accounting framework requires input prices to be positive (Berndt and Fuss, 1986). Therefore, the events of negative rental prices in a particular model may be considered as criteria for choosing a

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[21] 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 labour employed or on compensation paid to employees.

[22] 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.

[23] Barbara Fraumeni commented that the problem of negative rate of return may be handled by aggregating industry groups of similar characteristics. However, while we looked at the pattern of negative appearances we found that they are in industries not of near characteristics.

particular model of rate of return. The models that make a large number of negative rentals may be least preferred.

Table 4: Percentage of Negative Values in Rental Prices

Model	**NLD**	**FRA**	**GER**	**UK**	**US**	**Average**
INR	0.5	1.2	1.2	1.9	0.2	1.0
INRTAX	0.8	1.5	2.5	2.5	0.6	1.6
INRS	0.5	1.2	1.1	1.0	0.2	0.8
INRSTAX	0.8	1.5	2.6	1.3	0.4	1.3
IOR	0.5	1.1	1.0	0.7	0.2	0.7
IORTAX	0.8	1.2	2.6	0.9	0.2	1.1

Note: All numbers are in percentages

Table 4 provides the percentage of negative values that appeared for each model of rental prices. The table shows that the largest numbers of negative values appeared in the models that incorporate capital gain and tax (INRTX). Out of 3900 rental prices (26 industries × 6 asset types × 25 years), on average 1.6 percent of negative values are observed, with a maximum of 2.5 per cent in Germany and a minimum of 0.8 per cent in the Netherlands.[24] Similar to what we observe, Harper et al (1989) also found largest negative rental prices in INR, followed by INRS and IOR models. In general, Germany and UK have witnessed the largest number of negative rental prices while the lowest is found in the US. The industries that have produced negative rental prices in all countries are mining and quarrying, textiles, wood and wood products, petroleum and coal products, electrical and electronic equipments and transport equipments (Appendix Table 1). The asset that has produced negative rental prices in internal models in all the countries is non-residential structures. As noted by Bonde and Sørensen (2006) this may largely be due to the swing in the investment prices causing high capital gain component in this asset type. This is supported by the observation that among the three internal models IOR has produced the least number of negative rental prices, suggesting that the inclusion of capital gain causes the negative rental prices. Overall, it is hard to argue that one model is better than the other in terms of the presence of negative rental prices, as the difference in the number of negative rental prices produced by these alternative models are quite small. Though the IOR model seems to produce relatively less number of negative values, the difference between IOR and other models in terms of the number of negative rental prices is quite small. In all the cases, on average only less than 2 per cent of negative values are observed.

[24] Surprisingly, in the case of constant rates of return models, Germany has shown a positive number of negative values in the tax incorporated model. A detailed look at the data reveals that this is in the industry mining and quarrying, during the years 1996-2003. This may be attributed to the high subsidies given to this industry during this period. If we look at the taxes on production in German mining industry during this period, it is as high as (-) 102 per cent of real value added in 1996. These taxes have shown a declining trend in later years, though they declined only to (-) 68 per cent in 2003.

5.2 Effect of Alternative Rate of Return Models: Aggregate Results

We have calculated the rental share weighted capital service growth rates using (2) for all 26 industry groups in each country separately, over the period 1979-2003 using alternative rental prices. The resulting capital service growth rates along with capital stock growth rates for the aggregate economy are plotted in Figure 1.[25]It is quite clear that the capital services grow faster than capital stock in most years, thus leaving a gap between the levels of these two. This is due to the shift in the composition of capital; increasing share of short living assets will result in accelerated capital service growth, hence, following Harper et al (1989), we call it a 'composition effect'. It can be also seen from the Figure that the capital service growth rates produced by different models tend to differ, though not very significantly. While the difference is more prominent between internal and external models, particularly with those which do not include capital gain, it is trivial between internal models, in general. In the UK and France, the capital services derived using CER models tend to grow at a slower pace compared to the internal models. This is more visible in the UK, which is in conformity with Oulton (2007)[26]. The inclusion of tax in the calculation of rates of return and rental price makes the story not very different. It caused very little difference in the calculated growth rates.

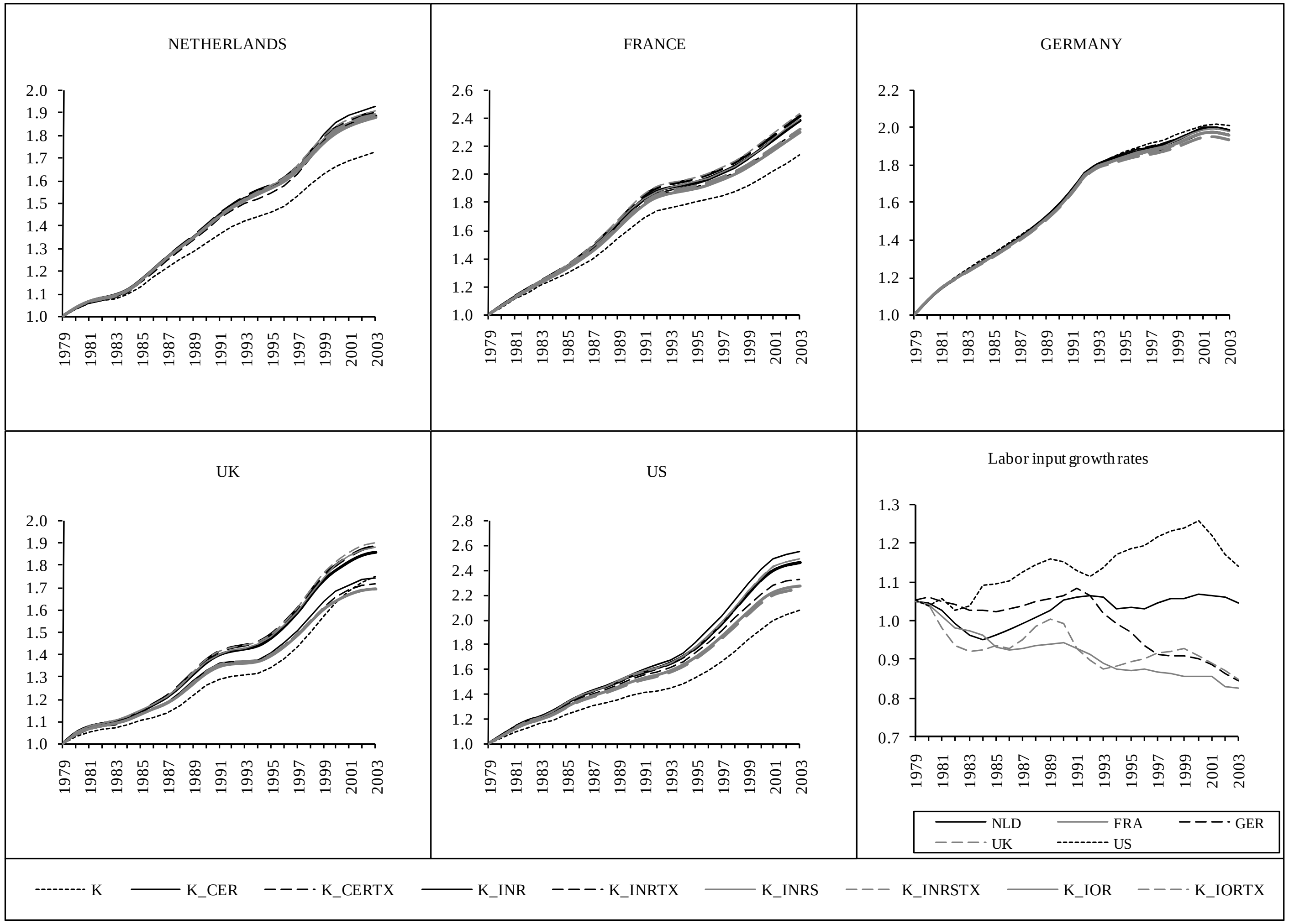
The capital service growth rates are plugged into equation (1) in order to calculate the MFP growth. A comparison of the MFPG obtained from different models will help us understand how sensitive the measured MFP growth is to these different capital aggregation procedures. The effect of alternate aggregation procedure on aggregate economy MFPG is depicted in Figures 2a to 2d.[27] The Figures depict the difference in average MFPG for the entire period, 1979-2003 along with two sub periods, 1979-1995 and 1995-2003 under various assumptions.

[25] The total economy capital and MFP growth rates are derived as simple average across industries. One could also derive the aggregate MFPG as a weighted average of individual industry growth rates. However, since our interest is to understand the sensitivity of these growth rates to alternate model specifications the former approach is appropriate.

[26] See Oulton (2007, Figure 2, pp. 311).

[27] The total economy capital and MFP growth rates are derived as simple average across industries. One could also derive the aggregate MFPG as a weighted average of individual industry growth rates. However, since our interest is to understand the sensitivity of these growth rates to alternate model specifications the former approach is more sensible.

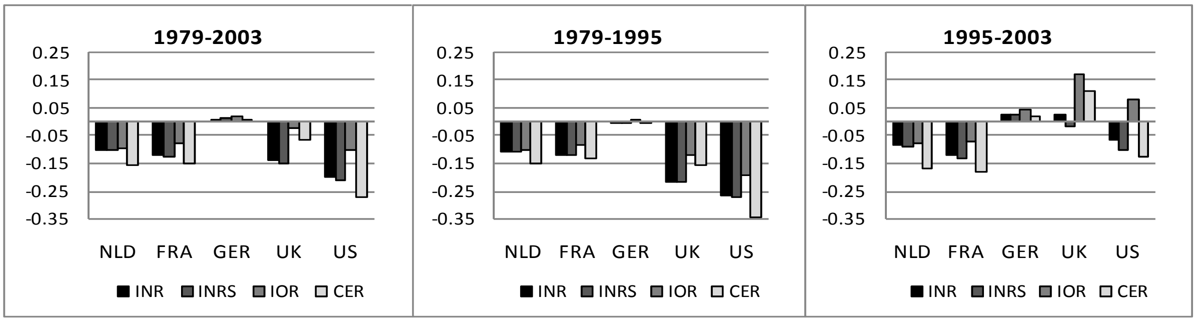
Figure 1: Growth of Capital (under various assumptions) and Labour Inputs, used in TFPG Calculation, 1979-2003



Notes: K is the capital stock and K_* are the capital services using * rate of return and the suffix TX indicates the presence of tax variable in rate of return. Labour input is the product of hours worked and labour composition (often considered as a measure of labour quality).

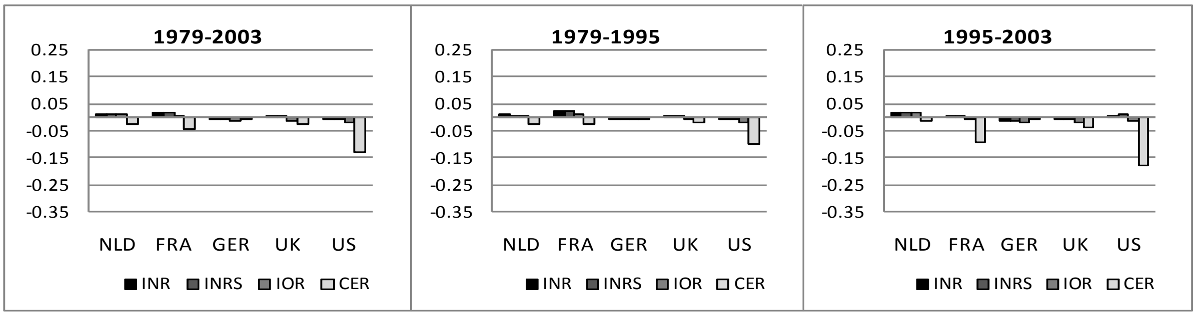
Figure 2: The Effect of Alternative Capital Aggregation on MFPG (in %)

Figure 2a: The Capital Composition Effect on MFPG



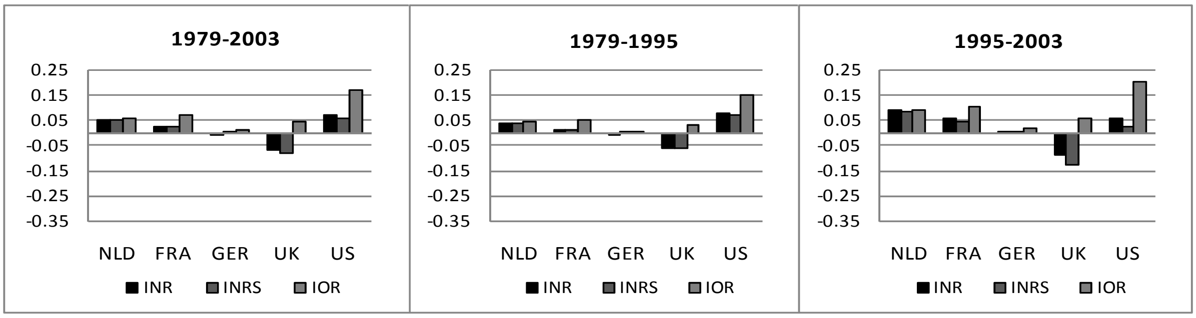
Note: MFPG using capital services - MFPG using capital stock.

Figure 2b: The Tax Effect on MFPG



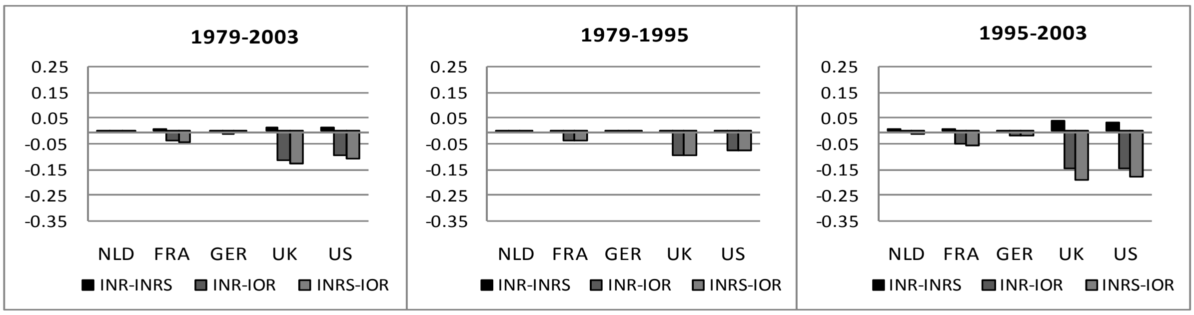
Note: MFPG using capital services without tax minus MFPG with tax.

Figure 2c: The Rate of Return Effect on MFPG (Internal vs. External)



Note: MFPG using internal models minus MFPG with external models.

Figure 2d: The Rate of Return Effect on MFPG (Internal vs. Internal)



Note: Difference in MFPG using alternative internal models as mentioned in legend. All are un-weighted averages across 26 industries

In Figure 2a the average composition effects on MFPG measured as the difference between the MFPG measured using the growth rate of capital service and capital stock are depicted. It may be noted that the larger composition effect could occur due to the shift towards equipment investment, particularly that of short-living equipments. Similarly, the decline in the relative price of an asset (for instance the decline in the price of equipment such as IT equipment relative to structures) would make the relative magnitude of capital gain term that is subtracted from the rental price equation smaller attributing it a larger weight in capital services (see Harper et al, 1989). Both these factors would cause a larger capital service growth rate, and lower MFPG. In most countries the capital composition effect on MFPG is negative indicating that capital stock tends to overestimate the MFPG. Exceptions to this phenomenon are Germany and the UK, particularly during the second period, 1995-2003. In general the effect is seen to be larger in the exogenous rate of return model and least in IOR models. Such large difference between capital service growth rate and capital stock growth rate in the case of exogenous rate of return is observed by Oulton (2007) in the case of UK. Our results are comparable to Harper et al (1989) for the United States, in terms of ranking of different models and signs of the effect, except for the CER model where the signs are different.

The second panel in the figure depicts the difference in measured MFPG when corporate taxes are included in rental price models. It is clear from the Figure 2b that the inclusion of tax variable has shown generally very meagre effects on MFPG. The differences are quite marginal and typically lower than 0.05 percentages. US is the only country where there is some difference observed when tax is incorporated throughout the period, but only in the constant external rate of return model. We conclude that the incorporation of taxes in the calculation of rental prices might be theoretically appealing, but empirically not very relevant.

To compare alternative models of rental prices, it can be seen that there are modest differences between external and internal models (Figure 2c). The external models tend to produce lower MFPG compared to the internal models. This is true in all the countries except in the UK, but only in models that incorporate capital gain. The effect is seen to be relatively larger in the US, particularly during 1995-2003, followed by the Netherlands and France. Notably the difference is larger when capital gains are excluded from internal models (i.e. IOR models). Thus the external models tend to be closer to internal models when capital gains are incorporated in the latter.

Between the different internal models there seems to exist no significant difference in most countries. Nevertheless, the inclusion of capital gain term in the internal models does make some differences at least in some countries (Figure 2d). For instance, in the US and in the UK, the difference between models with capital gain and without capital gain amounts up to more than –(0.15) percentage points during 1995-2003. In both these countries, the difference between INR with annual capital gain and INR with smoothed capital gain is also relatively more, though the magnitude is still trivial. This may suggest that difference in INR and IOR in these countries may be due to the swing in the investment prices that would affect the capital gain term. IOR model has generally shown a tendency to produce larger MFPG compared to the INR models.

5.3. Effect of Alternative Aggregation Procedure: Industry wise Results

The aggregate picture presented in the previous section, however, need not necessarily reflect the cross industry story. The results may change significantly across industries. We have measured the effect of capital composition and alternative rental price assumptions on the MFPG for 26 industry groups. The results are presented in Tables 6 to 9.

Table 6: Average Capital Composition Effect on MFPG, 1979-2003, Industry wise

ISIC	INR	INRS	IOR	CER	ISIC	INR	INRS	IOR	CER
01-05	0.08	0.08	0.09	0.10	34-35	-0.19	-0.20	-0.14	-0.13
10-14	-0.05	-0.07	-0.02	0.03	36-37	-0.05	-0.05	-0.03	-0.09
15-16	-0.10	-0.11	-0.06	-0.13	40-41	-0.15	-0.17	-0.06	-0.07
17-19	-0.04	-0.04	-0.02	-0.06	45	-0.01	-0.01	0.00	0.01
20	-0.06	-0.06	-0.01	-0.05	50-51	-0.04	-0.04	0.00	-0.15
21-22	-0.12	-0.12	-0.07	-0.16	52	-0.12	-0.12	-0.05	-0.09
23	-0.03	-0.05	0.00	-0.03	55	-0.04	-0.04	-0.01	-0.05
24	-0.16	-0.16	-0.10	-0.24	60-63	0.01	0.01	0.09	0.06
25	-0.08	-0.08	-0.05	-0.11	64	-0.35	-0.37	-0.17	-0.33
26	-0.09	-0.09	-0.03	-0.13	65-67	-0.30	-0.32	-0.18	-0.66
27-28	-0.10	-0.10	-0.07	-0.11	71-74	-0.33	-0.32	-0.22	-0.41
29	-0.10	-0.11	-0.06	-0.17	90-99	-0.12	-0.13	-0.06	-0.11
30-33	-0.19	-0.19	-0.13	-0.18	75-85	-0.12	-0.12	-0.08	-0.06
Average	***-0.11***	***-0.12***	***-0.06***	***-0.13***	***SD***	***0.10***	***0.10***	***0.07***	***0.15***

Note: Figures are MFPG using capital service growth rate minus MFPG using capital stock growth rates, averaged across countries (All in percentages).

As observed in the aggregate analysis, the industry picture also portrays an overestimation of MFPG when capital stock is used as a measure of capital input (Table 6). Industries communications (64), financial intermediation (65-67) and business services (71-74) have registered the largest composition effect, which may largely due to the growing importance of ICT capital in these service industries. Other industries followed the same trend include chemical products (24), electrical and electronic equipments (30-33) and transport equipment (34-35). These trends remain to be almost same in all the five countries (see Appendix Table 2). In all the industries except in agriculture, fishing and forestry (01-05) and in transport and storage (60-64), capital stock tends to overestimate MFPG in all models. It is important to note that the extent of the difference between capital stock and capital service growth rates (both in positive and negative cases) is high in all the countries, thus indicating the importance of taking composition effect into account while measuring capital input growth rates for the growth accounting purposes. As observed in the aggregate results, among the alternative models, CER has produces the largest differences in most industries, while IOR has produced the lowest. While almost 60 per cent of industries have shown an absolute difference of more than 0.1 percentage point in CER only less than 20 per cent have shown the same in IOR. Both INR and INRS have also followed the same trend as in CER, thus suggesting the role of capital gain term in bringing out the composition differences in capital assets.

Table 7: Tax Effect on MFPG: Pre Tax vs. Post Tax Rates of Return, Industry wise, 1979-2003

	Netherlands		**France**		**Germany**		**UK**		**US**	
ISIC	***INR***	***CER***	***INR***	***CER***	***INR***	***CER***	***INR***	***CER***	***INR***	***CER***
01-05	-0.04	0.05	0.01	0.01	-0.03	0.00	0.01	0.01	-0.07	-0.06
10-14	-0.02	-0.04	0.00	-0.02	-0.01	0.01	-0.09	0.01	0.03	-0.03
15-16	0.03	-0.02	0.03	-0.02	-0.01	0.01	0.02	-0.01	0.00	-0.16
17-19	0.01	-0.02	0.00	-0.03	-0.02	0.01	0.00	-0.02	0.00	-0.05
20	0.02	-0.02	0.00	-0.03	-0.01	0.01	0.01	0.00	0.01	-0.06
21-22	0.02	-0.04	0.02	-0.03	0.00	-0.03	0.02	-0.03	-0.01	-0.12
23	0.03	0.03	0.01	-0.04	0.06	0.14	-0.07	-0.02	0.04	-0.14
24	0.01	-0.03	0.04	-0.07	-0.01	-0.05	0.00	-0.02	-0.03	-0.25
25	0.02	-0.01	0.01	-0.08	0.00	-0.02	0.01	-0.02	0.00	-0.06
26	0.02	-0.02	0.02	-0.05	-0.03	0.01	0.03	-0.02	0.03	-0.09
27-28	0.04	-0.03	0.02	-0.02	-0.02	0.00	0.00	-0.01	0.02	-0.08
29	0.04	-0.01	0.01	-0.04	0.00	-0.01	0.00	-0.03	-0.01	-0.16
30-33	0.04	-0.04	0.02	-0.01	0.01	-0.02	0.01	-0.03	0.03	-0.13
34-35	0.02	0.00	0.04	-0.06	0.02	-0.03	0.01	-0.01	0.01	-0.09
36-37	0.01	-0.01	-0.01	-0.03	0.00	-0.01	0.00	-0.03	0.00	-0.08
40-41	0.03	-0.03	0.07	-0.03	-0.25	-0.03	-0.04	-0.04	0.06	-0.14
45	-0.01	-0.01	0.01	0.02	0.00	0.03	0.01	0.00	0.00	-0.04
50-51	-0.01	-0.06	0.00	-0.07	-0.05	-0.02	0.02	-0.01	0.00	-0.34
52	0.00	-0.03	0.03	-0.03	-0.01	-0.01	0.01	-0.01	0.01	-0.07
55	0.01	-0.03	0.03	-0.02	-0.04	0.01	0.03	0.00	0.01	-0.02
60-63	-0.02	0.01	0.05	0.03	-0.04	0.03	0.00	0.01	0.04	-0.03
64	0.06	-0.03	0.03	-0.02	0.15	0.00	0.02	-0.12	-0.03	-0.18
65-67	-0.03	-0.12	-0.04	-0.32	0.00	-0.14	0.04	-0.15	-0.15	-0.48
71-74	-0.03	-0.09	-0.02	-0.13	0.08	0.10	-0.02	-0.08	-0.09	-0.43
90-99	0.03	-0.02	0.03	-0.09	0.03	0.02	0.04	-0.01	0.02	-0.02
75-85	0.01	-0.01	0.02	-0.02	-0.04	0.00	0.02	-0.01	0.04	-0.03
Average	***0.01***	***-0.02***	***0.02***	***-0.05***	***-0.01***	***0.00***	***0.00***	***-0.03***	***0.00***	***-0.13***
SD	***0.02***	***0.03***	***0.02***	***0.07***	***0.06***	***0.05***	***0.03***	***0.04***	***0.04***	***0.12***

Note: Figures are MFPG estimated using rental prices without corporate tax -MFPG estimated using rental prices with corporate tax, under alternative assumptions (All in percentages).

Table 7 presents the tax effect on MFPG across industries. Since we observed no difference between different internal models in terms of the tax effect, we report the results only for the INR and CER models. The tax variable seems to show no effect on measured MFPG in the internal models. However, it makes notable differences in the MFPG at least in some industries -mostly in service sector industries- in external rate of return models. For instance, the external models shows a difference of 0.1 percent or more in industries financial intermediation (65-67) both in EU countries and in the US and in industries communications (64), business services (71-74), wholesale trade (50-51), electricity, gas and water (40-41), machinery (29), chemical products (24), petroleum and coal products (23) and food products (15-16) in the US. The only industries that have shown some differences in internal models are the financial intermediation (65-67) in the US and electricity, gas and water supply (40-41) in Germany. The observed differences are negative in most cases, indicating that the incorporation of tax variable reduces the estimated contribution of capital to output growth and hence produce a higher MFP growth.

Thus, to summarize, the impact of tax is negligible in most industries in the internal models both in the EU and the US, while it is important in some industries -mostly service industries- when the external models are considered. Thus if we read these observations along with the negligible differences observed at the aggregate level, we may conclude that despite its theoretical importance, from an empirical point of view the incorporation of tax makes no significant impact on the final growth rates of MFP in most industries and at the aggregate level.

Now, if we look at the differences between MFPG measured by alternative rental price models, we see a difference of more than 0.1 percent in a few industries in some countries (Tables 8 and 9). Within the three internal models-internal models with capital gain, without capital gain and with smoothed capital gain-there is hardly any noticeable difference between the first two models,[28] thus suggesting that the impact of price volatility on rental prices is trivial during the period under consideration (Table 8). However, there exists some difference between models with capital gain and without capital gain. Both in the US and in the UK, for instance almost half of the industries have shown a MFPG which is lower by more than 0.1 per cent when the capital gain term is included. The largest difference is observed in industries mining and quarrying (10-14), communications (64), electricity, gas and water (40-41) and transport and storage (60-63) in the US. In the UK, industries that have shown lower MFPG in IOR models include communications (64), business services (71-74), financial intermediation (65-67) and retail trade (52). A similar trend is seen in French electricity, gas and water generation sector (40-41). Thus, there seems to be some difference between the models that incorporate capital gain and those which do not, at the industry level, mostly in service sector industries in the UK and the US. In all these cases, the exclusion of capital gain term tends to underestimate the contribution of capital.

[28] Note that the difference between the first two columns (INR-IOR and INRS-IOR) under each country is the difference between two internal models with capital gain, which is quite small.

Table 8: Capital Gain Effect on MFPG: Internal Nominal vs. Internal Own Rates of Return, industry wise, 1979-03

	Netherlands		France		Germany		UK		US	
ISIC	***INR***	***INRS***	***INR***	***INRS***	***INR***	***INRS***	***INR***	***INRS***	***INR***	***INRS***
01-05	0.00	0.00	0.00	0.00	-0.01	-0.01	0.00	0.00	-0.04	-0.04
10-14	0.00	0.00	-0.03	-0.03	-0.01	-0.01	0.05	-0.05	-0.20	-0.18
15-16	-0.01	-0.01	-0.04	-0.04	-0.01	-0.01	-0.07	-0.08	-0.07	-0.08
17-19	-0.01	-0.01	-0.01	-0.01	0.00	0.00	-0.05	-0.05	-0.03	-0.04
20	-0.01	-0.01	-0.02	-0.02	-0.01	-0.01	-0.11	-0.10	-0.07	-0.07
21-22	-0.01	-0.01	-0.03	-0.03	-0.02	-0.02	-0.07	-0.08	-0.10	-0.12
23	0.01	-0.04	-0.03	-0.03	0.06	0.06	-0.05	-0.10	-0.14	-0.16
24	-0.01	0.00	-0.05	-0.05	-0.01	-0.01	-0.10	-0.11	-0.14	-0.16
25	-0.01	-0.01	-0.02	-0.02	-0.01	-0.01	-0.07	-0.08	-0.03	-0.04
26	-0.01	-0.01	-0.02	-0.03	-0.01	-0.01	-0.12	-0.11	-0.13	-0.13
27-28	-0.01	-0.01	-0.03	-0.03	0.00	0.00	-0.05	-0.05	-0.08	-0.10
29	-0.02	-0.02	-0.01	-0.01	0.00	0.00	-0.09	-0.09	-0.07	-0.08
30-33	-0.01	0.00	-0.02	-0.02	-0.01	-0.01	-0.11	-0.13	-0.13	-0.15
34-35	0.03	-0.02	-0.05	-0.06	0.00	0.00	-0.08	-0.09	-0.11	-0.12
36-37	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.04	-0.04	-0.06	-0.06
40-41	-0.02	-0.02	-0.17	-0.20	-0.04	-0.03	-0.11	-0.16	-0.12	-0.15
45	-0.01	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.04	-0.04
50-51	-0.01	-0.01	-0.02	-0.02	-0.01	-0.01	-0.11	-0.12	-0.05	-0.05
52	-0.01	0.00	-0.03	-0.03	-0.01	-0.01	-0.16	-0.16	-0.11	-0.13
55	-0.01	-0.01	-0.03	-0.04	-0.01	0.00	-0.04	-0.03	-0.03	-0.04
60-63	0.02	0.03	-0.07	-0.07	-0.08	-0.07	-0.15	-0.13	-0.15	-0.16
64	-0.01	-0.01	-0.11	-0.12	0.00	0.00	-0.59	-0.60	-0.18	-0.24
65-67	-0.01	-0.01	-0.13	-0.15	-0.03	-0.03	-0.24	-0.29	-0.18	-0.21
71-74	-0.01	0.00	-0.02	-0.02	-0.01	-0.01	-0.44	-0.41	-0.06	-0.07
90-99	-0.03	-0.02	-0.07	-0.08	0.00	0.00	-0.08	-0.10	-0.12	-0.14
75-85	-0.01	-0.01	-0.02	-0.03	-0.01	-0.01	-0.06	-0.06	-0.09	-0.10
Average	***-0.01***	***-0.01***	***-0.04***	***-0.05***	***-0.01***	***-0.01***	***-0.11***	***-0.13***	***-0.10***	***-0.11***
SD	***0.01***	***0.01***	***0.04***	***0.05***	***0.02***	***0.02***	***0.13***	***0.13***	***0.05***	***0.06***

Note: Figures are MFPG using internal rate of return with capital gain (INR and INRS) minus MFPG using internal rate of return without capital gain (IOR) (all in percentages)

Table 9: Rates of Return Effect on MFPG: Internal vs. External Rates of Return, industry wise, 1979-2003

	Netherlands		France		Germany		UK		US	
ISIC	***INR***	***IOR***	***INR***	***IOR***	***INR***	***IOR***	***INR***	***IOR***	***INR***	***IOR***
01-05	-0.13	-0.13	0.04	0.04	0.05	0.06	0.02	0.01	-0.07	-0.03
10-14	0.11	0.11	-0.06	-0.04	-0.02	-0.01	-0.24	-0.29	-0.22	-0.03
15-16	0.08	0.09	0.00	0.04	-0.02	-0.01	-0.05	0.03	0.15	0.22
17-19	0.03	0.04	0.03	0.04	-0.01	-0.01	-0.01	0.04	0.03	0.07
20	0.04	0.05	0.02	0.04	-0.02	-0.01	-0.11	0.00	0.01	0.09
21-22	0.10	0.12	0.03	0.06	0.01	0.03	-0.02	0.04	0.07	0.17
23	0.03	0.02	0.03	0.06	-0.03	-0.10	-0.03	0.02	0.03	0.17
24	0.08	0.09	0.08	0.13	0.04	0.05	-0.08	0.02	0.27	0.40
25	0.00	0.01	0.13	0.15	0.02	0.02	-0.04	0.03	0.06	0.09
26	0.09	0.10	0.04	0.07	-0.03	-0.02	0.05	0.17	0.04	0.17
27-28	0.09	0.11	0.00	0.02	-0.01	0.00	-0.04	0.01	0.01	0.09
29	0.09	0.11	0.04	0.06	0.01	0.02	-0.03	0.06	0.20	0.28
30-33	-0.03	-0.03	0.01	0.03	-0.01	0.00	-0.01	0.10	0.03	0.16
34-35	-0.09	-0.13	-0.03	0.02	0.02	0.02	-0.12	-0.04	-0.03	0.08
36-37	0.02	0.03	0.02	0.03	0.00	0.01	0.08	0.12	0.06	0.12
40-41	0.00	0.02	-0.17	-0.01	-0.06	-0.03	-0.13	-0.02	-0.06	0.06
45	0.02	0.03	-0.03	-0.02	-0.08	-0.07	-0.06	-0.05	0.01	0.05
50-51	0.17	0.18	0.11	0.13	-0.06	-0.04	0.05	0.16	0.27	0.32
52	0.08	0.09	0.05	0.08	-0.03	-0.02	-0.18	-0.02	-0.08	0.04
55	0.09	0.09	-0.05	-0.01	0.00	0.01	0.03	0.07	-0.02	0.01
60-63	0.03	0.00	-0.06	0.01	0.07	0.14	-0.14	0.01	-0.14	0.01
64	0.17	0.18	-0.09	0.02	0.11	0.11	-0.56	0.03	0.27	0.45
65-67	0.23	0.24	0.28	0.41	0.18	0.20	0.50	0.74	0.61	0.79
71-74	0.20	0.21	0.26	0.28	-0.07	-0.06	-0.60	-0.16	0.58	0.64
90-99	-0.05	-0.02	0.09	0.16	0.01	0.01	-0.02	0.06	-0.07	0.05
75-85	-0.03	-0.01	-0.03	0.00	0.00	0.01	-0.09	-0.02	-0.17	-0.08
Average	***0.06***	***0.06***	***0.03***	***0.07***	***0.00***	***0.01***	***-0.07***	***0.04***	***0.07***	***0.17***
SD	***0.09***	***0.09***	***0.10***	***0.10***	***0.06***	***0.06***	***0.20***	***0.17***	***0.20***	***0.21***

Note: Figures are MFPG using internal rate of return minus MFPG using external rate of return (all in percentages)

In Table 9, we provide the difference between internal and external models. Given the fact that there is hardly any difference between the two internal models that incorporate capital gain (INR and INRS), we have provided only the effect of INR and IOR models. Again in the US and in the UK a large number of industries have shown difference between internal and external models, but this number is quite low in other countries. In all the countries financial intermediation (65-67) has shown larger differences, accompanied by business services (71-74) in the Netherlands, France, the UK and the US. Such large difference between different rates of return models in service sector industries such as finance and business services are observed by previous studies also (e.g. Oulton, 2007). In most countries the MFPG produced by the internal models tend to be larger than that of the external models in a large number of industries, with the possible exceptions of Germany and the UK. As we observed before, the IOR models shows larger difference from the external models compared to INR models.

5.4 *Effect of Alternative Aggregation Procedures: Regression Analysis*

The above discussion based on visual inspection helps us understand the observed differences in MFPG under various assumptions. However, it would be interesting to see whether these observed differences are statistically significant. In order to test the statistical significance of these observed differences, we have estimated an OLS regression equation, which takes the following form:

$$\left[MFPG_{m,T}^{KS} - MFPG_{T}^{K}\right] = \beta_0 + \sum_{m=2}^{8} \beta_m D_m + \beta_T T + e \qquad (11)$$

where $MFPG_{KS}$ is the MFPG estimated using capital service growth rates under various assumptions and $MFPG_K$ is the MFPG estimated using capital stock growth rates. D_m's are dummy variables that take 1 for each of the 8 rate of return models (m=CER, CERTX, INR, INRTX, INRS, INRSTX, IOR and IORTX), and T is a period dummy variable that takes 1 for 1995-2003 period and zero otherwise. In order to avoid singular covariance matrix, one model is excluded; we exclude the CER dummy. The advantage of taking the composition effect on MFPG on the left hand side is that with a single regression we would be able to estimate the effect of using capital service growth rates instead of capital stock growth rate as well as the effect of various model assumptions regarding capital service aggregation. We had 416 observations (26 industries, 8 models and 2 time periods) in each country. The results are presented in Table 10.

Table10: Regression- Capital Composition Effect on MFPG on Alternative Rental Price Models

	Netherlands		France		Germany	UK		US	
Constnat	-0.143	**	-0.157	**	-0.005	-0.076		-0.345	**
	(0.03)		(0.018)		(0.032)	(0.05)		(0.039)	
CERTX	0.02		0.058	*	-0.001	0.023		0.141	**
	(0.041)		(0.024)		(0.042)	(0.066)		(0.052)	
INR	0.067		0.036		0.003	-0.065		0.068	
	(0.041)		(0.024)		(0.042)	(0.066)		(0.052)	
INRTX	0.052		0.022		0.012	-0.073		0.068	
	(0.041)		(0.024)		(0.042)	(0.066)		(0.052)	
INRS	0.064		0.029		0.005	-0.084		0.05	
	(0.041)		(0.024)		(0.042)	(0.066)		(0.052)	
INRSTX	0.048		0.015		0.016	-0.093		0.048	
	(0.041)		(0.024)		(0.042)	(0.066)		(0.052)	
IOR	0.074		0.078	**	0.015	0.049		0.178	**
	(0.041)		(0.024)		(0.042)	(0.066)		(0.052)	
IORTX	0.059		0.073	**	0.029	0.059		0.195	**
	(0.041)		(0.024)		(0.042)	(0.066)		(0.052)	
PERIOD	0.007		0.002		0.031	0.262	**	0.221	**
	(0.02)		(0.012)		(0.021)	(0.033)		(0.026)	
R^2	0.014		0.045		0.007	0.156		0.192	

Notes: Figures in parentheses are standard errors.

**indicates significance at 1 % level, * at 5 %.

The results are in conformity with our preceding observations. Since we exclude the CER model from right hand side of the above the specification, the intercept may be defined as the mean of the composition effect in the external rate of return model (without tax) during the period 1979-95. For all the countries the intercept is negative, though it is not significant in Germany and UK. As we noted before these are the two countries where we observed low composition effect during 1979-1995, particularly in the CER model. The negative sign shows that the capital stock significantly overestimates MFPG. The period dummy is positive for all countries, but significant only in UK and US. This coefficient should be interpreted with caution. It does not mean that the composition effect is higher in absolute magnitude during 1995-2003 compared to the previous period. Rather it implies that the negative capital composition effect on MFPG has declined significantly in both these countries during this period. In France and in the US the tax variable tends to play a significant role only in the constant rate of return models, while it is not significant in the other countries. There is no sign of difference in the internal models that include capital gain, annual and smoothed. Both in France and in the US internal models that do not incorporate capital gain component (IOR and IORTX) produce significantly higher composition effect. In both these countries, however, the coefficients of the IOR dummy are significant with and without tax, hence suggesting that the difference may not be due to the incorporation of tax, rather the capital gain component. In order to verify this we have estimated the model introducing a tax dummy that takes 1 for tax incorporated models. The results did not show any difference and are hence not reported. Incidentally, it is worth mentioning that Harper et al (1989) have also found a significant negative composition effect on capital service growth rates (implying positive effect on MFPG) in case of CER models. Thus the regression results validate our observations that while the tax variable is negligible, some differences are observed between MFPG produced by internal and external models. Importantly, there is notable difference between capital stock and capital service growth rates and the resultant MFP growth rates.

6. Conclusion

In this paper we attempted to understand the effect of alternative rental prices in capital aggregation on the measured growth rates of capital input and thereby multifactor productivity growth (MFPG). 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 empirical alternatives. This Paper has used four alternative rental price models, measured using internal rate of return with annual capital gain, internal rate of return with smoothed capital gain, internal rate of return with no capital gain and an external constant rate of return, in calculating capital service growth rates. Moreover, we attempted to understand the effect of incorporating taxes into all of these four models. The calculated capital service growth rates are used to calculate the MFPG using the growth accounting framework, in order to understand how sensitive the estimated MFPG's are to the use of different rental price models in capital aggregation.

Our results both at industry level as well as at aggregate economy level strengthen the case for using capital service growth rates instead of capital stock growth rates in growth accounting analysis. The composition effect, i.e. the difference between capital service and capital stock growth rates, is seen to be quite high in most industries in almost all the countries. This suggests that when the share of short-living asset increases in total capital stock, the use of capital stock in productivity analysis will overestimate actual MFPG.

Among the different internal rate of return models, the lowest number of negative rental prices is produced by the internal own rate of return model in almost all countries considered. This suggests that the incorporation of capital gain leads to negative rental prices. The negative rental prices may be an indication of the measurement error in capital compensation or in investment prices, as these two variables are crucial in the measurement of internal rate of return. Interestingly, even the use of a smoothed capital gain term, which is expected to reduce the volatility in investment price, does not reduce the number of negative rental prices significantly. Since the negative rental prices are theoretically inconsistent, the IOR model which produced the least number of negative rental prices may be considered superior to the ones with capital gain. However, since the number of negative values in all these models is quite small and the differences between different models are quite trivial, it is hard to make such a strong conclusion. Moreover, as noted by Hancock (1991), given the rise in world inflation rate it would be inappropriate to ignore capital gains and losses from user cost calculation.

The inclusion of corporate tax in the rental price calculation influences the measured growth rates of capital services and productivity only in a very few industries. The difference is found to be visible only in the constant external rate of return model both in the EU and the US for some service sector industries**.** More importantly the difference is quite negligible at the aggregate level. Therefore, from an empirical point of view, there is no strong evidence that the potential peril in using pre-tax rental prices in aggregating capital services for growth accounting analysis is very high, given this dataset and time period. This may, however, not be considered as an argument for the exclusion of corporate taxes in investment analysis.[29] The effect of differential taxes on investment is not tested here, rather from a strictly empirical perspective whether the tax makes any substantial difference in the conclusions regarding MFPG is examined. The cross-sectional implications of different tax regimes on investment behaviour are beyond the scope of the present study.

Among the alternative rental price models, however, there are marginal differences in the MFPG in some industries. The divergence is more between constant rates of return models and internal rates of return models, while it is relatively less between different internal models. This pattern holds across countries, though the number of industries registering differences is found to be high in the case of US.

Thus our results indicates that the choice of a particular measure of rate of return will have only less influence on the final conclusions derived on the contribution of MFPG and capital to economic growth. Though this choice may matter in some industries, it does not seem to matter much at the aggregate level. In particular, while the choice between exogenous and endogenous rate of return while aggregating capital services may be important for the measured MFPG, the choice between different internal models and the effect of corporate taxes are trivial.

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[29] For instance, Cummins et al (1996) observed significant tax effects on investment.

References

Balk, B.M (2007), "Measuring Productivity Change without Neoclassical Assumptions: A Conceptual Analysis", *CEPA Working Papers Series*, WP042007, School of Economics, University of Queensland, Australia.

Barro, R.J (1999), "Notes on Growth Accounting", *Journal of Economic Growth*, **4,** 119-137.

Berndt, E.R. (1990), "Comments on Hulten", in E.R Berndt and J. Triplett, eds., *Fifty Years of Economic Measurement*, NBER.

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, 961-89.

Berndt, E.R. and M.A. Fuss (1986), "Productivity Measurement with Adjustments for Variations in Capacity Utilization and Other Forms of Temporary Equilibrium', *Journal of Econometrics*, **33**, 7-29.

Bonde, K and H.S. Sørensen (2006), "Taxes and the Rate of Return in User Cost Expressions: Analysis of Different Approaches' Implications for Productivity Measure", Paper Presented at the *29th General Conference of the International Association for Research in Income and Wealth*, Joensuu, Finland.

Caselli, F (2004), "Accounting for Cross-Country Income Differences", *Handbook of Economic Growth*, 1A, North Holland, Elsevier.

Christensen, L.R. and D.W, Jorgenson (1969), "The Measurement of US Real Capital Input, 1929-1967", *Review of Income and Wealth*, **15**(4), 293-320.

Cummins, J.G., K.A. Hassett and R.G. Hubbard (1996), "Tax Reforms and Investment: A Cross-Country Comparison", *Journal of Public Economics*, **62**(1-2), 237-273.

Daveri, F (2004), "Delayed IT Usage: Is It Really the Drag on Europe's Productivity?", *CESifo Economic Studies*, 50(3), 397–421.

Denison, E.F (1969), "Some Major Issues in Productivity Analysis: An Examination of Estimates by Jorgenson and Griliches", *Survey of Current Business*, 1-27.

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, E (1980), "Aggregation Problems in the Measurement of Capital", in D. Usher, eds., *The Measurement of Capital*, Chicago, The University of Chicago Press.

Diewert, E (2001), **"**Measuring the Price and Quantity as Capital Services under Alternative Assumptions", *Discussion Paper* 01-24, Department of Economics, the University of British Columbia.

EU KLEMS Database (2007), Timmer, M.P., M. O'Mahony and B. van Ark, "The EU KLEMS Growth and Productivity Accounts: An Overview", *University of Groningen and University of Birmingham*.

Fraumeni, B.M (1997), “The Measurement of Depreciation in the US National Income and Product Accounts”, *Survey of Current Business,* 7-23

Hall, R. and D.W. Jorgenson (1967), Tax policy and investment behaviour, *American Economic Review,* **57**(3), 391-414.

Hancock, D (1991), *“A Theory of Production for the Financial Firm”*, Norwell, Massachusetts: Kluwer Academic Publishers.

Harper, M.J, E.R Berndt and D.O, Wood, (1989), “Rates of Return and Capital Aggregation Using Alternative Rental Prices”, in Jorgenson, D.W. and R. Landau, eds., *Technology and Capital Formation,* MIT Press.

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

Hulten, C.R. (1990), “The Measurement of Capital”, in E.R Berndt and J. Triplett, eds., *Fifty Years of Economic Measurement,* NBER.

Hulten, C.R. (2000), “Total Factor Productivity: A Short Biography”, *NBER working paper* 7471.

Hulten, C.R. and F. Wykoff (1981), “The Measurement of Economic Depreciation”, in Hulten, C.R, eds., *Depreciation, Inflation and the Taxation of Income from Capital*, Washington D.C., Urban Institute Press.

Inklaar, R, M. O’Mahony and M.P. Timmer (2005), “ICT and Europe’s Productivity Performance: Industry-level Growth Account Comparisons with the United States”, *Review of Income and Wealth,* **51**(4), 505-536.

Inklaar, R, M.P Timmer and B. van Ark (2008), “Market Services Productivity across Europe and the US”, *Economic Policy,* **25**(33), 139-194.

Jones, B.F. and B.A Olken, (2005), “The Anatomy of Start-Stop Growth”, *NBER Working Paper* No. W11528.

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

Jorgenson, D.W (1967), “The Theory of Investment Behaviour, ” in R. Ferber, eds., *Determinants of investment Behaviour,* New York, Columbia University Press, 247-59.

Jorgenson, D.W (2001), “Information Technology and the U.S. Economy”, *American Economic Review,* **91**(1), 1-32.

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

Jorgenson, D.W. and C.D Siebert (1968), “A Comparison of Alternative Theories of Corporate Investment Behaviour”, *American Economic Review,* **58** (4), 681-712.

Jorgenson, D.W. and K, Vu (2005), “Information Technology and the World Economy”, *Scandinavian Journal of Economics*, **107**(4), 631–650.

Jorgenson, D.W. and K. 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. and K.Y. Yun (1991), “The Excess Burden of Taxation in the U.S”, *Journal of Accounting, Auditing, and Finance,* **6**(4), 487-509.

Jorgenson, D.W. and M.A. Sulliven (1981) “Inflation and Corporate Capital Recovery”, in Hulten, C.R, eds., *Depreciation, Inflation, and the Taxation of Income from Capital,* 171-238, Washington, DC: The Urban Institute Press.

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

OECD (2001a), “*Measuring Capital: A Manual on the Measurement of Capital Stocks, Consumption of Fixed Capital and Capital Services”*, Paris, OECD.

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

O'Mahony, M and B. van Ark (2003), *EU Productivity and Competitiveness: An Industry Perspective - Can Europe Resume the Catching-up Process?*, Office for Official Publications of the European Communities, Luxembourg.

Oulton, N (2007), “Ex post versus Ex ante Measures of the User Cost of Capital”, *Review of Income and Wealth*, **53**(2), 295-317.

Schreyer, P (2004), “Measuring Multifactor Productivity when Rates of Return are Exogenous”, *Paper presented at the SSHRC International Conference on Index Number Theory and the Measurement of Prices and Productivity,* Vancouver.

Schreyer, P., P. Bignon and J. Dupont (2003), “OECD Capital Services Estimates: Methodology and a First Set of Results”, *OECD Statistics Working Paper* 2003/6.

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

Sørensen, P.B (2007), “Can Capital Income Taxes Survive? And Should They?”, *CESifo Economic Studies,* **53**(2), 172–228.

van Ark, B., M. O’Mahony and M.P Timmer (2008), “The Productivity Gap between Europe and the United States: Trends and Causes”, *Journal of Economic Perspective*, **22**(1), 25-44.

van Ark, B., R. Inklaar and R.H. McGuckin (2003), “ICT and Productivity in Europe and the United States: Where Do the Differences Come From?”, *CESifo Economic Studies*, **49**(3), 295–318.

Woodland, A.D (1975), "Substitution of Structures, Equipment and Labor in Canadian Production", *International Economic Review*, **16**(1), 171-87.

APPENDIX

Appendix Table 1: Percentage of Negative values in Rental Prices, industry wise

NLD	**INR**	**INRTX**	**INRS**	**INRSTX**	**IOR**	**IORTX**
17-19	2.0	2.0	2.0	2.0	2.0	2.0
20	-	-	-	-	-	0.7
23	2.0	3.3	0.7	2.0	0.7	2.0
25	1.3	3.3	2.0	2.7	1.3	3.3
30-33	3.3	4.7	4.0	4.7	3.3	4.7
34-35	4.7	8.7	4.7	8.7	5.3	7.3
Total	***0.5***	***0.8***	***0.5***	***0.8***	***0.5***	***0.8***
FRA						
10-14	13.3	15.3	12.7	13.3	12.7	13.3
17-19	-	2.0	-	2.0	-	-
20	3.3	3.3	3.3	3.3	2.7	3.3
23	0.7	0.7	0.7	0.7	0.7	0.7
26	4.7	4.7	4.7	4.7	4.7	4.7
27-28	2.7	3.3	2.7	3.3	2.7	3.3
30-33	0.7	2.0	-	2.7	-	-
34-35	6.7	8.0	6.7	8.0	5.3	6.7
40-41	-	0.7	-	-	-	-
Total	***1.2***	***1.5***	***1.2***	***1.5***	***1.1***	***1.2***
GER						
01-05	10.0	12.0	9.3	12.0	9.3	13.3
10-14	8.0	21.3	8.7	21.3	6.7	22.0
17-19	-	-	-	0.7	-	-
20	-	1.3	-	1.3	-	1.3
23	3.3	5.3	3.3	5.3	3.3	5.3
27-28	-	0.7	-	1.3	-	-
30-33	-	0.7	-	1.3	-	2.0
34-35	1.3	2.7	1.3	2.7	0.7	2.0
36-37	-	1.3	-	2.0	-	0.7
52	0.7	1.3	0.7	1.3	-	1.3
55	2.0	10.0	2.7	9.3	2.7	8.7
60-63	4.7	8.0	2.7	9.3	2.7	12.0
Total	***1.2***	***2.5***	***1.1***	***2.6***	***1.0***	***2.6***

UK	**INR**	**INRTX**	**INRS**	**INRSTX**	**IOR**	**IORTX**
01-05	1.3	2.0	-	-	-	-
10-14	2.0	2.0	1.3	1.3	-	-
20	-	1.3	-	-	-	-
21-22	3.3	4.0	2.7	3.3	2.7	2.7
23	6.7	8.0	4.7	5.3	3.3	4.0
24	2.0	2.0	0.7	1.3	-	-
25	2.7	2.7	2.7	2.7	1.3	2.0
27-28	6.0	6.0	4.7	5.3	4.0	4.7
30-33	2.0	2.7	-	0.7	-	-
34-35	9.3	12.7	6.7	9.3	7.3	8.0
40-41	-	0.7	-	-	-	-
52	-	1.3	-	-	-	-
55	0.7	1.3	-	-	-	-
60-63	6.0	7.3	1.3	1.3	-	-
64	3.3	5.3	0.7	3.3	-	1.3
71-74	2.0	2.0	-	-	-	-
90-99	0.7	0.7	-	-	-	-
75-85	2.7	3.3	-	0.7	-	-
Total	***1.9***	***2.5***	***1.0***	***1.3***	***0.7***	***0.9***
US						
10-14	0.7	4.0	-	-	-	-
20	-	0.7	-	0.7	-	-
21-22	-	0.7	-	-	-	-
26	0.7	0.7	0.7	0.7	0.7	0.7
30-33	0.7	2.0	-	2.7	-	0.7
34-35	1.3	1.3	1.3	1.3	1.3	1.3
45	0.7	1.3	-	-	-	0.7
60-63	-	1.3	-	1.3	-	-
90-99	2.0	4.0	2.7	2.7	2.0	2.7
Total	***0.2***	***0.6***	***0.2***	***0.4***	***0.2***	***0.2***

Note: Only industries with negative rentals are reported.

Appendix Table 2: Average Capital Composition Effect on MFPG, 1979-03, Industry wise

	Netherlands			France			Germany			UK			US		
ISIC	***INR***	***IOR***	***CER***	***INR***	***IOR***	***CER***	***INR***	***IOR***	***CER***	***INR***	***IOR***	***CER***	***INR***	***IOR***	***CER***
01-05	0.19	0.19	0.32	-0.03	-0.03	-0.07	0.16	0.17	0.11	0.06	0.06	0.04	0.03	0.07	0.10
10-14	-0.01	-0.01	-0.12	-0.13	-0.10	-0.06	-0.02	-0.01	0.00	0.15	0.09	0.39	-0.27	-0.08	-0.05
15-16	-0.10	-0.09	-0.18	-0.13	-0.10	-0.14	0.00	0.02	0.03	-0.13	-0.06	-0.09	-0.15	-0.08	-0.30
17-19	-0.09	-0.07	-0.11	-0.03	-0.02	-0.06	0.05	0.05	0.06	-0.07	-0.02	-0.05	-0.08	-0.04	-0.11
20	-0.10	-0.09	-0.14	-0.03	-0.02	-0.05	0.01	0.02	0.03	-0.03	0.08	0.08	-0.14	-0.06	-0.15
21-22	-0.15	-0.14	-0.25	-0.10	-0.07	-0.13	-0.04	-0.02	-0.05	-0.10	-0.03	-0.08	-0.20	-0.10	-0.27
23	-0.06	-0.07	-0.09	-0.09	-0.06	-0.11	0.18	0.12	0.21	0.18	0.23	0.21	-0.36	-0.22	-0.39
24	-0.09	-0.08	-0.17	-0.20	-0.15	-0.28	-0.07	-0.06	-0.11	-0.14	-0.04	-0.06	-0.30	-0.16	-0.56
25	-0.07	-0.06	-0.07	-0.09	-0.08	-0.22	-0.03	-0.02	-0.04	-0.11	-0.04	-0.07	-0.07	-0.04	-0.13
26	-0.09	-0.08	-0.19	-0.11	-0.08	-0.15	0.05	0.06	0.08	-0.11	0.01	-0.16	-0.19	-0.07	-0.24
27-28	-0.17	-0.16	-0.27	-0.07	-0.05	-0.07	0.02	0.02	0.03	-0.07	-0.02	-0.03	-0.20	-0.12	-0.22
29	-0.19	-0.17	-0.28	-0.06	-0.05	-0.10	-0.02	-0.01	-0.03	-0.08	0.00	-0.06	-0.17	-0.10	-0.37
30-33	-0.33	-0.32	-0.30	-0.08	-0.06	-0.09	-0.05	-0.04	-0.04	-0.10	0.01	-0.09	-0.38	-0.25	-0.41
34-35	-0.17	-0.21	-0.08	-0.22	-0.17	-0.19	-0.08	-0.08	-0.10	-0.15	-0.08	-0.03	-0.30	-0.19	-0.27
36-37	-0.05	-0.04	-0.07	-0.02	-0.01	-0.04	-0.03	-0.02	-0.02	-0.02	0.01	-0.10	-0.13	-0.07	-0.19
40-41	-0.17	-0.15	-0.17	-0.28	-0.11	-0.10	0.26	0.30	0.33	-0.07	0.04	0.06	-0.51	-0.39	-0.45
45	-0.02	-0.01	-0.04	0.00	0.01	0.03	0.04	0.05	0.12	-0.01	0.00	0.04	-0.08	-0.04	-0.09
50-51	-0.10	-0.09	-0.27	-0.06	-0.04	-0.17	0.03	0.05	0.09	-0.01	0.10	-0.06	-0.06	-0.01	-0.33
52	-0.06	-0.05	-0.14	-0.15	-0.11	-0.19	-0.01	0.00	0.02	-0.10	0.05	0.07	-0.27	-0.15	-0.19
55	-0.05	-0.04	-0.13	-0.11	-0.08	-0.07	0.10	0.11	0.10	-0.06	-0.03	-0.09	-0.07	-0.03	-0.04
60-63	0.11	0.09	0.09	-0.06	0.01	0.00	0.17	0.25	0.10	0.00	0.15	0.14	-0.18	-0.03	-0.04
64	-0.27	-0.26	-0.44	-0.20	-0.09	-0.11	-0.32	-0.32	-0.43	-0.61	-0.02	-0.05	-0.36	-0.18	-0.62
65-67	-0.24	-0.23	-0.47	-0.37	-0.25	-0.65	-0.17	-0.15	-0.35	-0.51	-0.26	-1.00	-0.22	-0.03	-0.82
71-74	-0.10	-0.10	-0.31	-0.12	-0.10	-0.38	-0.03	-0.02	0.04	-1.18	-0.73	-0.58	-0.22	-0.16	-0.80
90-99	-0.15	-0.12	-0.10	-0.28	-0.21	-0.37	-0.02	-0.02	-0.04	-0.13	-0.05	-0.11	-0.02	0.09	0.04
75-85	-0.08	-0.07	-0.05	-0.11	-0.08	-0.08	0.04	0.06	0.04	-0.14	-0.08	-0.05	-0.32	-0.23	-0.15
Average	***-0.10***	***-0.09***	***-0.16***	***-0.12***	***-0.08***	***-0.15***	***0.01***	***0.02***	***0.01***	***-0.14***	***-0.02***	***-0.07***	***-0.20***	***-0.10***	***-0.27***
SD	***0.11***	***0.10***	***0.16***	***0.09***	***0.06***	***0.14***	***0.11***	***0.12***	***0.15***	***0.27***	***0.17***	***0.25***	***0.13***	***0.10***	***0.24***

Note: Figures are MFPG using capital service growth rate minus MFPG using capital stock growth rates (All in percentages). Since the results for INR and INRS are almost the same, only INR based results are reported.

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