

University of Groningen

Measurement and analysis of capital, productivity and economic growth

Erumban, Abdul Azeez

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:
2008

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Erumban, A. A. (2008). *Measurement and analysis of capital, productivity and economic growth*. [Thesis fully internal (DIV), University of Groningen]. PrintPartners Ipskamp B.V., Enschede, The Netherlands.

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Chapter 3

Rental Prices, Rates of Return, Capital Aggregation and Productivity: A Sensitivity Analysis*

3.1 Introduction

In the previous chapter we discussed the importance of using capital services in productivity analysis instead of capital stock. However, we have not delved into the details of capital service prices, also called as rental prices, which is the central theme of this chapter. Capital service prices are not directly observed; rather the researcher has to impute them following certain theoretical yardsticks. The measurement of rental prices is fraught with a number of issues, which are often difficult to examine in a cross-country context due to limited data availability.

There exist alternate theoretical views on how to derive the various components of rental prices. For instance, in our previous analysis in chapter 2 we opted to use an external (or exogenous) rate of return in the rental price calculation. Nevertheless, there is no consensus in the literature on whether one should use an exogenous rate of return or an endogenous rate of return (Berndt, 1990; Schreyer et al., 2003). An arbitrary choice for a particular rate may influence the calculated growth rates of capital input and consequently the contributions of proximate factors to economic growth, thus affecting the conclusions inferred from the observed empirical results. Therefore, it is imperative to know the sensitivity of growth rates of aggregate capital and thereby MFPG to the particular assumptions one makes while deriving the rental prices for capital aggregation.

The aim of this chapter is to understand whether the use of different rates of return and rental price models in capital service aggregation produces significantly different capital services and thereby MFP growth rates. In this analysis, we move away from the large cross-country context of chapter 2 and restrict our analysis to four EU countries and the United States, as we have better data for these countries to test the sensitivity of various assumptions. Harper et al (1989) have conducted a study by utilizing five

* This chapter draws upon Erumban (2008), Rental prices, rates of return, capital aggregation and productivity: Evidence from EU and US, *CEifo Economic Studies*, 54 (3), 499-533.

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 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 measured MFPG as it will affect the cost share of capital and thereby the growth rate of capital services. 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 3.2.1 for a detailed discussion).

The chapter is organized into five sections. The second section of this chapter presents an elaborate discussion on the concept of rental price and its measurement. The alternative measurement approaches discussed in this section are used to test the sensitivity of MFPG to the alternative assumptions in the remaining part of the chapter. In Section three we discuss the data used in the empirical analysis. Empirical results are discussed in Section four, and finally Section five concludes the chapter.

3.2 Rental Prices: Concept and Measurement¹

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).

¹ This section follows largely from Hall and Jorgenson (1967) and Jorgenson and Sullivan (1981).

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 Jorgenson 1967; Christensen and Jorgenson, 1969). In the absence of corporate taxes, they derive this relationship as,

$$P^I(s) = \int_s^{\infty} e^{-(r+\delta)(t-s)} c(t) dt \quad (3.1)$$

where as in (2.6) P^I is the price of capital assets, r is the discount rate (or rate of return) and δ is the rate of depreciation rate of capital. 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:²

$$c_{i,t} = r_t P_{i,t-1}^I + \delta_i P_{i,t}^I - \dot{P}_{i,t}^I \quad (3.2)$$

where $\dot{P}_{i,t}^I$ 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 $\dot{P}_{i,t}^I = (P_{i,t}^I - P_{i,t-1}^I)$.

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

² Equation (3.2) is analogous to the one we have used in the previous chapter, i.e. (2.6), except that (2.6) contains no capital gain term, as we assumed an external real rate of return, which is net of capital gain.

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).³ 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; King, 1974; Sinn, 1991).⁴ In line with Hall and Jorgenson (1967) and Harper et al (1989), incorporating tax factors equation (3.2) can be rewritten for i^{th} asset as⁵

$$c_{i,t} = T_{i,t} \left[r_t P_{i,t-1}^I + \delta_i P_{i,t}^I - \dot{P}_{i,t}^I \right] + b_{i,t} \quad (3.3)$$

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):

$$T_{i,t} = \frac{1 - u_t z_{i,t} - k_{i,t}}{1 - u_t} \quad (3.4)$$

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.⁶

³ The empirical evidences on the effect of tax reforms on cost of capital and thereby investment decisions are mixed. For instance, Cummins et al (1996) shows significant tax effect, while a review by Chirinko (1993) shows evidence which is less supportive of tax effect on investment decisions.

⁴ 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. The effect of tax on investment has also been examined by Feldstein (1982)'s effective tax rate models.

⁵ See Jorgenson and Sullivan (1981) for a detailed discussion on the derivation of the tax incorporated rental price formula.

⁶ 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. Further discussions on effective tax rate measurement may be found in Fullerton (1999).

The user cost formulation in equation (3.3) is assumed to be equivalent to the marginal product of capital. 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.

The Components of Rental Prices

Equation (3.3) 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 chapter is concerned with the measurement of (3.3) 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 chapter.

Depreciation

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, 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 (3.3) 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).⁷ Depreciation rates may vary over time and across countries and industries. However, considering the computational simplicity and the empirical support provided

⁷ 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.

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 chapter. Rather, as in the previous chapter, we opt to follow general practice. We assume a geometric depreciation pattern (see footnote 8 in chapter 2 for a brief note on other forms of depreciation). Therefore, we concentrate below on the other two components — the rate of return and the capital gain.

Rates of Return

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.⁸ 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; Hulten, 1990; Diewert, 2001). 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

⁸ See Box 3.1 for a snapshot of these two approaches. Also see EUKLEMS (2007) and OECD (2001a) for a discussion of these alternatives.

internal rate is a better measure to use in a growth accounting exercise from a theoretical perspective, as suggested by Berndt (1990).

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 chapter 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.

$$M_t = \sum_{i=1}^n c_{i,t} K_{i,t}^s \quad (3.5)$$

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:

$$M_t = P_t^y Y_t - w_t L_t \quad (3.6)$$

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.⁹ 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:

⁹ Note that the sum of labour and capital compensation equals gross value added at factor cost under all the typical neoclassical assumptions concerning a production function (Berndt and Hesse, 1986). Also, the labour compensation should include compensation to self-employed. Otherwise, the property compensation will be overestimated.

$$IR_t = \frac{\left[M_t - \sum_{i=1}^n \left[\delta_{i,t} T_{i,t} P_{i,t}^I K_{i,t}^{st} - T_{i,t} \dot{P}_{i,t}^I K_{i,t}^{st} + b_{i,t} K_{i,t}^{st} \right] \right]}{\sum_{i=1}^n P_{i,t-1}^I T_{i,t} K_{i,t}^{st}} \quad (3.7)$$

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 (3.6) and (3.7) 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 (3.7).

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 exogenous information, for example, 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.

Box 3.1: Internal vs. external rate of return

	Internal (<i>ex post</i>)	External (<i>ex ante</i>)
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 <i>ex post</i>) rate (Oulton, 2007).
The-ory	Consistent with neoclassical theory, and hence the neoclassical growth accounting framework	No neoclassical assumptions
Advantages and Disadvantages	Assumes that sum of rental payments for all assets equal to total property compensation (M) that can be derived from value added as a residual after labour compensation, which implies	Do not impose the condition that the gross operating surplus is exhausted by factor payments.
	(i) if an asset is excluded rate of return will be overestimated (e.g. intangibles) ¹⁰	Independent of the number of assets, and therefore do not have the problem of overestimation 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.

¹⁰ 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.

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).¹¹ 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. Recent empirical studies also differ in the external rates used in productivity measurement. For instance, a range of rates such as a weighted average of corporate debt and corporate equity rate, with weights being the proportion of these two rates in business capital (Baldwin and Gu, 2007), an average of interest rate with different maturities (Diewert et al., 2005), a constant annual real interest rate plus rate of inflation (Diewert, 2001) etc., are all being used. 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.¹² An examination of the average bond rate and treasury rate (net of inflation), used in the previous chapter, also seems to support this assumption, as this rate ranges between 3 to 4 per cent between countries in our sample. In the present study, we use this 4 per cent constant external rate of return (hereafter CER).

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,

¹¹ 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 (Schreyer et al., 2004; Schreyer, 2004; Baldwin et al 2005). 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).

¹² Also see Oulton (2007) who makes a similar assumption.

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 (3.2) one way of incorporating capital gain into the measurement of rental prices is to assume a perfectly anticipated capital gain (Christensen and Jorgenson, 1969; Harper et al., 1989; Jorgenson and Yun, 1991). Both in (3.3) and in (3.7) 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. $\dot{P}_{i,t}^I = (P_{i,t}^I - P_{i,t-1}^I)$.¹³ 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

¹³ Diewert (1980), however, considers capital gain as the difference between current and future prices (Also see Harper et al., 1989). One may derive expected capital gain terms by using econometric techniques that will help one forecast next period’s asset prices using past information on its movement. Throughout this chapter, we follow Jorgenson’s approach, as most empirical studies followed this method.

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 (3.7), thus providing a third internal rate of return model which we call the INR with smoothed capital gain (INRS).

Table 3.1: Alternative rental price models

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

Note that in all the models we assume that the internal 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 3.7 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 3.1 lists these 8 rental price models.

3.3 Data and Variables

The data used in this study are based primarily on O'Mahony and van Ark (2003), and updates available through GGDC industry growth accounting database.¹⁴ The present study is conducted for four EU countries — Netherlands (NLD), France (FRA), Germany (GER) and UK — and the US using annual data for the period 1979-2003 for 26 industry groups listed in Table 3.2.

¹⁴ For a detailed description of this data see Inklaar et al (2005).

Table 3.2: 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-metallic 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

Note that in the previous chapter we have used the PWT data, which provides only three components of aggregate investment: construction, machinery and transport equipment. The GGDC dataset provides more detailed asset composition. We use six asset types, namely non-IT machinery, non-residential structures, transport equipment, IT equipment, communication equipment and software. Also, it is not possible to calculate the labour compensation from the PWT, which is essential for the computation of internal rate of return (see equation 3.7). Finally, to obtain a more disaggregated picture, in this chapter, we have data at industry level, which is not available from the PWT.

The empirical implementation in this chapter 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. The output is measured by Value added. 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 2.7). In the previous chapter, we have assumed a common labour share of 0.7 across countries, due to lack of data on employee compensation in a cross-country context. However, in this chapter, 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.¹⁵

Capital stock is estimated using the perpetual inventory method for six asset types using equation (2.2). The aggregate capital stock is arrived at using (2.3). The capital service growth rates are derived using equation (2.6) applying alternative rental prices calculated using different rates of return models listed in Table 3.1. A geometric rate of depreciation is assumed. These rates are based on Fraumeni (1997) and Jorgenson and Stiroh (2000) and are industry-specific (see Inklaar et al., 2005). Investment price deflators with base year 1995 are used to represent the asset prices.

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 (3.4), using the data on statutory tax rates on corporate income and the present

¹⁵ 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.

discounted value of depreciation allowances provided by Devereux, et al (2002).¹⁶ The statutory tax rates in the countries in our sample have shown a declining tendency over time, particularly during 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 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 3.7). 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 production¹⁷ 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

¹⁶ 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.

¹⁷ 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.

taxes not only on capital but also on employees' compensation. However, since the results are found to remain the same, they are not reported.

3.4 Empirical Results

As we have measured the rates of return and the rental prices using the four model assumptions, with and without corporate taxes (see Table 3.2), we have eight 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.

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 3.5) turns negative.¹⁸ This may result in negative rates of return. In such cases, the measured rental prices using the internal rate of return may also become negative. Negative rental prices can even arise when the rate of return is positive, but with large capital gains in the user cost formula. Such negative rental prices are theoretically inconsistent, as the growth accounting assumptions require input prices to be positive (Berndt and Fuss, 1986). Therefore, the occurrence of negative rental prices may be considered as one of the criteria for choosing a particular model of rate of return. The models that make a large number of negative rentals may be least preferred.

Table 3.3: 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

Notes: All numbers are expressed as percentages of total observations. INR is internal nominal rate of return with annual capital gain, INRS is INR with smoothed capital gain, and IOR is internal own rate of return (also see Table 3.1).

¹⁸ In cases where there are high net subsidies, or big losses, value added may become less than labour compensation resulting in negative capital compensation.

Table 3.3 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 observations (26 industries \times 6 asset types \times 25 years), on average 1.6 percent are negative values, with a maximum of 2.5 per cent in Germany and a minimum of 0.8 per cent in the Netherlands.¹⁹ 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 produce 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 3.1). Non-residential structures produces negative rental prices in internal models for all the countries. As noted by Bonde and Sørensen (2006) this may largely be due to the swing in 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 fewer negative values, the difference between IOR and other models is quite small. In all cases, on average only less than 2 per cent of negative values are observed.

Effect of Alternative Rate of Return Models: Aggregate Results

We have calculated the rental share weighted capital service growth rates using equation (2.5) for all 26 industry groups in each country separately, over the period 1979-2003 using alternative rental prices. These capital service growth rates are plugged into equation (2.8) in order to calculate the MFP growth. A comparison of the MFPG obtained from different models will help us understand how sensitive measured MFP

¹⁹ 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. Taxes on production in German mining industry during this period were as high as minus 102 per cent of real value added in 1996. These taxes have shown a declining trend in later years, but were still at minus 68 per cent in 2003.

growth is to these different capital aggregation procedures. The effect of alternate aggregation procedure on aggregate economy MFPG is depicted in Figures 3.1a to 3.1d.²⁰ 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.

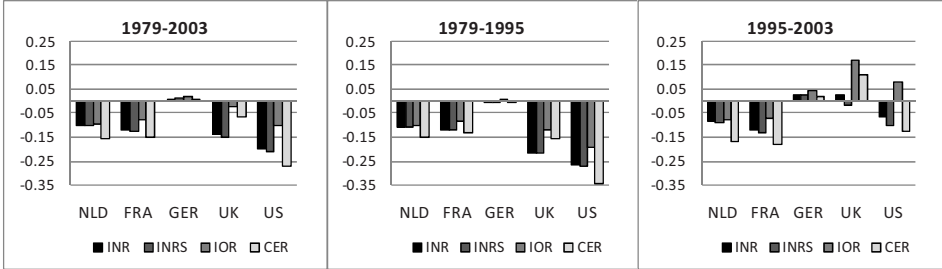
In Figure 3.1a the average composition effects on MFPG measured as the difference between the MFPG measured using the growth rate of capital service and capital stock are depicted. It may be noted that the larger composition effect could occur due to the shift towards equipment investment, particularly 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 the 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 raise the capital service growth rate relative to capital stock growth rate, and lower MFPG. In most countries the capital composition effect on MFPG is negative indicating that the use of capital stock tends to overestimate the MFPG. Exceptions are Germany and the UK, particularly during the second period, 1995-2003. In general the effect is larger for the exogenous rate of return model and smaller for IOR models. The large difference between capital service growth rate and capital stock growth rate in UK when exogenous rate of return is used is also observed by Oulton (2007). Our results are comparable to Harper et al (1989) for the United States, in terms of the ranking of different models and the signs of the effects, 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 the rental price models. It is clear from the Figure 3.1b that the inclusion of the tax variable has shown generally very minor effects on MFPG. The differences are quite marginal and typically lower than 0.05 percent. The US is the only country where there is some difference observed when tax is incorporated throughout the period, but only for 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 for the measurement of growth rates of MFP.

²⁰ 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 alternative model specifications the former approach is more sensible.

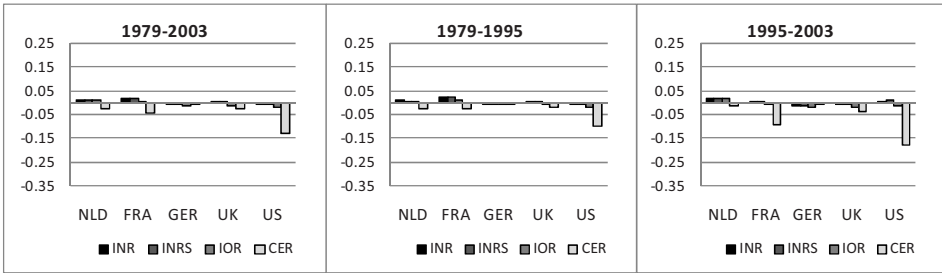
Figure 3.1: The effect of alternative capital aggregation on MFPG (in %)

Figure 3.1a: The capital composition effect on MFPG



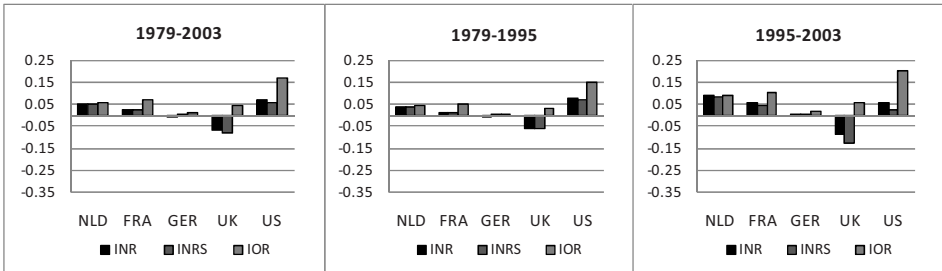
Note: MFPG using capital services minus MFPG using capital stock.

Figure 3.1b: The tax effect on MFPG



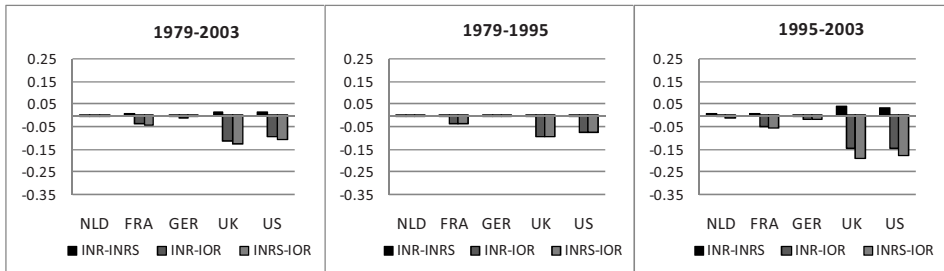
Note: MFPG using capital services without tax minus MFPG with tax.

Figure 3.1c: The rate of return effect on MFPG (internal vs. external)



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

Figure 3.1d: The rate of return effect on MFPG (internal vs. internal)



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

To compare alternative models of rental prices, it can be seen that there are only modest differences between external and internal models (Figure 3.1c). The external models tend to produce lower MFPG compared to the internal models. This is true in all countries except 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 be no significant difference in most countries. Nevertheless, the inclusion of the capital gain term does make some differences at least for a few countries (Figure 3.1d). For instance, for the US and in the UK, the difference between models with capital gain and without capital gain amounts to more than 0.15 percentage points during 1995-2003. In both countries, the difference between INR with annual capital gain and INR with smoothed capital gain is also bigger, even though the magnitude is still trivial. This may suggest that difference in INR and IOR in these countries may be due to the change in the investment prices that would affect the capital gain term. The IOR model has generally shown a tendency to produce larger MFPG compared to the INR models.

Effect of Alternative Aggregation Procedure: Industry wise Results

The aggregate picture depicted in the previous section, however, need not necessarily reflect the cross-industry story. Table 3.4 shows the differences between capital service

and capital stock growth rates for 26 industry groups and Tables 3.5 3.4 to 3.7 depict the difference in MFPG produced by different models.

Table 3.4: 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

Notes: Figures are MFPG using capital service growth rate minus MFPG using capital stock growth rates, averaged across 5 countries (all in percentages). SD is standard deviation.

Just as for the aggregate analysis, the industry picture portrays an overestimation of MFPG when using capital stock as a measure of capital input (Table 3.4). Communications (64), financial intermediation (65-67) and business services (71-74) are the industries that have registered the largest composition effect, which may be 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 the same for all five countries (see Appendix Table 3.2). In all industries except agriculture, fishing and forestry (01-05) and transport and storage (60-63), the use of 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 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 produced the largest differences for 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 the capital gain term in bringing out the composition differences in capital assets.

Table 3.5: Tax effect on MFPG: Pre tax vs. post tax rates of return, industry wise, 1979-2003

ISIC	Netherlands		France		Germany		UK		US	
	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
<i>Average</i>	<i>0.01</i>	<i>-0.02</i>	<i>0.02</i>	<i>-0.05</i>	<i>-0.01</i>	<i>0.00</i>	<i>0.00</i>	<i>-0.03</i>	<i>0.00</i>	<i>-0.13</i>
<i>SD</i>	<i>0.02</i>	<i>0.03</i>	<i>0.02</i>	<i>0.07</i>	<i>0.06</i>	<i>0.05</i>	<i>0.03</i>	<i>0.04</i>	<i>0.04</i>	<i>0.12</i>

Notes: Figures are MFPG estimated using rental prices without corporate tax minus MFPG estimated using rental prices with corporate tax, under alternative assumptions (all in percentages). SD is standard deviation.

Table 3.5 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, there are notable differences in MFPG in some industries — mostly in service industries — when using 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) for the US. The only industries that show some differences in internal models are 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 the tax variable reduces the estimated contribution of capital to output growth and hence produce a higher MFP growth. 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.

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 for some countries (Tables 3.6 and 3.7). Within the three internal models — with annual capital gain, without capital gain and with smoothed capital gain — there is hardly any noticeable difference between the first two models,²¹ thus suggesting that the impact of price volatility on rental prices is trivial during the period under consideration (Table 3.6). However, there are some differences between models with 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 differences are observed in 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

²¹ 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.

trend is seen in the electricity, gas and water generation sector (40-41) in France. Thus, there seems to be some difference between models that incorporate capital gain and those which do not, mostly in service sector industries in the UK and the US. In all cases, the exclusion of capital gain term tends to underestimate the contribution of capital to growth.

Table 3.6: Capital gain effect on MFPG: Internal nominal vs. internal own rates of return, industry wise, 1979-03

ISIC	Netherlands		France		Germany		UK		US	
	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
<i>Average</i>	<i>-0.01</i>	<i>-0.01</i>	<i>-0.04</i>	<i>-0.05</i>	<i>-0.01</i>	<i>-0.01</i>	<i>-0.11</i>	<i>-0.13</i>	<i>-0.10</i>	<i>-0.11</i>
<i>SD</i>	<i>0.01</i>	<i>0.01</i>	<i>0.04</i>	<i>0.05</i>	<i>0.02</i>	<i>0.02</i>	<i>0.13</i>	<i>0.13</i>	<i>0.05</i>	<i>0.06</i>

Notes: 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). SD is standard deviation.

Table 3.7: Rates of return effect on MFPG: Internal vs. external rates of return, industry wise, 1979-2003

ISIC	Netherlands		France		Germany		UK		US	
	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
<i>Average</i>	<i>0.06</i>	<i>0.06</i>	<i>0.03</i>	<i>0.07</i>	<i>0.00</i>	<i>0.01</i>	<i>-0.07</i>	<i>0.04</i>	<i>0.07</i>	<i>0.17</i>
<i>SD</i>	<i>0.09</i>	<i>0.09</i>	<i>0.10</i>	<i>0.10</i>	<i>0.06</i>	<i>0.06</i>	<i>0.20</i>	<i>0.17</i>	<i>0.20</i>	<i>0.21</i>

Notes: Figures are MFPG using internal rate of return minus MFPG using external rate of return (all in percentages). SD is standard deviation.

In Table 3.7, 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 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 are also observed in previous studies also (e.g. Oulton, 2007). In most countries the MFPG produced by the internal models tends to be larger than that of external models in a large number of industries, with exception of Germany and the UK. As we observed before, the IOR models shows larger differences relative to the external models compared to INR models.

Effect of Alternative Aggregation Procedures: Regression Analysis

The above discussion which is based on visual inspection of the results helps to understand the observed differences in MFPG under various assumptions. However, are these observed differences statistically significant? In order to test for this, we have estimated an OLS regression equation, which takes the following form:

$$\left[MFPG_{m,T}^{KS} - MFPG_T^K\right] = \beta_0 + \sum_{m=2}^8 \beta_m D_m + \beta_T T + e \quad (3.8)$$

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 eight 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 as the dependent variable is that with a single regression we are 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 3.8.

Table 3.8: Regression — Capital composition effect on MFPG on alternative rental price models

	Netherlands	France	Germany	UK	US
Constnat	-0.143 ** (0.03)	-0.157 ** (0.018)	-0.005 (0.032)	-0.076 (0.05)	-0.345 ** (0.039)
CERTX	0.02 (0.041)	0.058 * (0.024)	-0.001 (0.042)	0.023 (0.066)	0.141 ** (0.052)
INR	0.067 (0.041)	0.036 (0.024)	0.003 (0.042)	-0.065 (0.066)	0.068 (0.052)
INRTX	0.052 (0.041)	0.022 (0.024)	0.012 (0.042)	-0.073 (0.066)	0.068 (0.052)
INRS	0.064 (0.041)	0.029 (0.024)	0.005 (0.042)	-0.084 (0.066)	0.05 (0.052)
INRSTX	0.048 (0.041)	0.015 (0.024)	0.016 (0.042)	-0.093 (0.066)	0.048 (0.052)
IOR	0.074 (0.041)	0.078 ** (0.024)	0.015 (0.042)	0.049 (0.066)	0.178 ** (0.052)
IORTX	0.059 (0.041)	0.073 ** (0.024)	0.029 (0.042)	0.059 (0.066)	0.195 ** (0.052)
PERIOD	0.007 (0.02)	0.002 (0.012)	0.031 (0.021)	0.262 ** (0.033)	0.221 ** (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 noted before these are the two countries where we observe 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.²²

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 significant differences between the internal models that include capital gain, annual and smoothed. Both in France and 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, suggesting that the difference may not be due to the incorporation of tax, but to 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 therefore 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 a notable difference between capital stock and capital service growth rates and the resultant MFP growth rates.

3.5 Concluding Remarks

In this chapter 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 the price of capital services measured through rental prices. The 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 chapter used four alternative rental price models, measured using the internal rate of return with annual capital gain, the internal rate of return with smoothed capital gain, the internal rate of return with no capital gain and the external constant rate of return, in calculating capital service growth rates. Moreover, we

²² For instance, if the composition effect is -0.5 during the first period and -0.1 during the second period, in terms of absolute effect it is still high during the first period. However, the sign of this effect is negative. During the second period, on the other hand, the magnitude of the negative effect has declined.

attempted to quantify 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 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. This implies that the incorporation of capital gain produces 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 prices, 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, the number of negative values is small in all models and the differences between different models are often trivial. 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 in 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 a conclusive argument for the exclusion of corporate taxes in investment analysis.²³ The effect of differential taxes on incentive to

²³ For instance, Cummins et al (1996) observed significant tax effects on investment.

invest is not studied here. Rather, we looked at, from a strictly empirical perspective, whether including or excluding taxes makes any substantial difference in the conclusions regarding MFPG. 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 larger between constant rates of return models and internal rates of return models, while it is relatively small 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.

Our results indicate that the choice of a particular measure of rate of return will have little influence on the final conclusions derived on the contribution of MFPG and capital to economic growth. Though the choice may matter in some industries, it does not make much difference at the aggregate level. In particular, while the choice between exogenous and endogenous rate of return may be important when aggregating capital services to obtain MFPG, the choice between different internal models and the effect of corporate taxes are trivial

Since we have used the internal rates of return in our empirical analysis, a caveat may be added. This rate may produce biased results, if not all assets are included in the capital stock. In our analysis, we have considered six asset types which are all tangible assets.²⁴ It has been argued that intangible assets can be very crucial in an economy's performance.²⁵ It is now widely known that a substantial and growing part of investment, particularly in the private business sector, in developed countries (as in our sample) is taking place in intangibles. However, the lack of reliable statistics on these aspects makes it empirically difficult to incorporate. The negligence of intangible assets from capital stock will result in underestimating the true contribution of capital to growth (see Abramovitz, 1993; Basu et al., 2002; Corrado et al., 2006), and it will lead to an upward bias in the estimated

²⁴ Capital assets can be tangible or intangible. The tangible assets belongs to usual capital equipments having physical substance, such as machinery, equipment and structures, while the intangible belongs to those assets that are not physical in nature. For instance, intellectual property rights such as patents can be considered as intangible assets.

²⁵ For instance, the importance of intangibles in economic performance has been highlighted from the perspective of the increasing share of service sector in output and employment (Vickery and Wurzburg, 1992). Basu et al (2003) argues that the unobserved investments in intangible assets can explain the productivity distance between the UK and the US in the late 1990s. See also Schreyer et al (2004) for a discussion.

internal rate of return. This would mean that the internal rate of return may overestimate the growth rate of capital services and thereby underestimate MFPG. Such a phenomenon, however, is not seen in our results, as the external rates of returns are not found to consistently produce significantly higher MFPG than the internal measures.

