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MEASUREMENT AND ALLOCATION OF CAPITAL INPUTS WITH TAXES: A SENSITIVITY ANALYSIS FOR OECD COUNTRIES

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Taxes affect the measurement of capital inputs. The paper provides an assessment of these impacts in a cross-country framework where heterogeneity of corporate taxation across industries and asset types is accounted for. The results show that taxes change the relative prices of capital types, which, in turn, has implications on the estimated capital quality and reallocation effects in the traditional growth accounting framework. Omitting tax parameters is a source of mismeasurement, particularly when the rental price of capital assets is constructed using an external rate of return, leading to biased capital costs and profits rates. It is shown that differential taxation results in a deadweight loss in terms of misallocated capital inputs, predominantly due to composition effects within industries.

JEL Codes: E01, E22, H25

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1. Introduction

Measuring the cost of capital inputs is of primary importance in the productivity literature. As a matter of fact, the 2008 edition of the System of National Accounts explicitly considers volumes and prices of capital assets an integral element of the national accounts. Hence, a number of contentious methodological issues related to the adequate measurement of capital inputs have been brought to the forefront (Jorgenson and Schreyer, 2013). In this framework, relatively little attention has been so far devoted to the effects that taxes have on capital inputs through their impact on absolute and relative prices of different assets.

Typically, tax systems provide for heterogeneous treatment of capital with regard to the type of assets concerned, the industry in which assets are used, and the ownership of capital. Specific examples are accelerated depreciation for certain asset categories, special fiscal provisions applicable only to some types of economic activity, different tax rates applicable to corporations and unincorporated businesses or households, or preferential fiscal treatment to foreign investment compared to domestic investment. Departing from the framework with homogenous capital, thus simply allowing for heterogeneous capital assets and noting that tax rules differ along several dimensions, naturally offers several ways to uncover tax-driven distortions in the allocation of capital. For instance, some industries

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might be more reliant on certain types of assets, such as specialized or computerized machinery, for technological reasons. Those industries are likely to benefit significantly if the tax system implicitly favors those asset categories compared to other types of capital. Similarly, differences in the tax treatment of assets might be accentuated by temporary tax subsidies, such as bonus depreciation schemes typically enacted to stimulate investment during slumps. By targeting specific asset classes, those schemes have been found to affect significantly the composition of investment between long- and short-lived assets in the U.S. (House and Shapiro, 2008). All in all, taxation is not neutral with respect to the composition and allocation of productive capital.

This paper analyzes the impact that accounting for corporate taxes has on capital input measures and on implied profitability in the corporate sector and overall economic efficiency. Hence, the paper can be placed in the strand of literature investigating the sensitivity of capital input measures to alternative methodological choices in the traditional Jorgensonian growth accounting exercises. In this framework, while assessments of the impact of taxes have been carried out for single countries, the U.S. and Canada in particular, the paper contributes by offering a cross-country perspective so far relatively unexplored, mainly due to the information requirements on national tax systems. In fact, while macroeconomic variables are elaborated and made readily accessible in the national accounts by statistical agencies, keeping track of (often frequently changing) tax provisions is not straightforward. Furthermore, by showing how differential taxation affects the level and structure of prices for capital assets, the paper offers a simple illustration of the contribution of taxes to the allocation of productive capital. In particular, it quantifies a deadweight loss generated by differential taxation with a deviation from a hypothetical benchmark where the marginal tax burden is equalized across asset types and industries. Thus, the paper is also related to the burgeoning literature on the misallocation of resources. For instance, Fernald and Neiman (2011) highlight how, in a model with homogeneous capital, heterogeneous tax subsidies targeting producers attract capital to the tax-favored sector. This has important consequences on the measurement of technology, and thus might lead one to wrongly impute the main drivers of growth.

The rest of the paper is laid out as follows. Section 2 illustrates the theoretical background, and Section 3 the practical implementation, including the data used in the analysis. Section 4 describes the main findings of the growth accounting exercise, while Section 5 provides a measure of the aggregate deadweight loss of differential taxation. Concluding comments are offered in Section 6.

2. Conceptual Framework

As a starting point of the analysis, it is useful to recall the growth accounting framework proposed by Jorgenson and Griliches (1967) based on production possibility frontiers. The aggregate production function, say F, for industry j at time t, is:

$$Y_{jt} = F\left(\tilde{K}_{jt}\left[K_{1jt}, K_{2jt}, .. K_{njt}\right], L_{jt}\right) \tag{1}$$

where Y is value added, L is the labor input in the production process, and $\tilde{K}$ is an aggregator of capital services from n different types of assets.[1] For any given asset category, the flow of productive services from the cumulative stock of past investments, or capital services, is considered as the appropriate measure of capital input for production and productivity analysis in traditional growth accounting exercises (Schreyer, 2003). In this paper, I will focus mainly on the issue of capital inputs measurement and aggregation, leaving aside the broader picture of accounting for value added growth, and its determinants. Needless to say, given the change in value added, assumptions and measurement issues related to the capital factor will have a direct bearing on the estimated evolution of technical change as captured by multifactor productivity.[2]

The fact that assets are heterogeneous implies that each type of capital has specific service levels. For instance, buildings account for the largest part of the total stock by value, but their contribution to production spans over a long service life, often decades. On the other hand, a unitary investment in an asset that can be scrapped after only a few years will generate a significant level of capital services annually, as this will serve to repay fast economic depreciation and obsolescence. For any type of asset, the flow of productive services is generated by the cumulative stock of past investments in a proportional manner. Thus, the aggregation of heterogeneous assets is based on the discrete-time Tornqvist index, whereby the growth rate of each type of capital is weighted by its share in total capital income:

(2) $$\Delta \ln \tilde{K}_{jt} = \sum_{i}^{n} \bar{v}_{ij,t} \Delta \ln K_{ij,t},$$

where $\bar{v}_{ij,t} = \left(v_{ij,t} + v_{ij,t-1}\right)/2$ and $v_{ij,t} = c_{ij,t}K_{ij,t} \Big/ \sum_{i}^{N} c_{ij,t}K_{ij,t}$. In equation (2), $\tilde{K}_{jt}$ is the aggregate capital service, $K_{ij,t}$ is the capital stock of asset i, $c_{ij,t}$ is its rental price, and $v_{ij,t}$ are the weights, given by the two-period average shares of each component in total capital income. The weights capture the marginal product of the asset. Hence, they effectively incorporate the qualitative differences in the contribution of heterogeneous asset to production, as the capital composition changes. Since marginal revenue equals marginal cost at equilibrium, the weighing procedure ensures that assets with a higher price also have a larger influence in the aggregate capital input index. As is apparent from (2), the two main components of the capital service measure are the capital stock and the service price (or rental price) of the capital assets. They are discussed in turn.

Given the volume of real investment I for asset i, in industry j, at time t, the capital stock K can be estimated using the perpetual inventory method as follows:

[1]The capital input measure for each type of asset is itself an aggregator across different vintages of the asset. Assuming separability with respect to other elements in the production function implies that the marginal rate of substitution between any pair of vintages of a particular type of asset is independent of other inputs. This is important as it allows constructing the capital services measure with further aggregation ("bottom up" approach) and independently of other inputs in the production process.

[2]Under the assumptions of competitive output market, full input utilization, and constant returns to scale, the growth rate of TFP is obtained in the translog form by subtracting the growth rates of the inputs (labor and capital), opportunely weighted by their respective shares in nominal output, from the growth rate of output.

(3) $$K_{ij,t} = (1-\delta_i)K_{ij,t-1} + I_{ij,t},$$

where δ_i represents the (constant) geometric depreciation rate of the capital asset. Importantly, (3) assumes that the different vintages of the same assets are perfect substitutes after accounting for economic depreciation (see footnote 1). Hence, starting from the initial value given by the cumulative value of past investment, in each period the capital stock evolves in line with net investment, given by total (or gross) investment netted out of the replacement component ($\delta_i K_{ij,t-1}$).[3]

The other essential element in (2) is the user cost, or rental price, of the capital asset. The rental price for capital represents the unit cost of using a capital good for a specified period of time. As the rental price cannot be directly observed, unlike for wage rates or product prices, it has to be estimated. In particular, when firms are price-takers in the market for capital assets, the rental price of capital can be imputed from the relationship between the price of a new asset and the discounted value of all future services derived from that asset (Hall and Jorgenson, 1967). In the absence of taxes, the rental price is:

(4) $$c_{ijt} = r_t p^k_{ij,t-1} + \delta_i p^k_{ij,t} - \left(p^k_{ij,t} - p^k_{ij,t-1}\right)^e,$$

where r is the rate of return on alternative investments, $p^k_{ij,t}$ is the price of the asset i, δ_i again denotes the rate of economic depreciation, and $\left(p^k_{ij,t} - p^k_{ij,t-1}\right)^e$ is the expected capital gain from holding the asset.

2.1. *The Role of Taxes*

Since income from capital assets is subject to taxation, it is realistic to assume that taxes will alter investment behavior.[4] Accounting for tax policy in the neoclassical investment model leads to the tax-adjusted rental price of capital (Jorgenson and Yun, 1996):

(5) $$c^{tax}_{ij,t} = T_{ij,t}\left[r^{TAX}_t p^k_{ij,t-1} + \delta_i p^k_{ij,t} - \left(p^k_{ij,t} - p^k_{ij,t-1}\right)^e\right] + \tau^P_{ij,t} p^k_{ij,t-1},$$

where $\tau^P_{ij,t}$ is the effective rate of property taxation, and $T_{ij,t}$ is the tax wedge, calculated as:

(6) $$T_{ij,t} = \frac{1 - u_t z_{ij,t} - \kappa_{ij,t}}{1 - u_t}.$$

[3]*Ceteris paribus*, given the initial stock, the size of replacement investment, that is, investment required to keep the stock of the capital asset constant, depends on the economic depreciation rates. The faster the economic depreciation, the higher will be, *ceteris paribus*, the replacement component in gross investment.

[4]In the neoclassical world, under the assumption of perfectly competitive output market and no adjustment costs, the desired level of the capital stock can be derived from the equilibrium condition that the value of the marginal product of capital be equal to its rental price. Assuming a Cobb–Douglas production function, as in Hall and Jorgenson (1967), the desired capital stock is $K^*_{t+1} = (\phi\upsilon)Y_t c_t^{-1}$, where ϕ is the share of capital input, and υ is the returns to scale parameter. The equilibrium condition pins down an inverse relationship between changes in the user cost and in the capital stock, as investment takes place so as to fill the gap between the desired and the actual level of capital.

In (6), u_t is the statutory rate of taxation on corporate income at time t, $z_{ij,t}$ denotes the present value of the depreciation deduction for tax purposes on a unit of investment on asset i over the lifetime of the investment, and $\kappa_{ij,t}$ is the effective rate of the investment tax credit, which directly reduces the tax liability in proportion to the investment made. At the margin, an increase in the investment tax credit or an increase in the present value of depreciation allowances—stemming from a decrease in the tax useful life of the assets or from the use of accelerated depreciation schemes—reduce the tax wedge. In both instances, the magnitude of the reduction decreases with the statutory corporate income tax rate u. All other factors being equal, an increase in the statutory rate u increases the wedge.[5]

3. Practical Implementation and Data

The data used in the analysis are taken primarily from the EU KLEMS dataset, which provides volume and price series on a number of fixed reproducible assets for European and other advanced economies, compiled using a harmonized methodology (O'Mahony and Timmer, 2009). In the dataset, aggregate capital breaks down into seven asset categories: computers, communication equipment, transport equipment, other machinery and equipment, industrial buildings, residential structures, and software. These, in turn, can be grouped into ICT (computing and communication equipment, software) and non-ICT capital (the other assets). Industry-specific price indices for each asset are also made available, as well as standard national accounts aggregates, such as value added and labor compensation. I include 24 industries (ISIC-1 classification) adding up to the market economy (the industry coverage is reported in the Appendix).[6] The analysis covers 10 European countries (Austria, Denmark, Finland, France, Germany, Italy, the Netherlands, Spain, Sweden, the United Kingdom) plus Japan and the U.S.

3.1. *The Rental Price of Capital*

Calculating the rental price of capital requires a number of preliminary methodological choices. Ultimately, a balance must be struck between the concerns derived from economic theory and actual feasibility, given also the measurement challenges on some variables. In what follows, I discuss the main components of the rental price, focusing on the direct implications of omitting vs. including taxes. Hence, I do not delve into concerns related to the measurement of capital (such as,

[5]The overall impact on the rental price depends on the whether the rate of return is assumed to be affected or not by the change in the corporate income tax rate. In other words, the corporate tax is borne by the firm. Under different assumptions concerning corporate tax incidence, changes in the statutory rate might turn neutral with respect to the rental price of capital, depending on the combined effects of the investment tax credit and the depreciation allowances (Hall and Jorgenson, 1996).

[6]The excluded industries are public administration and defense, health and education services, other community, social, and personal services, and services produced by private households. In those industries profit maximization most likely does not apply, and the price formation mechanism is not determined via market transactions. As is customary, the real estate industry is excluded on the grounds that its income mostly comprises imputed rents from owner-occupied housing.

for instance, economic depreciation rates), where I follow practices that are relatively well-established in the literature. Details on the methodology can be found in the Appendix.

3.1.1. The Required Rate of Return

The rate of return represents the opportunity cost of holding an asset. As such, it may be considered as a nominal rate for the financial costs associated with real investment, or as the opportunity cost of employing capital elsewhere in the production process (OECD, 2009). Two approaches are commonly adopted in the literature to estimate the rate of return. Rather than discussing their theoretical underpinnings, detailed, for instance, in OECD (2009) and Oulton (2007), here I focus on the practical implications they have for the analysis. The first approach uses the same information employed in the growth accounting exercise in a balancing relationship. Hence, this measure defines the internal (also referred to as endogenous, or *ex-post*) rate of return, as it relies on realized *ex-post* returns based on national accounts. The alternative method reflects the actual information set before investment decisions are taken.[7] Thus, an exogenous (or external) rate, for instance the market interest rate, is selected as reflecting more adequately an *ex-ante* measure of the opportunity cost of real investment.

The internal rate is estimated starting from the accounting identity defining gross operating surplus (GOS) as a residual measure after the labor factor has been remunerated from the income generated:

$$GOS_{j,t} = p_{j,t}Y_{j,t} - w_{j,t}L_{j,t}, \tag{7}$$

where $Y_{j,t}$ indicates the value added of industry j at time t, $p_{j,t}$ is its price, $L_{j,t}$ denotes the labor input, and w_{jt} is the nominal wage rate. GOS is interpreted as a measure of normal profits from business activity, including mixed income as the remuneration of the self-employed, and, as such, it is assumed to remunerate all types of capital factors measured by the national accounts. Thus, the assumption typically made empirically is that GOS equals the sum over all asset types of the rental payments:

$$GOS_{j,t} = \sum_{i}^{n} c_{ij,t}K_{ij,t}. \tag{8}$$

This setup is consistent with perfect competition in the output market and constant returns to scale in production. The equality in (8) is achieved by appropriately choosing the values of the net rates of return on the assets, assumed to adjust endogenously. In the more general case with taxes, following Christensen and Jorgenson (1969), the internal rate is measured as the residual of property income after adjusting for economic depreciation, capital gain, and corporate and property taxes, as follows:

[7] Oulton (2007) proposes a hybrid approach to estimate the growth of aggregate capital services, whereby aggregation at the level of the individual assets is made with the *ex-ante* return, while aggregation across industries employs the *ex-post* rate of return.

$$(9) \qquad r_{j,t}^{\text{int}} = \frac{GOS_{j,t} + \sum_{i}^{n} T_{ij,t}\left(p_{ij,t}^{k} - p_{ij,t-1}^{k}\right)^{e} K_{ij,t} - \sum_{i}^{n} T_{ij,t}\delta_{i} p_{ij,t}^{k} K_{ij,t} - \sum_{i}^{n} \tau_{ij,t}^{P} K_{ij,t}}{\sum_{i}^{n} p_{ij,t-1}^{k} T_{ij,t} K_{ij,t}}.$$

Omitting taxes requires imposing $T_{ij,t} = 1$ and $\tau_{ij,t}^{P} = 0$ in (9), for all i, j and t, where $\tau_{ij,t}^{P}$ is the effective rate of property taxation, and $T_{ij,t}$ is the marginal fiscal burden on the income from the capital asset. As is apparent, the internal rate is constant for all assets but allowed to vary across industries (and time). By construction, it fully exhausts capital income.

Although the internal rate is theoretically consistent under perfect competition and constant returns to scale, its empirical validity hinges upon the conjecture that realized *ex-post* returns adequately reflect the marginal product of capital assets. As an alternative method, free from restrictive theoretical assumptions, the external approach uses *ex-ante* information, whereby the rate of return is approximated by some exogenous rate of return on alternative (including financial) investments. In this case, implementation challenges are mainly empirical and concern which rate best proxies the cost of investing.[8] I follow Inklaar (2010), and use financial market data to build an *ex-ante* measure of the financial cost of new investment. Consistent with the corporate finance literature, I employ a weighted average of the returns on debt and equity, with the weights given by the shares of debt and equity in total finance (see the Appendix for details on the variables used). This choice of weights assumes that the marginal investment has the same financing structure as the average one. Admittedly, this is quite a restrictive assumption, but also a well-established one in empirical applications using aggregate data, also in light of the unresolved theoretical dispute on the actual marginal source of finance (debt vs. equity).[9] Since the rates used are in practice netted out of taxes, the before-tax rates—which are relevant in the scenario without taxes—are obtained by dividing the observed after-tax rate of return by $(1 - u)$, where u is the statutory tax rate on corporate income.[10] Letting the pre-tax returns be affected by taxes for given after-tax rates is akin to assuming that the burden of the corporate tax is borne by capital (Gravelle and Smetters, 2001).

3.1.2. The Capital Gain Term

The anticipated capital gain on the asset measures the change in the value of the asset, independent from the effects of ageing. The size of this term might be particularly relevant for some asset categories, such as computers, due to embodied technological progress, which translates mainly into lower market prices. Again, there are different ways in which asset revaluation can be incorporated into

[8]Different alternative measures have been proposed in the literature. Diewert (2004) suggests the use of a constant real interest rate of 4 percent, which would be consistent with the long-run economy-wide observed real rate of return for OECD countries, nominalized by applying consumer price inflation. By contrast, Schreyer (2010) employs a simple average of short- and long-term market rates.

[9]Additional financial variables, such as retained earnings and the relative cost, are more difficult to calculate with precision from aggregate data, as they require balance sheet information.

[10]Thanks are extended to an anonymous referee for making this point.

the rental price of capital. Essentially, they require assumptions on how expectations on future prices are formed.

In the case of perfect foresight, notably in the Berndt and Fuss (1986) setting, the capital gain term can be represented by the actual annual change in the asset price. Potential drawbacks of this approach arise from rapidly increasing prices (such as those for structures), driving the user cost into negative territory, and fluctuations in asset prices, leading to large variability of the rental price and, thus, in the contribution of assets to overall output growth. Both instances are difficult to reconcile with production theory. Abandoning the perfect foresight assumption ideally requires modeling the expectation formation process. In practice several alternatives to the use of actual price changes have been proposed, such as VAR forecasting models (Verbrugge, 2008) and autoregressive–moving-average (ARMA) models (Oulton, 2007). Following Gilchrist and Zakrajsek (2007), I simply use moving averages, which have the additional appeal of smoothing excessive variability in the series. Thus, as a sensitivity test on the different approaches, I employ both the actual annual price changes (as in the perfect foresight hypothesis), and a three-year centered moving average. As common in the literature, in case negative user costs arise for some countries/industries/years, I constrain the values to zero, on the grounds that assets generating a negative return would not plausibly be employed in production.

3.1.3. The Tax Component

Including taxes in the neoclassical user cost requires a forward looking indicator of the effective tax burden on the different assets, reflecting tax provisions at the time of investment. The relevant tax parameters are taken from ZEW (2013), which provides detailed information on the relevant corporate tax provisions, cross-classified by industry and asset in a way that is fully consistent with the EU KLEMS classification.[11] Since the tax parameters are available for the period 1991–2007, these are the years covered in my analysis.

Assets with a useful tax life longer than the year benefit from depreciation allowances for tax purposes. Ideally, tax depreciation should not diverge from economic wear and tear.[12] If tax deductions are more generous than economic depreciation, the tax system implicitly generates a subsidy for the capital asset, as

[11]ZEW (2013) uses the same industry breakdown and, most importantly, the same assets categories as EU KLEMS. Although those could be considered as aggregates from more heterogeneous asset types, to which, arguably, specific depreciation rules might apply, nonetheless the differences are likely to be of second order, because, in practice, individual assets are usually pooled into relatively broad classes for tax purposes. Moreover, the matching ensures a much higher level of accuracy than that achieved in existing cross-country studies. For instance, Erumban (2008) applies tax data for industrial buildings and plant and machinery only to the full set of EU KLEMS capital assets. In general, tax provisions vary also by institutional sector, that is, corporate vs. households. Although tax rules at the level of the shareholder are also available, following Harper *et al.* (1989) I consider the corporation as the relevant level for the analysis.

[12]Brazell and Mackie (2000) highlight two desirable features of economic depreciation. First, it allows the investor to recover the initial investment tax free while applying the statutory tax rate to the return from that investment. This implies that granting tax allowances based on economic depreciation will tax capital income at the level implied by the statutory tax rate. Second, if reinvested, economic depreciation, measuring the expected decline in the real market value of the asset as it ages, allows the taxpayer to maintain the initial value of the investment.

TABLE 1
Economic Depreciation Rates and First Year Allowance for Tax Purposes (in %)

	Economic Depreciation		First Year Tax Allowance*	
Asset Type	Min	Max	Min	Max
Computing equipment	31.5	31.5	12.5	43.8
Communication equipment	11.5	11.5	8	40
Software	31.5	31.5	6.7	100
Transport equipment	9.2	22.7	12.5	33.3
Other machinery and equipment	9.4	14.7	12.5	50
Industrial buildings	2.4	3.4	2.5	50
Residential structures	1.1	1.1	1.3	50

*Includes bonus depreciation.

the marginal effective tax rate on the asset is then lower than the statutory rate. The extent of the subsidy may vary across capital assets.[13] Rather than approximating the change in the value of the assets as they age, depreciation deductions are normally specified according to the tax lifetime and the depreciation method applicable to the asset (class). The recovery period determines the number of years over which depreciation deductions can be claimed. The depreciation method specifies the annual amount of the allowance, thus indicating how the (historical) cost of the asset is to be allocated over time.[14] Table 1 reports the first year allowance rate granted to the different asset types within the tax systems in the sample. In general, there is significant variability in the tax allowance rates, magnified by temporary bonus depreciation rules. When compared to economic depreciation rates, minimum allowances appear particularly ungenerous for assets with a short economic life such as computers and software. The latter, however, might benefit from immediate expensing in some instances.[15] For the other asset categories the minimum first year tax allowance does not significantly diverge from the minimum economic depreciation rate. The discrepancy becomes however marked for the maximum rates, which are inflated by bonus depreciation allowing for an immediate tax deduction of up to half the investment outlay.

[13]As emphasized by Hulten and Wykoff (1980), the theory of tax incidence suggests that the issue may arise of who benefits from the subsidies implied by the divergence between fiscal and economic depreciation. If a depreciation subsidy is unexpectedly given to a certain type of asset, the after-tax rate of return to that asset will increase. Thus, investment will flow toward the subsidized asset. Since after-tax rates of return (in each risk class) tend to be equated in a competitive capital market, with a fixed supply of capital, the rates of return of other assets will tend to increase. Thus, the subsidy will ultimately benefit different types of assets.

[14]The most common depreciation schedules are the straight line and the declining balance, normally with the possibility of a switchover. The stream of deductions is constant over the lifetime of the asset under the straight line method, whereas it decreases exponentially under the declining balance method. Thus, for a given tax useful life, the declining balance method provides for accelerated depreciation compared to the straight line method. In the sample of countries/years/industries, structures are almost exclusively depreciated according to the straight line method. Tax treatment of other assets is more heterogeneous, with declining balance applying frequently to non-ICT equipment. Since tax systems might allow for the taxpayer to choose among different depreciation rules for the same asset, the discussion assumes that the most generous alternative is adopted.

[15]Since immediate expensing implies that the net present value of depreciation allowances equals one, absent investment tax credits, the rental price of the asset is the same with and without taxes. Thus, the effective marginal tax rate for software is zero in this case.

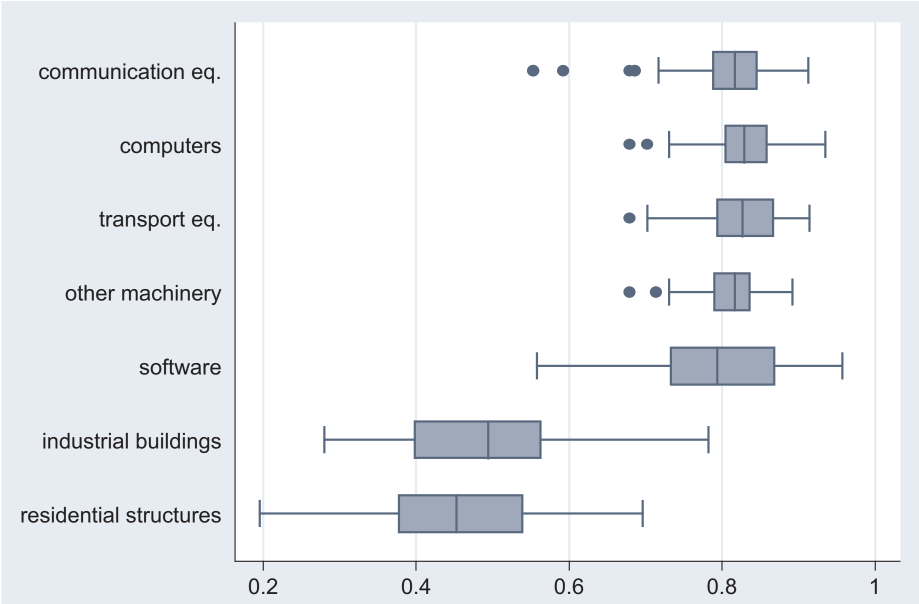

Figure 1. Net Present Value of Tax Depreciation Allowances by Asset Type

The degree of heterogeneity in the tax treatment of the assets is again apparent once one looks at their useful life for tax purposes, or the number of years when depreciation allowances can be claimed. For the different types of machinery, including ICT capital, useful tax life ranges between 3 and 8 years. For software, it ranges between 1 and 15 years, whereas structures can be depreciated over periods between 14 and 40 years. All in all, the differences in the tax treatment of the different assets in the national tax codes is reflected in the level and the variability in the (average) net present value of depreciation allowances graphed in Figure 1.

In the absence of tax credits,[16] the other main tax parameter is the statutory rate on corporate income. Corporate tax rates are in general on a downward trend during the sample period. Overall, the average top statutory rate declines from 41 percent in 1991 to 33 percent in 2007. Country-specific dynamics are also relevant. At the beginning of the sample period, France, Sweden, and the U.K. were the low-tax jurisdictions, whereas in 2007 those are Austria, Denmark, and the Netherlands. While Japan is among the top-quartile of corporate tax rates throughout the period, in 1991 capital is taxed relatively heavily also in Germany and Italy. At the end of the period, in contrast, Spain and the U.S. are counted among the high tax countries.

The tax-adjusted rental price of capital includes an effective rate of taxation on property, or, more in general, on production, denoted $\tau^{P}_{ij,t}$ in (5). Revenues from these taxes are available in the national accounts, but they normally include

[16]An investment tax credit was in place in the U.S. between 1962 and 1986.

TABLE 2
RATES OF RETURN (IN %, AVERAGE OVER 1991–2007)

	Internal Rate		External Rate	
Country	Without Taxes	With Taxes	Without Taxes	With Taxes
aut	14.6	11.4	9.3	6.1
dnk	10.0	7.9	8.9	6.0
esp	17.7	12.2	13.3	7.4
fin	14.4	11.9	11.8	8.4
fra	15.0	11.8	12.0	7.7
ger	8.1	5.1	12.6	6.3
ita	10.3	6.8	12.3	6.7
jpn	14.1	9.0	5.3	2.8
nld	13.3	10.0	11.3	7.5
swe	10.4	8.6	9.2	6.8
gbr	14.2	10.6	12.1	8.3
usa	18.9	13.7	10.2	6.0
average	13.5	10.0	10.7	6.7

indirect taxes (i.e., taxes on products) as well as taxes on production, mostly consisting of property taxes.[17] Only the latter are relevant for the analysis, though, as they also need to be subtracted from residual income when computing the internal rates of return, as shown in (9).[18] I use Eurostat data on taxes on stocks to parse taxes on property and taxes on products in the OECD National Accounts database, where they constitute a single aggregate. Since the breakdown is only available at the aggregate level, I impute the industry level variables assuming that an industry pays taxes on production in proportion with its share in the capital stock of structures. Accordingly, I assume that only structures bear those taxes. Thus, the industry-level effective tax rate is obtained by dividing taxes on production by the corresponding tax base, namely the stock value of structures.

4. Results

Results are presented using a bottom-up approach, and focusing on the variables that are directly affected by taxes. At higher levels of aggregation, the results are reported separately by the rate of return used, while they are averaged across the two alternative methods of calculating the asset revaluation term.

4.1. *The Rates of Return*

Before analyzing in detail the rental price of capital, it is useful to investigate the properties of the rates of returns. Table 2 reports the country-level internal and external rates, both with and without taxes, averaged over the sample period. Taxes significantly reduce the rates of returns. The overall average internal rate is

[17]Indirect taxes are mainly 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. Other taxes on production consist mainly of taxes on the ownership or use of land, building, or other assets used in production.

[18]Value added includes operating surplus, compensation to employees, and taxes on production.

13.5 percent over the period, whereas the external rate is around 11 percent. With taxes, the overall averages are around 10 and 7 percent, respectively. The country-specific average internal rates range from 8.1 percent in Germany to 19 percent in the U.S. With taxes, these levels decrease to almost 5.1 and 14 percent, respectively. The minimum for external rates is 5.3 percent in Japan, while the maximum reaches 13.3 percent in Spain. Once taxes are included the values decrease to 2.8 and 7.4 percent, respectively. While the alternative rates of return are quite similar in Italy, Denmark, and Sweden, the finding that internal rates are larger than external ones is not unusual in the literature. The result could be driven by the competitive conditions in the different industries, or simply by methodological choices that neglect scale economies or some assets used in production. In this respect, Inklaar (2010) shows that including land and inventories has a significant impact on the estimated internal returns for the U.S.[19] Moreover, the rising importance of intangibles, given also their complementarity with ICT capital, is likely to affect the calculation of internal returns significantly in the period under analysis. Corrado *et al.* (2009) show indeed that for the U.S. economy, including intangibles such as R&D, brand equity, and firm-specific resources like organizational capital, substantially increases the contribution of capital to economic growth compared to traditional analyses.

The evolution of the two series over time is somewhat different, with the internal rate rising after the early 1990s, while the cost of finance is on a downward trend (see Figure 2). Such patterns are consistent, for instance, with the evidence reported in Schreyer (2005) for Canada and Inklaar (2010) for the U.S., who shows internal rates constantly above 10 percent after 1991, and on a steep upward trend from the early 2000s. At the same time, the downward trend in external rates is common to the cost of both equity and debt, because of rising stock values in the 1990s, particularly in the U.S., and declining bond rates, especially in Europe where a convergence process was under way.

Since the internal rates are defined at the industry level, it is also useful to compare their variability across industries. Figure 3 plots industry rates averaged over the entire period. They are remarkably heterogeneous, ranging from 3 percent in the agriculture and transport industries to above 20 percent in wholesale trade and finance. Financial intermediation is a noticeable outlier. Contributing to that, are not only the very high returns experienced starting from the mid-1990s, but also, and more fundamentally, the fact that current statistical methods might significantly overestimate banking output. As highlighted by Basu *et al.* (2011), adjusting for risk would lead to rates of return that are closer to the average observed for the market economy.

As the heterogeneity in the rates of return carries over to the other results that follow, more detailed methodological considerations are in order. Economic factors like risk and product market competition are likely to affect significantly realized returns at the industry level. In addition, as explained above, methodological choices might play an important role. All in all, while uncertainty for the external rate is confined to the choice of the relevant financial return(s), the

[19]Conversely, taking account of other types of capital, such as natural resources, does not seem to be equally impacting at the aggregate level (Brandt *et al.*, 2013).

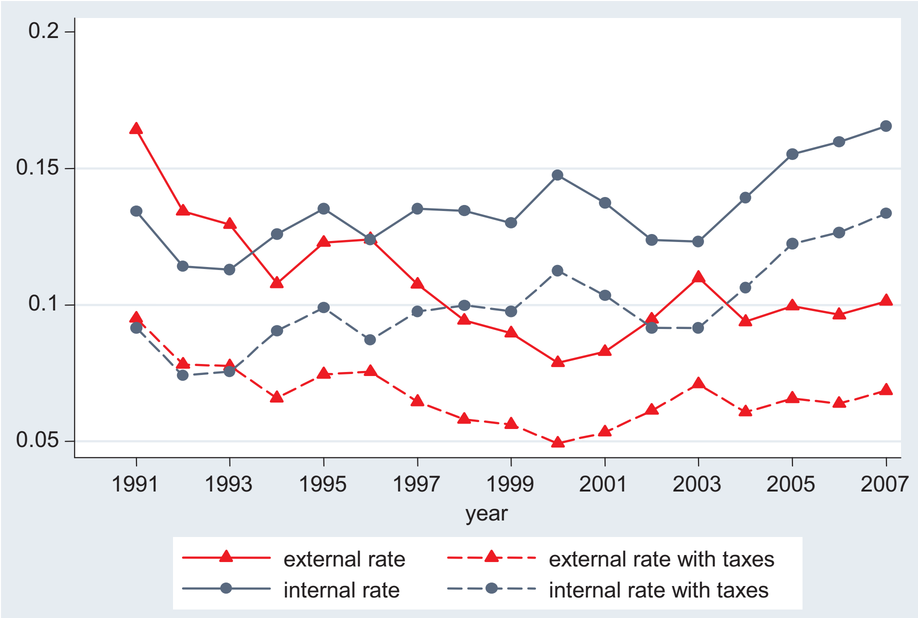

Figure 2. Average Internal and External Rates of Return (in %)

internal rate is inherently subject to more substantial economic and statistical uncertainty. An indication of that is provided by the very large dispersion of the internal rates across industries. First, residual income is invariably measured with error, because it captures all measurement errors related to the labor factor. In this respect, the classification of labor compensation from self-employment might be an additional source of concern for some countries. Second, defining investment the industry level is not free from problems, as shown by the discrepancies arising in the results from alternative methodologies, viz. the bottom-up preceding from firm-level investment, and the top-down, which allocates investment from national accounts data (Beckerand Haltiwanger, 2006). In this case, due to leasing, the allocation of capital derived from the national accounts does not completely reflect the allocation according to effective use.

4.2. *The Rental Price of Capital*

The effects of including taxes on the rental price of capital are twofold. On the one hand, taxes reduce the rates of return, both the internal and the external ones. *Ceteris paribus*, this decreases the rental price of capital. The decrease is proportionally larger for slowly depreciating assets, thus leading to a more accentuated difference between high rental price and low rental price assets. By contrast, as shown in (5), including tax parameters has a direct positive effect on the rental price of capital, but the effect is proportionally smaller for fast depreciating assets. In fact, the tax wedge is larger for assets with a longer useful tax life, for which the net present value of the allowances to be deducted from the tax base is relatively

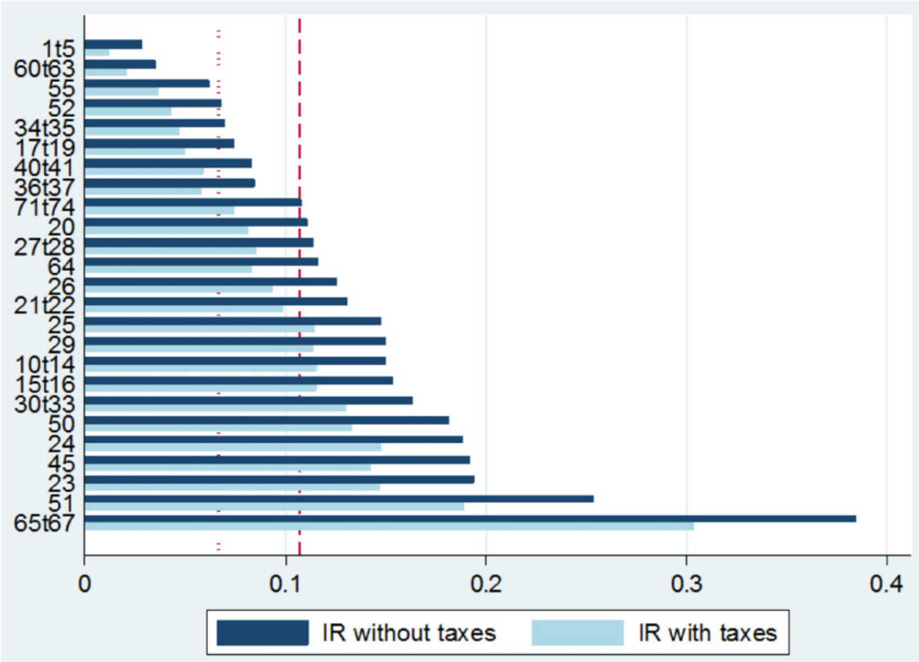

Figure 3. Average Internal Rates of Return by Industry

Note: Horizontal bars are the industry-specific internal rates of return. Vertical lines represent the external rates, both without taxes (dashed line) and with taxes (dotted line). Series are averaged across countries and years.

low. In addition, the stock of industrial and residential structures might be liable to real estate tax, which again raises the rental price of these assets. This will attenuate the difference between high rental price and low rental price capital assets. All in all, the two effects tend to offset one another, such that the direction of the change following the inclusion of taxes is ultimately to be assessed empirically. Overall, the net effect of introducing taxes on the rental price of capital essentially depends on the type of asset. Taxes are found to increase the rental price of the fastest depreciating assets, while the direction of the impacts tends to be reversed for equipment with a longer useful life. In the case of structures, the effects are less clear-cut across rates of return, since, with low depreciation rates, they tend to be determined by the (positive) capital gain terms, and their size relative to the returns.

4.3. *Capital Composition at the Industry Level*

Tax parameters affect the changes in the growth of capital services through their effect on the relative rental price of different assets. To quantify the impacts of the inclusion of taxes, I calculate the capital composition effect at the industry level. Capital composition is defined as the difference between the volume change of aggregate capital services and the change of the capital stock. As the latter variable does not account for asset heterogeneity, the difference between the two measures is often considered as an index of capital quality. In fact, an increase in the index would indicate a compositional shift toward capital assets with relatively high unit rental price, and thus high marginal productivity, per period.

Table 3 reports the average capital composition effect for different industry aggregates: the market economy, manufacturing industries, and market services. The calculated values are positive, indicating that the fastest growing assets are those with a larger weight, viz. higher rental price. The results for market services show that, in general, capital composition is lower with internal rates of return than with external rates. This finding matches other evidence in the literature for single countries, like Baldwin and Gu (2007) for Canada, and reflects the properties of the rates of return. As discussed earlier, the endogenous rate of return is in general higher than the exogenous rate of return, particularly for market services. Moreover, a higher rate of return leads to a lower growth of capital composition and capital service input, because the use of a high rate of return attenuates the difference in the rental price of capital arising from differences in the economic depreciation rates of the different assets. *Ceteris paribus*, the larger the gap, the larger will be the difference in the capital composition effect calculated with the alternative rates of return. The picture appears more blurred when the whole market economy—and, to a lesser extent manufacturing—is considered, due to the combined effect of different industry-specific internal rates and mix of capital assets.

Including taxes generally increases the capital composition index calculated with exogenous returns, while the direction of the changes with the endogenous returns is not equally clear-cut in the cross-country comparison. Overall, the levels of the calculated composition indices are generally higher in market services than in the manufacturing industries, signaling the different degree of reliance on short-lived, high rental price capital assets.

Table 4 reports the bias in the estimated capital composition effect stemming from neglecting taxes in the calculations, separately for ICT and non-ICT assets, and for aggregate capital. Since capital composition is obtained by subtracting the growth of the capital stocks from the growth in capital services, and the former is not influenced by the inclusion of the tax variables, the bias also equals that in the underlying growth of capital services. I find that ignoring taxes in general leads to a downward bias in the capital composition index when the external rate of return is used, while results with internal rates are more mixed. Overall, the negative bias is largely due to the contribution of ICT assets.

The difference in the impacts of omitting the tax variables is partly due to the differences in the effects of taxes on the rates of return, and the interplay with the economic depreciation rates, as discussed in Section 4.2. Moreover, when the external rate is used, taxes also affect the aggregation weights by changing the cost share of capital. Before turning to this issue and investigating its implications, I complete the growth accounting exercise by considering aggregate capital services.

4.4. *Growth of Aggregate Capital Inputs and Reallocation*

To estimate the growth of capital services for the market economy, two alternative approaches can be used. The bottom-up approach derives capital

TABLE 3

Capital Composition Effect (Average Over Industries in 1991–2007; Standard Deviation in Italics)

	Market Economy				Market Services				Manufacturing			
	Internal Rate		External Rate		Internal Rate		External Rate		Internal Rate		External Rate	
Country	Without Taxes	With Taxes	Without Taxes	With Taxes	Without Taxes	With Taxes	Without Taxes	With Taxes	Without Taxes	With Taxes	Without Taxes	With Taxes
aut	0.06	0.12	0.22	0.34	0.26	0.34	0.56	0.71	0.04	0.10	0.14	0.27
	1.09	*1.15*	*1.00*	*1.10*	*1.27*	*1.33*	*1.28*	*1.39*	*1.04*	*1.10*	*0.92*	*1.03*
dnk	1.26	1.30	1.06	1.28	1.32	1.37	1.55	1.80	1.54	1.57	1.04	1.26
	3.98	*3.91*	*2.43*	*2.67*	*3.13*	*3.24*	*2.97*	*3.11*	*4.86*	*4.71*	*2.31*	*2.62*
esp	0.20	0.18	0.39	0.55	0.50	0.52	0.88	1.25	0.12	0.11	0.17	0.23
	0.89	*0.94*	*1.01*	*1.32*	*1.10*	*1.18*	*1.36*	*1.78*	*0.66*	*0.66*	*0.69*	*0.83*
fin	0.59	0.58	0.46	0.54	0.75	0.72	0.56	0.65	0.35	0.37	0.50	0.58
	2.91	*2.83*	*1.48*	*1.53*	*3.77*	*3.71*	*2.08*	*2.13*	*1.38*	*1.39*	*1.26*	*1.32*
fra	0.42	0.39	0.47	0.49	0.43	0.39	0.62	0.66	0.45	0.40	0.44	0.46
	1.12	*1.10*	*0.75*	*0.79*	*0.71*	*0.67*	*0.78*	*0.84*	*1.35*	*1.34*	*0.77*	*0.80*
ger	0.49	0.46	0.08	0.17	1.23	1.11	0.30	0.52	0.11	0.13	0.07	0.11
	2.05	*1.80*	*0.64*	*0.83*	*2.60*	*2.29*	*0.99*	*1.26*	*0.63*	*0.69*	*0.35*	*0.44*
ita	0.19	0.23	0.13	0.20	0.45	0.49	0.34	0.45	–0.02	0.03	–0.02	0.03
	0.97	*1.02*	*0.71*	*0.79*	*1.37*	*1.48*	*0.97*	*1.10*	*0.68*	*0.68*	*0.50*	*0.53*
jpn	0.35	0.32	0.44	0.42	0.48	0.45	0.74	0.71	0.39	0.36	0.41	0.38
	1.02	*1.05*	*0.93*	*0.90*	*1.55*	*1.70*	*1.42*	*1.41*	*0.69*	*0.63*	*0.53*	*0.47*
nld	0.72	0.78	0.54	0.63	0.59	0.66	0.72	0.86	0.90	0.95	0.55	0.62
	2.07	*2.07*	*1.40*	*1.41*	*1.42*	*1.43*	*1.54*	*1.60*	*2.53*	*2.54*	*1.37*	*1.35*
swe	1.17	1.14	1.12	1.12	1.52	1.48	1.61	1.65	0.85	0.85	0.86	0.83
	1.78	*1.84*	*1.43*	*1.44*	*1.96*	*1.97*	*1.71*	*1.68*	*1.28*	*1.44*	*1.07*	*1.06*
gbr	0.34	0.43	0.33	0.43	0.39	0.44	0.53	0.56	0.26	0.37	0.34	0.47
	1.61	*1.61*	*1.35*	*1.34*	*1.89*	*1.97*	*1.58*	*1.58*	*1.32*	*1.24*	*1.24*	*1.21*
usa	0.45	0.51	0.83	1.07	0.54	0.60	1.04	1.32	0.36	0.43	0.75	0.99
	1.21	*1.28*	*1.29*	*1.39*	*1.69*	*1.75*	*1.70*	*1.74*	*0.92*	*1.00*	*0.99*	*1.12*

Note: Capital composition is obtained as the difference between the growth of capital services and the growth of the underlying capital stock, averaged across industries.

TABLE 4

Bias in Capital Composition from Omitting Taxes (Market Economy)

	Internal Rate			External Rate		
Country	Total Capital	ICT Assets	Non-ICT Assets	Total Capital	ICT Assets	Non-ICT Assets
aut	−0.06	−0.03	−0.02	−0.12	−0.06	−0.01
dnk	−0.03	−0.14	0.00	−0.21	−0.17	−0.01
esp	0.01	0.00	0.03	−0.16	−0.04	−0.08
fin	0.01	0.05	−0.01	−0.08	0.02	−0.02
fra	0.04	−0.03	0.02	−0.03	−0.05	−0.01
ger	0.08	0.00	−0.04	−0.09	−0.13	0.00
ita	−0.04	−0.27	0.01	−0.06	−0.33	0.00
jpn	0.02	−0.03	0.03	0.02	−0.03	0.02
nld	−0.06	−0.11	0.00	−0.09	−0.16	0.01
swe	0.06	−0.02	0.08	0.00	−0.04	0.03
gbr	−0.09	−0.07	−0.06	−0.10	−0.11	−0.05
usa	−0.07	−0.01	0.04	−0.24	−0.04	−0.01

Note: The bias is obtained as the difference between capital composition calculated without taxes and capital composition with taxes.

services growth by aggregating capital services at the industry level. Within each industry, in turn, capital services are obtained by aggregation of the various asset types. The top-down approach proceeds inversely, and requires the aggregation of asset types directly at the level of the market economy to derive the growth rate of aggregate capital input.

In the bottom-up approach the industry-specific measures of capital services are weighted by the relative size of the industry and then summed across all industries. Hence, the market economy is treated as a weighted sum of the underlying industry-level production structure. Accordingly, the growth of aggregate capital services can be expressed as:

$$\Delta \ln \tilde{K}_t = \sum_j \bar{v}_{j,t} \Delta \ln \tilde{K}_{jt} = \sum_j \bar{v}_{j,t} \left(\sum_i \bar{v}_{ij,t} \Delta \ln K_{ij,t} \right), \tag{10}$$

where $\bar{v}_{j,t}$ is the two-period average share of industry j in the value of aggregate capital input, and $\Delta \ln \tilde{K}_{jt}$ is the growth of industry-level capital services, calculated as in (2), which in turn can be expressed as the volume index of the individual assets, where the weights are their shares over industry-level capital $\left(\bar{v}_{ij,t}\right)$.

Under the top-down approach, it is first necessary to derive a measure of the asset-specific capital input at the level of the market economy:

$$K_{i,t} = \sum_j K_{ij,t}.$$

Thus, the growth of capital services is:

$$\Delta \ln \tilde{K}'_t = \sum_i \bar{v}_{i,t} \Delta \ln K_{i,t}, \tag{11}$$

where $\overline{v}_{i,t}$ is the two-period average share of asset *i* in the aggregate value of capital input. This approach is based on the assumption of an aggregate production function, which involves a single price for a particular type of input, independent of the industry where it is used. More specifically, the top-down approach assumes that the user cost of capital of an asset and the rate of return are the same across industries. This might be particularly unrealistic when inputs are heterogeneous, as pointed out by Jorgenson *et al.* (1987).

In spite of its restrictive assumptions, the top-down approach can be thought of as a benchmark achievable under full mobility of capital, and, thus, equalized returns across industries. As such, the discrepancy between the bottom-up and the top-down approaches is informative *per se*, as a measure of the reallocation of capital across industries. In particular, the reallocation term can be expressed as the difference between aggregate capital service growth calculated with the bottom-up and the top-down approaches, or:

$$(12) \qquad reall = \Delta \ln \tilde{K}_t - \Delta \ln \tilde{K}'_t = \sum_j \overline{v}_{j,t} \left(\sum_i \overline{v}_{ij,t} \Delta \ln K_{ij,t} \right) - \sum_i \overline{v}_{i,t} \Delta \ln K_{i,t}.$$

A positive value for the reallocation term arises when capital is moving toward the industries where it earns the largest returns. The reallocation term averaged over the sample period for the different countries is shown in Figure 4. Capital reallocation appears mostly positive, and, at around 0.7 percent, is largest in Germany, arguably because of substantial economic restructuring following political re-unification. The reallocation effect is around 0.2 for the U.S., the same order of magnitude found by Jorgenson and Schreyer (2013). Negative capital reallocation is found for Denmark and Japan, as documented also in Fukao *et al.* (2011). Not including taxes mostly results in an estimated reallocation effect biased toward zero, leading to underestimating the extent to which capital moves across industries, driven by larger returns.

4.5. *Capital Costs and Profitability*

In discussing the rates of return, it has been highlighted how the endogenous approach, relying on specific theoretical assumptions, derives the total compensation to the capital factor from gross operating surplus, that is, the share of national income not accruing to labor. Treating capital income as a residual implies that, once accounted for, taxes will not affect the total compensation to capital but will be reflected only in the level of the industry-specific internal rates of return, as shown in (9). Adopting an exogenous rate of return implies that capital compensation can be derived directly from the product of the rental price of capital and the stock of the capital assets. Hence, gross operating surplus cannot be considered as exhausting capital compensation any longer. As a direct consequence of the differences in the rates of return, the calculated remuneration to capital might differ from residual income. This implies that the expression in (8) is replaced by

$$(13) \qquad GOS_{j,t} = \sum_i^n c_{ij,t} K_{ij,t} + M_{j,t},$$

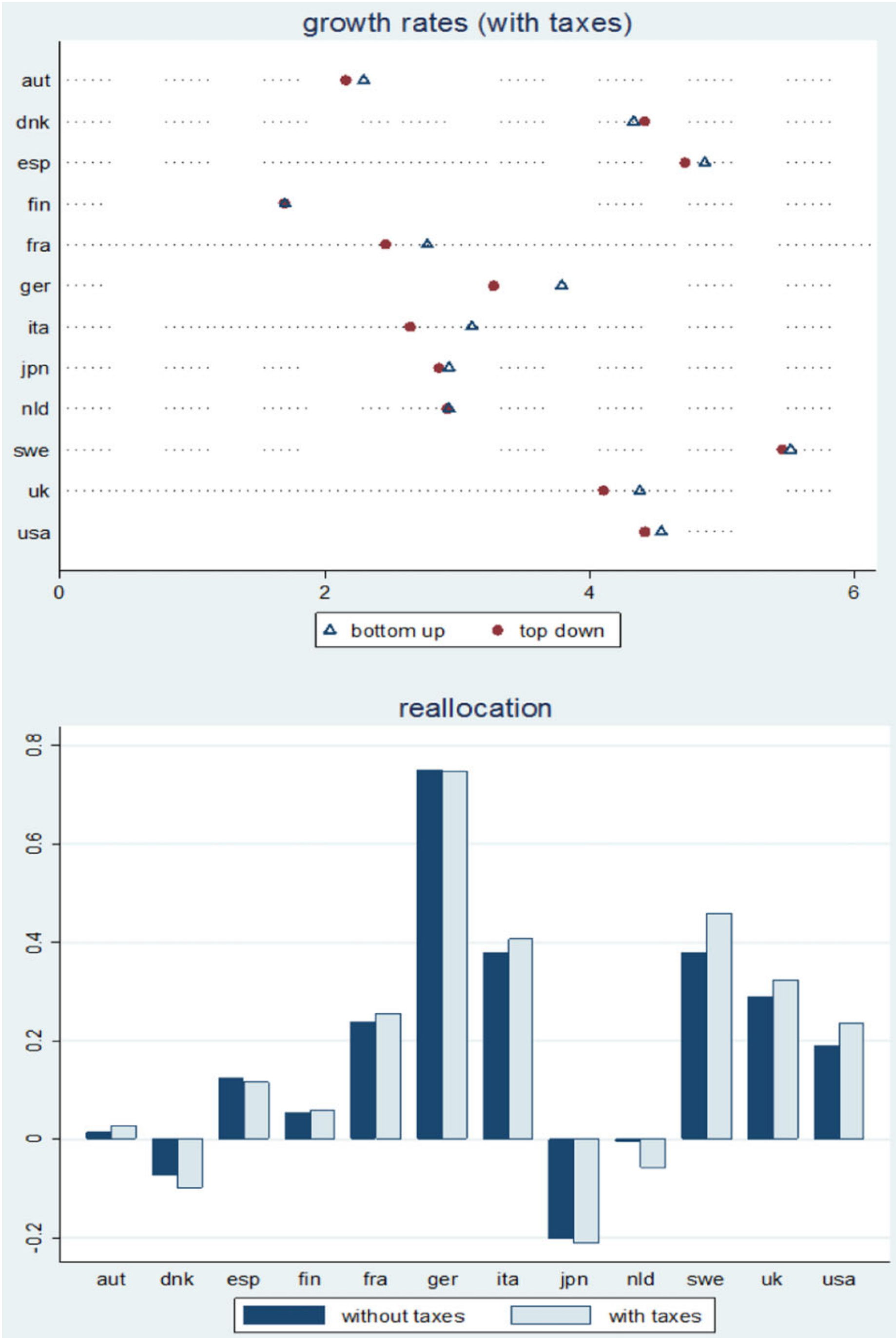

Figure 4. Aggregate Capital Services: Growth Rates and Reallocation (in %)

Note: Growth rates calculated with internal rates of return. Reallocation is the difference between the overall growth rate of capital obtained by aggregating industry-specific growth rates (bottom-up approach) and the rate calculated at the level of the market economy (top-down approach).

where M denotes the difference between gross operating surplus, obtained from the national accounts as residual income, and the observed remuneration of the capital assets. Moreover, the cost share of capital estimated with the external rates of return will not be the same depending on whether or not taxes are introduced in the calculations.

The reasons why capital compensation might differ from GOS are basically the same ones driving the difference between the internal and the external rates of return discussed in Section 0, namely risk, product market competition, economies of scale, and methodological choices. Omitting some types of capital assets not only leads to large internal rates of return, but also keeps the level of total capital costs with external returns artificially low. Thus, detecting implausibly large discrepancies between GOS as residual income and capital compensation might provide an important health warning on the possibility of measurement error in the data. All in all, although differences between the two measures are likely to emerge in the data, capital compensation cannot plausibly be larger than residual income for extended periods of time, as this would imply that firms are systematically making losses.

Figure 5 plots the difference between aggregate residual income and the remuneration of capital calculated using the exogenous return in the rental price, with and without taxes, expressed as a percentage of value added. In general, the difference is positive, implying that residual income is larger than capital compensation, although for some years the opposite is true.[20] Including taxes decreases the cost share of capital—Japan being a noticeable exception—but in general does not dramatically change its size relative to residual income. All in all, excluding taxes reduces the difference between the two aggregates, with the size of the reduction being comparatively larger in the high tax economies such as Italy, Spain, and Germany. In the latter country, the inclusion of taxes brings capital costs roughly in line with the level of residual income.

A more direct measure of the impacts that including taxes has on capital compensation estimated with the external rate of return can be derived by calculating the capital share in total costs, or:

$$\sigma_t = \sum_j \sum_i c_{ij,t} K_{ij,t} \Big/ \sum_j \left(\sum_i c_{ij,t} K_{ij,t} + w_{j,t} L_{j,t} \right),$$

where, as before, $w_{j,t}L_{j,t}$ represent the remuneration of labor. How does the inclusion of taxes affect the evolution of the cost share of capital over time? To answer this question, it is informative to split the change in the cost share of capital into two different components, capturing the within-industry and the between-industry dynamics. The aggregate cost share of capital can also be expressed as a weighted average of industry-level capital shares, denoted by $\sigma_{j,t}$,

[20]In Italy capital costs are larger than residual income throughout the sample period. This might be a consequence of the very large number of self-employed in the country, which most likely inflate the share of mixed income attributed to the labor factor, thus leading to an underestimated share of income attributed to capital as a residual. According to the Eurostat Labour Force Survey, in Italy the self-employed were 27 percent of total employment in Italy in 2000, against a sample average of 12.5 percent. The value is relatively stable over time, hovering at around 24 percent at the end of the sample period.

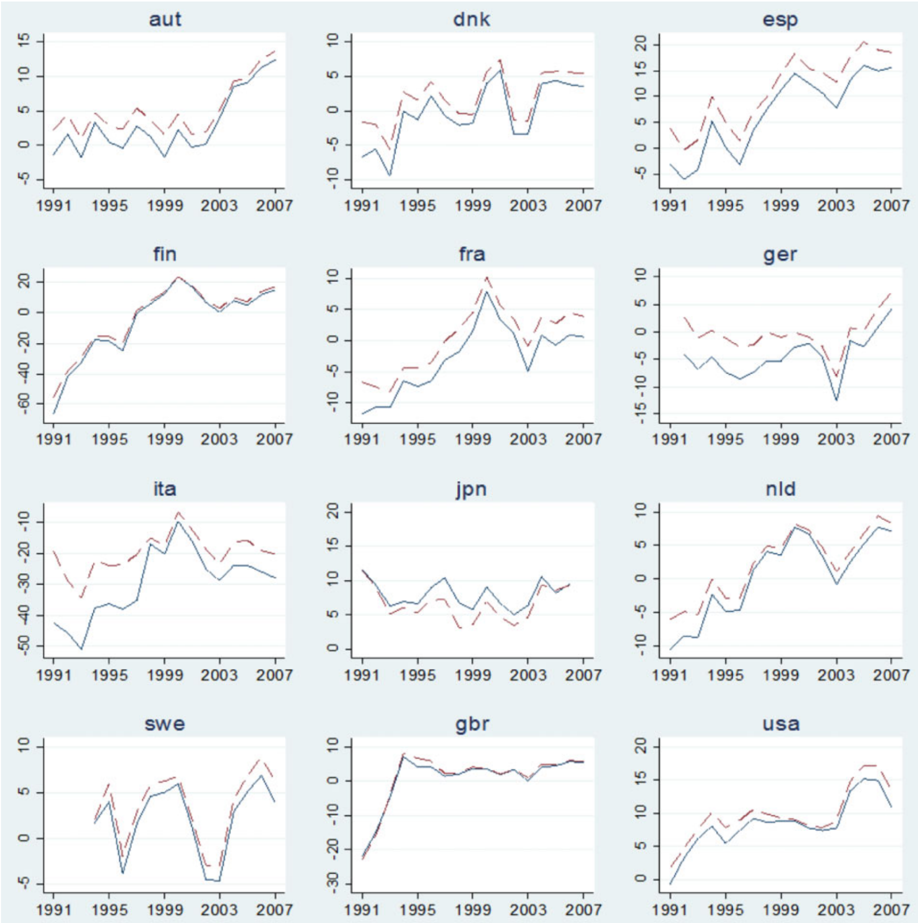

Figure 5. Residual Income vs. Capital Costs (as % of value added, market economy)

Note: The figure plots the difference between residual income and capital costs, as a percentage of value added, for the market economy, without taxes (solid line) and with taxes (dashed line).

namely: $\sigma_t = \sum_j \omega_{j,t}\sigma_{j,t}$, where $\omega_{j,t}$ represent the share of industry j in total production costs. Consequently, changes in the within component reflect changes in the aggregate capital share due to changes in industry-level capital shares, holding constant the industrial composition of economic activity. On the other hand, changes in the between component of the capital cost share reflect changes in the aggregate capital share due to changes in economic activity across industries, holding constant the capital share of each industry. Formally:

$$(14)\quad \Delta\sigma_t = \sigma_t - \sigma_{t-1} = \sum_j \frac{1}{2}\left(\omega_{j,t} + \omega_{j,t-1}\right)\left(\sigma_{j,t} - \sigma_{j,t-1}\right) + \sum_j \frac{1}{2}\left(\sigma_{j,t} + \sigma_{j,t-1}\right)\left(\omega_{j,t} - \omega_{j,t-1}\right),$$

where the first addendum denotes the within-industry component and the second the between component. Thus, I calculate the change in the aggregate capital cost

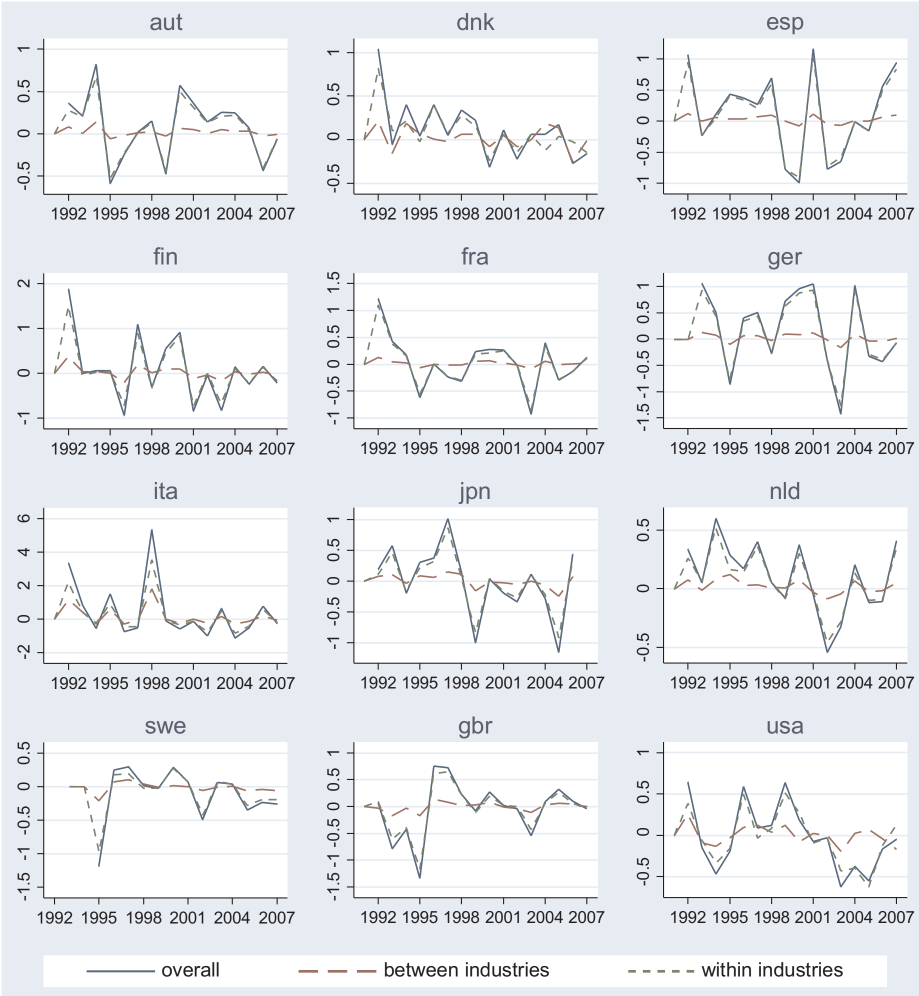

Figure 6. Change in the Capital Cost Share

Note: The figure plots the difference between the change in the capital share in total costs with taxes and the change in the capital share without taxes, calculated using the external rates of return.

share, and its components, both with and without taxes. The difference between the corresponding series with and without taxes is shown in Figure 6. As is apparent, the difference in the evolution of the capital share is rather volatile, particularly in the first half of the sample period, as a result of the variability in external rates. The series peaks in several countries around 1.5–2 pp (in absolute value), and even reaches 5 pp in Italy, coinciding with the strong decrease in rates of return and the corporate tax rate. Throughout the period, the aggregate dynamics is virtually driven by adjustment in capital investment within industries, with the changes between sectors playing a relatively limited role.

As discussed above, the fact that payments to the capital factor do not sum up to residual income after labor has been remunerated implies that producers are

TABLE 5
Capital Shares and Implied Profitability

Country	Internal Rate	External Rate			
		Cost Share of Capital		Implied Profit Rate	
	Revenue Share of Capital	Without Taxes	With Taxes	Without Taxes	With Taxes
aut	34.4	32.2	30.8	3.0	5.1
dnk	30.7	30.9	29.3	–0.4	1.9
esp	35.9	30.9	27.6	6.8	11.2
fin	32.9	34.6	33.1	–5.7	–2.9
fra	28.2	30.0	27.9	–2.9	0.3
ger	27.1	28.4	25.7	–2.5	1.3
ita	29.4	45.3	41.1	–29.6	–19.9
jpn	37.9	32.5	33.5	8.0	6.6
nld	31.8	31.2	30.0	0.5	2.3
swe	32.2	28.7	27.8	4.0	5.4
gbr	28.1	27.5	27.1	0.5	1.1
usa	32.1	25.8	24.6	8.4	9.9
average	31.7	31.5	29.9	–0.9	1.8

making economic profits (or losses). Table 5 reports the period average cost shares of capital for the market economy, measured with and without taxes, and, for comparison, the equivalent with internal rates (capital share of revenue). Omitting taxes leads to estimated capital cost shares ranging from 26 percent in the U.S. to 45 percent in Italy, whereas with tax those levels decrease to 25 and 41 percent, respectively. On average, including taxes decreases the cost share of capital by 1.5 pp across countries and years, to 31.5 percent. Again, the differences are particularly marked in the high tax countries, like Italy, Germany, and Spain. The implied profit rates that can be retrieved from these shares are reported in the last two columns.[21] Average profit rates are in general positive, with the exception of Italy and Finland. The sustained losses recorded in Italy are most likely to be attributed to measurement issues in labor compensation, as discussed above. In contrast, the result for Finland is driven by the exceptionally low profitability recorded in the early 1990s. The positive profit rates without taxes range from 0.5 percent in the U.K. and the Netherlands to 8.4 in the U.S. Larger implied profit rates with taxes clearly stem from the working assumption implicit in the construction of the external rates of return that the burden of taxation is borne by capital.

5. The Deadweight Loss of Differential Taxation

The analysis so far has assessed the consequences of including corporate taxes on the measurement of the capital input against a benchmark where taxation is

[21]Instantaneous economic profits are $\pi = pY - wL - \Sigma_i c_i K_i$, and the resulting profit rate is $\pi/pY = 1 - wL/pY - \Sigma_i c_i k_i/pY = 1 - s_L - s_K$. Under a Cobb–Douglas production function for value added like $Y = AK^{\alpha}L^{\beta}$, as shown in Hall (1990), the first-order condition for labor yields that the output elasticity is a mark-up over the share of payments to labor in total revenue, or $\beta = \mu(wL/pY)$, where $\mu \equiv (1 + (\partial p/\partial Y)(Y/p))^{-1}$. Likewise, the Euler equation for capital implies that the output elasticity is a mark-up over the share of payments to capital in total revenue, $\alpha = \mu(cK/pY)$. With constant returns to scale, $\alpha + \beta = 1$. Thus, summing and rearranging the first-order conditions shows that the output elasticities for each factor are given by the factor's share in total production cost. Algebraic manipulations allow one to express the profit rate as $(1 - s_L - \alpha)/(1 - \alpha)$.

absent. This section takes a different perspective in that, considering taxation as the baseline, it aims at quantifying the aggregate impacts of differential taxation across assets and industries. Again, given the information requirements on detailed tax provisions, existing studies focus on single countries, mainly the U.S. For instance, Diewert (1981) quantifies the effects of differential tax treatment in terms of output loss given the production possibilities frontier. An alternative approach, inspired by the seminal work of Harberger (1966), focuses on the welfare impacts. The analysis that follows is based on the contribution of Gravelle (1981) and Auerbach *et al.* (1983), who investigate the distortions in the corporate sector. To isolate the effect of the tax parameters, I recalculate the rental price of capital without the capital gain term. This implies that firms hold static expectations on the relative price of assets, and rules out resale of capital. Likewise, I perform the exercise using only the external rates of return, to avoid results being driven by the variability in the industry-specific internal rates. Instead, they will not depend on the economic characteristics of the industry where the assets are used, but only on the different level of effective capital taxation.

As in Fullerton and Henderson (1989), I consider the unitary social cost of taxing asset i in industry j as the rental price of capital net of the replacement rate:

$$c_{ij}/p_{ij} - \delta_i = \rho_{ij}.$$

The capital stock can be redefined such that the relative price of the assets is normalized to 1, or $p_{ij} = 1$. The setup is again the standard one where each industry j produces using a Cobb–Douglas production technology in each type of capital (indexed with i) and labor:

$$Y_j = A_j \prod_i K_{ij}^{\alpha_{ij}} L_j^{1-\alpha_j}, \tag{15}$$

with $\alpha_j = \Sigma_i \alpha_{ij}$. In this framework, the analytical expression for the distortions can be directly computed (and is derived in the Appendix). In particular, given the observed output levels produced by each industry, it is possible to calculate how much of the existing capital input could be disposed of if the remaining capital were allocated optimally. In formulas, the distortion, or welfare cost in terms of misallocated capital, as a fraction of actual capital input, can be expressed as:

$$D = \frac{\sum_j \bar{Y}_j \alpha_j \tilde{\rho}_j^{-1} \sum_i \frac{\alpha_{ij}}{\alpha_j}\left(\frac{\tilde{\rho}_j}{\rho_i} - 1\right) + \sum_j \bar{Y}_j \alpha_j \tilde{\rho}_j^{-1}\left[1 - \left(\frac{\tilde{\rho}_j}{\tilde{\rho}}\right)^{1-\alpha_j}\right]}{\sum_j \bar{Y}_j \alpha_j \tilde{\rho}_j^{-1} \sum_i \frac{\alpha_{ij}}{\alpha_j}\left(\frac{\tilde{\rho}_j}{\rho_i}\right)}. \tag{16}$$

In (16), $\tilde{\rho}_j = \prod_i \rho_i^{\alpha_{ij}/\alpha_j}$ is the weighted geometric mean of the required, before-tax rates of return in industry j, and $\tilde{\rho}$ is the aggregate return, obtained as a weighted average of the industry-specific rates $\tilde{\rho}_j$. Finally, $\bar{Y}_j$ is the actual level of output in industry j, and α and $1 - \alpha$ are the parameters of the Cobb–Douglas technology, which equal the corresponding shares in total factor costs.[22]

[22]See footnote 21.

TABLE 6

Welfare Cost of Differential Corporate Taxation (in % of the Aggregate Capital Input)

Country	Within Industries	Between Industries	Total
aut	0.62	0.01	0.64
dnk	0.51	0.12	0.62
esp	0.88	0.02	0.90
fin	0.45	0.07	0.52
fra	0.59	0.03	0.62
ger	0.57	0.02	0.59
ita	0.80	0.02	0.81
jpn	0.47	0.02	0.49
nld	0.56	0.04	0.60
swe	0.34	0.07	0.41
gbr	0.44	0.06	0.50
usa	0.71	0.09	0.80
average	0.58	0.05	0.63

Note: The welfare cost is calculated as the difference between the actual level of capital inputs and the cost-minimizing level of capital inputs which would produce the same level of output, for given labor utilization, under equalized taxation across capital assets and industries.

The analytic expression for the welfare cost comprises two non-negative components. The first is zero only if there is uniform taxation within each industry, or $\rho_i = \tilde{\rho}_j$. Thus, it captures the distortion due to differential taxation of assets within industries. The second component is zero only if the weighted geometric means of the before-tax rates of return in each industry are the same, or $\tilde{\rho}_j = \tilde{\rho}$. Therefore, it reflects the distortion due to variability in the level of taxation across industries. The results are reported in Table 6. On average, in each year in the sample period roughly 0.6 percent of the capital input is misallocated due to differential taxation. The values are very heterogeneous across countries, ranging from roughly 0.4 percent in Sweden to 0.9 percent in Spain. On average, around 90 percent of the estimated distortion is to be attributed to the variability of effective taxation within industries. Hence, the differential fiscal treatment of assets seems relatively sizable, and, accordingly, determines almost fully the recorded capital misallocation. By contrast, differences in taxation across industries are comparatively small, and thus seem to exert a rather limited impact on the overall distortion. Misallocation between industries is particularly marked in Denmark, Finland, Sweden, the U.K., and the U.S. A closer inspection of the data shows that those economies have the largest values of ICT capital intensity. Since ICT assets appear relatively concentrated is some industries, the pattern of the welfare costs closely mirrors the variability in the intensities across industries.

6. Conclusion

Taxes affect the measurement of capital inputs. In particular, discrepancies between economic depreciation and deduction for fiscal purposes imply that the tax system provides heterogeneous incentives to investment into different capital types. In turn, this might benefit those industries that rely more on the tax-favored assets for technological reasons. The paper provides an assessment of such impacts in a cross-country framework where heterogeneity of corporate taxation across industries and asset types is accounted for. The results indeed show that taxes affect the relative prices of capital types due to their combined effects: directly, on the rental prices; and indirectly, on the rates of return. In general, taxation tends to increase the rental price of the fastest depreciating assets, while the impacts tend to be opposite for equipment with a longer useful life. In the case of structures, which have the lowest economic depreciation rates, the effects are mostly determined by the (positive) capital gain terms, and their size relative to the rate returns. In the paper, external rates of return—which should reflect the *ex-ante* opportunity cost of investment—are constructed from market variables that proxy the cost of equity and debt.

Including tax parameters in the traditional growth accounting framework leads to a larger capital quality effect (the difference between the growth of capital services and the growth of the underlying capital stock) at the industry level—particularly when the external rate of return is used—mainly driven by the contribution of longer-lived ICT assets. Likewise, while omitting taxes does not seem to bias significantly the growth rate of aggregate capital inputs, it does so when it comes to the associated reallocation effects, which are, in general, relatively mild.

Allowing for exogenously derived rates of return implies that capital costs can be obtained independently of measures of residual income in the national accounts. Consequently, the size of the aggregate remuneration of capital will be different depending on whether or not tax parameters are included. I find indeed that, while capital costs increase without taxes in all countries considered except Japan, in general they fall short of residual income. Similarly, both the levels and the changes of the share of capital in total production costs are affected by the inclusion of taxes. In this respect, the discrepancies in the evolution of the cost share with and without taxes are almost exclusively due to composition effects within industries. The importance of intra-industry differences—originated by differences in the tax treatment of capital assets—compared to the differences across industries is confirmed in the hypothetical scenario where the marginal tax burden is equalized across the board. Taking that as a benchmark, differential taxation leads to a non-negligible deadweight loss in terms of misallocated capital inputs, particularly when it comes to the capital mix within industries.

All in all, the paper offers a cross-country perspective on how taxes, by altering relative investment prices, affect the level and the composition of capital inputs. While corroborating previous evidence from single country studies, for example the U.S., the results show considerable cross-country variation, driven by factors specific to the countries and the period reviewed. Such heterogeneity stems from differences in both national tax rules and economic features. When it comes to the former, against the background of globally declining statutory rates on corporate income, remaining divergences in asset-specific tax depreciation allowances—for both ICT assets and traditional capital types—have acquired growing importance. This is reflected in the finding that within-industry distortions in the allocation of capital inputs—resulting from the divergences in the marginal tax burden across assets—are by far larger than the distortions brought about by differential taxation across industries, which also account for the different mix of capital assets. Among the economic factors, important structural developments appear to be the main drivers behind the uncovered heterogeneity. In particular, capital deepening caused by the rapid accumulation of ICT assets has taken place unevenly across the countries reviewed, with the U.S., the U.K., and Scandinavian countries, especially Sweden, experiencing a marked acceleration.

Empirically, at the highest level of disaggregation, differences in the relative magnitude of the internal and external rates of return as well as in the levels of the internal rates across industries and countries matter for the variation in the results. As discussed above, external rates would better reflect the *ex-ante* character of investment decisions, which also justifies the use of a single rate even in the case of multiple assets. While the absence of variability in the rates across different capital types is difficult to rationalize once returns have been realized, more serious statistical and economic concerns arise for the calculations of the endogenous rates. These are linked directly to the measurement of gross operating surplus and allocation of capital inputs across industries, which is subject to significant error. The argument for using appropriately chosen external rates becomes then more compelling in a cross-country framework, where the different sources of uncertainty might have an uneven bearing on the measured rates.

All in all, omitting tax parameters might not only be a source of measurement error in the context of aggregate growth accounting, but also hide important dynamics leading to (mis)allocation of capital. In this respect, the results suggest that properly measuring capital costs with an external rate of return would require additional efforts on the part of statistical agencies in order to keep track of the relevant tax parameters. The issue seems particularly relevant given that the use of external rates of return has been repeatedly advocated, for instance by Diewert *et al.* (2004) and Inklaar (2010) among others, and also in the light of the recent advances in national accounting allowing explicitly for full reporting of the capital input accounts.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher’s web-site:

Appendix 1: Sample coverage
Appendix 2: Calculation of the external rate of return
Appendix 3: Derivation of the deadweight loss of differential taxation