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Investment and Firm-Specific Cost of Capital: Evidence from Firm-Level Panel Data

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Abstract: To study the effects of taxes on investment, this paper employs a novel firm-level dataset of German manufacturing companies which combines survey data with financial accounts. The information enables us to construct indicators of the cost of capital which capture the specific conditions of each firm including its location as well as asset and capital structures. Our results indicate that, in order to identify tax effects, it is important to take this firm-specific variation into account. In particular, accounting for the firms' capital structure is found to be crucial; ignoring this variation would result in insignificant tax effects and specification problems.

Keywords: Cost of Capital; Investment; Capital Structure; Firm-Level Data; Survey Data; Local Business Tax; Business Expectations; GMM

JEL Classification: H25, H32, H73

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1 Introduction

The adverse effects of corporate taxation on investment and the stock of capital are key issues in academic and public debates about tax policy. While empirical research generally supports significant effects, the available evidence differs with regard to the strength of the influence (surveys are provided by Chirinko, 2002, and Hubbard and Hassett, 2002). A larger literature shows that providing empirical evidence about how changes in taxes affect investment and the stock of capital has proved to be rather difficult. With regard to investment, research could take advantage of the immediate effects of tax changes on the value of firms, and studies relying on the q-theory of investment have detected substantial tax effects (*e.g.*, Cummins, Hassett, and Hubbard, 1994). Regarding the effects on the capital stock, however, most research has found only small effects. The dominant approach taken in the literature is concerned with the effects of the cost of capital on investment. Macroeconomic research following the so-called neoclassical approach using time-series data faces a host of problems such as simultaneity and aggregation biases. But also studies using firm-level data often find only small effects (*e.g.*, Chirinko, Fazzari, and Meyer, 1999). While the approach relying on the cost of capital has the advantage that relevant parameters associated with corporate taxation can be included such as the statutory tax rate, tax-depreciation allowances and special tax incentives, empirical research indicates that it is difficult to find sufficient institutional variation. This is a problem in particular in the context of domestic firms that are subject to the same tax law – in contrast to multinational firms that operate in different countries.

Even if the same tax law applies to all firms, it is well known that the tax system treats firms differently. For instance, different types of assets like buildings or machinery are taxed differently due to differences in depreciation allowances. Moreover, corporate tax systems usually discriminate between different sources of finance. As a consequence, the cost of capital differs across firms and also reforms in the tax system, which introduce exogenous variation in key tax parameters, are influencing firms differently. To explore the research opportunities that arise from the firms' heterogeneity with regard to asset and capital structures, this paper employs a novel firm-level dataset of German manufacturing companies which enables us to compute firm-specific indicators of the cost of capital. The institutional setting in Germany provides us with further opportunities to identify tax effects since the local business tax varies at the level of municipalities. Furthermore, with data covering the period 1994-2007 we can exploit major institutional changes in the tax law.

The results support the importance of using firm-specific variation for identifying tax effects. Our key finding is that GMM estimation of a partial adjustment model which takes account of firm-specific differences yields a significant cost of capital elasticity of the stock of capital of about unity of larger (in absolute terms). However, ignoring firm-specific variation results in weaker tax effects and is associated with specification problems.

The paper is organized as follows. In Section 2 we derive the firm-specific measure of the cost of capital and discuss how to implement it empirically. Dataset and investigation approach are discussed in Section 3. Section 4 provides results using a distributed lag model, which has often been used in the literature. Section 5 reports results obtained from a GMM approach that is particularly suited to exploit the opportunities arising from panel data. In Section 6 we finally explore the role of the firm-specific variation by abstracting from the local variation in the business tax rate and fixing capital and asset structures. Finally, Section 7 provides a brief summary and concludes.

2 Investment and Firm-Specific Cost of Capital

To capture the role of taxation for company investment, we follow the cost of capital approach dating back to Jorgenson (1963), Hall and Jorgenson (1967), and King (1974), and further developed by Devereux and Griffith (1998, 2003). This approach is based on the view that a capital stock is optimal if the effect of a marginal addition to the capital stock on the firm value is zero. Before deriving a firm-specific indicator of the cost of capital, the following subsection briefly discusses the determination of the firm value.

Basic Model of Firm Value As usual, we derive the firm value V_t at the end of period t by considering the arbitrage equilibrium condition between investment in the firm's equity relative to investment in some alternative asset with a fixed rate of interest. Following Devereux (2004), abstracting from shareholder taxation, the arbitrage equilibrium condition can be specified as

$$(1+r)\,V_t = \frac{1}{1-c}D_{t+1} + V_{t+1}, \tag{1}$$

where r is the nominal rate of return on a risk-free asset and D_{t+1} denotes dividend payments. c captures a tax credit for profit distribution. More precisely, c is the corporation tax rebatement expressed as a fraction of dividends.[1] According to equation (1), at the end of period $t+1$, the return from lending in the amount of V_t (left hand side) is required to be equal to the payoff from an investment in equity (right hand side), the latter consisting of dividend payments and a change in firm value. We could also take account of new share issues in the definition of the firm value. But, since we abstract from the taxation at the level of shareholder it is not meaningful to discuss the discrimination of the tax system with regard to new equity.

Assuming that the firm value is bounded,[2] repeated substitution enables us to solve for the firm value as a present value of dividends

$$V_t = \frac{\gamma}{1+r}\left(D_{t+1} + \frac{1}{1+r}D_{t+2} + \left(\frac{1}{1+r}\right)^2 D_{t+3} + ...\right), \tag{2}$$

where the parameter $\gamma \equiv \frac{1}{(1-c)}$ captures the tax advantage of distributing profits relative to retaining profits which arises from the presence of the dividend tax credit. Dividend payments obey

$$D_{t+1} = (1-\tau)\,(1+\pi)\,F\,(K_t) - q_{t+1}I_{t+1} + B_{t+1} - (1+(1-\tau)\,r)\,B_t + \tau\varphi\left(q_{t+1}I_{t+1} + K_t^T\right). \tag{3}$$

Here, $F(K_t)$ is output in period $t+1$ depending on the existing capital stock K_t, τ reflects the statutory tax rate, π is the (general) inflation rate relative to the current output price p_t, which is set to unity, for simplicity. I_{t+1} is investment, B_t is the existing stock of debt served at the common rate of interest r and B_{t+1} is the stock of debt at the end of the period $t+1$. φ is the

[1] This captures a specialty of the German corporation tax (see McDonald, 2001, for a discussion), which has been abolished in 2001, however.

[2] Formally, $\lim_{T\to\infty}.\left(\frac{1}{1+r}\right)^{T-t} V_T = 0$

capital allowance rate capturing tax depreciation allowances and K_t^T is the *tax accounting* value of the capital stock defined as

$$K_t^T = (1-\varphi)q_{t-1}I_{t-1} + (1-\varphi)K_{t-1}^T \quad = \quad (1-\varphi)\, q_{t-1}I_{t-1} + (1-\varphi)^2\, q_{t-2}I_{t-2} + ... \tag{4}$$

q_t is the price of the capital good increasing each period according to the inflation rate π^I such that $q_{t+1} = (1+\pi^I)q_t$. Similar to the output price, q_t is set to unity. The accumulation equation is

$$K_{t+1} = (1-\delta)\, K_t + I_{t+1} \tag{5}$$

where δ is the rate of economic depreciation.

Cost of Capital with Retained Earnings To derive the cost of capital we follow Devereux (2004) and consider a hypothetical investment increasing the capital stock by one unit in period t and assume that the company's general purpose is the maximization of the firm value, *i.e.* the market value V_t. The optimal capital stock can be found using equations (1) to (5) and setting $\partial V_t / \partial K_{t+1} = 0$. As a result, we get the first order condition

$$(1-\tau)\,(1+\pi)\, F'\,(K_{t+1}) = (1-A)\left(r + \delta(1+\pi^I) - \pi^I\right)$$

reflecting that, in the optimum, the after-tax value of output (left hand side) in period $t+1$ is equal to the cost of increasing K_t. A is the net present value of allowances if declining-balance depreciation is applied,[3] with

$$A \equiv \frac{\tau\varphi(1+r)}{\varphi + r}. \tag{6}$$

Obviously, the first order condition does not allow for changes in debt or new equity finance. Instead, it is implicitly assumed that the unit increase of the capital stock is financed by a reduction in dividends, *i.e.* by retained earnings. The cost of capital, defined as the minimum acceptable

[3]The present value of depreciation allowances depends on the type of asset, the respective depreciation rate and allowance scheme. In the case of straight-line depreciation, $A \equiv \frac{\tau\varphi(1+r)}{r}(1 - \frac{1}{(1+r)^n})$ where n is the number of years for which depreciation allowances can be claimed. For more information, see also the Appendix.

pre-tax rate of return, is

$$coc^{RE} \equiv \frac{(1-A)}{(1-\tau)(1+\pi)}\left(r+\delta\left(1+\pi^I\right)-\pi^I\right)-\delta. \tag{7}$$

Cost of Capital and the Firm's Capital Structure While we have assumed so far that the marginal source of finance is retained earnings, let us augment the model to include debt as an additional source of financing. If the firm uses debt finance, it benefits from the deductibility of interest payments in determining corporate profits. As a consequence, the cost of capital tends to be lower with debt finance. While this seems to suggest that the most tax efficient way to finance investment is to rely exclusively on debt finance, the corporate finance literature emphasizes non-tax determinants of capital structure choice. Due to information asymmetries, debt finance can play an important role in reducing incentive problems associated with the management of the firm (Aghion and Bolton, 1989). In a similar vein, Jensen (1986) argues that debt might be helpful to reduce disincentives associated with free cash flow. Moreover, debt finance is associated with agency cost due to potential conflicts between equity and debt claimants (*e.g.*, Jensen and Meckling, 1976; Myers, 1977). To take these considerations into account, we might assume that each firm has a specific target value for the share of debt based on incentive considerations alone. Let us specify this target level with λ. If deviating from this target value is associated with costs, optimal investment finance will trade off the tax-advantage from using more debt against the costs associated with distorting the capital structure (Huizinga, Laeven, Nicodeme, 2006). For simplicity, one might assume that the cost of deviating from the optimal mix of financing with debt and retained earnings is very high. With this assumption, an investment project will be financed usually with a ratio of debt to capital that is consistent with the target level λ. If the cost of deviating from the preferred capital structure is less than prohibitive, the actual share of debt used to finance investment is determined by a function $\Lambda(\lambda, \Delta)$, which is increasing in the preferred debt-to-capital ratio λ as well as in the tax-advantage of using debt, denoted with Δ, which is derived below.

With a share Λ of investment being financed with new debt and only a share $1-\Lambda$ being financed with retained earnings, the cost of capital will differ from the base case analyzed above. The derivation of the cost of capital with debt finance is the same, except that we have to consider an increase in borrowing during the investment period (see (3)). Note that we follow Devereux (2004) and assume that debt is increased only temporarily and repaid after one period. With a share of debt finance Λ, the adverse effect of investment on dividends is reduced

$$\frac{\partial D_t}{\partial K_{t+1}} = -q_t \left(1 - \tau\varphi\right) \left(1 - \Lambda\right).$$

In the second period, however, dividends decline since debt obligations are served and repaid.

$$\frac{\partial D_{t+1}}{\partial K_{t+1}} = -\left(1 + \left(1 - \tau\right) r\right) \left(1 - \tau\varphi\right) q_t \Lambda.$$

Taking these additional effects into account in the derivation, we can specify the cost of capital with a share Λ of debt finance as:

$$coc \equiv coc^{RE} - \Lambda \underbrace{\frac{\left(1 - \tau\varphi\right)\left(r\tau\right)}{\left(1 - \tau\right)\left(1 + \pi\right)}}_{\Delta}, \tag{8}$$

where Δ is the difference between the cost of capital entirely using retained earnings and entirely relying on debt finance. As already noted, if the cost of deviating from the preferred capital structure is less than prohibitive, the actual share of debt used to finance investment is a function $\Lambda\left(\lambda, \Delta\right)$ of the preferred debt-to-capital ratio and the differential cost of capital Δ. This has some implications for the empirical analysis, which are further discussed below.

Cost of Capital and the Firm's Asset Structure To further take account of differences in the investment projects undertaken and to be able to calculate tax-depreciation allowances for each firm, we also consider a company's asset structure. While we do not have information about actual investment project's characteristics, we aim at capturing differences related to the firm-specific characteristics of the production process. Taking three types of assets into account, namely industrial buildings (B), plant/ machinery (M) and inventories (STO), we construct weights Ω for each firm with $\Omega^B + \Omega^M + \Omega^{STO} = 1$:

$$\Omega^B = \frac{B}{B+M+STO}$$
$$\Omega^M = \frac{M}{B+M+STO}$$
$$\Omega^{STO} = \frac{STO}{B+M+STO}$$

We use these weights to calculate firm-specific depreciation rates δ, firm-specific rates of capital allowances ψ and net present values of allowances, A, depending on both asset-specific depreciation rates and allowance schemes:

$$\delta = \delta^B\Omega^B + \delta^M\Omega^M + \delta^{STO}\Omega^{STO}$$
$$\psi = \psi^B\Omega^B + \psi^M\Omega^M + \psi^{STO}\Omega^{STO}$$
$$A = A^B\Omega^B + A^M\Omega^M + A^{STO}\Omega^{STO}.$$

Not only in the case of the capital structure, but also with regard to asset structures, differences in the tax treatment might exert some distortions. This would suggest that the shares Ω^B Ω^M, and Ω^{STO}, might be correlated with the differential tax effects A^B, A^B, and A^{STO}.

3 Data and Investigation Approach

The empirical analysis employs an unbalanced panel of matched survey and financial statement data which focuses on German firms and covers the period 1994-2007. Institutional details and tax parameters including the tax rate at each firm's location are used to calculate the cost of capital as outlined in the previous section. The survey data stems from the manufacturing sector of the monthly ifo Business Survey and allows us to control for a firm's business expectations (*commercial expectations*) or current business situation (*state of business*). This information is captured by ordinal variables, where a value of 1 indicates an 'improved/improving' situation or expectations, 0 means 'unchanged/unchanging' and -1 reflects a 'deteriorated/deteriorating' assessment. To account for differences between firms' current business situations, we include indicators of the state of business or the business expectations at the time of investment planning, *i.e.* during the last 6 months preceding the investment period.

In total, there are about 8000 observations based on 1835 firms in the dataset but only for about 2300 observations information on all required covariates and instrumental variables is available for our preferred specification. Table (1) provides some descriptive statistics for our sample containing unweighted annual averages of the variables employed.[4] Obviously, sales and asset figures indicate a period of growth during the 1990s and a weaker performance in the subsequent period after the introduction of the Euro and the so called 'dot-com' bubble. From 2004 onwards, there are more companies and thus more balance sheets included in the underlying financial statement data.[5]

To compute the cost of capital we follow Devereux and Griffith (1999, 2003) and Yoo (2003), and fix the rate of economic depreciation at $\delta^M = 12.25\%$ for machinery, $\delta^B = 3.61\%$ for buildings and $\delta^{STO} = 0\%$ for inventories, as these are not depreciable.[6] Depreciation rates for tax purposes, *i.e.* capital allowances for industrial buildings, machinery and inventory are computed following the tax law. As in the study by Yoo (2003) and Devereux *et al.* (2008) we take account of both allowance rates and information on the taxation-relevant lifetime of an asset. With regard to the net present value of depreciation allowances we follow German tax law and use straight-line depreciation for buildings and the declining-balance method for machinery. Furthermore, the tax rate τ in equation (8) is the year-specific statutory tax rate on retained earnings, including the corporation tax, the solidarity surcharge as well as the local business tax. The latter is taken into account separately for each firm and year and depends on a firm's location in Germany. Some more details on the tax system and recent reforms are given in the Appendix. To compute the user cost of capital given in (8) we take annual data on nominal interest and inflation rates.[7] Exploiting the micro-level

[4]We measure investment and the capital stock by tangible assets. For further information on the dataset used see the Appendix and Hoenig (2010).

[5]When the dataset was established, most of the balance-sheets for the year 2007 were not yet available such that the number of observations in our sample drops again in 2007.

[6]According to tax law, we apply the LIFO method to valuate inventory.

[7]Information on nominal interest rates is taken from the German Council of Economic Experts, inflation rates are based on the yearly consumer price index of the Federal Statistical Office. In this respect, the inflation rate of output is set equal to the inflation rate in the capital stock.

Table 1: Summary Statistics of Firm Variables

	1995	1996	1997	1998	1999	2000	2001
Tangible assets (Mill. EUR)	96.56	104.62	103.15	112.60	113.35	108.73	74.79
	(281.17)	(292.83)	(299.51)	(311.80)	(307.07)	(325.29)	(125.42)
Sales (Mill. EUR)	762.89	810.85	873.74	936.09	849.09	650.59	473.94
	(2713.59)	(2840.30)	(3164.36)	(3403.08)	(3173.81)	(1805.60)	(802.18)
Cost of Capital	.097	.092	.073	.077	.075	.076	.045
	(.019)	(.015)	(.012)	(.011)	(.010)	(.011)	(.006)
State of business	-.004	-.184	.051	.049	.015	.192	-.065
	(.554)	(.517)	(.565)	(.546)	(.541)	(.548)	(.506)
Commercial expectations	-.042	.021	.132	.042	.058	.096	-.130
	(.395)	(.412)	(.396)	(.383)	(.395)	(.394)	(.415)
Number of observations	173	176	163	157	164	152	140

	2002	2003	2004	2005	2006	2007
Tangible assets (Mill. EUR)	65.37	93.38	74.05	65.71	58.58	90.90
	(92.88)	(304.67)	(274.25)	(244.42)	(221.09)	(312.61)
Sales (Mill. EUR)	479.27	635.13	507.93	466.03	439.03	710.07
	(834.24)	(1916.27)	(1827.81)	(1732.47)	(1826.55)	(2572.56)
Cost of Capital	.050	.047	.034	.031	.036	.035
	(.006)	(.006)	(.006)	(.005)	(.006)	(.006)
State of business	-.238	-.122	.059	.043	.307	.401
	(.506)	(.545)	(.537)	(.555)	(.574)	(.557)
Commercial expectations	.026	.121	.076	.068	.090	.104
	(.421)	(.426)	(.442)	(.387)	(.388)	(.371)
Number of observations	138	172	197	260	310	187

All values represent unweighted averages, standard deviations in parentheses. Variables state of business and commercial expectations refer only to the second half of the year.

information in our dataset which reports each company's capital structure in the financial account statements we are able to compute a firm-specific, time-varying measure of Λ.[8]

With regard to the cost of capital, the figures emphasize the consequences of the 2001 tax reform which was intended to improve the German position in international tax competition by lowering the statutory tax rate at the company level. Since an important part of the tax burden originates in the local business tax, the cost of capital displays substantial variation across space (see Figure 1). Considering average sales, rather large companies seem to be included in the sample. Nevertheless, the annual median value of sales makes up some 20 % of the annual mean. This points at a skewed distribution which is also reflected by the large standard deviations.

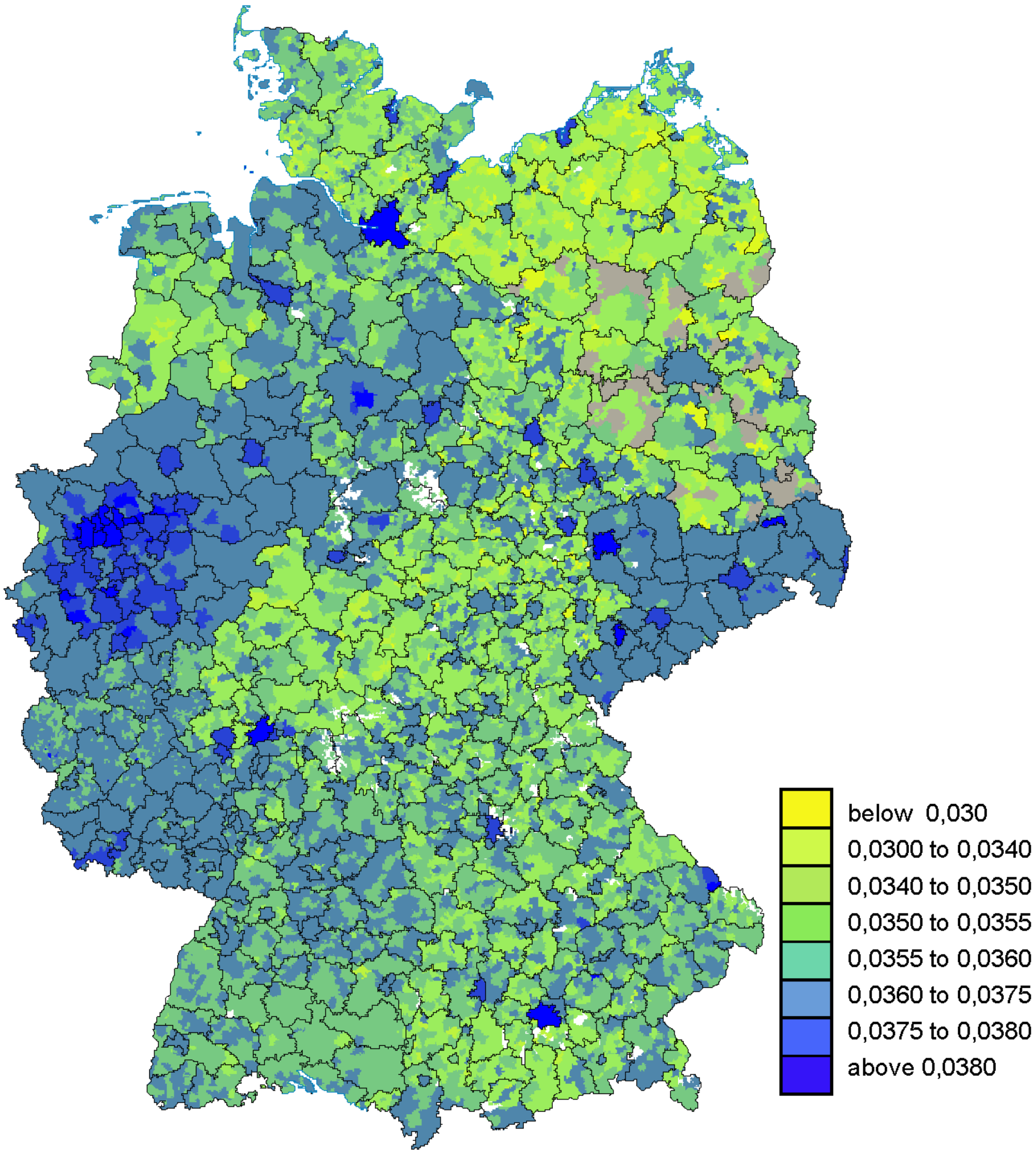
While the cost of capital captures both the local business tax and federal taxes as well their interaction, it does not take account of some specific features of the local business tax. Although this tax is primarily levied on profits, there are important additions to the tax base, in particular, 50% of long-term interest is added.[9] This element of the tax might exert effects on the choice between different sources of finance. A second important element is that for multiregional corporations with branches and/or subsidiaries in different locations, there is formula apportionment based on the payroll. As is well known from the theoretical literature on formula apportionment (Gordon and Wilson, 1986), such institutions alter the nature of the tax and, at least partially, the tax becomes a tax on the formula weights. With payroll as formula weight, we should expect that high tax rates provide incentives to substitute labor with other inputs and factors such as capital. To take account of this effect we test for a separate impact of an index that captures this incentive. The details of the computation of this index are provided in the Appendix.

The starting point to derive a useful specification for our empirical investigation is a neoclassical production function with capital and labor as inputs to production. Assuming perfect competition, we can easily derive the first order condition for the optimal capital stock to get a static log-linear

[8] Λ is defined as the share of debt to total capital with debt being interest-bearing debt and total capital being the sum of nominal capital, capital and profit reserves as well as total debt.

[9] In 2008, which is not included in our estimation sample, the additions have been changed by a major tax reform.

Figure 1: Cost of Capital in 2006



Map plots the cost of capital for an investment financed with retained earnings using average values for the debt-to-capital ratio and the asset structure. White spots refer to missing data.

relationship between the capital stock, the output and the cost of capital of a company

$$K_t^\star \equiv \kappa^\sigma Y_t coc_t^{-\sigma},$$

where σ is the elasticity of substitution between labor and capital. If investment projects take more than one period in order to be realized, however, investment will be spread over multiple periods and a firm's capital stock deviates from its optimal level. The literature in the tradition of Jorgenson (1963), therefore, explains the current capital stock by a sequence of terms

$$\ln K_t = \sum_{i=0}^{n} w_i \left[\ln Y_{t-i} - \sigma coc_{t-i}\right].$$

In order to remove time-invariant determinants and to facilitate the measurement of determinants of output and the user cost, much of the literature uses a first differenced version of this equation. Taking account of possible differences in the effects of output and cost of capital, the literature (see Chirinko, 1993) employs a function

$$\Delta \ln K_t = \sum_{i=0}^{n} \alpha_i \Delta \ln Y_{t-i} + \sum_{i=0}^{n} \theta_i \Delta \ln coc_{t-i} + \epsilon_t, \tag{9}$$

where the change in the stock of capital (in logs) with regard to the previous period is the dependent variable. If lag-length is chosen correctly, autocorrelation is no longer present and estimation is carried out using OLS or, perhaps, using IV approaches to control for possible simultaneity biases with regard to the contemporaneous variables.

With micro-level panel data and depending on the adjustment cost function, it seems a bold attempt to include a number of lags of explanatory variables that is sufficient to remove all autocorrelation. If the available time span is limited[10], however, as is usually the case with firm level panel data, an alternative and perhaps more appropriate approach is to employ a partial adjustment model that explicitly takes account of first-order autocorrelation and avoids using higher order lags of explanatory variables

$$\Delta ln(K_t) = \rho ln(K_{t-1}) + \alpha ln(Y_t) + \theta ln(coc_t). \tag{10}$$

[10] See Dwenger (2010) for an approach that combines ADL and partial adjustment models.

Taking a firm's sales as our output variable $Y_{i,t}$ and including the firm-specific cost of capital as specified in section (2) along with further relevant variables, the regression equation becomes:

$$\begin{gathered} ln(K_{i,t}) = (1+\rho)ln(K_{i,t-1}) + \alpha ln(Y_{i,t}) + \beta comex_{i,t} + \theta ln(coc_{i,t}) + \phi_t + u_{i,t}, \\ u_{i,t} = \eta_i + \varepsilon_{i,t} \end{gathered} \tag{11}$$

where $ln(K_{i,t})$ is the capital stock of firm i in year t. Here, the coefficient $(1+\rho)$ on the lagged capital stock $ln(K_{i,t-1})$ reflects the adjustment process triggered by current investment. As already mentioned, beyond a firm's sales and capital cost we include a firm's appraisal of its actual state of business ($stb_{i,t}$) at the beginning of year t. Similarly, in an alternative setting, we include the firm's commercial expectations ($comex_{i,t}$) measured as the average expectation of firm i over the second half of period $t-1$. Furthermore, to control for time effects common to all firms and to capture cyclical productivity or price-level shocks, equation (11) includes period-specific intercepts ϕ_t. In addition, the error term $u_{i,t}$ contains η_i, denoting a firm-specific fixed effect controlling for unobservable company characteristics, and $\varepsilon_{i,t}$, which is the remaining disturbance term.

From an econometric point of view, the specification in equation (11) faces problems of simultaneity and endogeneity as the contemporaneous cost of capital and sales variables are possibly correlated with the error term. Moreover, the inclusion of the lagged dependent variable results in the well-known dynamic panel bias in the presence of time-invariant firm-specific fixed effects (see Nickell, 1981). Since a simple fixed effect estimation may yield biased and inconsistent estimates, we utilize a Generalized Method of Moments (GMM) estimator. This estimator allows us to handle not only the dynamic structure of the model and predetermined or endogenous explanatory variables, but also firm-specific factors, heteroskedasticity, and autocorrelation of individual observations. More specifically, we employ the system GMM estimator outlined by Arellano and Bover (1995) and refined by Blundell and Bond (1998) since it alleviates some of the shortcomings of the Arrelano-Bond (1991) first-difference GMM estimator, if applied to autoregressive models for moderately persistent series in short panels.[11]

[11] Some difficulties in application of the difference GMM estimator are mentioned in Blundell and Bond (1998), Beck, Levine and Loayza (2000) or Griliches and Hausman (1986). To implement the system GMM estimator we use the xtabond2 command in STATA introduced by Roodman (2006).

4 Results of the Distributed Lag Model

Taking the existing literature as a point of departure, we follow Chirinko, Fazzari and Meyer (1999) and start with the distributed lag model (9) to estimate the relationship between taxation and company investment. Table 2 provides some basic results for different numbers of lags. In this model, the response of the capital stock to changes in the firm-specific cost of capital is captured by the sum of coefficients.

Though the coefficient of determination tends to increase with the inclusion of higher order lags, the results of specifications with more than one or two lags are somewhat disappointing. While the sales variable judged on basis of the sum of coefficients proves significant throughout all specifications, the cost of capital variable shows only small and often insignificant effects.

Table 3 provides some further results of specifications including fixed time effects (see DL4b) and/or utilizing instrumental variables (see DL5a and DL5b), which may take account of possible simultaneity biases. Following Chirinko et al. (1999) we use twice lagged levels of variables as instruments in this first-differenced equation. However, the number of observations gets very small and the standard errors become large.

5 Results of the Dynamic Panel Data Model

As already mentioned, and in contrast to the estimators used in the traditional literature, GMM estimation seems preferable as this allows us to take account of autocorrelation explicitly and to handle the endogeneity of the variables while allowing for firm-specific factors. To eliminate the time-invariant firm effects and exclude any bias potentially arising from unobserved heterogeneity, equation (11) is first transformed into differences:

$$\Delta ln(K_{i,t}) = (1+\rho)\Delta ln(K_{i,t-1}) + \alpha \Delta ln(Y_{i,t}) + \beta \Delta comex_{i,t} + \theta \Delta ln(coc_{i,t}) + \Delta \phi_t + \Delta u_{i,t}. \quad (12)$$

Table 2: Results of Distributed Lag Model using Firm-Specific Cost of Capital and Fixed Effects

$\Delta \ln(K_{i,t})$	(DL0)	(DL1)	(DL2)	(DL3)	(DL4a)
$\Delta \ln(Y_{i,t})$					
α_0	.285 (.031)***	.466 (.048)***	.442 (.062)***	.454 (.058)***	.455 (.069)***
α_1		.193 (.043)***	.205 (.065)***	.157 (.062)***	.058 (.073)
α_2			.007 (.060)	-.035 (.071)	.050 (.087)
α_3				.038 (.070)	.026 (.092)
α_4					-.089 (.084)
SUM(α)	.285 (.031)***	.658 (.072)***	.654 (.120)***	.537 (.158)***	.500 (.242)**
$\Delta \ln(coc^{fs}_{i,t})$					
θ_0	-.047 (.032)	-.064 (.039)*	-.094 (.053)*	-.060 (.053)	-.095 (.057)*
θ_1		-.058 (.040)	-.075 (.054)	-.118(.067)*	-.095 (.077)
θ_2			-.024 (.058)	-.086 (.072)	.002 (.092)
θ_3				-.057 (.063)	.008 (.088)
θ_4					.106 (.069)*
SUM(θ)	-.047 (.032)	-.122 (.063)*	-.194 (.136)	-.321 (.221)	-.075 (.308)
$\Delta stb_{i,t}$					
β_0	.019 (.011)*	.000 (.014)	-.002 (.018)	.021 (.018)	.018 (.021)
β_1		-.007 (.014)	-.025 (.020)	-.014 (.020)	-.021 (.024)
β_2			.001 (.018)	.019 (.020)	.014 (.025)
β_3				.002 (.017)	.005 (.023)
β_4					.010 (.019)
SUM(β)	.019 (.011)*	-.006 (.024)	-.026 (.044)	.028 (.055)	.027 (.083)
Observations	1731	1245	902	657	479
R^2	.065	.102	.086	.150	.154

Following Chirinko *et al.* (1999), the dependent variable is firm investment scaled by the capital stock in the previous period. Long-run sales and cost of capital effects are represented by the sum of coefficients outlined in the last row, respectively. The same is true for the appraisal of the state of business. OLS estimates. Time effects are ignored in this specification. Standard errors are given in parentheses. * denotes significant at 10%; ** significant at 5%; *** at 1%.

Table 3: Results of Distributed Lag Model using Firm-Specific Cost of Capital and Instrumental Variables

Δ ln($K_{i,t}$)	(DL4a)	(DL4b)	(DL5a)	(DL5b)
Δ ln($Y_{i,t}$)				
α_0	.455 (.069) ***	.445 (.070) ***	.044 (.428)	-1.176 (6.558)
α_1	.058 (.073)	.099 (.073)	.252 (.298)	2.070 (8.887)
α_2	.050 (.087)	.077 (.088)	.111 (.141)	.838 (4.075)
α_3	.026 (.092)	.065 (.093)	-.221 (.212)	.159 (1.456)
α_4	-.089 (.084)	-.050 (.085)	-.104 (.127)	.813 (4.057)
SUM(α)	.500 (.242) **	.637 (.246) ***	.082 (.716)	2.703 (12.792)
Δ ln($coc^{fs}_{i,t}$)				
θ_0	-.095 (.057)*	-.184 (.133)	-.400(.220) *	-13.669 (65.512)
θ_1	-.095 (.077)	-.213 (.156)	.381 (.380)	6.582 (34.963)
θ_2	.002 (.092)	-.016 (.148)	.350 (.321)	.635 (3.663)
θ_3	.008 (.088)	-.023 (.149)	.418 (.351)	-2.310 (9.995)
θ_4	.106 (.069) *	.323 (.139) **	.451 (.271) *	-.069 (1.588)
SUM(θ)	-.075 (.308)	-.112 (.475)	1.199 (1.189)	-8.832 (38.481)
$\Delta stb_{i,t}$				
β_0	.018 (.021)	.026 (.021)	-.036 (.046)	.117 (.526)
β_1	-.021 (.024)	-.012 (.025)	-.056 (.044)	-.008 (.206)
β_2	.014 (.025)	.021 (.025)	-.024 (.047)	-.105 (.717)
β_3	.005 (.023)	.022 (.024)	-.062 (.048)	.´014 (.187)
β_4	.010 (.019)	.018 (.020)	.016 (.026)	.057 (.207)
SUM(β)	.027 (.083)	.076 (.085)	-.161 (.167)	.075 (.721)
Observations	479	479	470	470
R^2	.154	.188	.	.

Following Chirinko *et al.* (1999), the dependent variable is firm investment scaled by the capital stock in the previous period. Long-run sales and cost of capital effects are represented by the sum of coefficients outlined in the last row, respectively. The same is true for the appraisal of the state of business. Time effects are ignored in the specifications a) but taken into account in the specifications with b) label. Columns 4a and 4b report OLS estimates. Columns DL5a) and DL5b) report IV estimates using second and further lags of the (undifferenced) endogenous regressors. Standard errors are given in parentheses. * denotes significant at 10%; ** significant at 5%; *** at 1%.

Regarding the explanatory variables we only treat the survey variable as weakly exogenous - all other variables are considered to be contemporaneous. Provided that there is no serial correlation in the error terms, second or higher order lags of the variables in levels constitute a set of valid instruments for the differences of the endogenous variables. In a similar manner, one can conclude that suitable instruments for the levels equation are the first differences of the corresponding variables if there is no correlation with the firm-specific effects.[12]

To test the validity of these conditions we employ the specification tests suggested by Arellano and Bond (1991) and Arellano and Bover (1995). The condition of no second or higher order serial autocorrelation in the errors is tested by computing AR(1) and AR(2) autocorrelation statistics. While the AR(1) statistic should show significance, a significant AR(2) statistic would indicate a misspecification of the model. The assumption that there is no correlation between the fixed effects and the differenced instruments is tested using a Sargan, or Hansen-J statistic on the overidentifying restrictions which tests the overall validity of the instruments.[13] Additionally, we apply the Difference-in-Hansen test of exogeneity according to Bond, Hoeffler and Temple (2001) to test whether the supplementary instruments of the levels equation have explanatory power. If the model is correctly specified, both tests should fail to reject the null hypothesis.[14] A general problem of the dynamic GMM approach is, however, to find a parsimonious specification that employs only a limited number of moment conditions as GMM estimators based on too many instruments have been shown to suffer potentially from severe overfitting biases in small samples. For this reason we carry out robustness checks suggested by Roodman (2006, 2008).

Regression results of the dynamic panel model according to (11) are reported in Tables 4 and 5.

[12] Arellano and Bover (1995) show that only the first lag of the difference is needed as instrument as further lagged differences only result in redundant moment conditions.

[13] The Sargan statistic is a special case of the Hansen J test under the assumption of conditional homoskedasticity. In our case heteroskedasticity and autocorrelation is present, so the Hansen J test is the diagnostic to evaluate the suitability of the model.

[14] The Difference-in-Hansen statistic is computed as the difference between two Hansen J statistics with the null hypothesis that the specified variables are proper instruments for the levels equation. If we cannot reject the null, the instruments satisfy the orthogonality conditions meaning that we can include the levels equation in the GMM estimation using lagged differences as instruments for the levels.

In general, we use the two-step system GMM estimator along with the finite-sample correction by Windmeijer and standard errors of coefficients as well as test statistics robust to heteroskedasticity. After robustness checks using different lags of the endogenous variables as instruments, we restrict the number of instruments to second lags of the endogenous variables in order to avoid instrument proliferation. However, as can be seen in Column (1) of Table 4 the number of instruments is still large which is why, in the following columns (and, for direct comparison, Column (2)), we further restrict the overall set by using the same vector of instruments across all time periods. According to standard significance levels, both specifications pass the tests. The p-values for the Hansen-statistics imply that, provided the model is specified correctly, we cannot reject the null hypothesis that the respective instruments, as a group, are exogenous. Moreover, the Difference-in-Hansen tests of exogeneity of instrument subsets suggest that system GMM is valid and that the additional instruments for the levels equations are uncorrelated with the fixed effects. Finally, also the tests on first and second order autocorrelation suggest that the models are correctly specified as the null of no second order serial correlation in the differenced error term cannot be rejected.

We prefer the specification in Column (2) since, under system GMM, the bias in the coefficients tends to be smaller if the same set of instruments is used for all equations (see Roodman, 2008). In fact, the point estimate in Column (2) seems plausible, suggesting that the impact of the cost of capital on investment is rather large and significant with an elasticity of -1.03, although it is estimated rather imprecise, according to the large standard error.

Regarding the coefficient of the state of business variable, we find that a positive appraisal of a firm's current business situation has a significant positive effect. More specifically, in case of improved economic conditions, the capital stock tends to increase by about 8%. If the company considers its business situation to be unchanged, there is no effect on investment and in case of a deteriorated state of business at the time of investment planning, the capital stock is reduced by about 8%. Moreover, if we instead use the commercial expectations variable, (see Column (3)), the results do not vary by much, indicating that expectations and current business appraisal provide similar information. Including expectations as well as current business appraisal (results not shown), we find, however, that the state of business variable dominates expectations, indicating stronger predictive power. This corresponds with the higher standard deviation of state of business

Table 4: RESULTS USING FIRM-SPECIFIC COST OF CAPITAL

$\ln(K_{i,t})$	(1)	(2)	(3)	(4)	(5)
$\ln(K_{i,t-1})$	.817 ***	.468 ***	.483 ***	.468 ***	.493 ***
	(.102)	(.171)	(.168)	(.165)	(.172)
$\ln(Y_{i,t})$	.217 **	.348 **	.364 **	.359 **	.373 **
	(.090)	(.158)	(.163)	(.157)	(.167)
$stb_{i,t}$	.037 *	.077 **		.078 **	
	(.020)	(.034)		(.034)	
$comex_{i,t}$			.101 *		.098 *
			(.058)		(.056)
$\ln({coc^{fs}}_{i,t})$	-.345	-1.03 *	-1.05 *	-1.15 *	-1.16 *
	(.264)	(.606)	(.625)	(.636)	(.640)
$ATI_{i,t}$				5.47 *	4.48
				(3.33)	(3.25)
Observations	2369	2369	2368	2367	2366
Number of instruments	86	20	20	21	21
AR(1) (p-value)	.000	.007	.002	.005	.002
AR(2) (p-value)	.391	.127	.156	.129	.157
Hansen test of joint validity of instruments (p-value)	.324	.221	.126	.153	.084
Difference-in-Hansen test (p-values)					
All system GMM instruments	.129	.221	.126	.153	.084
Those on lagged investment only	.361	.229	.232	.176	.212

Dependent variable is firm investment. Its lag as well as sales and cost of capital are treated as endogenous and instrumented with GMM-style instruments as explained in the text. Variables comex and stb are treated as exogenous. Robust standard errors are given in parentheses, time constants are not reported due to joint insignificance. * denotes significant at 10%; ** significant at 5%; *** at 1%.

as compared to expectations.

Estimations (2) and (3) equally point at a cost of capital elasticity close to unity. If the significant lagged coefficient of the dependent variable is interpreted as being indicative of a partial adjustment mechanism, the elasticity estimate for the cost of capital only captures the short-term effect. The long term effect would then be obtained by dividing the cost of capital coefficient by the parameter estimate of ρ, which is equal to unity minus the coefficient of the lagged dependent variable. With regard to specifications (2) and (3), the point estimate of the long-run effect is about twice as large (-1.93 and -2.03) as the basic elasticity estimate. However, due to the large standard errors (1.14 and 1.21), these estimates are not significantly different from (minus) unity. Thus, we cannot reject the hypothesis that an increase in the cost of capital by one percent implies a decline in the stock of capital by about 1 percent in the short as well as in the long-run.[15]

Regarding the magnitude of the tax effect, existing studies report lower elasticities, such as -0.25 (Chirinko, Fazzari and Meyer, 1999) or -0.4 (Chirinko, Fazzari, and Meyer, 2011) or in the range of -0.5 to -1.0 (Cummins, Hassett and Hubbard, 1994). However, the literature using German data generally points at slightly larger effects than studies using US data. Harhoff and Ramb (2001) employ the approach by Chirinko *et al.* (1999) and yield an elasticity of -0.42 compared to -0.25. More recently, Dwenger (2010) using an error correction framework reports a point estimate of the long-term elasticity of about -1.29. A possible explanation for the larger elasticities in the German context may be the large importance of the local business tax. A high tax burden might exert stronger empirical effects on investment since firms may respond to a higher tax burden not only by substituting capital with labor but also in terms of the location of capital.[16]

Specification in Columns (4) and (5) include another tax variable, the apportionment tax index, which controls for other effects on the capital stock exerted by the local business tax (for derivation, see Appendix). As we argued above, due to formula apportionment, it seems likely that the

[15]To further test for robustness, we attempted to include higher-order lags. While higher-order lags have not been found to be significant, the specifications suffered from various problems.

[16]Dwenger and Walsh (2011) use tax loss-carry forwards in order to identify tax incentives and obtain a lower elasticity for Germany. It is interesting to note, however, that their analysis focuses on the corporation tax. Hence, a likely location incentive of the business tax is not taken into account.

statutory tax rate exerts a positive impact on the capital stock due to capital-labor substitution. While we do find a positive effect, it is only weakly significant. Consistent with the positive effect, the cost of capital elasticities tend to be slightly larger in columns (4) and (5) – however, since estimates are not very precise, the differences in the elasticity estimates are not statistically significant.

6 The Importance of Firm-Specific Differences

Having provided empirical evidence which exploits firm-specific variation in the cost of capital, we aim at exploring the importance of using this variation for the empirical results. Recall that the above analysis takes account of firm-specific capital and asset structures as well as of the location-specific business tax rate. To see whether this is crucial for finding tax effects, in this section, we abstract from the local variation in tax rates and base the analysis on the assumption that capital or asset structures are fixed. In a sense, we are employing indicators of a representative rather than a firm-specific tax burden, something that is often done in the empirical literature analyzing tax effects.

While Column (2) of Table 5 simply repeats the basic results in the case of firm-specific cost of capital from above, Columns (6) to (8) provide results where the cost of capital is computed by making use only of some part of the firm-specific variation. All estimates are obtained from the two-step system GMM estimator with finite-sample correction and robust standard errors as in (2). The results displayed in Column (6) report results from a specification where the tax indicator ignores the firm-specific differences in the capital structure and employs an average figure of the capital structure. Accordingly, the estimate for the tax effect decreases drastically. Moreover, the various specification tests indicate problems with this specification since both the Hansen as well as Difference-in-Hansen tests indicate misspecification. Column (7) reports results of a specification where the tax indicator takes account of the firm-specific capital structure but employs the average asset structure. While the estimated coefficient points at a significant effect, the elasticity turns out to be larger. The results presented in Column (8) have been obtained ignoring the variation in the local business tax rate. Instead a uniform local business tax rate is used. The results are

Table 5: Results using Averages

$\ln(K_{i,t})$	(2)	(6)	(7)	(8)
$\ln(K_{i,t-1})$	.468 ***	.494 ***	.413 ***	.471 ***
	(.171)	(.107)	(.156)	(.166)
$\ln(Y_{i,t})$	.348 **	.328 ***	.456 ***	.342 ***
	(.158)	(.130)	(.155)	(.155)
$stb_{i,t}$	.077 **	.075 **	.053	.079
	(.034)	(.035)	(.037)	(.033)
$\ln({coc^{fs}}_{i,t})$	-1.026*			
	(.606)			
$\ln({coc^{avgdebt}}_{i,t})$		-.467		
		(1.79)		
$\ln({coc^{avgassets}}_{i,t})$			-1.390**	
			(.708)	
$\ln({coc^{avlocal}}_{i,t})$				-1.054
				(.639)
Observations	2369	2369	2369	2369
Number of instruments	20	20	20	20
AR(1) (p-value)	.007	.003	.003	.001
AR(2) (p-value)	.127	.230	.159	.128
Hansen test of joint validity of instruments (p-value)	.221	.036	.372	.198
Difference-in-Hansen test (p-values)				
All system GMM instruments	.221	.036	.372	.208
Those on lagged investment only	.229	.023	.243	.214

Dependent variable is firm investment. Its lag as well as sales and cost of capital are treated as endogenous and instrumented with GMM-style instruments as explained in the text. Variable stb is treated as exogenous. Robust standard errors are given in parentheses, time constants are not reported due to joint insignificance. Column (6) report estimation results if an average debt ratio is used for calculating the cost of capital measure, column (7) assume average asset weights, and column (8) reports results where the local tax rate is assumed to be equal to the national average. * denotes significant at 10%; ** significant at 5%; *** at 1%.

not much different from (2), and the point estimate of the effect of the cost-of-capital is almost not affected. However, probably due to the induced measurement error, the standard error of the coefficient slightly increases while the Hansen statistic decreases.

7 Summary

While several papers analyzing the relationship between investment and taxation consider homogeneous companies, this paper computes firm-and location-specific indicators of the cost of capital in order to analyze the tax effects on investment decisions. A novel dataset for German firms in the period 1994 to 2007 is used, which contains balance-sheet as well as survey data and provides us with information about companies' financial and asset structures. Additionally, we supplement information on the local business tax rate faced by each firm.

To analyze the impact of a change in the cost of capital on investment, we estimate a traditional ADL model as well as a dynamic panel model using GMM techniques which explicitly takes account of the lag of the capital stock. Along with firm's sales as an indicator of a firm's output, we use the state of business enclosed in the survey data as control variables. The results obtained using the GMM estimator turn out to be much more convincing than the estimation which relies on the ADL model.

Our findings indicate a robust, significant negative impact of a firm's cost of capital on investment, the elasticity of the cost of capital being in the range of -1 or below. Accordingly, a one percent increase in the capital cost is associated with a decrease of the capital stock by about 1 percent or more. As is discussed in the literature, a unit value coefficient should be expected if the elasticity of substitution between labor and capital is unity. However, our results point at a larger long-run effect, which could reflect the importance of the local business tax rate for the cost-of-capital. Arguably, the high local tax burden causes not only substitution effects regarding the capital-labor ratio but exerts an additional adverse location effect.

To capture some further peculiarities of corporate taxation in Germany, we have also included an indicator that captures incentives arising from formula apportionment for the local business tax. The results provide some support for the view that, since the formula is based on payroll, – conditional on the cost of capital – a higher tax burden exerts a separate positive impact on the capital stock, since firms resort to a higher capital intensity.

We also find that a firm's appraisal of its current business situation at the time of investment planning plays an important role in our regressions. Depending on whether the current state of business is good or bad, investment increases or decreases by almost 8 %. Similarly, optimistic or pessimistic expectations about the future increase or decrease investment by approximately 10%.

To investigate the role of the local business tax and to analyze the importance of using firm-specific instead of uniform tax indicators, we consider alternative specifications of the tax incentive by making specific assumptions about the local business tax rate and about a company's capital and asset structures. While tax effects are also found if the firm-specific asset structure is ignored, abstracting from the firm-specific local business tax rate results in less precise estimates of tax effects which turn out to be insignificant. A specification ignoring firm-specific differences in the capital structure does not detect any tax effects and is also plagued with misspecification. Thus, our results underline the importance of considering firm-specific variation for identifying tax effects, in particular, the firm-specific variation in the capital structure turns out to be crucial.

Appendix

A.1 Datasource

Firm-level data are taken from the Economics and Business Data Center in Munich which provides the EBDC dataset combining survey data from the Ifo Business Surveys and financial statement data from the firm databases Amadeus and Hoppenstedt (see Hoenig, 2010, for an overview).[17] By adding information on tax rates and firm location we can further calculate firm-specific statutory

[17] Specific information on the Ifo Business Surveys can be found in Becker and Wohlrabe (2008).

tax rates and, using balance-sheet information on a firm's capital and asset structure,[18] we can compute the aforementioned cost of capital variable. This can then be analyzed together with a firm's investment, sales and business expectations.

Data from the Ifo Business Survey one has is collected monthly and refers to products instead of companies. We collapsed the information by year and company after constructing semi-annual indicators as mentioned in the text.

A.2 German Tax System

During the period 1994-2007 corporations were subject to various income taxes, including the corporation tax, the business tax on income and capital, and the solidarity surcharge. There are major changes in the tax law, most important, perhaps, the replacement of the full imputation and split rate system by the so-called half-income system in 2001. The separate corporation tax rates - one on retained earnings and one on distributed profits - have been replaced by a lower, overall tax rate accompanied by a broadening of the tax base. Moreover, the tax credit associated with dividend payments has been changed from $c = 30\%$ to $c = 0$. As a result, for the time span 1994-2000, γ in equation (2) is equivalent to $\gamma \equiv \frac{(1-m^D)(1-\tau^{dp})}{(1-c)(1-z)(1-\tau)}$ with τ^{dp} being the statutory tax rate on distributed profits including solidarity surcharge and business taxes. Table (A.1) displays the parameters used in the user cost of capital calculations. Besides the headline rates on retained earnings (and distributed profits until 2000 in brackets) we present the solidarity surcharge and the average business tax in our sample for each year. Furthermore, we show the discrimination variable γ and the statutory tax rates on retained earnings (distributions) including surcharge and business tax and taking the deductibility of the latter into account.

[18] We only use balance-sheet information from Hoppenstedt in our estimations.

Table A.1: Tax Parameters for the Cost of Capital

year	Headline rates retained earnings (distributed profits) in %	Solidarity surcharge in %	Business tax in %	Statutory tax rates retained earnings (distributed profits) in %	γ
1994	45.0 (30.0)	0	15.94	53.76 (41.16)	1.82
1995	45.0 (30.0)	7.5	15.95	56.61 (43.05)	1.87
1996	45.0 (30.0)	7.5	16.17	56.72 (43.20)	1.87
1997	45.0 (30.0)	7.5	16.30	56.79 (43.29)	1.87
1998	45.0 (30.0)	5.5	16.41	56.09 (42.86)	1.86
1999	40.0 (30.0)	5.5	16.45	51.71 (42.89)	1.69
2000	40.0 (30.0)	5.5	16.17	51.54 (42.70)	1.69
2001	25.0	5.5	16.40	38.45	1
2002	25.0	5.5	16.20	38.30	1
2003	26.5	5.5	16.00	39.49	1
2004	25.0	5.5	15.91	38.09	1
2005	25.0	5.5	15.99	38.15	1
2006	25.0	5.5	16.01	38.16	1
2007	25.0	5.5	16.13	38.25	1

The solidarity surcharge's assessment base is the overall corporate income tax that has to be paid. There was no solidarity surcharge in 1994. The business tax as displayed here is calculated as the yearly average out of the sample, but we do not account for specific adjustments in the computation of the business income. The basic federal rate (Steuermeßzahl) is 5%, the collection rate (Hebesatz), which is fixed by municipalities, is the source of variation in the business tax. The statutory tax rates for retained earnings (distributed profits) include the solidarity surcharge and the business tax and are the rates used in our calculations for the firm-specific cost of capital.

A.3 Definition of Apportionment Tax Index (ATI)

Since the local business tax is subject to a scheme of formula apportionment, it might tend to further exert effects on firm decisions. In particular, since payroll serves as formula weight, companies might use more capital in high-tax jurisdictions. To capture this effect, we construct an apportionment tax index (ATI) which captures the relative tax burden of a muncipality (in the following, for simplicity, we suppress the time index t.)

For each firm the business tax T^{GSt} is calculated as $T^{GSt} = t^{GSt}(\Pi - T^{GSt})$, where Π is profit and $t^{GSt} = \frac{0.05*cr}{100}$. cr is the local collection rate in % set by the municipality. Therefore, T^{GSt} can be written as

$$T^{GSt} = \frac{cr * 0.05}{100 + (cr * 0.05)}\Pi = \frac{cr/100 * 0.05}{1 + (0.05 * cr/100)}\Pi$$

With a corporate income tax rate of t^{KSt} (including solidarity surcharge), the corporate income tax payment T^{KSt} amounts to $T^{KSt} = t^{KSt}(\Pi - T^{GSt})$.

Therefore, the total tax burden T is

$$T = T^{KSt} + T^{GSt} = t^{KSt}(\Pi - T^{GSt}) + T^{GSt}.$$

If we consider two jurisdictions and an apportionment of business tax payments according to the shares s_1 and s_2, with $s_1 + s_2 = 1$, the business tax burden in both jurisdictions results as

$$T_i^{GSt} = t_i^{GSt}(\Pi s_i - T_i^{GSt}) \quad = \frac{t_i^{GSt} s_i \Pi}{1 + t_i^{GSt}}, \qquad \forall \quad i = 1, 2,$$

with $T^{GSt} = T_1^{GSt} + T_2^{GSt}$ and $\frac{\Delta T_i^{GSt}}{\Delta s_i} \geq 0$.

As a consequence, the total tax burden amounts to

$$T = t^{KSt}[\Pi - \frac{t_1^{GSt} s_1 \Pi}{1 + t_1^{GSt}} - \frac{t_2^{GSt} s_2 \Pi}{1 + t_2^{GSt}}] + \frac{t_1^{GSt} s_1 \Pi}{1 + t_1^{GSt}} + \frac{t_2^{GSt} s_2 \Pi}{1 + t_2^{GSt}}.$$

Rearranging this expression we obtain

$$T = t^{KSt}\Pi + \frac{(1-t^{KSt})t_1^{GSt}\,(s_1+s_2)\,\Pi}{1+t_1^{GSt}} + \Pi s_2 \left[\frac{(1-t^{KSt})t_2^{GSt}}{1+t_2^{GSt}} - \frac{(1-t^{KSt})t_1^{GSt}}{1+t_1^{GSt}}\right]. \tag{A.13}$$

Accordingly, the overall tax burden can be described by the federal tax burden and the local tax burden in municipality 1. In addition, we have some third term that captures the tax burden on the formula weight. To interpret this term, assume that a company is located in municipality 1, where the business tax is smaller than in municipality 2, i.e. $t_2^{GSt} > t_1^{GSt}$. As a consequence, this third term is positive. Due to the apportionment, the firm obtains a reduction in the total tax burden if employment in region 2 is reduced such that s_2 declines. This last term, therefore, captures the incentive to distort the formula weight.

To capture this incentive we determine some general reference point and define the apportionment tax indicator (ATI) for a selected year as follows.

$$ATI_i \equiv \frac{(1-t^{KSt})t_i^{GSt}}{1+t_i^{GSt}} - \frac{(1-t^{KSt})t_R^{GSt}}{1+t_R^{GSt}}.$$

Obviously, we have $\frac{\Delta ATI_i}{\Delta t_i^{GSt}} \geq 0$. As reference point we choose the municipality with the minimum tax rate. Until 2003, we can assume that $t_R^{GSt} = 0$, whereas we have $t_R^{GSt} = \frac{0.05*200}{100}$ due to the minimum collection rate of 200% introduced by the federal legislator in 2004.

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