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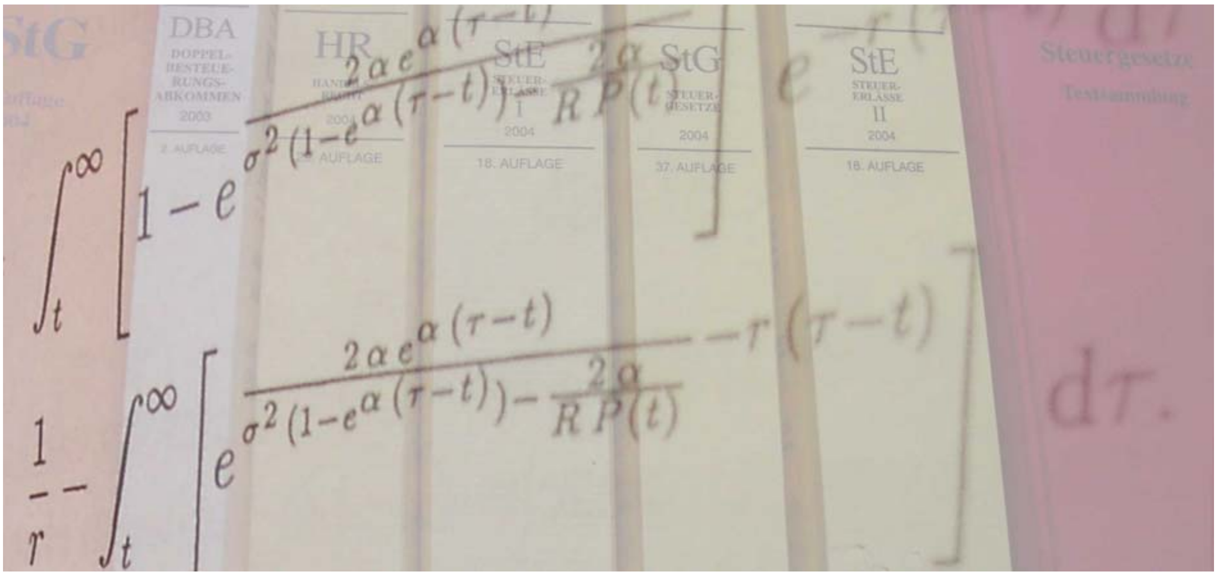

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Corporate taxation and investment: Explaining investment dynamics with firm-level panel data

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Abstract

Using a firm-level panel data set I assess whether dynamic models of investment provide an empirically fruitful framework for analyzing tax effects on changes in capital stock. In particular I estimate a one-step error correction model (ECM) complementing the usual estimation of a distributed lag model. A correction term accounts for non-random sample attrition, which has not been considered in previous studies on investment even though most (if not all) panel data sets on firms are incomplete. Both, ECM and distributed lag model, suggest that user cost of capital and output have an economically and statistically significant influence on capital formation. In the ECM, however, estimates are larger in size and match theoretical predictions more closely. My preferred estimate of -1.3 implies that a decrease in the user cost of capital by 10 percent will increase the firm's capital stock by 13 percent, on average. Taking my elasticity estimate to the Corporate Tax Reform 2008 I would expect that the reform only slightly increases capital stock, since the rather strong reduction in corporate income tax rate was partly compensated for by stricter depreciation allowances. Investment dynamics appear to be crucial for the coefficients of cash flow variables in investment equations. While cash flow effects are present in the (first-differenced) distributed lag model, they vanish in the ECM. This leads me to conclude that well documented cash flow effects point at dynamic misspecification in previous studies.

Keywords: Taxation; Business investment; User cost of capital; Dynamic specification
JEL Classification: E22; H25; H32

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1 Introduction

In this paper I assess whether dynamic models of investment provide an empirically fruitful framework for analyzing tax effects on changes in the capital stock. The main focus of the paper is the estimation of an error correction model which allows me to model investment dynamics explicitly. So far, drawing on the work by Chirinko, Fazzari and Meyer (1999), other studies based on micro data have documented a significant response of capital spending to its user cost, where the user cost of capital combines prices, corporate income tax, allowances, interest, and depreciation rates. The empirical framework of these estimations, however, is based on autoregressive distributed lag models, where short-run dynamics result from an empirical specification search rather than being imposed *ex ante*; long-term effects are simply calculated as the sum of the coefficients of short-run adjustment.

Under certain testable assumptions, the autoregressive distributed lag model may be reparameterized as an error correction model. While short-run investment dynamics are again found from an empirical specification search, the long-term formulation of the capital stock in the error correction model is consistent with a simple neoclassical model of the firm's demand for capital. In the error correction model, the long-term level of capital thus equals the optimal capital stock, i.e., the level of capital that maximizes the discounted value of all future income streams. Since firms' optimal capital stock also depends on its user cost, a fall (rise) in the user cost of capital will lead firms to expand (reduce) their capital stock. Because of quadratic adjustment costs or adaptive expectations, they may not fully adapt in the first place but slowly shift their capital stock to the optimal one.[1] Both the adjustment process and the long-term equilibrium relationship are distinguishable in the error correction model.

In the following I will estimate two models: the distributed lag model to compare results to the existing literature,[2] and the error correction model to learn more

[1]These factors would yield a simple specification of the form $k_t = \alpha_0 + \beta_1' X_t + \beta_2' X_{t-1} + \lambda k_{t-1} + u_t$, where k_t is the capital stock at time t, β_1 and β_2 are column vectors of regression coefficients, X_t and X_{t-1} are column vectors of explanatory variables at time t and $t-1$, and u_t is an unobserved error term.

[2]Chirinko et al. (1999) and subsequent work have merely assumed extrapolative expectations

about the dynamics of investment. There are several methodological problems which include unobserved firm heterogeneity, measurement error in the user cost of capital (Goolsbee 2000), simultaneity bias (Goolsbee 1998), and lagged dependent variable in the error correction model. While it seems impossible to control for these factors on the basis of a single cross section, I argue that the user cost elasticity can be identified by taking advantage of a panel and by using GMM methods. The panel data set I use for the estimations is the Hoppenstedt company database provided by Hoppenstedt firm information GmbH. The data set covers the years 1987 to 2007 and contains detailed accounting data for a large number of German non-financial corporations that are subject to publication requirements.

In spite of a variety of advantages, the use of a long panel data set implies one major problem, which is sample attrition. The longer the sequence of years, the more likely it is that firms drop out of the sample. Observations on firms may be missing for several reasons, including bankruptcy, cessation of business, merger, falling below thresholds which affect publication requirements, etc.. In theory, if firms are randomly missing, the investment function may be estimated using the incomplete panel data set as if it was complete. In practice, estimates can be biased without an appropriate correction if firms are missing for certain specific reasons which are, conditional on the explanatory variables included in the investment equation, not independent of the determinants of the decision to invest. In papers on investment, the fact that most (if not all) panel data sets on firms are incomplete, and the potential bias associated with this fact, have received little attention. To address the concern of non-random sample attrition, I include a correction term drawing on the work by Wooldridge (1995, 2002).

Estimating the first-differenced distributed lag model, I find a long-term user cost elasticity of -0.6. These estimates compare to what was documented for Germany in the literature (Chatelain, Hernando, Generale, von Kalckreuth and Vermeulen 2001, Harhoff and Ramb 2001, von Kalckreuth 2001). The only study

and no adjustment costs. This assumption leads to a distributed lag model which does not include the lagged dependent variable. Further, Chirinko et al. (1999) estimate the investment equation in rates of changes to account for large differences in firm size, i.e., they estimate a first-differenced distributed lag model.

with lower estimates for Germany is the study by Ramb (2007). Using the method of simulated marginal tax rates (Graham 1996), Ramb estimates a long-term elasticity of the simulated marginal tax rate to investment activity between -0.2 and -0.1.[3] The estimation of the error correction model yields a robust, statistically significant, and relatively large point estimate of the user cost elasticity. The point estimate of the long-term elasticity of -1.3 implies that a decrease in the user cost of capital by 10 percent will increase capital by 13 percent. Further, I find that firms quickly adjust to the new optimal capital stock: about half of the gap between existing and optimal capital stock is closed within a year.

Interestingly, well-known cash flow effects are present in the distributed lag model but vanish in the error correction model. This finding conflicts with the view that cash flow effects can be seen as evidence for the importance of financial constraints (see, e.g., Fazzari, Hubbard and Petersen 1988, 2000). In fact, it suggests that in the distributed lag model, cash flow may act as a proxy for omitted expected future profitability variables (e.g., Kaplan and Zingales 1997, 2000; Bond, Elston, Mairesse and Mulkay 2003) which becomes insignificant once the investment equation is dynamically correctly specified.

The remainder of the paper is organized as follows. The next section briefly describes the user cost of capital and argues that the user cost provides sufficient variation to identify the user cost elasticity. The data set I use in the study and the empirical methodology are introduced in Section 3. Estimation results of the first-differenced distributed lag model and the error correction model are presented in Section 4. Section 5 summarizes my main results and concludes.

[3] In Ramb's study, the simulated tax rate is solely driven by the tax rate, loss offsetting rules, and the (simulated) tax base. All other effects incorporated in the user cost of capital such as depreciation allowances are assumed to be identical for all firms. For this reason, Ramb's estimate is not directly comparable to the studies estimating the user cost elasticity, the present paper included.

2 Firm-specific variation in the UCC

My goal is to estimate the user cost elasticity of investment. Identification of this elasticity comes from the user cost of capital (UCC), which varies across firms and over time. The definition of the UCC in this study is standard and based on the work by Jorgenson (1963), Hall and Jorgenson (1967), and King and Fullerton (1984). Following their approach, the UCC is the minimal rate of return a firm must earn on investments before taxes, i.e., it is the discount rate a firm should use in evaluating investment projects. As earnings from the investment are taxed and because the tax system provides for some allowances for investment goods, the UCC is not only a function of economic variables but also of taxation. This introduces further variation as major reforms in the tax system have taken place in Germany in recent years. In the following, I will briefly present the way I calculate the user cost of capital. In doing so, I will also introduce those features of the German tax system that are particularly relevant for the decision to invest.

The $UCC_{i,j,a,t}$ for firm i in industry j with asset a at time t is given by

$$UCC_{i,j,a,t} = \frac{p_t^I}{p_{j,t}^S} \frac{(1 - z_{a,t}) \left(\theta_{i,t}(r_{i,t}\kappa_{i,t}^f) + \delta_{j,a,t}^e \right)}{1 - \tau_t}, \tag{1}$$

where p_t^I is a price deflator for investment goods and $p_{j,t}^S$ is the industry j specific output price at time t. The ratio of these price indices reflects capital gains (or losses) that may occur if capital goods' prices are expected to rise (fall) relative to the prices of output goods. Capital gains alleviate the effect of economic depreciation ($\delta_{j,a,t}^e$) in lowering the asset's value. Assets are assumed to deteriorate exponentially, which renders the economic depreciation rate invariant to the interest rate (Auerbach 1983). Information on economic depreciation is available at the industry-level for two different assets a, property with buildings and fixed tangible assets.

To account for deterioration, the tax system provides depreciation allowances.[4]

[4] In Germany, an investment tax credit only exists for an initial investment in Eastern Germany (*Investitionszulage*). There is no investment tax credit for a replacement investment or an investment in Western Germany.

Depreciation allowances $z_{a,t}$ follow different methods in Germany: While property with buildings is depreciated on a straight-line basis, fixed tangible assets could be depreciated according to the declining-balance method until 2007. Firms were allowed to change from the declining-balance to the straight-line method once the latter was beneficial. The rates of depreciation are set in the German income tax law and in industry-specific tables which are issued by the Federal Ministry of Finance. In recent years, these rates have been changed regularly (for details see the Data Appendix A.1). When calculating the discounted value, I take changes in rates into account and also correct for inflation, since historical-cost depreciation acts to increase taxes with inflation. Note due to data restrictions I can only consider regular depreciation allowances. Accelerated depreciation allowances for investment in Eastern Germany which were introduced after reunification,[5] extraordinary depreciation allowances for some industries (e.g., agriculture), and additional depreciation allowances for small and medium-sized businesses cannot be taken into account.

The tax rate τ_t includes the corporate income tax rate on retained earnings and the solidarity surcharge for Eastern Germany.[6] The solidarity surcharge was introduced in 1991. Since then, the solidarity surcharge has varied between 0 percent and 7.5 percent. Corporate income taxation has not only undergone changes in tax rates but also a fundamental change in the tax system: While the German corporate tax system applied the tax-credit method until 2000, taxation has followed the half-income method since 2001.[7] An overview of all corporate income tax and

[5] See *Fördergebietsgesetz*.

[6] To keep things manageable I only include taxes on profit and do not consider the local business tax and the real estate tax. The real estate tax ties in with the assessed tax value of property. The assessed tax value cannot be deduced from the corporate balance sheet information but is calculated by the local tax authorities based on government tables using criteria such as the location, age, size, and characteristics of a property. Disregarding the local business tax and the real estate tax clearly leads to an underestimation of the user cost of capital. Leaving aside these taxes, however, is without loss of generality for my estimations in first-differences as long as the collection rates fixed by the municipality have not changed over time. Since these collection rates are very stable over time (see statistics on property taxes), disregarding the local business tax and the real estate tax should not change results.

[7] Under the tax-credit method, the tax burden on the corporate level was only meant as a means to ensure taxation of capital income and was credited against the personal income tax of the shareholder. Retained profits were taxed at a much higher rate than distributed profits. Under the half income method, the corporate income tax rate is uniform and lower for both retained and distributed profits. In return, the corporate income tax is definite since 2001. Half

solidarity surcharge rates can be found in Appendix A.2.[8]

Taxation also matters for firms' financial costs. King and Fullerton (1984) argue that the firm's financial cost $\theta_{i,t}$ in a world of distortionary taxes will differ from the market interest rate and, in general, will depend on the source of finance. Consequentially, the authors advocate a measure of financial cost which is a weighted average of the financial costs induced by the different financial sources, i.e., which considers a preferential tax treatment of debt.[9]

As first pointed out by Hansson and Stuart (1985), such a measure may be less convincing on closer inspection than it appears at first glance. Drawing on an equilibrium perspective, they suggest that additional costs of debt, like bankruptcy costs, may balance the tax advantage of debt on the margin exactly. This implies that the difference between the rate of return to investment and the rate of return required by the investor does not always entirely consist of taxes but also of invisible costs. Then, observable differences in tax rates across sources of finance represent "an equilibrium in which additional marginal costs of using tax-favored sources just balance the tax advantages of these sources" (Hansson and Stuart 1985, p.829). Hansson and Stuart thus claim that it is the maximum tax rate across sources of finance that should be taken instead of the weighted average of all sources. Getting to the bottom of their argument, Sinn (1993) presents a theoretical model of the firm's investment and financial decisions where invisible costs of debt finance such as risk of bankruptcy are taken into account. These invisible costs of debt finance are assumed to depend on the firm's stock of capital or on its stock of equity. In his "invisible cost model" Sinn shows that Hansen and Stuart have been mistaken: the (user) cost of capital is a weighted average of the cost of debt and the cost of retained earnings where the weights are marginal debt-asset and equity-asset

of the dividends are additionally subjected to personal income tax.

[8]The Hoppenstedt company database does not provide information on tax loss carry-forward. For that reason, I have to assume that the marginal tax rate τ_t equals the statutory corporate income tax rate plus solidarity surcharge even though the marginal tax rate τ_t might be zero for companies whose amount of profit is small relative to the volume of the corporation's tax loss carry-forward.

[9]This is in line with the pecking order theory of financing advocated by Myers and Majluf (1984) according to which firms prefer internal financing when available, and prefer debt over equity if external financing is required.

ratios.[10]

Taking Sinn's finding seriously, I thus calculate firm-specific financial costs as a weighted average of after-tax interest rates, where the weights depend on the firm's mixture of financial sources. Following King and Fullerton (1984), I thereby distinguish three different sources of finance (retained earnings, debt, and new equity) and two types of investors (private and institutional shareholders). The calculation of the firm's financial costs $\theta_{i,t}(r_{i,t}\kappa^{f}_{i,t})$ is done in two steps. In the first step, I compute the after-tax interest rate for every source of finance f depending on the firm's interest rate $r_{i,t}$ and taxation (Table 1). In the calculation of the after-tax interest rates I focus on the firm level; unfortunately, I am forced to neglect personal income taxation, since I do not have any information about a corporation's shareholders. However, comprehensive information on shareholders and the sources of their residual income would be necessary to consider personal tax liabilities. This somewhat less precise calculation of the after-tax interest rates impair results only in the event of personal income tax reforms affecting firms differently. General changes in the level of the personal income tax over time (i.e., tax reforms altering tax rates uniformly over tax brackets) are captured in the deterministic time trend. Differences in the personal income taxation of shareholders across firms that arise because of the firm-specific financial structure are absorbed in the firm-specific effects.

Table 1: After-tax interest rate $\theta_t(r_{i,t})$ by source of finance and by type of shareholder

Financing through...	**private shareholder**	**institutional shareholder**
retained earnings	$\theta^{retain,p}_{i,t}(r_{i,t}) = r_{i,t}$	$\theta^{retain,inst}_{i,t}(r_{i,t}) = r_{i,t}$
debt	$\theta_{i,t}(r_{i,t})^{debt,p} = r_{i,t}(1-\tau_t)$	$\theta^{debt,inst}_{i,t}(r_{i,t}) = r_{i,t}(1-\tau_t)$
new equity		
until 2000	$\theta^{new,p}_{i,t}(r_{i,t}) = r_{i,t}(1-\tau_t)$	$\theta^{new,inst}_{i,t}(r_{i,t}) = \frac{r_{i,t}}{1-\tau^{distr}_t}(1-\tau_t)$
since 2001	$\theta^{new,p}_{i,t}(r_{i,t}) = r_{i,t}(1-\tau_t)$	$\theta^{new,inst}_{i,t}(r_{i,t}) = r_{i,t}(1-\tau_t)$

Source: King and Fullerton (1984), own calculations.

In the second step, these firm-specific after-tax interest rates are weighted with

[10]The reasonable assumption behind this result is that the additional, invisible cost on debt is reduced *ceteris paribus* if equity financing is increased.

the firm's share of fixed assets financed by retained earnings ($\kappa_{i,t}^{retain}$), debt ($\kappa_{i,t}^{debt}$), and new equity ($\kappa_{i,t}^{new}$) at time t.[11] I further assume that 70 percent of shareholder are institutional ($inst$) and 30 percent are private (p) shareholders:[12]

$$\begin{aligned}\theta_{i,t}(r_{i,t}\kappa_{i,t}^{f}) = (\kappa_{i,t}^{retain,p} + \kappa_{i,t}^{retain,inst})\theta_{i,t}^{retain} + (\kappa_{i,t}^{debt,p} + \kappa_{i,t}^{debt,inst})\theta_{i,t}^{debt} \\ + \kappa_{i,t}^{new,p}\theta_{i,t}^{new,p} + \kappa_{i,t}^{new,inst}\theta_{i,t}^{new,inst}.\end{aligned} \tag{2}$$

As pointed out by Weichenrieder (2008), the use of weighted averages also has its downside: Comparison of financial costs or the UCC over time (or across countries) may be blurred, since changes in taxation interact with changes in firms' financial structure. He therefore suggests simplifying firm- or industry-specific weighted averages to the overall cost of debt finance once the Miller equilibrium holds. In the Miller equilibrium (Miller 1977), a clientele effect caused by the interaction of corporate and personal income taxation assimilates effective tax rates for retained earnings and debt.[13] Weichenrieder hence argues that the marginal investor in the Miller equilibrium should be indifferent between debt and equity. This leads him to conclude that in the Miller equilibrium financial costs can be approximated with the overall interest rate. He underlines, however, that this approach also comes at a cost, since both personal income taxation at the shareholder level and corporate taxation interact. Given that I have to neglect personal income taxation because of data limitations, I cannot pursue this approach in all details. In a robustness check, however, I calculate the UCC using the overall yield on corporate bonds and see results unchanged.

Finally, the overall $UCC_{i,j,t}$ for firm i in industry j at time t is given by the

[11] Of course, these observable shares do not necessarily coincide with the *marginal* ratios. Unfortunately, the marginal financial structure cannot be deduced from the data. That is why I use the average within a given year as a proxy.

[12] Anecdotal evidence suggests that more than 50 percent of the shareholders are institutional ones (Deutsches Aktieninstitut 2007). Experimenting with a segment of institutional shareholders amounting to 60 percent and 80 percent does not change results at all.

[13] Highly taxed investors prefer dividends and capital gains, since these sources of income are taxed at a lower personal income tax rate than interest payments. By contrast, individuals with low income prefer to save privately and to have interest payments taxed at a low personal income tax rate.

weighted average of its asset-specific user costs:

$$UCC_{i,j,t} = \sum_{a} UCC_{i,j,a,t} \kappa^{a}_{i,t}, \tag{3}$$

where $\kappa^{a}_{i,t}$ is the firm-specific share of assets a in total assets. By this means, the user cost of capital is calculated for each firm. The UCC hence varies because of changes in taxation and in macroeconomic factors. Most variation, however, stems from varieties in the firms' financial structure and in the asset mix they use.

3 Data and estimation strategy

3.1 Data

The principal data requirement for the estimation of the user cost elasticity of the capital stock are cross-section and time-series micro data for the user cost of capital and the gross investment rate. For my study, I link two data sources that each provide information particularly well-suited to my objectives: detailed company accounting data made available by Hoppenstedt firm information GmbH, and industry-level information maintained by the German Statistical Offices and the German Central Bank.

Hoppenstedt provides accounting data for a large part of German corporations which are subject to publication requirements. It is hence neither comprehensive nor representative.[14] The data set includes information on time invariant firm characteristics such as industry, region, legal form, and year of foundation. Moreover, and most importantly for my analysis, the data set covers balance sheet positions and firms' profit and loss accounts in great detail. In particular, it records ac-

[14]Unfortunately, I cannot compute the coverage of the Hoppenstedt balance sheet database concerning the whole corporate sector because it is unknown how much non-financial corporations in Germany invest per year. Information is available for mining, quarrying, and manufacturing firms (incorporate and non-incorporate companies), which invested about 47.7 billion euro in 1997 (in the middle of my observation period). In the same year, Hoppenstedt corporations in these industries used in the estimations invested about 21.8 billion euro. Further, companies in mining, quarrying, and manufacturing all together employed about 7.8 million persons; of which, 4.1 million were employed at corporations in the Hoppenstedt database.

quisition,[15] disposal, and withdrawal of fixed assets. This allows me to derive the firm-specific gross investment rate ($I_{i,t}$), which is normalized by the replacement cost value of capital stock ($K_{i,t-1}$). Replacement values are not available in the data but must be estimated from historic cost data using the perpetual inventory method. Cash flow ($CF_{i,t}$), which is income plus non-cash expenses like depreciation allowances, is also scaled by the beginning-of-period capital stock. Output is measured by sales ($S_{i,t}$). Nominal sales data are taken from the Hoppenstedt net sales figure and deflated by an industry-specific output price deflator. The growth rate of sales is defined as ($\Delta S_{i,t}/S_{i,t}$). The derivation of the replacement cost values of the capital stock and of the other explanatory variables used in my regression analysis are described in more detail in the Data Appendix A.1.

To calculate the *UCC* as described before, I complement the data set with information on the prices of investment goods (p^I_t) and output prices ($p^S_{j,t}$), as well as on economic depreciation rates for buildings and fixed tangible assets ($\delta^e_{j,a,t}$). This industry-level information is merged with the individual data and was obtained from the German Statistical Offices; it is also described in more detail in the Data Appendix A.1.

At the time of writing this paper the Hoppenstedt company database contained financial statements from 1987 to 2007. I exclude companies which have changed their accounting year during this period, so that all sets of accounts used would cover a 12-month period. Further excluding companies with less than four records,[16] and restricting my sample to firms with limited liability, leaves me with an unbalanced sample of 4,642 non-financial firms. The number of records per firm varies between four and twenty-one. In the appendix, descriptive statistics are provided which show the structure of the sample by number of observations per company (Table A.2), the distribution of observations over years (Table A.3), and the distribution of firms over industries (Table A.4).

In contrast to what was used in earlier studies for Germany (e.g., Harhoff and

[15] This includes direct purchases of new fixed assets and those gained through acquisitions.

[16] As a minimum I include two lags into my regression analysis. In my analysis, I consider changes in the explanatory variables, which means that the firm must have been in the data set in the three preceding years; this implies that I need at least four records per firm.

Ramb 2001), I exclusively use individual financial statements. One might object that subsidiaries do not have a free hand in taking their investment decisions because of the group structure. Even though there is no information about it, it seems plausible that it is the mother company (and not subsidiaries) that takes the decision to invest. Notwithstanding this aspect, I argue that capital formation depends on the user cost of capital at the *firm* level - and not at the group level. This is because depreciation allowances etc. are applied to the firm capitalizing the good. My argument becomes clearer if we think about a conglomerate, which consists of subsidiaries active in different industries. If a change in politics raises the UCC for subsidiary A but reduces it for subsidiary B, this may leave the UCC at the group level unchanged. However, a change in user cost of capital at the firm level may well lead subsidiary A to disinvest and subsidiary B to invest. Using consolidated financial statements would imply a loss of information, since neither the change in user cost of capital nor the change in capital might be observed.[17]

Table 2 provides some descriptive statistics of the variables used in the estimation over the period 1987 to 2007. As noted earlier, the Hoppenstedt company database contains accounting information for corporations subject to publication requirements. In Germany, mainly large and very large firms are liable to publication requirements. This is also reflected in the average capital stock which amounts to about 70 million euro. On average, a firm's gross investment represents 13.1 percent of its existing capital stock. This average rate and the median gross investment to capital ratio (6.2 percent) are compatible with moderate capital stock growth.[18] Both mean and median sales grew very slowly in the sample at a rate of 0.1 percent and 0.6 percent, respectively. In the observation period, the user cost of capital grew slightly on average (+1.6 percent) but declined for the median company (-1.4 percent). A decline in the UCC is exactly what we would expect as tax reforms significantly reduced the corporate income tax rate for all companies; because output prices and economic depreciation rates developed unequally

[17] A similar argument applies to the question whether data on business units should be used. Since it is again the firm level where tax rules are applied, I argue that not data on business units but firm data is appropriate.

[18] The economic depreciation rate is about 3% to 5% for structures and 8% to 12% for fixed tangible assets.

over industries, it is nevertheless conceivable that the user cost of capital grew marginally for some firms.

Table 2: Descriptive statistics for micro data

Variable	Mean	Median	Within-firm stand. deviat.[a]	Firm-specific time variation[b]
$K_{i,t}$ (in 1,000 euro)	69,498	12,283	23,539	0.998
$I_{i,t}/K_{i,t-1}$	0.131	0.062	0.192	0.999
$S_{i,t}$ (in 1,000 euro)	268,000	70,700	191,067	0.996
$\Delta S_{i,t}/S_{i,t-1}$	0.001	0.006	0.202	0.995
$CF_{i,t}/K_{i,t-1}$	0.053	0.012	0.118	0.998
$UCC_{i,t}$	0.140	0.135	0.030	0.782
$\Delta UCC_{i,t}/UCC_{i,t-1}$	0.016	-0.014	0.282	0.940
Number of observations			29,595	

Notes: $I_{i,t}/K_{i,t-1}$ is the ratio of investment to the beginning-of-period capital stock, $S_{i,t}$ are firms' real sales in 1,000 euro, $\Delta S_{i,t}/S_{i,t-1}$ is firm sales growth, $CF_{i,t}/K_{i,t-1}$ is the ratio of firm cash flow to the beginning-of-period capital stock, $UCC_{i,t}$ is the User Cost of Capital, and $\Delta UCC_{i,t}/UCC_{i,t-1}$ is the percentage change in this variable.

[a] Using mean-differenced variables, the within-firm standard deviation measures variation in the time dimension of the panel only.

[b] Following Chirinko et al. (1999), this measure is computed as one minus the R^2 statistic from a regression of each mean-differenced variable on a set of time dummies.

Source: Hoppenstedt company database, own calculations, 1987 to 2007.

The within-firm standard deviation shows that there is substantial variability over time. This is particularly true for changes in the user cost of capital which are driven by tax reforms, financing costs, and price trends. Identification, however, is not mainly based on aggregate time trends but on firm-specific variation. Drawing on the calculations in Chirinko et al. (1999), I measure the firm-specific time variation as one minus the R^2 statistic from a regression of each mean-differenced variable on a set of time dummies. The firm-specific time variation in the data that is not due to aggregate time effects is given in the last column of Table 2. This proportion is high for the variables in rows one to five where it amounts to more than 99 percent. It is lower for the user cost of capital because to a larger extent variation in the UCC is determined by aggregate factors such as tax rates or price trends. Firm-specific variation is further reduced as I do not have firm-specific economic depreciation rates or price indices but have to resort to industry-level information. These aggregate factors, albeit important, do not fully explain time-series variation in the user cost of capital. On the contrary, there is still substantial micro-level variation as 78 percent of the variation in the UCC

is due to firm-specific factors.

3.2 Models and estimation strategy

The main focus of the paper is to estimate both short-term and long-term effects of changes in corporate taxation on a firm's investment decision and capital stock. While the error correction model has the drawback of relying less on theory, it has the advantage of imposing less structure than Q or Euler equation models (Bond, Elston, Mairesse and Mulkay 2003). In particular, it does not require quadratic adjustment costs.[19] Even though the error correction model cannot be explicitly derived from a dynamic optimization problem such as Q or Euler models, the long-term formulation for the level of capital is consistent with a simple neoclassical model of the firm's demand for capital. This and the dynamics in its modeling makes the error correction model superior to the (first-differenced) distributed lag model, which is the prevailing empirical specification. In the following, I will estimate both the error correction and the distributed lag model, and use the latter to compare results to the existing literature. Before briefly describing both models in the next paragraphs, I will first introduce the relationship between capital, the user cost of capital, and output.

3.2.1 The optimal capital stock

The demand for capital and, in a dynamic perspective, the demand for investment can be derived from the first-order conditions of profit-maximizing behavior with static expectations (Eisner and Nadiri 1968). Using a production function with constant elasticity of substitution (σ) between capital and labor,[20] the optimal capital stock $K^*_{i,t}$ for firm i at time t can be written (Arrow, Chenery, Minhas and

[19]Quadratic adjustment costs have been criticized as empirically implausible (Doms and Dunne 1998) and too strict in the context of investment under (partial) irreversibility (Dixit and Pindyck 1994).

[20]A production function with constant elasticity of substitution nests Leontief ($\sigma = 0$) and Cobb-Douglas ($\sigma = 1$) production functions.

Solow 1961; Behrman 1982) as

$$K^*_{i,t} = A_i T_t {S_{i,t}}^{\beta} UCC^{-\sigma}_{i,t}, \tag{4}$$

where $\beta = \sigma + \frac{1-\sigma}{\nu}$.

The optimal level of capital depends on a firm's level of output or sales $S_{i,t}$, on a firm-specific distribution parameter A_i explaining firm-specific relative factor shares of labor and capital,[21] on technology T_t as well as on the firm's user cost of capital as defined in equations (1) and (3). In this partial analysis, the optimal capital stock is independent of the wage level, i.e., companies are assumed to be price-takers on the labor market.[22] Note the elasticity of capital to sales is unity ($\beta = 1$) if the production function has constant returns to scale ($\nu = 1$) or if the elasticity of substitution equals one ($\sigma = 1$), i.e., with a Cobb-Douglas production function. The parameter of interest in this paper is the long-term elasticity of capital stock with respect to the UCC which is given by $-\sigma$.

In a frictionless world, the log of the current optimal capital stock $k^*_{i,t}$ is simply a long-linear function of current sales in log ($s_{i,t}$), logarithmized current user cost of capital ($ucc_{i,t}$), a firm-specific effect a_i, and a deterministic time trend capturing technological progress:

$$k^*_{i,t} = c + a_i + \beta s_{i,t} - \sigma ucc_{i,t} + \sum_{t=1}^{T-1} \tau d_t. \tag{5}$$

If, however, costs of adjustment and uncertainty are introduced, the current capital stock depends on both, the *current* values of sales and user cost of capital in logs and the *past* values of these variables as well as of the capital stock.[23] Appending

[21] Beyond firm-specific relative factor shares, the parameter might also capture a firm-specific price markup in monopolistic markets.

[22] In the econometric analysis differences in the wage level over time and across firms are captured in the deterministic time trend and in the firm-specific effects.

[23] Adjustment costs are assumed to be a function either of the rate of gross or net investment and are rationalized by reference to the costs of disruption, the training of workers, management problems and the like (e.g., Eisner and Strotz 1963, Lucas 1967, Gould 1968, Treadway 1969). They may also be justified by reference to supply side factors, by supposing that the supply curve of capital goods to the firm is upward sloping (e.g., Foley and Sidrauski 1970, 1971). Nickell (1977) rationalizes lags by combining delivery lags and uncertainty. Harvey (1990) neatly

a stochastic error term $\varepsilon_{i,t}$ the current capital stock can be expressed as follows:

$$k_{i,t} = c + a_i + \sum_{h=1}^{H} \phi_h k_{i,t-h} + \sum_{h=0}^{H} \beta_h s_{i,t-h} - \sum_{h=0}^{H} \sigma_h ucc_{i,t-h} + \sum_{t=1}^{T-1} \tau d_t + \varepsilon_{i,t}. \tag{6}$$

It is important to note that expectational variables in the process generating the data imply potential problems in the estimation of short-run effects and long-term solutions. To be precise, the investment equation cannot be identified without knowledge of the series underlying the expectation formation process. Since in that case the explanatory variables are not contemporaneously uncorrelated with the error term for the parameters of interest, short-run and long-term effects are possibly not consistently estimated. As is shown in more detail by Banerjee, Dolado, Galbraith and Hendry (1993), however, non-stationarity of capital and co-integration between capital, sales, and user cost of capital can lead to consistent estimation of the long-term solution in an error correction framework in spite of the lack of weak exogeneity. Nevertheless, in the presence of expectational variables, the short-run coefficients remain mis-estimated in the error correction model, too. For this reason, I will mainly focus on the long-run coefficient that are consistently estimated in either case.

3.2.2 The (first-differenced) distributed lag model

Since firm-data are usually right skewed and show large differences in firm size, Eisner and Nadiri (1968) and Chirinko et al. (1999) propose to specify the equation for capital with all variables as ratios or rates. Taking differences of equation (6) and accounting for partial adjustment and extrapolative expectations leads to the following first-differenced autoregressive distributed lag model:

$$\Delta k_{i,t} = \sum_{h=1}^{H} \phi_h \Delta k_{i,t-h} + \sum_{h=0}^{H} \beta_h \Delta s_{i,t-h} - \sum_{h=0}^{H} \sigma_h \Delta ucc_{i,t-h} + \Delta\varepsilon_{i,t}. \tag{7}$$

distinguishes both effects. He shows that in a world with adaptive expectations, the optimal capital stock depends on lagged sales and user cost of capital whereas the currently optimal capital stock depends on lagged capital stock if capital is only partially adjusted.

Next, the change in capital can be approximated by investment. For this purpose I divide investment into replacement components (I_t^r) and net investment (I_t^{net}). Following Chirinko et al. (1999) I assume that capital depreciates geometrically at a firm-specific constant rate (δ_i), which varies with a firm's mix of capital assets; this means that replacement investment is proportional to the capital stock available at the beginning of the year. Net investment is the change in the capital stock between years t and $t-1$. Investment can hence be written as

$$I_{i,t} = I_{i,t}^r + I_{i,t}^{net} = \delta_i K_{i,t-1} + (K_{i,t} - K_{i,t-1}). \tag{8}$$

I then scale investment by the beginning-of-year capital stock and use equation (8) to obtain an approximation for the change in capital

$$\frac{I_{i,t}}{K_{i,t-1}} - \delta_i = \frac{K_{i,t} - K_{i,t-1}}{K_{i,t-1}} \simeq k_{i,t} - k_{i,t-1}. \tag{9}$$

Substituting this approximation into equation (7) leads to

$$\frac{I_{i,t}}{K_{i,t-1}} = \delta_i + \sum_{h=1}^{H} \phi_h \frac{I_{i,t-h}}{K_{i,t-h-1}} + \sum_{h=0}^{H} \beta_h \Delta s_{i,t-h} - \sum_{h=0}^{H} \sigma_h \Delta ucc_{i,t-h} + \Delta\varepsilon_{i,t}. \tag{10}$$

In their seminal paper, Chirinko et al. (1999) did not include the lagged dependent variable and simplified the model above to a (first-differenced) distributed lag model. As the latter model has since prevailed in the literature, I estimate their simplified specification, too.[24] Similarly, I also include cash flow relative to the existing capital stock as a measure of liquidity (cf. Fazzari, Hubbard and Petersen 1988, 2000). This leads to the following estimation equation:

$$\begin{aligned} \frac{I_{i,t}}{K_{i,t-1}} = \delta_i &+ \sum_{h=0}^{H} \beta_h \Delta s_{i,t-h} - \sum_{h=0}^{H} \sigma_h \Delta ucc_{i,t-h} \\ &+ \sum_{h=0}^{H} \gamma_h \frac{CF_{i,t-h}}{K_{i,t-h-1}} + \Delta\varepsilon_{i,t}. \end{aligned} \tag{11}$$

[24]Unlike, for instance, Chatelain et al. (2001) and Harhoff and Ramb (2001) I do not think that time trends in growth rates are sensible and for this reason do not include time dummies into the first-differenced equation.

It is worth noting that a significant cash flow effect can reflect the presence of financing constraints on investment. However, its is well known that financial constraints are not the only possible interpretation of significant coefficients on the cash flow variables. If investment depends on expected future sales and if cash flow acts as a proxy for these omitted expected future profitability variables, cash flow coefficients would be significant even in the absence of financing constraints (e.g., Kaplan and Zingales 1997, 2000).

In the estimation equation above, the long-term user cost elasticity of capital is captured by the sum of the σ's. There is no explicit modeling of the equilibrium relationship between capital, output, and user cost of capital. To learn more about this long-term relationship and the dynamics of investment, I also estimate an error correction model, which is derived in the next paragraph.

3.2.3 The error correction model

The error correction model was first introduced into the investment literature by Bean (1981). The main idea is to nest a long-term specification for the firm's demand for capital (depending on sales and the user cost of capital) within a regression setting that immediately yields parameters describing the extent of short-run adjustment to disequilibrium. As a prerequisite, capital, sales, and the user cost of capital must be co-integrated. Whether this holds can be tested using a panel co-integration test (Westerlund 2007).[25] Once the variables are co-integrated, the parameter estimates are consistent and follow the standard normal distribution asymptotically, i.e., usual t-tests are valid.

Reparameterizing equation (6),[26] reducing the auto-regressive component to one lag, and approximating the change in capital stock by equation (9) leads to the

[25] I am aware of the fact that the test has higher power in samples where T is substantially larger than N. Even in small samples, however, the Westerlund test outperforms residual-based panel co-integration tests (Westerlund 2007).

[26] For reparametrization one has to replace $k_{i,t}$ by $k_{i,t} = k_{i,t-1} + \Delta k_{i,t}$. Subtracting and adding $\beta_h s_{i,t-h}$ and $\sigma_h ucc_{i,t-h}$ and rearranging yields equation (12).

error correction model:

$$
\begin{aligned}
\frac{I_{i,t}}{K_{i,t-1}} &= c_{ECM} + \sum_{h=0}^{H} \mu_h \Delta s_{i,t-h} - \sum_{h=0}^{H} \alpha_h \Delta ucc_{i,t-h} \\
&\quad + (\phi - 1) \left[k_{i,t-1} - c + \sigma ucc_{i,t-1} - \beta s_{i,t-1} - \sum_{t=1}^{T-1} \tau' d_t - \eta_i' \right] + \varepsilon_{i,t},
\end{aligned}
\tag{12}
$$

where $\tau' = -\frac{1}{(\phi-1)}\tau$ and $\eta_i' = -\frac{1}{(\phi-1)}(a_i + \delta_i)$.

This estimation equation separates out short-run and long-term effects of a change in sales or user cost of capital. Immediate effects of a change in the user cost of capital are captured by α_0, i.e., a reduction in the UCC by 10 percent will immediately increase capital by α_0 times 10 percent. Further, a change in the UCC will influence capital in the long-run, since capital, user cost of capital, and output also have an equilibrium relationship. This equilibrium effect is given by $-\sigma$.

It is important to underline, however, that $-\sigma$ in the error correction model is not directly comparable to what is estimated as long-term elasticity in the estimation equation according to Chirinko et al. (1999): They estimate equation (6) in changes without including lagged capital (*first-differenced* distributed lag model); the error correction model is a direct reparametrization of equation (6), i.e., of the *autoregressive* distributed lag model in *levels*.

The term $(\phi - 1)$ in the error correction model reveals how fast firms adapt their capital stock to the optimal one in equilibrium. If $(\phi-1)$ is small in absolute value, capital is slowly adjusted while it quickly comes close to its equilibrium value if $(\phi - 1)$ is large in absolute terms. As a general rule, error correcting behavior requires that $(\phi-1)$ is negative. A negative coefficient implies that a capital stock below the optimal level is associated with investment and *vice versa*. Whether the actual capital stock is below or above its equilibrium value can be seen from the term in squared brackets, which also involves the variables in levels. If levels were omitted only short-run dynamics would be picked up which is inappropriate as long as capital adjusts slowly.

The "classical" error correction model is estimated in two steps (Engle and Granger

1987). First, the long-term parameters are estimated by running a static regression in levels. Second, the dynamics are estimated using the error correction term, which is the residuals from the static regression. Stock (1987) and Banerjee, Dolado, Hendry and Smith (1986) present evidence that this estimator is consistent if the variables are co-integrated but may lead to a finite sample bias. In practice, this finite sample bias might be of particular importance if the error term is autocorrelated. In either case, the proceeding leads to inconsistent standard errors of the equilibrium estimates. To avoid biased estimates in small samples and to facilitate the estimation of the equilibrium parameters, Bewley (1979) proposed a one-step error correction model that I will adopt in the following. The Bewley transformed version of the error correction model allows for a single-step estimation and can be written as follows:

$$\begin{aligned} k_{i,t} = c'_{ECM} + \vartheta' k_{i,t-1} + \sum_{h=0}^{H} \mu_h \Delta s_{i,t-h} - \sum_{h=0}^{H} \alpha_h \Delta ucc_{i,t-h} \\ - \sigma' ucc_{i,t-1} + \beta' s_{i,t-1} + \sum_{t=1}^{T-1} \tau d_t + a_i + \varepsilon_{i,t}, \end{aligned} \tag{13}$$

where $c'_{ECM} = c_{ECM} - (\phi - 1)c$, $\vartheta' = 1 + (\phi - 1)$, $\sigma' = -(\phi - 1)\sigma = -(\vartheta' - 1)\sigma$, and $\beta' = -(\phi - 1)\beta = -(\vartheta' - 1)\beta$.

While the short-run effects in the Bewley transformed model directly correspond to the ones estimated in two-steps, the long-term impact of the user cost on capital must be calculated as $-\sigma = \frac{\sigma'}{\vartheta' - 1}$. The standard error for the long-term multiplier is not directly estimated but can be derived with the help of the delta method.

Note one could also estimate a different version of the model, which is appealing, since long-term multipliers come along directly with their standard error.[27] This

[27] This model can be written as follows:

$$\begin{aligned} k_{i,t} = c''_{ECM} - \vartheta'' \Delta k_{i,t-1} - \sum_{h=0}^{H} \mu''_h \Delta s_{i,t-h} + \sum_{h=0}^{H} \alpha''_h \Delta ucc_{i,t-h} \\ - \sigma ucc_{i,t-1} + \beta s_{i,t-1} + \sum_{t=1}^{T-1} \tau d_t + a_i + \varepsilon_{i,t}, \end{aligned}$$

with $c''_{ECM} = \frac{1}{1-\phi} c$, $\vartheta'' = -\frac{1}{1-\phi}\phi$, $\mu_h'' = -\frac{1}{1-\phi}\mu_h$, and $\alpha_h'' = -\frac{1}{1-\phi}\alpha_h$.

model, however, also comes at a cost, since the short-run effects are not for direct reading.[28] For this reason, I prefer the Bewley-transformed error correction model.

3.2.4 Estimation strategy

The Bewley-transformed error correction model includes the lagged dependent variable. Because the lagged dependent variable in panel data is necessarily correlated with a firm-specific effect,[29] a simple Ordinary Least Squares (OLS) regression is biased and inconsistent. The estimation of the Bewley-transformed error correction model thus calls for an instrumental variable (IV) technique.

Besides the inclusion of the lagged dependent variable, there are two more reasons to use instruments. First, Goolsbee (2000) has shown that the coefficient of the user cost of capital in an OLS regression is considerably biased towards zero because of measurement error in the UCC (attenuation bias). As, for instance, information on economic depreciation rates is not available for each single firm but only at the industry level, measurement error is probably also present in my user cost variable. Second, with an upward sloping supply curve for capital, a reduction in tax rates drives up prices in the short-run, which in turn might inhibit an expected increase in investment (Goolsbee 1998, 2004). I therefore have to deal with a simultaneity bias between the UCC and investment shocks which distorts the user cost elasticity towards zero. A similar argument suggests that simultaneity between investment shocks and interest rates biases the coefficient of the user cost of capital (Chirinko et al. 1999). Further, investment shocks may be contemporaneously correlated with output and cash flow. Both measurement error and simultaneity bias require an instrumental variable estimation which results in consistent and unbiased estimates.

I therefore estimate the dynamic regression model above using Generalized

[28] They must be calculated as $\mu_h = -\mu''_h(1-\phi)$ and as $\alpha_h = -\alpha''_h(1-\phi)$ which is a bit tedious, since the velocity of adjustment $(\phi - 1)$ is not directly estimated. As $(\phi - 1)$ is negative, this implies that all short-run effects are given with opposite sign.

[29] Such unobserved firm characteristics might be a firm's capacity for innovation or managerial abilities. The firm-specific effect can also be interpreted as a component of the usual rate of investment at which the firm's adjustment costs are zero.

Method of Moments (GMM) which controls for biases due to endogenous explanatory variables and firm fixed effects. In the paper, I report results for the heteroscedasticity-robust two-step "System-GMM". This estimator uses the lagged levels of dependent and independent variables as instruments for the difference equation and the lagged difference of dependent and independent variables as instruments for the level equation (Blundell and Bond 1998).[30] Since standard errors in the usual two-step GMM estimator are downward biased in finite samples, the Windmeijer correction is used (Windmeijer 2005).

Only in the absence of higher-order serial correlation in the error $\varepsilon_{i,t}$, does the GMM estimator provide consistent estimates of the parameters in the investment equation. To test for second-order serial correlation in the differenced residuals, I use the Arellano-Bond test (Arellano and Bond 1991).[31] In this context I also report robust Sargan tests of overidentifying restrictions.

The last methodological topic I want to raise is sample attrition. Since I use panel data over a horizon of twenty years, I see firms dropping out of my sample. The reasons for attrition are manifold, they include bankruptcy, cessation of business, merger, and falling below the thresholds for disclosure requirement. If firms are randomly missing, sample attrition will not bias results; the investment function could be estimated using the incomplete panel data set as if it was complete. However, one might argue that dropping out of the sample does not randomly occur but is related to investment. There might be unobservable characteristics affecting the survival of firms or their size relevant to publication requirements

[30] I do not report results estimated with "Difference-GMM" (Arellano and Bond 1991) and "Forward-GMM" (Arellano and Bover 1995). These estimators can be subject to large finite-sample biases, since the correlation between the explanatory variables in differences and their lagged levels becomes weak in highly persistent series (Blundell and Bond 1998). One indication of whether these biases are likely to be serious can be obtained by OLS levels and within-groups estimates which are biased upwards and downwards, respectively. These estimations show that firms' capital stock is highly persistent: an OLS regression of the current capital stock on the one in the previous year leads to a coefficient of 0.95 and the within estimation to an estimate of 0.70.

[31] For consistent estimation, the error $\varepsilon_{i,t}$ is required to be serially uncorrelated. If $\varepsilon_{i,t}$ are serially uncorrelated, then $\Delta\varepsilon_{i,t}$ are necessarily correlated with $\Delta\varepsilon_{i,t-1}$, but $\Delta\varepsilon_{i,t}$ will not be correlated with $\Delta\varepsilon_{i,t-k}$ for $k \geq 2$. If the estimation requirements are fulfilled, I therefore expect to reject the Arellano-Bond test for zero autocorrelation in the first-differenced errors at order 1 but not at order 2.

which are correlated with unobservable firm characteristics that also affect the decision to invest.[32] In this case, estimation of the investment function without an appropriate correction can be biased. Surprisingly, this problem has received little attention in papers on investment so far. To allay doubts about the unbiasedness of my estimates, I include a term which corrects for sample attrition. Following a three-step procedure proposed by Wooldridge (1995, 2002),[33] I first estimate the probability of dropping out of the sample in the following period. In probit models, this probability is estimated separately for each year.[34] Second, I calculate the inverse Mills ratio for each period ($\lambda(x_i d_t)$) and third, add it to the estimation equation. Since usual standard errors are inconsistent, I bootstrap standard errors in all regressions.

4 Results

In this section, I present regression estimates for the user cost elasticity. I begin with GMM results for the (first-differenced) distributed lag model, which eliminates firm-specific effects and accounts for possible endogeneity problems. The Westerlund panel co-integration test (Westerlund 2007) reveals co-integration between capital, user cost of capital, and sales (Table A.5). The test result thus calls for a specification that nests the equilibrium relationship. For this reason, I esti-

[32]If attrition only operates through the firm-specific, time-invariant effect a_i (δ_i), first-differencing the estimation equation solves selection. By contrast, if attrition operates both through a_i (δ_i) and $\varepsilon_{i,t}$ a correction term is needed.

[33]Errors in the selection equation are allowed to display serial correlation and unconditional heteroscedasticity but are assumed to be normally distributed. The procedure does not impose distributional assumptions about the error term and the firm-specific effects in the equation of interest. The unobserved effect and regressors are allowed to be arbitrarily correlated and attrition may depend on the unobserved effect. Though, the correction procedure requires that the functional form of the conditional mean of the firm-specific effects in the equation of interest is specified. Further, the cross-section observations are assumed to be independent and identically distributed. In the original model the assumption of strict exogeneity of the regressor is imposed. Wooldridge, however, argues that it is possible to allow for variables that are not strictly exogenous under reasonable extensions of the assumptions.

[34]Explanatory variables in this estimation are: Firm size (number of employees, balance sheet total), variables indicating economic difficulties (reduction in employees by more than 10 percent compared to the previous year, annual loss), and year of foundation.

mate the one-step Bewley-transformed error correction model.[35] This estimation leads to my preferred, relatively large estimate of the user cost elasticity, which is about -1.3 in the long-run.

4.1 Estimates comparable to the literature

Table 3 presents GMM estimates of equation (11), with and without cash flow. The instruments used were at least twice lagged values of the explanatory variables, which allows for contemporaneous correlation between these variables and shocks to the investment equation, as well as correlation with unobserved firm-specific effects. Hence, current user cost of capital, output, and cash flow are treated as being potentially endogenous. In addition to the Sargan-Test for overidentifying restrictions, I also report the Arellano-Bond-Test testing for serial correlation in the differenced residuals.

The estimates in Table 3 are directly comparable to the existing literature using distributed lag models. As noted before, the (long-term) user cost elasticity in this model is given by the sum of σ's. Estimating the model without cash flow I find an elasticity of -0.55 while it amounts to about -0.62 when I include cash flow. In the model without cash flow the null hypothesis of capital being inelastic with respect to its user cost can be rejected at the 5%-level, while the variable is significant at every conventional significance level in the model including cash flow.

Compared to the existing literature, my point estimates without and with cash flow are surprisingly similar,[36] even though there are several differences between my estimation and previous studies: First, Harhoff and Ramb (2001), von Kalckreuth (2001) and Chatelain et al. (2001) use consolidated and not individual financial statements as I do. Second, all three studies use the German Central Bank's corporate balance sheet database. This data set may be sampled differently as it does not rely on publication requirements but originates from the

[35] As a supplement, I also provide results for the "classical" two-step error correction model in the appendix (Table A.6).

[36] Compared to the elasticity of -0.25 estimated by Chirinko et al. (1999) for the US, the user cost elasticity of German companies seems to be larger in general.

Table 3: Results estimated with (first-differenced) distributed lag model and Generalized Method of Moments

$I_{i,t}/K_{i,t-1}$	**Excluding cash flow**	**Including cash flow**
$\lambda(x_i d_t)$	0.031	0.073
	(0.006)	(0.029)
$\Delta ucc_{i,t}$		
σ_0	-0.190	-0.266
	(0.053)	(0.092)
σ_1	-0.228	-0.268
	(0.075)	(0.106)
σ_2	-0.127	-0.136
	(0.072)	(0.074)
σ_3	-0.010	0.050
	(0.158)	(0.159)
SUM(σ)	**-0.553**	**-0.620**
	(0.254)	**(0.215)**
$\Delta s_{i,t}$		
β_0	0.055	0.084
	(0.036)	(0.036)
β_1	0.048	0.057
	(0.045)	(0.044)
SUM(β)	**0.103**	**0.141**
	(0.074)	**(0.074)**
$CF_{i,t}/K_{i,t-1}(\gamma)$	-	0.138
	-	(0.003)
Number of firms	3,968	3,968
(Number of observations)	(24,762)	(24,762)
Sargan-Test (p-value)	0.999	0.787
Arellano-Bond-Test (p-value), order 1	0.090	0.155
Arellano-Bond-Test (p-value), order 2	0.788	0.636

Notes: Estimates with micro data and Generalized Method of Moments as described in the text. A full set of time dummies is included. Bootstrapped standard errors are in parentheses. The instruments for the first-differenced regression are the values (in levels) of $\Delta ucc_{i,t}$ lagged two through nine years and $\Delta s_{i,t}$ and $CF_{i,t}/K_{i,t-1}$ lagged two through three years.
Source: Hoppenstedt company database, own calculations, 1987 to 2007.

Central Bank's function of performing credit assessments within the scope of its rediscount-lending operations (for details and additional bibliographical references see von Kalckreuth 2001). Third, previous studies do not explicitly control for sample attrition while a correction term is included in all specifications in the present study.[37] Since a two-sided t-test reveals that the correction term ($\lambda(x_i d_t)$) is sta-

[37] In first-difference estimations, time-invariant sampling schemes are purged from the regression by fixed effects. If the sampling, however, has changed, explicit selection correction is warranted.

tistically significantly different from zero at the 1%-level (without cash flow) and 5%-level (with cash flow), firms indeed seem to leave the data set non-randomly. Thus uncontrolled sample attrition potentially biased results in earlier studies. However, comparing regression results from Table 3 to the coefficients estimated in a model without selection correction does not show any important differences.[38] This indicates that, even though companies drop out of the sample non-randomly, controlling for sample attrition has almost no effect on the user cost elasticity, at least for the Hoppenstedt database.

Similar to what was found in the literature before, the sum of the coefficients of sales is clearly below one (point estimate of 0.10 without and 0.14 with cash flow) and not compatible to what is usually assumed in theory.[39] The point estimate for cash flow, by contrast, is statistically significant and relatively large: Increasing cash flow by 10 percent immediately increases capital by 1 percent. Insofar as cash flow seems to be an important determinant of investment, omitting it from the estimation equation will lead to an omitted variable bias in the estimated user cost elasticity if the user cost of capital and cash flow are correlated.

In general, cash flow effects are interpreted either as evidence for the importance of financial constraints (e.g., Fazzari, Hubbard and Petersen 1988, 2000) or as a proxy for future profitability (e.g., Kaplan and Zingales 1997, 2000). Differentiating the "financial" versus the "fundamental" determinants of investment is fruitful, since financial frictions might translate into important efficiency costs of profit taxation (Keuschnigg and Ribi 2009). In the following, I will argue that cash flow effects may result from dynamic misspecification, since they disappear once investment dynamics are correctly specified within the error correction model. This is in line with what was found by Bond, Elston, Mairesse and Mulkay (2003) in the context of financial factors and investment.

[38] Results can be obtained upon request.

[39] As shown in Section 3.2.1 constant returns to scale imply a point estimate of one. A point estimate below one implies increasing returns to scale.

4.2 Investment dynamics

Since the first-differenced distributed lag model does not account for the equilibrium relationship between capital, sales, and user cost, I prefer estimating an error correction model. As discussed above, this model can be used to estimate the long-term elasticity of the capital stock with respect to its user cost, while allowing for the fact that this adjustment does not occur immediately. Because of the drawbacks associated with the "classical" two-step error correction model, I confine these results to the appendix (Table A.6) and exclusively present results of the single-step estimation in the main text.

The GMM results for the one-step error correction model are summarized in Table 4. Beforehand, the estimation results have undergone several robustness check and are not sensitive to the instrumentation choices.[40]

First, I refer to regression results in column (1) which is without cash flow. All point estimates have the expected sign. The long-term user cost elasticity is calculated as $-\sigma'$ divided by $-(1-\vartheta')$. This yields a statistically significant and relatively large long-term multiplier which amounts to -1.29 (standard error of 0.18). Hence, a rise in the user cost of capital by 10 percent decreases capital by about 13 percent in the long run. A two-sided Chi-square test suggests that the elasticity is not statistically different from minus one (p-value: 0.107).[41] Compared to the point estimate of -0.6 in the previous section, the coefficient appears rather large. It is, however, not uncommon that equilibrium elasticities are large *vis-à-vis* the effects estimated in distributed lag models: Exploiting co-integration methods, Caballero, Engel and Haltiwanger (1995) estimate the long-term relationship between logarithmized capital-output ratio and user cost of capital. They report an average elasticity of investment with respect to capital of -1.0, the neoclassical benchmark. Cummins, Hassett, Hubbard, Hall and Caballero (1994) use tax reforms as natural experiments for evaluating the responsiveness of investment

[40] Mairesse, Hall and Mulkay (1999), Harhoff and Ramb (2001), and von Kalckreuth (2001) report on instability in their estimation results regarding the choice of instruments.

[41] Of course, the model could be also estimated under the restriction of a Cobb-Douglas production function. To allow for a maximum of flexibility, I estimate the model without restriction but use the parameter estimate for a plausibility check.

Table 4: Results estimated with one-step error correction model and Generalized Method of Moments

$k_{i,t}$	**Without cash flow** (1)	**With cash flow** (2)
$k_{i,t-1}(\vartheta')$	0.318	0.294
	(0.057)	(0.054)
Selection correction ($\lambda(x_i d_t)$)	-0.082	-0.087
	(0.018)	(0.019)
User cost of capital (σ')	-0.881	-0.861
	(0.138)	(0.145)
Sales (β')	0.447	0.448
	(0.072)	(0.075)
$\Delta ucc_{i,t}$		
α_0	-0.537	-0.515
	(0.079)	(0.084)
α_1	-0.139	-0.137
	(0.034)	(0.035)
α_2	-0.050	-0.050
	(0.017)	(0.017)
$\Delta s_{i,t}$		
μ_0	0.283	0.277
	(0.059)	(0.063)
μ_1	0.070	0.072
	(0.021)	(0.022)
μ_2	0.035	0.038
	(0.014)	(0.015)
$CF_{i,t}/K_{i,t-1}$		
γ_0	-	-0.014
	-	(0.011)
Constant	2.051	2.483
	(1.254)	(1.298)
Number of firms	3,968	3,968
(Number of observations)	(24,762)	(24,762)
Sargan-Test (p-value)	0.775	0.642
Arellano-Bond-Test (p-value), order 1	0.002	0.007
Arellano-Bond-Test (p-value), order 2	0.366	0.273

Notes: Estimates with micro data and Generalized Method of Moments as described in the text. A full set of time dummies is included. Bootstrapped standard errors are in parentheses. The instruments for the first-differenced regression are the values (in levels) of $\Delta ucc_{i,t}$ and $\Delta s_{i,t}$ lagged two through seven years.
Source: Hoppenstedt company database, own calculations, 1987 to 2007.

to its user cost and find long-term elasticities between -0.5 and -1.0. In an earlier study based on aggregate data, Caballero (1994) reports an elasticity of the capital-output ratio to the cost of capital close to minus one.[42]

[42]Note that researchers who have worked with aggregate data have had great difficulty in providing empirical evidence that taxes matter for capital formation (cf. Chirinko 1993; Caballero 1999; Hassett and Hubbard 2002 for surveys of this literature). The reasons for the failure were

The coefficients on the short-run effects show that companies relatively quickly adjust to a change in user cost of capital. α_0 implies that a reduction of the user cost by 10 percent will immediately increase capital by 5 percent, i.e., about half of the gap between current and optimal stock of capital is closed in the first year. This finding might be important news for policymakers who can stimulate short-term capital spending and stabilize business fluctuations by lowering the user cost of capital.

Let me now turn to the equilibrium relationship between capital and sales. The long-term effect of output on capital is given by $-\beta'$ divided by $-(1-\vartheta')$. At 0.65 (standard error of 0.10), the effect of output on capital in equilibrium is larger than what was found in the first-differenced distributed lag model but still implies increasing returns to scale; a two-sided Chi-square test rejects the null hypothesis of constant returns to scale at any conventional level (p-value: 0.000). Since the data set in this study mainly contains large corporations which potentially benefit from increasing return to scale, a point estimate below one is plausible.[43] In either case, the estimate is much closer to theoretical predictions than the estimate usually found in distributed lag models. Again, the coefficients on the short-run effects of sales on capital suggest that companies relatively quickly shift their capital stock if sales increase or decrease.

The coefficient on the selection term is highly significant. To determine whether estimates in earlier studies on investment, not accounting for non-random sample attrition, have been biased, I compare the point estimates to a regression without correction term. The comparison again shows that there is virtually no difference between the estimates of the two regressions.[44] This implies, at least for the data set used in this study, that sample attrition is present but does not affect the user

various: insufficient variation in the user cost of capital to identify tax effects, measurement error in that investment depends upon observed current and expected future values of many fundamentals, and small samples problems of co-integrating procedures that tend to downward bias the user cost elasticity particularly when adjustment costs are important.

[43] Note this does not conflict with an equilibrium perspective, since optimal, finite firm size might be defined by other factors such as managerial capacity limits or provisions on the employment rights of employees operating the machines, which are more generous for employees working for larger firms (e.g., employees of larger firms are entitled to a works council). Firm growth may also be limited by legal rules or the antitrust agency.

[44] Results can be obtained upon request.

cost elasticity.

Let me now turn to the regression including cash flow (Table 4, column (2)). First of all, the estimation results show that including cash flow in the regression equation does not change results. Second, the point estimate for cash flow is close to zero and insignificant. Since both results also hold if several lags of cash flow are introduced, I do not reproduce results here. This finding contradicts significant cash flow effects in the distributed lag model but is in line with results reported by other researchers. Not including the user cost of capital, Bond, Elston, Mairesse and Mulkay (2003) analyze the effects of output and cash flow on capital in different countries. They remark that significant cash flow effects have been present in restricted reduced-form specifications but have vanished in more complete dynamic specifications. They therefore conclude that "there is some indication that the cash-flow variables proxy for omitted dynamics in simpler dynamic specifications" (Bond, Elston, Mairesse and Mulkay 2003, p.160).[45] To be precise, financial variables may appear to be significant in distributed lag models, even though they play no role in the structural model for investment but merely help to forecast future values of the fundamental determinants of investment.[46] For this reason, I cannot concur with other authors (e.g., Harhoff and Ramb 2001) stating that the (first-differenced) distributed lag model produces the most appropriate estimation results. On the contrary, I suspect well documented cash flow effects in the distributed lag model may appear merely because of dynamic misspecification. Accounting for co-integration between capital, user cost of capital, and sales, I further find more plausible estimates for the long-term effect of output on capital than in the distributed lag model.

For these reasons, my preferred specification is the one-step error correction model

[45] Another strand of the literature associates significant cash flow effects with measurement errors in Q-models. For instance, Bond, Klemm, Newton-Smith, Syed and Vlieghe (2004) find that cash flow effects disappear when analysts' earnings expectations are included in the investment regression. Similarly, Erickson and Whited (2000) use information in higher-order moments to control for measurement error in q and obtain insignificant cash flow coefficients. An overview of the associated literature is given in Cummins, Hassett and Oliner (2006).

[46] This shows that reduced form models are subject to the famous Lucas critique (Lucas 1976) because parameters of the structural adjustment process are interfused with parameters of the expectation formation process.

without cash flow. This specification gives an estimate for the long-run effect of the user cost of capital on capital formation of -1.29. The user cost of capital, however, is influenced by a mixture of variables including interest rate, tax rate, economic depreciation rate etc.. That is, it cannot be directly influenced by policymakers who can only determine depreciation allowances, tax rates, and the fiscal treatment of different financial sources. To evaluate the effect of changes in these variables on the user cost of capital and the capital stock, I simulate the policy implications of the most recent tax reform in Germany, the Corporate Tax Reform 2008 (*Unternehmensteuerreform 2008*). This reform reduced the uniform corporate income tax rate from 25 percent to 15 percent. At the same time, the tax base was broadened by deteriorating depreciation allowances. In particular, the option to depreciate fixed assets according to the declining-balance method was abolished. *Ceteris paribus*, the lowering of the corporate income tax rate led to a reduction in the user cost of capital; this decrease, however, was partly compensated for by the deterioration of depreciation allowances. In my sample, the reform lowered the user cost of capital by 0.08 percent, on average.[47] Applying my elasticity estimate of -1.29, I would expect that the reform increases capital stock by only 0.11 percent in the long run. Hence, any expectation of a large increase in investment because of the reform seems inappropriate, since the rather strong reduction in corporate income tax rate was undermined by stricter depreciation allowances.

5 Conclusion

Using a firm-level panel data set I estimate the user cost elasticity of capital in a dynamic framework. More precisely, I estimate an error correction model where short-run adjustments and long-term equilibrium effects can be distinguished. So far, drawing on the work by Chirinko et al. (1999), other studies based on micro data have focused on (first-differenced) distributed lag models, which do not explicitly allow for an equilibrium relationship between capital, its user cost, and

[47] In 2001, the average user cost of capital was 0.14589; applying the tax rules 2008 yields a user cost of capital of 0.14577 *ceteris paribus*.

sales. Short-run dynamics result from an empirical specification search rather than being imposed *ex ante*; long-term effects are simply calculated as the sum of the coefficients of short-run adjustment.

To account for non-random sample attrition which may bias estimation results, all regressions include a term correcting for firms dropping out of the sample. Surprisingly, this issue has not been raised in previous studies even though most (if not all) panel data sets on firms are incomplete and estimates may be biased for this reason. While the coefficient of the selection term is statistically significant, it is found to be of minor importance for the estimation of the user cost elasticity, at least for the Hoppenstedt database used in this study.

First, I estimate the popular (first-differenced) distributed lag model to compare results to estimates from previous studies. This regression setting yields a user cost elasticity of -0.6 which is very similar to what was found by Harhoff and Ramb (2001) (-0.4), von Kalckreuth (2001) (-0.5), and Chatelain et al. (2001) (-0.7). Similar to what was previously found in the literature, the (first-differenced) distributed lag model leads to implausible low point estimates for output which casts doubt on the validity of these estimates.

Second, as a novel contribution to the literature on tax effects in investment equations, I estimate an error correction model. Since the "classical" two-step error correction model suffers potentially from finite sample biases, I mainly rely on a one-step Bewley-transformed error correction model. My estimation yields a robust, statistically significant, and relatively large user cost elasticity. My preferred estimate of -1.3 implies that a decrease in the user cost of capital by 10 percent will increase the firm's capital stock by 13 percent, on average. Taking my elasticity estimate to the Corporate Tax Reform 2008, the most recent tax reform in Germany, I would expect that the reform only slightly increases capital stock, since the rather strong reduction in corporate income tax rate was partly compensated for by stricter depreciation allowances. Further, my preferred specification shows that firms quickly adjust to the new optimal capital stock: about half of the gap between the existing and the optimal capital stock is closed within a year. Implying increasing return to scale the elasticity of capital towards output seems to be below unity but is more reasonable in size than in the distributed lag model.

Investment dynamics appear to be crucial not only for the effect of output on capital but also for the effect of cash flow variables in investment equations. While well-known cash flow effects are present in the (first-differenced) distributed lag model, they vanish in the error correction model. This finding conflicts with the view that cash flow effects can be seen as evidence for the importance of financial constraints (e.g., Fazzari, Hubbard and Petersen 1988, 2000). In fact, it rather suggests that cash flow may act as a proxy for omitted expected future profitability variables (Kaplan and Zingales 1997, 2000; Bond, Elston, Mairesse and Mulkay 2003) which becomes insignificant once the investment equation is dynamically correctly specified. For this reason I cannot agree with Harhoff and Ramb (2001) when they state that the distributed lag model produces the most appropriate estimation results. On the contrary, sensitivity of cash flow coefficients leads me to conclude that well documented cash flow effects point at dynamic misspecification.

A Appendix

A.1 Data

This appendix describes the calculation of the principle variables used in the estimation and the data sources used in the study.

(Gross) Investment $I_{i,t}$

Gross investment is defined as additions to fixed tangible assets and structures less disposals from fixed tangible assets and structures.

Sales $S_{i,t}$

Sales is measured by revenue/turnover from Hoppenstedt, and it is deflated by industry-specific output price indices provided by German Statistical Office.

Cash flow $CF_{i,t}$

Cash flow is the sum of several variables from Hoppenstedt. Cash flow includes:

1. Income before extraordinary items
2. Depreciation
3. Deferred taxes
4. Extraordinary items and discontinued operations.

Income before extraordinary items and depreciation are seldom missing from firms' profit and loss accounts. If information on these two items is missing, cash flow is also assumed to be a missing value. The other two items (deferred taxes and extraordinary items), by contrast, are missing for a large share of companies. Following Chirinko et al. (1999) I assume their values to be zero when they are missing. Most firms' profit and loss account in the data set follow the whole expenditure method. While depreciation for these firms refers to the whole amount of depreciation in a given year, deprecation of firms applying the cost of sales method only refers to depreciation attributable to goods sold. These differences in definition are neglected in the construction of my cash flow variable.

Capital stock $K_{i,t}$

Capital input is measured by the real replacement value of equipment and structures. The real replacement value of capital is not available in the data, and must be estimated from historic cost data. The replacement cost value of tangible fixed assets and structures are assumed to equal their historic costs in the first year a firm appears in the data set (adjusted for previous years' inflation). Thereafter, the replacement cost value is updated using the perpetual inventory formula:

$$P_t^I K_t = (1-\delta) P_{t-1}^I K_{t-1} \frac{P_t^I}{P_{t-1}} + P_t^I I_t \tag{14}$$

where $t = 1987, ..., 2007$,

K_t capital stock,
P_t^I price of investment goods,
I_t real investment,
δ depreciation rate.

Depreciation rates of 12.25 percent per year for fixed tangible assets and 3.61 percent per year for buildings are assumed. These values are taken from OECD (1991). As a sensitivity test, I recalculated the capital stock taking a depreciation rate of 8 percent from (Bond, Harhoff and Van Reenen 2003). This did not change regression results.

Price indices p_t^I and $p_{j,t}^S$

There are two price indices: The national price index for investment goods (p_t^I) and the price index for output goods ($p_{j,t}^S$). The German Statistical Office constructs p_t^I on the country level only (*Investitionsgüterindex*). $p_{j,t}^S$ is available for manufacturers on a disaggregate level (*Erzeugerpreisindex*): These days firms have to declare their price of sale for approximately 1,600 representative types of goods. On the basis of these prices, the Statistical Offices calculate detailed sales price information for each industry j. I use this information at the 4-digit industry level.

Rate of economic depreciation $\delta_{a,j,t}^e$

The rate of economic depreciation $\delta_{a,j,t}^e$ can be derived from information out of the national accounts' capital stock (*Kapitalstockrechnung*), which is provided by the German Statistical Office. The rate varies across assets a, i.e., fixed assets and structures, industries j (4-digit level), and over time. I calculated the rate as economic depreciation for asset a in prices of 2000 divided by stock of asset a in prices of 2000.

Depreciation allowances $z_{a,t}$

Depreciation allowances $z_{a,t}$ follow different methods in Germany: While structures are depreciated on a straight-line basis, fixed assets could be depreciated according to the declining-balance method until 2007. When calculating depreciation allowances, I considered these differences. Depreciation allowances also vary over time as fiscal rules were changed several times.

Structures: Until 2000, the taxation-relevant lifetime of structures was 25 years. Since 2001 this lifetime has been prolonged to $33\frac{1}{3}$ years.

Fixed assets: Until 2000, the yearly rate for the declining-balance method was 0.3. In 2001 it was reduced to 0.2. If depreciation allowances on the straight-line basis exceeded those on the declining-balance method, firms were allowed to switch methods. This privilege is taken into account. Unfortunately, there is no information on the relevant lifetime for different fixed assets, which vary considerably. I therefore assumed that the relevant lifetime amounts to 10 years (year 1997) on average. A research project on depreciation allowances in Germany concludes that reforms in 1998 and 2001 worsened depreciation allowances by approximately 30 percent (Oestreicher and Spengel 2002). I scaled the average lifetime accordingly (1998 to 2000: 13 years, 2001 to 2008: 16.9 years).

Firm-specific interest rate $r_{i,t}$

The firm-specific interest rate $r_{i,t}$ is approximated as interest payments in a given year divided by long term debt at the end of the year.

Overall yield on corporate bonds r_t

In a robustness check, I use the overall yield on corporate bonds r_t. This information is provided by the German Central Bank in its series "Yields on debt securities outstanding issued by residents / Corporate bonds / Monthly average" (WU0022).

A.2 Statutory tax rates

Table A.1 shows the evolution of tax rates over time.

Table A.1: Statutory tax rates 1987-2008

year	Corporate income tax on retained profits	Corporate income tax on distributed profits	Solidarity surcharge
1987	56%	36%	-
1988	56%	36%	-
1989	56%	36%	-
1990	50%	36%	-
1991	50%	36%	3.75%
1992	50%	36%	3.75%
1993	50%	36%	-
1994	45%	30%	-
1995	45%	30%	7.5%
1996	45%	30%	7.5%
1997	45%	30%	7.5%
1998	45%	30%	5.5%
1999	40%	30%	5.5%
2000	40%	30%	5.5%
2001	25%	25%	5.5%
2002	25%	25%	5.5%
2003	26.5%	25%	5.5%
2004	25%	25%	5.5%
2005	25%	25%	5.5%
2006	25%	25%	5.5%
2007	25%	25%	5.5%
2008	15%	15%	5.5%

Sources: Own presentation, corporate income tax law, 1987 to 2008, solidarity surcharge law, 1991 to 2008.

A.3 Additional descriptives and results of the two-step error correction model

My sample consists of 4,642 firms which have at least four records in the data set (Table A.2). Table A.3 shows the distribution of observations over years. Most firms have their headquarters in Western Germany; only about 13 percent of all firms are located in Eastern Germany. All companies were allocated to thirteen industries according to their main activity as is shown in Table A.4.

Table A.2: Number of records per company

Number of records per company	Number of companies
4	685
5	553
6	491
7	438
8	379
9	285
10	227
11	192
12	168
13	255
14	263
15	94
16	110
17	102
18	52
19	26
20	84
21	238
Total	4,642

Source: Hoppenstedt company database, own calculations, 1987 to 2007.

Table A.3: Composition of the sample: years

Year	Number of observations with at least three lags
1990	888
1991	1,089
1992	1,110
1993	1,151
1994	1,211
1995	1,230
1996	1,286
1997	2,267
1998	2,128
1999	1,981
2000	1,873
2001	1,880
2002	1,952
2003	2,032
2004	2,129
2005	2,092
2006	1,990
2007	1,306
Total	29,595

Source: Hoppenstedt company database, own calculations, 1987 to 2007.

Table A.4: Composition of the sample: industries

Industry	Number of companies
Agriculture, forestry, fishery	26
Mining, quarrying	30
Consumer goods, goods for intermediate	
Consumption goods industry	791
Producers goods	829
Electricity and water supply	505
Construction	122
Wholesale and retail trade, repair of goods	475
Hotels and restaurants	27
Transport, storage and communication	275
Financial intermediation	68
Real estate and renting	507
Services for private sector	649
Services for public sector and households	338
Total	4,642

Source: Hoppenstedt company database, own calculations, 1987 to 2007.

Table A.5: Westerlund panel co-integration test

Westerlund test statistic	Value	z-value	p-value
Group-mean tests			
Gt[a]	-2.904	-28.416	0.000
Ga[a]	-128.683	-573.736	0.000
Panel tests			
Pt[b]	-9.550	-40.686	0.000
Pa[b]	-18.152	-66.146	0.000

Notes: Westerlund panel co-integration test calculated with Stata command xtwest (Persyn and Westerlund 2008).

[a] For group tests: $H_0^G : \alpha_i = 0 \; \forall i$ versus $H_1^G : \alpha_i < 0$ for at least some i; a rejection should be taken as evidence of co-integration for at least one of the cross-sectional units.

[a] For panel tests: $H_0^P : \alpha_i = 0 \; \forall i$ versus $H_1^P : \alpha_i < 0 \; \forall i$; a rejection should be taken as evidence of co-integration for the panel as a whole.

Sources: Hoppenstedt company database, own calculations, 1987 to 2007.

Table A.6: Results estimated with two-step error correction model and Generalized Method of Moments

$I_{i,t}/K_{i,t-1}$	**Two-step estimation**
1. step: equilibrium effects	
User cost of capital (σ)	-1.687
	(0.036)
Sales (β)	0.635
	(0.006)
Constant	1.739
	(0.128)
Year dummies	included
Firm-specific effect	included
2. step: investment dynamics	
Selection correction ($\lambda(x_i d_t)$)	-0.078
	(0.089)
$\Delta ucc_{i,t}$	
α_0	-0.422
	(0.173)
α_1[a]	-0.707
	(0.360)
α_2	0.078
	(0.069)
$\Delta s_{i,t}$	
μ_0	0.238
	(0.160)
μ_1[b]	0.441
	(0.182)
μ_2	0.015
	(0.061)
Velocity of adjustment $(1-\phi)$[c]	-0.478
	(0.263)
Constant	0.589
	(0.310)
Number of firms	3,968
(Number of observations)	(24,762)
Sargan-Test (p-value)	0.999
Arellano-Bond-Test (p-value), order 1	0.094
Arellano-Bond-Test (p-value), order 2	0.870

[a] Note that, while the change in the first year is given by α_0, the effect in the second year cannot be directly taken out of the regression output. Calculating it leads to an estimate of -0.38: $-(\sigma-1)(1-\phi)-\alpha_0-(1-\phi) = -(-1.687-1)(-0.478)-(-0.422)-(-0.478) = -0.38$.

[b] The effect in the second year is given by: $(\beta-1)(1-\phi)-\mu_0-(1-\phi) = 0.41$.

[c] In every year, 47.8 percent of the remaining gap between current and optimal capital stock are removed. In the first year $(1-\phi) = 48\%$ directly gives the percentage of capital adjusted. In the second year the adjustment amounts to $(1-\phi)$ times one minus the adjustment in the first year ($(1-\phi)(1-0.48) = 48\%(1-0.48) = 24.96\%$) and so on.

Notes: Estimates with micro data and Generalized Method of Moments as described in the text. A full set of time dummies is included. Bootstrapped standard errors are in parentheses. The instruments for the first-differenced regression are the values (in levels) of $\Delta ucc_{i,t}$ lagged two through seven years and $\Delta s_{i,t}$ lagged two through five years.

Source: Hoppenstedt company database, own calculations, 1987 to 2007.

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