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Abhandlungen

Firm Size Matters – An Analysis of Size Effects on Investment Using Firm-level Panel Data

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I. Introduction

In this paper, we investigate the impact of firm size on investment behaviour of German firms within the framework of the Q-theory.[1] Our aim is to find further evidence on the relationship between cash flow and investment and the interaction with firm size, because on the one hand small firms are often regarded as the driving force of growth, but as suffering from financial constraints on the other hand.

Policy makers often show a preference for supporting small firms and promoting them financially.[2] In Germany there is currently some ongoing debate about small to medium-sized firms ("Mittelstand") being financially constraint, because of tightened credit policy by banks. Tax reductions and easing credit restrictions are regarded by many politicians as one way of supporting especially smaller firms and stimulating their investment. In this context, the question arises as to whether there is a failure in financial markets that constrains the investment behaviour of small firms.

Firm size plays a crucial role in the debate on liquidity constraints and its effect on investment. Firm size is frequently used as an *a priori* indicator of the existence of liquidity constraints, based on the assumption that small firms have less access to capital than larger firms (Fazzari, Hubbard and Petersen (1988)). Therefore, through analysing the cash flow effect within different classes of firm size, the hypothesis that firms face some form of liquidity constraints and hence the notion of a perfect capital market is tested.

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* I would like to thank an anonymous referee for helpful comments.
1 See *Tobin* (1969) and *Hayashi* (1982).
2 See *Weinberg* (1994).

The existence of liquidity constraints means that credit-capital markets do not always clear. Liquidity constrained firms which have profitable potential investment projects will depend on internal finance when outside finance is denied. According to Stiglitz and Weiss (1981), credit rationing is not neutral with respect to firm size. Because of adverse selection in a market with asymmetric information, the likelihood of a firm being subject to credit rationing decreases with its size. Especially since the work by Fazzari, Hubbard and Petersen (1988) a wave of empirical studies have emphasized the existence of liquidity constraints and found them, among other factors, to depend on firm size.

It seems probable that liquidity constraints are less severe or even non-existent in Germany, because of the close and longstanding lending relationships between firms and banks. In contrast to the more market-based system in the USA, the German financial institute system can be regarded as rather bank-based.[3] While there is some empirical evidence in the context of Q-models for an influence of liquidity constraints on the investment behaviour of German firms based on less well-suited sectoral data (Behr and Bellgardt (1998, 2000)), there is little evidence for German firms using firm-level panel data. Using the same firm-level data base, the user-cost approach of von Kalckreuth (2001) and Chirinko and von Kalckreuth (2002), provides evidence of the existence of cash flow effects. Based on a smaller sample of 213 firms using balance sheet data Harhoff (1998) finds week evidence of cash influence on investment.[4]

One of the few exceptions is the work of Audretsch and Elston (2002). Based on a small sample of 100 firms listed at the stock exchange they inquired “Does firm-size matter?” by analysing the investment behaviour of German firms within the framework of the Q-model. With special emphasis on the role of firm size, the authors found ambiguous evidence of the effect of firm size and cash flow on investment.

We extend the work of Audretsch and Elston through analysing a larger sample of 2,314 instead of only 100 firms and apply dynamic panel data estimation methods.

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3 See *Cable* (1985).

4 Since cash flow lagged one period is insignificant, but lagged two periods is significant, the results are difficult to interpret. The more so, as the remaining four variables of the accelerator investment equation are all statistically insignificant. (See *Harhoff* (1998), p. 437.)

II. Firm Size and Financing Investment

The links between internal funds and investment leads to the question whether cyclical economic movements are accelerated by "financial factors".[5] With respect to the financing of risky investment projects, asymmetrical information could lead to a gap between the costs of internal funds and those of external financing. A second issue is the importance of monitoring costs arising from asymmetrical information and incentive problems, and how firm's external financing costs will be affected by the nature of monitoring costs. Some models even predict cost advantages for firms monitored constantly by financial intermediaries, compared to firms not monitored in this manner.[6]

Stiglitz and Weiss (1971) point out that the riskiness of borrowing rises with the rate of interest which can encourage lenders to limit the supply of loans. Because the information available to lenders about a firm applying for a loan is, inter alia, dependent of firm size, it is reasonable to assume that the availability and cost of loans are also dependent on firm size.

In Germany, bank loans play a crucial role in financing corporate investment and the dependence on bank loans increases on average as firm size declines. The descriptive evidence shows that the average ratio of long-term bank debt to total debt is 0.14 for all firms in the sample. When splitting the data set into three classes according to firm size, measured as balance sheet total assets, into three classes, we find that the smallest firms have a ratio of 0.160, but the largest firms only 0.105. Therefore the relationship with banks is evidently stronger for small firms than for larger firms.

Relying on intermediation by banks could add a cost component to the costs of financing investment. On the other hand, the close relationship of German firms to their financing banks can be seen as a constant process of monitoring that could reduce the problem of asymmetrical information. Accordingly, the negative effect of firm size on the access to liquidity might be offset by the positive monitoring effect. This may cast doubt on the assumption of small German firms being more liquidity constrained than large firms. Indeed, it has been argued that this special institutional feature of the German financial system precludes liquidity

5 An overview is given in *Hubbard* (1998), see also *Bernanke, Gertler* and *Gilchrist* (1996) and *Gertler* (1988).

6 See *von Thadden* (1990) and *Cable* (1985).

constraints (Cable (1985)). Of course, monitoring is not costless and these additional costs again may, even with reduced asymmetrical information, drive a wedge between internal and external financing costs.

III. Deutsche Bundesbank's Corporate Balance Sheet Statistics

Since only a fraction of an economy's firms are quoted on stock markets, the concept of using stock market data to study corporate investment behaviour excludes the majority of firms from an empirical investigation.[7] The empirical analysis is based on financial statements statistics from the Deutsche Bundesbank.[8] The time period covered by our sample is from 1987 to 1998. The need for detailed schedules of fixed asset movements to apply an algorithm for calculating the capital stock at replacement costs, shrinks the available data to 2,314 firms included in the final estimations.[9]

IV. *Q* and Capital Stock at Replacement Values

One of the most important variables for the analysis of investment decisions is the capital stock. The challenge is to transform historical cost data depreciated not by economic considerations, but rather through tax oriented depreciation rates into unreported and probably unknown economically meaningful data at current replacement values. The basic idea of our algorithm is to split the current capital stock into two additive components.[10] The first component contains the vintages, which are still used and were already part of the capital stock at the beginning of the first year in the data set. The second component consists of the capital goods, which were invested during the period covered by the data set. The main problem is the transformation of existing capital stock at the beginning of the first year covered by the data set t_0 into values at replacement cost. By doing so, we disaggregate the capital stock into separate vintages for structures and equipment. Because the depreciation given in

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7 Apart from the argument of data availability, the empirical results using stock market data have been rather disappointing, see the overview by *Chirinko* (1993).

8 See *Deutsche Bundesbank* (1998) and *Stöss* (2001).

9 For details about cleaning procedures see the appendix.

10 For further details of the algorithm for calculating the capital stock at replacement values, see *Behr* and *Bellgardt* (2002). For a discussion of different algorithms suggested in the literature see *Lindenberg* and *Ross* (1981), *Lewellen* and *Badrinath* (1997).

the balance sheet data is driven mainly by tax considerations, it would lead to a severe underestimation of the lifetime of capital goods. Therefore, we use sectoral data which we assume will conform more to economic concepts. The vintages and investment in the following years, the letter being measured much more accurately, will be calculated through the use of the classic perpetual inventory method.

While the use of balance sheet data facilitates the study of the investment behaviour of a large number of heterogeneous firms, the unavailability of market values of shares necessitates the use of alternative measures to derive expected discounted values of future profits. We use the approach of Abel and Blanchard (1986) in estimating the market values of equity based on a VAR-forecasting model, while we use uncorrected balance sheet figures for debt.[11] The VAR-model contains three variables, pre-tax profits (PTP, x_1), sales (S, x_2) and cash flow (CF, x_3).[12] In our final estimates we make use of the forecasts based on a VAR containing one lag, but we obtain comparable results when using two lags.

In short notation the system of (seemingly) unrelated equations could be written as:

$$\mathbf{x}_{it} = \mathbf{A}\mathbf{x}_{i,t-1} + \varepsilon_{it}$$

Assuming a stationary process for each point of time *t*, the one-period-ahead forecast can be estimated by:

$$\hat{\mathbf{x}}_{i,t+1} = E\left[\mathbf{x}_{i,t+1} | \mathbf{x}_{it}\right] = \hat{\mathbf{A}}\mathbf{x}_{i,t}$$

and iterated further on.[13] Using these forecasts, the discounted value of future profits at time *t* can be calculated as follows, where it is assumed that profit is the first of the three variables used in the VAR[14]:

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11 This approach was extended to panel data by *Gilchrist* and *Himmelberg* (1995, 1998).

12 The use of pre-tax profits is inevitable, because the apparent tax rate often yields implausible values and enormous variance. This is due to the fact that the data base contains firms of different legal status and no information about the dividend policy and debit carried forward.

13 This formulation of the forecast process does not take into account the existence of individual fixed effects. Either these effects must be cancelled out by some data transformation (averaging or differencing) or they have to be explicitly estimated. Because of subtracting individual means in the final investment equation, the individiual fixed effects do not influence the investment equations. To assess the empirical values of *Q*, we estimate the fixed effects explicitly.

14 Instead of using an indefinite forecast horizon, our calculation ceases after 200 forecasting periods.

$$V_{i,t} = \sum_{\tau=1}^{\infty} E\left[x_{1i,t+\tau}|\mathbf{x}_{it}\right]\delta_{t,\tau}^{\tau}$$

$$\hat{V}_{i,t} = \sum_{\tau=1}^{\infty} \hat{x}_{1i,t+\tau}\delta_{t,\tau}^{\tau}$$

$$\text{with } \delta_{t,\tau}^{\tau} = \frac{1}{(1+r_{t,\tau})^{\tau}}.$$

In order to discount future profits, we use the capital market interest rate as a measure of the opportunity costs.[15] The estimated discounted value of future profits $\hat{V}_{i,t}$ is taken as part of the nominator to calculate firm and year-specific Q.[16]

The approach used in this paper is based on the formula used by Erickson and Whited (2000a) to calculate Tobin's Q for firm i at period t as the ratio of the market value of equity (V_{it}) plus the market value of outstanding debt (D_{it}) minus the replacement value of all remaining assets (apart from the capital stock) (N_{it}) to the replacement value of the capital stock (K_{it}):[17]

$$Q_{it} = \frac{V_{it} + D_{it} - N_{it}}{K_{it}}$$

While the direct forecasting approach is aimed to use all available information contained in balance sheet information, most comparable studies rely on market values of equity. Instead of modelling expectations explicitly, market values represent implicitly the expectations of market participants. A priori it is not known, which approach is more adequate. While it would be of interest to compare market values and explicitly estimated values of equity, to our knowledge no such comparison has been carried out in literature. But even a comparison would not settle the question, which estimates are to be preferred. Comparing our results with rather disappointing (Chirinko (1993)) empirical findings for the Q-

15 For each year we use the current term structure of capital market interest rates for 1 to 9 years maturity in order to calculate the present value of profits. For discounting forecasts beyond 9 years, the interest rate with a maturity of 9 years is used. In this respect we differ from earlier approaches (*Gilchrist* and *Himmelberg (*1995, 1998), *Bontempi* et al. (2001)), where a fixed interest rate for all years and for all maturities is assumed.

16 The forecasting procedure to calculate Q is conducted for the three sectors, manufacturing, construction and commerce separately.

17 The VAR-model the calculation of Q for individual firms is based on, was separately estimated for the three different sectors.

approach based on market values, at least does not suggest the direct forecasting approach being inferior.

V. Empirical Findings

We first present descriptive statistics before turning to regression results. Table 1 contains descriptive evidence relating to three size classes according to the firm's total assets. It can be seen that the investment ratio is highest for the small firms (16.5 %), while it is just below 13 % for the largest firms. The small firms yield the highest profitability measured by *Q*, as well as the highest sales to capital ratio. In contrast, the cash flow per unit of capital is well below average for the small of firms.

Throughout we use real total assets to indicate firm size. In this respect we deviate from Audretsch and Elston, who used the number of employees to measure firm size. While there is controversy over the appropriate indicator for size, we see real total assets as the most comprehensive measure of size.[18]

Table 2 contains linear correlations of the variables used in the following regression analysis. Beside real total assets, which is used to split the sample into classes of different size, we include the logarithm of real total assets, which is included as an additional regressor in some regressions. Since all estimated panel data models include fixed firm effects, the correlations of firmwise demeaned variables should be of interest. These correlations are given in the appendix.

We find that lagged investment and sales strongly correlate with investment, even slightly stronger than *Q*. For demeaned variables we find that *Q* shows the strongest correlation with investment (0.28).

Since the famous paper by Fazzari, Hubbard and Petersen (1988), supplemented *Q* equations are regarded as a suitable means of assessing liquidity effects on investment (see e. g. Blundell et al. (1992), Cleary (1999), Lang et al. (1991)). The significance found for the additional variables can either indicate that valuable information contained in variables like sales and cash flow is not captured by *Q*, or that firms are liquidity con-

[18] E. g. *Gilchrist* and *Himmelberg* (1995) and *Oliner* and *Rudebusch* (1992) use capital stock to split firms into groups according to "size". Since the capital stock is used as denominator for independent variable (investment ratio), this would result in a nonlinear negative relation by definition. Therefore we prefer real total assets.

Table 1

Descriptive Statistics for Classes by Firm Size
(Mean, Standard Deviation in Parentheses)

	All	*class 1 (smallest)*	*class 2*	*class 3 (largest)*
n	23,140	7,720	7,710	7,710
I/K	0.145 (0.18)	0.165 (0.22)	0.143 (0.17)	0.128 (0.13)
Q	1.592 (1.81)	1.792 (1.91)	1.518 (1.71)	1.465 (1.77)
S/K	5.979 (7.88)	8.253 (10.55)	5.317 (6.26)	4.365 (5.24)
CF/K	0.146 (0.92)	0.105 (1.22)	0.15 (0.79)	0.182 (0.66)
RTA	126.442 (959.94)	4.185 (2.84)	15.843 (9.31)	359.458 (1638.38)

Table 2

Linear Correlations

	I/K	$(I/K)_{-1}$	Q_{-1}	$(S/K)_{-1}$	$(CF/K)_{-1}$	RTA_{-1}	$\ln(RTA_{-1})$
I/K	1	0.25	0.19	0.25	0.07	–0.01	–0.06
$(I/K)_{-1}$	0.25	1	0.11	0.27	0.08	–0.01	–0.03
Q_{-1}	0.19	0.11	1	0.15	0.1	–0.03	–0.07
$(S/K)_{-1}$	0.25	0.27	0.15	1	0.09	–0.04	–0.17
$(CF/K)_{-1}$	0.07	0.08	0.1	0.09	1	0.01	0.05
RTA_{-1}	–0.01	–0.01	–0.03	–0.04	0.01	1	0.37
$\log(RTA_{-1})$	–0.06	–0.03	–0.07	–0.17	0.05	0.37	1

straint.[19] If there is a wedge between internal and external costs of finance or if the firm is financially constrained and unable to raise external funds to finance its investment, the availability of liquidity might

19 See the overview articles by *Chirinko* (1993) and *Hubbard* (1998).

influence investment. Relying on the latter interpretation, the significance of the cash flow parameter in Q investment equations is generally seen as an indication of the existence of capital market imperfections. Since the theoretically derived estimation equation contains solely Q as a sufficient statistic, we first estimate a static fixed effects model.

$$\widehat{\left(\frac{I}{K}\right)}_t = a_i + \underset{(40.07)}{0.0666}\, Q_{t-1} \qquad n = 23{,}140$$

As could be already expected regarding the correlation coefficient of demeaned variables (see appendix), Q exerts a significant influence on the investment ratio. While there is no formal derivation of a linear relationship between additional variables in the theoretically justified equation, we supplement the static equation with lagged investment ratio, lagged sales and lagged cash flow ratio. Ad hoc supplementing is common practice to test for linear influences of variables not contained in the explicitly derived investment equation (see e.g. Hubbard (1998), Harhoff (1998), Blundell et al. (1992), Oliner and Rudebusch (1992), von Kalckreuth (2001), Tahmiscioglu (2001)).[20] Hence, following this estimation strategy allows to compare empirical findings with previous findings in the literature.[21]

We commence the empirical analysis using the complete data set covering three main sectors: manufacturing, construction and commerce[22]. The following dynamic investment equations are estimated using a direct bias correction method[23] and in addition to Q contain sales (S) and cash flow (CF).[24]

$$\widehat{\left(\frac{I}{K}\right)}_t = a_i + \underset{(9.26)}{0.0626}\left(\frac{I}{K}\right)_{t-1} + \underset{(32.24)}{0.0548}\, Q_{t-1} + \underset{(21.79)}{0.0081}\left(\frac{S}{K}\right)_{t-1} + \underset{(0.78)}{0.0009}\left(\frac{CF}{K}\right)_{t-1} \qquad n = 23{,}140$$

20 Supplemented Q equations can be theoretically justified relaxing assumptions of perfect credit and product markets. E.g. *Schiantarelli* and *Georgoutsos* (1990) derive a Q-estimation equation including sales based on the assumption of imperfect competition in product markets.

21 Additionally it can be argued, that the omission of important variables, as especially sales turns out to be, leads to an omitted variable bias.

22 The sector "commerce" consists of wholesale and retailing.

23 For details see *Hansen* (2001) and *Behr* and *Bellgardt* (2002).

24 The comparable LSDV and GMM estimates are contained in the appendix.

The cash flow parameter is insignificant, but the sales variable indicates that there is still some relevant information in sales not captured by the measure of Q. The measure of profitability (Q) is far more powerful in explaining investment behaviour than sales and cash flow. Therefore, we interpret the result therefore as supporting evidence for the Q theory of investment. Since "the Q-model's empirical performance has been generally unsatisfactory",[25] the strongest influence of the Q measure hints for adequacy of the direct forecasting model.

The results do not suggest for the presence of an independent significant cash flow influence. This result differs from several findings in the literature. In several studies cash flow was found significant when added to Q investment equations.[26] When using a GMM estimating approach instead of the direct bias correction method, cash flow is even found to exert a negative influence on investment, if using all available observations. The result of no significant positive cash flow influence has from our point of view to be attributed to the direct forecasting approach used to derive "market" values of equity. Since cash flow is contained in the VAR model to extrapolate profits, information of cash about future profitability should be extracted, which is obviously less the case when relying on stock market prices of equity or using accelerator models.[27]

Next, we test whether firm size at the beginning of period (ln RTA), effects investment significantly. Therefore, the investment equation is supplemented with the logarithm of the real balance sheet total.

$$\left(\frac{\hat{I}}{K}\right)_t = a_i + \underset{(13.31)}{0.0769}\left(\frac{I}{K}\right)_{t-1} + \underset{(27.63)}{0.0483}\,Q_{t-1} + \underset{(22.13)}{0.0082}\left(\frac{S}{K}\right)_{t-1}$$

$$+ \underset{(1.08)}{0.0013}\left(\frac{CF}{K}\right)_{t-1} - \underset{(-14.57)}{0.0743}\ \ln RTA_{t-1} \qquad n = 23{,}140$$

We find that firm size has a strong and significant negative effect on investment, while the empirical results for the other variables are similar. This finding corresponds with the correlations of demeaned vari-

25 *Chirinko* (1993). See also comparative study by *Samuel* (1998), in which the Q-model is ranked worst among five competing investment models.

26 See e.g. *Fazzari, Hubbard* and *Petersen* (1988), *Chirinko* and *Shaller* (1995).

27 Of course now the critique of cash flow containing information about profits, which sheeds doubt on the interpretation of the liquidity effect interpretation can now be reversed. One might argue, that Q based on the direct forecasting approach could possibly contain pure liquidity effects. This point has still to be regarded as unsettled.

ables. The logarithm of real total assets is practically uncorrelated with the explanatory variables but correlates negatively with investment ratio (-0.17).[28]

In the following section we split the data set into sub samples according to firm size. When estimating dynamic investment functions for each of the three different classes of firms, we find several striking results. The larger the firm, the less its investment is influenced by Q, while its dependence on lagged investment increases.[29]

With respect to the cash flow influence, we find, somewhat unexpectedly, that only medium-sized firms react to cash flow by increasing investment. The cash flow parameter is not statistically significant for any group of firms. Using a different database and stock market data, Audretsch and Elston (2002) found a similar pattern, that medium-sized firms only exhibit cash-flow sensitivity.

In particular, the finding that the smallest firms reveal no change in investment spending in response to changes in their net wealth, contradicts the predictions of the information cost-model. According to the theoretical predictions of the model of asymmetric information, especially small firms should have the greatest informational disadvantages, leading to high information costs when depending on outside finance.

The finding of strong positive sales effects on investment can be either seen as indicating remaining information contained in sales on future profits not captured by Q or as indicating the presence of market imperfections in the product markets. Since sales turns out strongly significant even for the group of largest firms, this casts doubt on the latter interpretation.

It is also worth considering, whether firm size, measured as real total assets (RTA), has a direct influence on investment activity.[30] While the descriptive evidence suggests such a relationship, which was also found in the aggregate investment function, in the multivariate context, the partial effect of firm size on investment cannot be inferred from the aver-

28 Since all explanatory variables except "size" have the capital stock as denominator, they rather measure some kind of productivity than size. The sales to capital stock ratio, e.g. can be seen as measuring the sales productivity of the capital stock.

29 This effect might, of course, be partly due to the fact that several overlapping investment projects within larger firms will smooth out discontinuities.

30 See the appendix for data description.

Table 3

Q Investment Functions for Class Sizes
(Parameter, t-Value in Parentheses)

	All	*class 1 (smallest)*	*class 2*	*class 3 (largest)*
n	23,140	7,720	7,710	7,710
$(I/K)_{i,t-1}$	0.0626 (9.26)	0.0252 (2.16)	0.0635 (5.4)	0.152 (13.13)
$Q_{i,t-1}$	0.0548 (32.24)	0.0701 (21.45)	0.0544 (17.87)	0.0331 (15.06)
$(S/K)_{i,t-1}$	0.0081 (21.79)	0.006 (10.55)	0.0136 (17.31)	0.0105 (13.31)
$(CF/K)_{i,t-1}$	0.0009 (0.78)	–0.0022 (–1.05)	0.0029 (1.22)	–0.001 (–0.51)

age investment rates in the different size-classes. Table 4 contains the estimated investment functions, supplemented by lagged firm size.

When analysing the firms in the three different classes, the firm size itself shows a strong negative influence in all of them. This means that the negative partial relationship between firm size and investment is present within all classes of firms. The firm-size parameter, as well as its significance, decreases for larger firms. Again, no group of firms displays a significant reaction to cash flow.

Because the analysis so far was based on the data file containing firms of three very distinct broad sectors, manufacturing, construction and commerce, the value of the results presented so far may be questioned because of the very distinct features of firms belonging these different sectors. To investigate the existence of sectoral effects we split the data set according to these three main sectors.

Table 5 contains descriptive measures, the unweighted mean of firm individual rates and the standard deviation thereof. Firms belonging to different sectors are up to quite different production technologies and probably different investment behaviour.

It can be seen that the sales to capital ratio for commerce is almost three times the ratio of manufacturing and construction firms. While the

Table 4

Direct Influence of Firm Size

(Parameter, t-Value in Parentheses)

	All	*class 1 (smallest)*	*class 2*	*class 3 (largest)*
n	23,140	7,720	7,710	7,710
$(I/K)_{i,t-1}$	0.0769 (11.3)	0.0403 (3.44)	0.0827 (6.97)	0.1618 (13.92)
$Q^a_{i,t-1}$	0.0483 (27.63)	0.0624 (18.58)	0.0469 (14.95)	0.0288 (12.66)
$(S/K)_{i,t-1}$	0.0082 (22.13)	0.0061 (10.84)	0.0137 (17.56)	0.0108 (13.71)
$(CF/K)_{i,t-1}$	0.0013 (1.08)	–0.0016 (–0.79)	0.0028 (1.16)	–0.0013 (–0.64)
$\ln RTA_{i,t-1}$	–0.0743 (–14.57)	–0.0978 (–9.39)	–0.0823 (–9.45)	–0.0463 (–7.13)

sector construction has the highest investment ratio (17.1 %), it has the lowest Q, in average just about 1.2. The fact that construction firms are more than five times and manufacturing firms still 4.5 times larger than commerce firms is remarkable and means that a grouping by size has mainly the effect of varying shares of sectors in different classes by size. The following table contains the shares of these three sectors in the different classes by firm size.

The cross table makes evident, that the class of smallest firms contains a majority of firms belonging to the sector commerce (55 %), while the class of largest firms contains mainly manufacturing firms (73 %) and only 21 % commerce firms.

In the following we estimate dynamic investment functions supplemented by lagged total assets for the three sectors separately. It is evident that firms in each sector react most strongly on Q. We find that the strong negative effect of firm size on investment is present within the sectors manufacturing and commerce.

For construction firms only the negative effect is insignificant. The previous findings for the cash flow resemble. There is no significant posi-

Table 5

Descriptive Statistics by Sectors
(Mean, Standard Deviation in Parentheses)

	All	*Manufact.*	*Construct.*	*Commerce*
n	23,140	13,420	1,120	8,600
I/K	0.145 (0.18)	0.141 (0.16)	0.171 (0.18)	0.149 (0.2)
Q	1.592 (1.81)	1.517 (1.76)	1.201 (1.94)	1.76 (1.86)
S/K	5.979 (7.88)	3.509 (3.57)	4.364 (3.22)	10.045 (10.93)
CF/K	0.146 (0.92)	0.155 (0.77)	0.137 (1.03)	0.133 (1.10)
RTA	126.442 (959.94)	175.348 (1232.03)	209.561 (758.44)	39.302 (154.3)

Table 6

Share of Sectors in Classes by Size

Share of sectors	*All*	*class 1 (smallest)*	*class 2*	*class 3 (largest)*
Manufacturing	0.58	0.41	0.60	0.73
Construction	0.05	0.04	0.05	0.06
Commerce	0.37	0.55	0.35	0.21
All sectors	1	1	1	1

tive effect of cash flow present that could be interpreted as indicating financial constraints.

VI. Conclusion

In this paper, we analysed size effects on the investment behaviour of German firms within the framework of the Q-theory. Because of the use

Table 7

Average Q Investment Functions for Sectors Containing Real Firm Size
(Parameter, t-Value in Parentheses)

	All	*Manufact.*	*Construct.*	*Commerce*
n	23,140	13,420	1,120	8,600
$(I/K)_{i,t-1}$	0.0769 (11.3)	0.0921 (10.28)	0.0903 (2.97)	0.0189 (1.67)
$Q_{i,t-1}$	0.0483 (27.63)	0.0485 (21.79)	0.0496 (7.71)	0.0395 (12.79)
$(S/K)_{i,t-1}$	0.0082 (22.13)	0.0184 (18.12)	0.0247 (7.35)	0.0081 (17.18)
$(CF/K)_{i,t-1}$	0.0013 (1.08)	–0.0001 (–0.07)	–0.0089 (–1.76)	0.0017 (0.85)
$\ln RTA_{i,t-1}$	–0.0743 (–14.57)	–0.0789 (–12.58)	–0.0113 (–0.59)	–0.0909 (–9.83)

of anonymous individual firm balance sheet data, no stock market measure of Q is available. The database contained 2,314 firms covering the twelve years 1987 to 1998.

The descriptive evidence revealed small firms to have on average the largest investment ratios. When examining the effect of size on investment behaviour, the investment ratio of German firms is found to be significantly negatively related to total assets. This surprisingly strong effect is evident even within classes of different size.

While the study provides strong evidence of a significant negative effect of firm size on investment, the results relating to cash flow influence do not suggest severe liquidity constraints, which would otherwise indicate the existence of a balance sheet channel for monetary effects.

In view of the theoretical discussion of information costs, the finding that even the smallest of firms are not subject to liquidity constraints is surprising, but confirms the results obtained by Audretsch and Elston (2002). One possible explanation might be the particular features of the German bank-based financial system being especially supportive of the smallest firms.

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Appendix

Data Description

Cash flow is measured as net income plus depreciation plus change in provisions.

To prevent outliers biasing the results we drop the upper and lower 0.5 % of the observations of the following nine variables:

– ratio of aggregated investment to the aggregated capital stock,
– ratio of investment in equipment to the capital stock of equipment,
– ratio of investment in structures to the capital stock of structures,
– ratio of pre-tax profits to the capital stock,
– ratio of sales to the capital stock,
– ratio of cash flow to the capital stock,

and in a second filtering procedure of

– average Q.

The balancing of the data after eliminating the outliers leaves 2,344 firms in the sample. Because of lags, the period available covers 10 years, 1989–1998.

Throughout the analysis we use with one exception all variables at nominal values. The reason for doing so is the use of ratios in the investment equation:

$$\left(\frac{\hat{I}}{K}\right) = a_i + \beta_1 \left(\frac{I}{K}\right)_{-1} + \beta_2 Q_{-1} + \beta_3 \left(\frac{S}{K}\right)_{-1} + \beta_4 \left(\frac{CF}{K}\right)_{-1}$$

By dividing through the capital stock, the resulting ratios contain the relevant information for the investor (according to our understanding). We do not see a ratio of e.g. Sales in prices of year $t-k$ to the capital stock at prices of year $t-k$ as relevant information to the investor. With the same reasoning, we do not believe an investor would decide about investment in prices of year $t-k$ divided by the capital stock in prices of year $t-k$.

The use of nominal values has practical reasons as well. There is neither firm-level price information to deflate the nominal values, nor do all variables (think about the cash flow) have the structure of a product of prices multiplied by quantities. Therefore the use of constant prices might lead to unrealistic figures and misleading results. Because firm-level price data is not available, one might consider using sectoral price information, which is available for some of the variables. This procedure could only be applied to some variables (*I, K*) and not to others (*CF*, market value of the capital stock).

Therefore, an alternative method would be the use of an economy-wide price measure e.g. the price index of final national uses to prevent trends in the data from merely increasing price levels. Of course, for the ratios, these price indices would cancel out. The only variable we use in real values, is the balance sheet total as a measure of firm size. Here, we use the price index of final national uses.

Table A1

Linear Correlations, Firmwise Demeaned Variables

	I/K	$(I/K)_{-1}$	Q_{-1}	$(S/K)_{-1}$	$(CF/K)_{-1}$	RTA_{-1}	$\ln(RTA_{-1})$
I/K	1	0.06	0.28	0.25	0.03	–0.02	–0.17
$(I/K)_{-1}$	0.06	1	0.06	0.33	0.04	0	0.09
Q_{-1}	0.28	0.06	1	0.21	0.05	–0.05	–0.32
$(S/K)_{-1}$	0.25	0.33	0.21	1	0.06	0	–0.04
$(CF/K)_{-1}$	0.03	0.04	0.05	0.06	1	–0.01	0.05
RTA_{-1}	–0.02	0	–0.05	0	–0.01	1	0.16
$\log(RTA_{-1})$	–0.17	0.09	–0.32	–0.04	0.05	0.16	1

GMM-Estimates

Table A2

Average Q Investment Functions for Sectors Containing Real Firm Size
(Parameter, t-Value in Parentheses)

	All	*Manufact.*	*Construct.*	*Commerce*
n	18,512	10,736	896	6,880
$(I/K)_{i,t-1}$	0.0461 (4.27)	0.0598 (4.92)	0.0218 (2.52)	–0.0166 (–1.24)
$Q_{i,t-1}$	0.0294 (5.16)	0.0250 (3.79)	0.0562 (29.3)	0.0105 (1.45)
$(S/K)_{i,t-1}$	0.0054 (6.34)	0.0106 (6.02)	0.0221 (12.1)	0.0066 (8.01)
$(CF/K)_{i,t-1}$	–0.0106 (–2.22)	–0.0069 (–1.24)	–0.0229 (–10.7)	0.0095 (0.93)
$\ln RTA_{i,t-1}$	–0.1093 (–2.78)	–0.1674 (–4.26)	–0.0474 (–3.98)	–0.2137 (–3.97)
Sargan	0.000	0.000	0.474	0.001
AR(2)	0.349	0.739	0.962	0.595

We use as GMM-instrumentes the investment ratio lagged at least two periods and the remaining variables at least one further period. The equations show no sign of second order autocorrelation. The Sargan test for indicates problems of overidentifying restrictions. For comparability we use the same set instruments for all equations.

Summary

Firm Size Matters – An Analysis of Size Effects on Investment Using Firm-level Panel Data

We analyse the effect of firm size on the investment behaviour of German firms within the framework of the Q-theory. Our database contains 2,314 firms covering the time period 1987 to 1998. Descriptive evidence shows small firms to reveal the highest investment ratios. Estimating dynamic Q-investment functions we find very strong negative effects of firm size on investment. The strong negative effect is prevailing even within subgroups of firms based on sector and size. The evidence on the role of cash flow is week. Especially small firms seem unaffected by cash flow, after controlling for investment opportunities via Q. (JEL E22, G32, L00)

Zusammenfassung

Größeneffekte im Investitionsverhalten – Eine Untersuchung auf Basis von Mikrodaten

Im Rahmen der Q-Theorie wird der Einfluss der Unternehmensgröße auf das Investitionsverhalten von Unternehmen untersucht. Die Datenbasis bilden Bilanzdaten von 2314 Unternehmen der Jahre 1987 bis 1998. Als deskriptiver Befund ergibt sich, dass kleinere Unternehmen im Vergleich zu größeren Unternehmen deutlich höhere Investitionsraten aufweisen. Dynamische Panelschätzungen zeigen einen signifikant negativen Einfluss der Unternehmensgröße auf die Investitionstätigkeit. Der Größeneffekt ist auch innerhalb von Unternehmensgrößenklassen und Sektoren signifikant negativ. Für den Cash-flow zeigt sich, selbst für die Gruppe der kleinsten Unternehmen, ein nur sehr schwacher Einfluss auf das Investitionsverhalten.