Zeitschrift für Wirtschafts- u. Sozialwissenschaften (ZWS) 113 (1993), S. 579 - 595
Duncker & Humblot, Berlin

An Empirical Analysis of West German Corporate Investment Decisions Using Company-Level Panel Data*

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In dem Papier wird zunächst ein um Finanzierungsaspekte erweitertes q-Modell der Investition präsentiert. Im Anschluß daran wird die sich ergebende Investitionsfunktion unter Verwendung einzelwirtschaftlicher Unternehmensdaten für die Bundesrepublik Deutschland ökonometrisch geschätzt.

I. Introduction

In the past decade we have experienced a world-wide divergence of stock market activity and economic development. In the past in West Germany asset prices indicated economic up- and down-turns fairly stably one year in advance. This empirical fact has led to a recent rush to implement q-based investment equations in West Germany. This tight pattern between asset prices and real economic activity, however, is loosened considerably within the 1980s. Two fields of interesting questions are posed by this structural break in this relationship. One field might concern the forecasting aspect of the loss of "asset prices" as a leading indicator of economic performance. Secondly, since we are in fact discussing the interaction of financial and real factors, there is a necessity for further analysis of the structure of an economy in these terms. This paper is concerned with the effects of financial markets on investment expenses. It is laid out as follows. In section II the intertemporal optimisation problem of the firm is extended to take account of (potential) financial constraints. Section III contains a survey of methods of estimation focusing application as well as the empirical results. The final section provides a brief summary and some conclusions.

* The research was supported by the German National Science Foundation (Deutsche Forschungsgemeinschaft) under grant number Fu 178/2-1. The second author also acknowledges support from a Heisenberg Fellowship and the London Business School Centre for Economic Forecasting under ESRC grant number WB01250034. The paper has been presented at the annual meetings of the European Economic Association in Cambridge (August/September 1991) and the Verein für Socialpolitik in Lugano (October 1991). Final responsibility for the contents rests solely with the authors.

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II. Optimal capital accumulation for the constrained firm

Consider a price-taking firm acting to maximise the present value of cash flows, V:

$$V(0) = \int_0^\infty [p(t)\,Y(t) - w(t)\,L(t) - p^I(t)\,I(t)]\,e^{-rt}\,dt, \tag{1}$$

where p, w, and p^I are the prices of output, labour, and investment goods, respectively; L, I, and Y are labour, investment and output and r is the (constant) interest rate.

The firm is assumed to have a putty putty constant-returns-to-scale production function:[1]

$$Y(t) = F[K(t), L(t)], \qquad \forall t, \tag{2}$$

and, following Hayashi, we introduce an adjustment cost function with constant returns by assuming[2]

$$\dot{K}(t) = \psi[I(t), K(t)] - \delta K(t), \qquad \forall t. \tag{3}$$

I units of gross investment do not necessarily turn into capital; only $\psi \times 100$ per cent does. In other words, $\psi(\cdot)$ represents the *effective* accumulation rate.

The point of departure from the basic q-theoretic framework is the explicit introduction of *financial factors* into our model. The budget constraint of the firm implies that the firm is facing bankruptcy when

$$pF(K, L) - wL - p^I I + BL < 0, \tag{4}$$

where BL is the borrowing limit set by the banks and bondholders.[3] Given the risk of financial distress the banking sector will pay attention to indicators of *solvency* and *liquidity* as a matter of principle and may bring

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[1] $F(\cdot)$ is assumed to have continuous first- and second-order partial derivatives of the form $F_K > 0$, $F_L > 0$, $F_{KK} < 0$, $F_{LL} < 0$, $F_{KL} > 0$. Additionally, the Inada conditions which bound K and L away from zero are fulfilled, i.e. $F_L(K, 0) = F_K(0, L) = \infty$ for positive K and L.

[2] The installation function is defined as in *Hayashi* 1982 and must satisfy the following conditions: $\psi(0, K) = 0$, $\psi_I(I, K) > 0$, $\psi_{II}(I, K) < 0$, $\psi_I(0, K) \leq 0$, $\psi_{IK}(I, K) > 0$.

[3] A central question is why bankruptcy should ever occur if the process involves real costs (transactions costs of liquidation and/or reorganization). In such circumstances avoiding financial distress is always in the interest of the claimants (bank lenders, bondholders and equity holders) of the firm taken as a whole. Liquidation therefore occurs only because there is a conflict of interest among the various claimants and an asymmetry in their negotiating and controlling abilities. These differences are addressed, for example, by *Bulow/Shoven* 1978.

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external financial constraints to bear. With given equity capital there is therefore necessarily an upper limit to the firm's potential to finance investment.[4] As it stands, equation (4) is tautological so far, for we haven't actually specified the crucial variable, BL. To incorporate the variable BL into the present model, we suppose that the (potential) borrowing limit depends upon Altman's *Z-score model* indicator.[5] We suppose that the Z-variable has the form

$$(5) \qquad Z = Z(K, D, r, w, V^E), \qquad Z_K > 0, Z_V{}^E > 0, Z_D < 0, Z_r < 0, Z_w < 0,$$

where V^E is the market value of equity and D is the level of debt.[6] The sequence of possible external financial constraints can then be written as a threshold value $Z^*_{t=0,\ldots,\infty}$.[7]

The firm's optimisation problem is therefore to maximise (1) subject to the constraint of the technology (2) and the law of motion for the capital stock (3); additionally, we now add the (potential) financial constraint it faces.

$$(6) \qquad V(0) = \int_0^\infty [p(t)\,Y(t) - w(t)\,L(t) - p^I(t)\,I(t)]\,e^{-rt}\,dt,$$

subject to

$$\begin{aligned} \dot{K}(t) &= \psi[I(t), K(t)] - \delta K(t), && \forall t, \\ Y(t) &= F[K(t), L(t)], && \forall t, \\ Z(t) &\geq Z^*, && \forall t. \end{aligned}$$

[4] There are also other lines of argument. The literature on credit rationing by banks and other lenders may help explain the limits to corporate borrowing. See, for example, *Jaffee/Russell* 1976 and *Stiglitz/Weiss* 1981, 1983. *Greenwald/Stiglitz/Weiss* 1984 extend the credit rationing result to show that rationed borrowers cannot resort to equity financing without increasing cost of capital. Additionally, investment decisions by a levered firm may be inefficient because there may be investments that raise firm value but lower share value and vice versa implying *agency costs* of debt. As the level of debt increases, the investments adopted may tend more and more to deviate from those that maximize the joint interests of both stockholders and bondholders, i.e. the degree of inefficiency may increase and can result in creditors' limiting the amount of money they will lend to the firm. Finally, the argument is compatible with the role of bond covenants in the control of bondholder-stockholder conflicts analyzed by *Smith/Warner* 1979.

[5] See *Altman* 1968, 1977 and *Brealey/Myers* 1988, 732. Higher Z-scores imply higher solvency. In Altman's sample of U.S. companies the average nonbankrupt firm had a Z-score of 4.89, while the average bankrupt firm had a Z-score of -0.26 one year before bankruptcy.

[6] *Myers* 1977, for example, has argued that a firm's capacity to issue debt is closely related to its assets-in-place. A more precise definition of the variable Z is given in the data Appendix.

[7] The assumption of potentially binding financial constraints is nowadays a standard practice in order to incorporate financial considerations into investment models. See *Whited* 1990 for example.

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Following *Seierstad/Sydsæter* 1987, we can write the Lagrangean, $\mathscr{L}$, (ignoring timescripts) as[8]

$$\text{(7)} \qquad \mathscr{L} = pF(K, L) - wL - p^I I + \lambda[\psi(I, K) - \delta K] + \mu[Z^* - Z(\cdot)],$$

and the first-order conditions are:

$$\text{(8)} \qquad K: d(\lambda e^{-rt})/dt = -\partial \mathscr{L} e^{-rt}/\partial K$$

$$\Rightarrow \dot{\lambda} = \lambda[r + \delta - \psi_K(\cdot)] - [pF_K(\cdot) - \mu Z_K(\cdot)],$$

$$\text{(9)} \qquad L: \partial \mathscr{L}/\partial L = 0 \qquad \Rightarrow pF_L(\cdot) = w,$$

$$\text{(10)} \qquad I: \partial \mathscr{L}/\partial I = 0 \qquad \Rightarrow p^I = \lambda \psi_I(\cdot),$$

$$\text{(11)} \qquad Z^* \leq Z(\cdot); \qquad \mu \geq 0 \qquad \text{with complementary slackness.}$$

Finally, the solution to the firm's optimisation problem must also satisfy the transversality condition:

$$\text{(12)} \qquad \lim_{t \to \infty} K(t) \lambda(t) e^{-rt} = 0.$$

Equation (8) says that λ is the present discounted value of future profits resulting from an extra unit of capital. The additional profits result not just from extra productive capacity represented by the term $pF_K(\cdot)$ but also from installation cost savings represented by the $\psi_K(\cdot)$ term. μ reflects the fact that the firm may be financially constrained, which creates a wedge between $\lambda(t)$ and the discounted marginal revenue products the firm would earn in a situation of no financial constraints. Equation (9) is the well-known marginal productivity of labour condition. (11) simply says that the Z-score variable cannot be lower than Z^*. When actual Z does so μ becomes positive reflecting the firm being constrained. Condition (10) allows for a first characterisation of the optimality condition for investment:[9]

$$\text{(13)} \qquad \lambda(t)/p^I(t) = 1/\psi_I(t) \qquad \Rightarrow$$

$$\text{(14)} \qquad I(t)/K(t) = \ell[q(t)] \qquad \text{with} \qquad q = \lambda(t)/p^I(t).$$

Just as in *Hayashi* 1982, the optimal investment rate is a function of *marginal q*, which is represented by the ratio of $\lambda(t)$ to $p^I(t)$.

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[8] The problem of maximization subject to an inequality constraint is solved by introducing a new Lagrangean multiplier to take account of the additional (potential) constraint.

[9] If there are no adjustment costs, i.e. $\psi_I(\cdot) = 1$, then the market value of the firm would increase by λ for one additional unit of investment.

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It is now straightforward to derive the relationship between *marginal q* and *average Q*. We will use a proof similar to that given by *Hayashi* 1982, in particular we are also assuming linear homogeneity of both the production and the installation cost function. Differentiating the expression for the stock market value of the firm gives[10]

$$\dot{V} - rV = -(pY - wL - p^I I) \tag{15}$$

$$= \{ p [F_K(\cdot) K + F_L(\cdot) L] - wL - p^I I \},$$

using the constant returns to scale property of the production function. Substituting for $F_K(\cdot)$, $F_L(\cdot)$, $p^I I$, cancelling and collecting terms:

$$-(\dot{V} - rV) p = -p \dot{\lambda} K + p \lambda K (r + \delta) - p \lambda [\psi_K(\cdot) K + \psi_I(\cdot) I] + p \mu Z_K(\cdot) K. \tag{16}$$

Using the adjustment cost function with constant returns

$$\psi_K(\cdot) K + \psi_I(\cdot) I = \psi(\cdot) = \dot{K} + \delta K, \tag{17}$$

and substituting we deduce

$$(\dot{V} - rV) = \dot{\lambda} K + \lambda \dot{K} - \lambda r K - \mu Z_K(\cdot) K, \tag{18}$$

$$(V - \dot{\lambda} K) = r (V - \lambda K) - \mu Z_K(\cdot) K. \tag{19}$$

By integration we obtain the relationship between *marginal q* and *average Q*:

$$V - \lambda K = \int_t^\infty \{ \mu(S) Z_K(\cdot) K \} e^{-r(s-t)} ds \quad \Rightarrow \tag{20}$$

$$\frac{\lambda}{p^I} = \frac{V}{p^I K} - \frac{\int_t^\infty \{ \mu(s) Z_K(\cdot) K \} e^{-r(s-t)} ds}{p^I K} \quad \Rightarrow \tag{21}$$

$$q = Q - \frac{\int_t^\infty \{ \mu(s) Z_K(\cdot) K \} e^{-r(s-t)} ds}{p^I K}. \tag{22}$$

In this generalisation of *Hayashi*'s 1982 popular result the equality of marginal q and average Q is augmented by a new term which depends on the indicator of solvency $Z(\cdot)$. For empirical purposes it is therefore not suffi-

[10] Similar derivations are given in *Precious* 1987, 65-6.

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cient to simply compile average Q but the extent of financial solvency must also be determined. In other words, in the presented set-up we can invoke a new explanation of financial variables in Q-type investment equations.

III. Empirical results

(a) Data

The empirical analysis employs 1983 through 1987 cross-sectional data for 80 large quoted West German industrial and commercial companies. The data are drawn from two principal sources. Balance sheet and profit and loss account data are obtained from the *MicroEXSTAT* international database which has been developed by Extel Financial Ltd. in conjunction with the London Business School. Any data missing from the EXSTAT file are taken from the *Hoppenstedt* publications. From the total sample in the database we deleted all firms that did not have a complete record on the variables included in our analysis.[11]

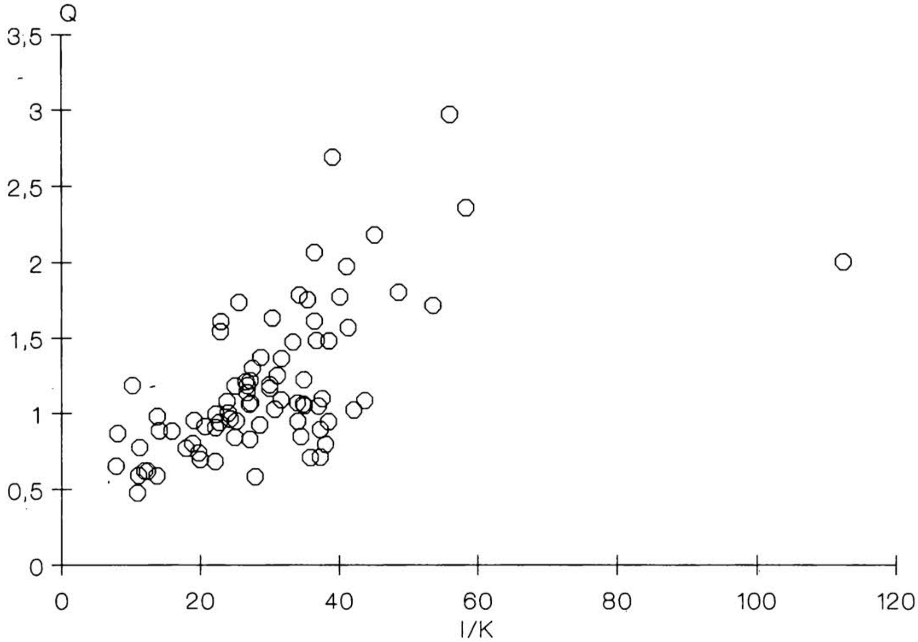

Figure I: Cross-Sectional Analysis of (I/K) and Q

[11] The equity of all remaining 80 firms is publicly traded on the Frankfurt Stock Exchange. A list of the companies included is provided upon request. The exact definition of the data is explained in the Appendix.

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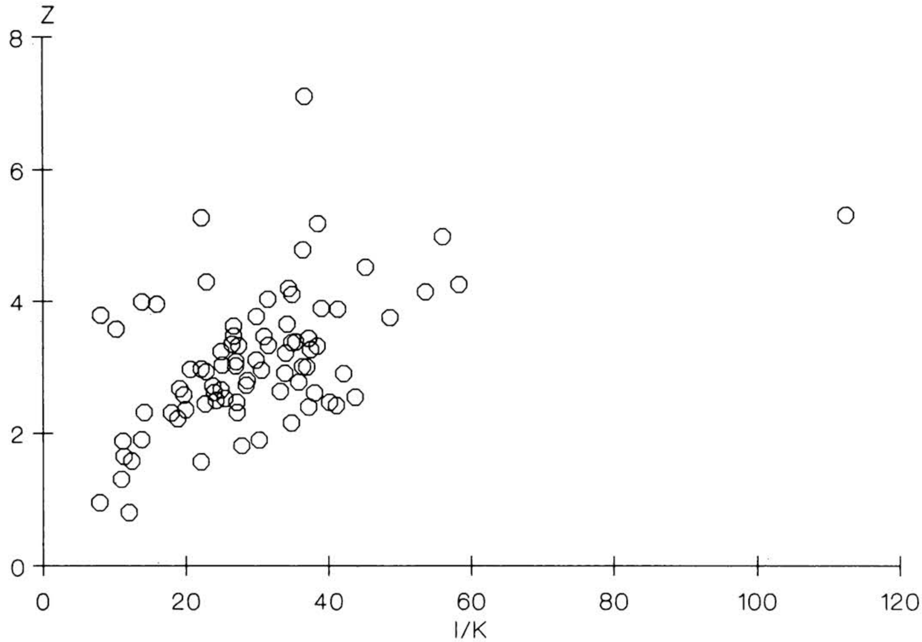

Figure II: Cross-Sectional Analysis of (I/K) and Z

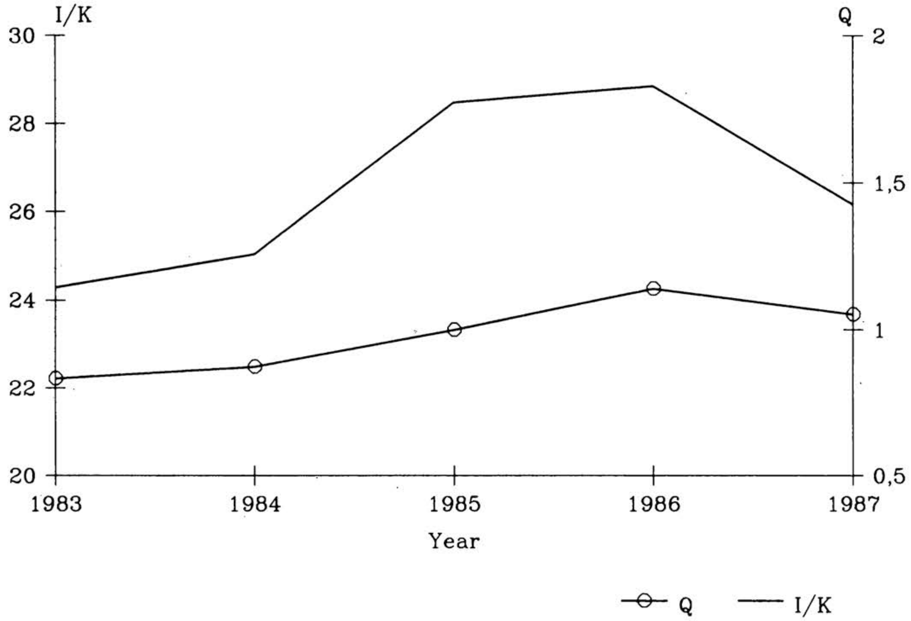

Figure III: Time Series Development of (I/K) and Q

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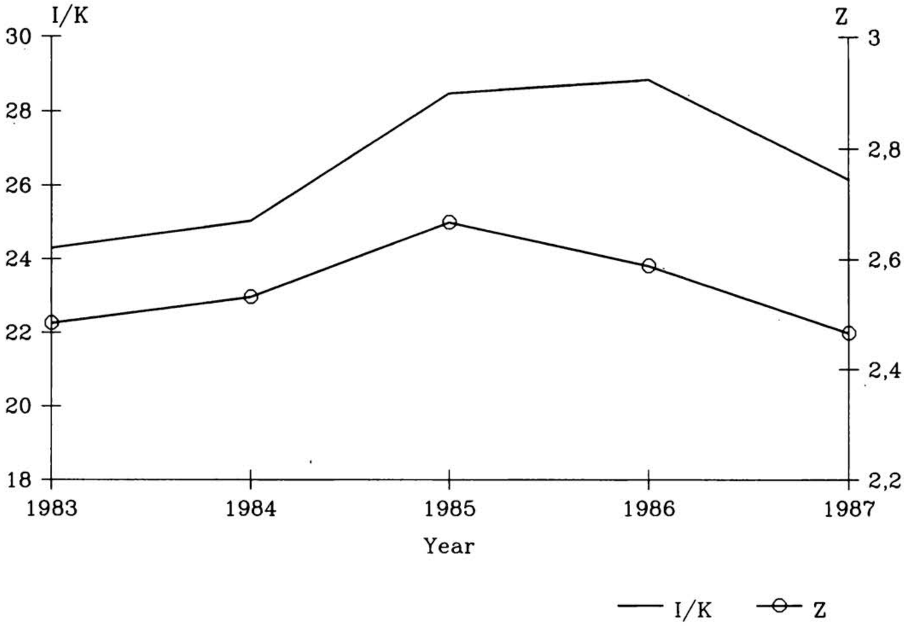

Figure IV: Time-Series Development of (I/K) and Z

The two scatter diagrams illustrate the relationship between the investment rate (I/K) and Q or Z. Each point represents a value pair of one company. The values pairs contain five-year averages of investments and Q's or Z's. Tobin's Q theory lets us expect the pattern in Figure I, which exhibits strong positive correlation between investment expenses and Q. Clearly, as can be seen in figure II, investments and Altman's Z-score variable are also positively correlated.[12] Figure III and IV are the time series complements to figure I and II. They contain weighted (I/K), Q and Z averages for each sample year.[13] It is apparent that (I/K) and Q run parallel, while there seems to be a one period lag between (I/K) and Z.

(b) Empirical methodology

The first model used in the empirical work is the so-called *covariance model*. The idea behind the covariance model is that each cross-sectional unit is characterised by its own intercept. This feature is incorporated into

[12] Both figures show an outlier arising from a company which has undertaken significant extraordinary depreciation within the sample period. Excluding the firm from our sample does not alter the qualitative results reported below. The econometric results for the panel data set excluding the outlier are given in footnote 22.

[13] Each firm has been weighted with its share in total fixed assets.

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the regression equation by the introduction of binary dummy variables. If the sample data are represented by observations on N ($i = 1, 2 \ldots, N$) cross sectional units over T ($t = 1, 2, \ldots, T$) periods of time the equation to be estimated then becomes

$$(23) \qquad Y_{it} = \sum_{j=1}^{N} \beta_{1j} D_{jt} + \sum_{k=2}^{K} \beta_k X_{kit} + \varepsilon_{it}, \qquad \varepsilon_{it} \sim N(0, \sigma^2),$$

where the β_k represent the slope coefficients that are common to all cross-sectional units, Y_{it} is the dependent variable, the X_{kit} are the explanatory variables, and D_{jt} are (0,1)-dummy variables taking values of 1 for the i^{th} cross-sectional unit and zero otherwise. Specifically,

$$(24) \qquad D_{jt} = \begin{cases} 1 & \text{if } j = i \\ 0 & \text{otherwise} \end{cases}.$$

Several features can be discerned at this point. In this approach a dummy variable corresponding to each firm takes the value 1 for observations on firm j but zero for observations on all other firms, i.e. the equality of the slope coefficients from one cross-section to another is accepted, but it is assumed that the intercepts differ. This specification is an attempt to adjust for missing independent variables in the model. A well-known feature of this model is that the least squares estimator of β is consistent.

A different approach when pooling time-series and cross-sectional data is the so-called *error-component model*. The basic assumption here is that the regression disturbance is composed of two independent components – one component associated with the cross-sectional units, and the second associated with time *and* the cross-sectional units.

$$(25) \qquad Y_{it} = \beta_{1i} + \sum_{k=2}^{K} \beta_k X_{kit} + \nu_{it},$$

$$(26) \qquad \nu_{it} = u_i + \varepsilon_{it},$$

where

$$(27) \qquad u_i \sim N(0, \sigma_u^2),$$

$$(28) \qquad \varepsilon_{it} \sim N(0, \sigma_\varepsilon^2),$$

and the components u_i and ε_{it} satisfy the following conditions:[14]

[14] The following assumptions imply that ν_{it} is homoskedastic with variance $Var(\nu_{it}) = \sigma^2 = \sigma_u^2 + \sigma_\varepsilon^2$.

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$$(29) \qquad E(u_i \varepsilon_{it}) = 0,$$

$$(30) \qquad E(u_i u_j) = 0, \qquad (i \neq j),$$

$$(31) \qquad E(\varepsilon_{it} \varepsilon_{is}) = E(\varepsilon_{it} \varepsilon_{jt}) = E(\varepsilon_{it} \varepsilon_{js}) = 0, \qquad (i \neq j; \quad t \neq s).$$

Feasible estimation of the model is possible using GLS or Aitken estimators.[15]

Finally, the question which model is appropriate for the underlying data generating process can be decided on grounds of statistical tests. The *error-component model* is based on the assumption of the presence of specific cross-sectional effects. A diagnostic test statistic is *Breusch/Pagan*'s 1980 Lagrange multiplier test statistic

$$(32) \qquad LM = \frac{NT}{2(T-1)} \cdot \left\{ \frac{\sum_i (\sum_t \varepsilon_{it})^2}{\sum_i \sum_t \varepsilon_{it}^2} - 1 \right\}^2 \sim \chi^2(1).$$

This is a test of the *error-component model* against the classical regression model *without* cross-sectional dummy variables.[16] A further test is *Hausman*'s 1978 chi-squared statistic for testing whether the *error-component model* (*GLS*) is an appropriate alternative to the *covariance dummy variable model* (*OLS*). Because both $\hat{\beta}_{GLS}$ and $\hat{\beta}_{OLS}$ are consistent estimators when the assumptions of the error components model hold, but only $\hat{\beta}_{OLS}$ is consistent *and* efficient when the u_i and X_i are correlated, a test of whether the *GLS* estimator is an appropriate alternative to the least squares estimator can be based upon the difference $\hat{\beta}_{GLS} - \hat{\beta}_{OLS}$. The test statistic and its asymptotic distribution become

$$(33) \qquad H = (\hat{\beta}_{GLS} - \hat{\beta}_{OLS})' [Var\{\hat{\beta}_{OLS}\} - Var\{\hat{\beta}_{GLS}\}]^{-1} (\hat{\beta}_{GLS} - \hat{\beta}_{OLS}) \sim \chi^2(K),$$

where K is the number of explanatory variables (excluding the constant term).[17]

(c) Regression results

The general form of the reduced-form investment equation that we examine is

$$(34) \qquad (I/K)_{it} = f(Q)_{it} + g(Z)_{it} + \varepsilon_{it},$$

[15] *Swamy/Arora* 1972 have shown that there are an infinite number of asymptotically efficient estimators for this model.

[16] Large values of the test statistic *LM* favour the error component model.

[17] See *Hausman* 1978 and *Judge* et al. 1988, 490 for further details. Further information on testing is provided in *Taylor/Hausman* 1981. Large values of *H* weigh in favor of the fixed effects dummy variable model.

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where $(I/K)_{it}$ represents the investment rate in plant and equipment for firm i during period t; Q represents Tobin's *average* Q-value and ε is a white-noise error term. The function $g(\cdot)$ depends on the solvency indicator Z; it represents the sensitivity of investment to financial factors. All variables are logged. Table I reports on the results of regressions involving 400 observations of individual firms. Initially, in estimating equation (34) we have allowed for a richer dynamics. In particular, we also entered both current and lagged values of Q and Z. The coefficients of the lagged variables, however, were generally insignificant.[18] In view of this fact and no hint of serial correlation in the error term[19] we decided to simply drop the lagged explanatory variables.[20]

Table I

Investment Rate as a Function of Q and Z

Variable	Fixed Effects Model		Random Effects Model
	Constrained	Unconstrained	
Constant	2.77	–	2.68
	(33.6)		(23.7)
Q_t	0.55	0.34	0.46
	(7.47)	(2.7)	(5.0)
Z_t	0.40	0.65	0.49
	(5.2)	(3.9)	(4.7)
R^2	0.33	0.69	0.33
SSR	90.36	42.67	90.75
Diagnostics:	$F(79, 318) = 4.50$		
	$LM = 130.16$		
	$H = 2.57$		

Note: The results were estimated by LIMDEP which is the copyright of W. Greene. The dependent variable is $(I/K)_{it}$. Sample period is 1983 to 1987; 80 companies; 400 observations. The fixed company dummies in the specification in column 2 are not reported. t-values are given in parantheses. The F-statistic tests the null hypothesis that the company dummies are all equal. Both the LM and the H test statistic are explained in the text.

[18] The coefficients of the lagged variables (t-statistics in parantheses) were: $Q_{t-1} = -0.01$ (0.1); $Z_{t-1} = 0.24$ (1.5).

[19] We have checked whether it is desirable to correct for autocorrelation in the pooled model. When re-estimating the equations assuming an $AR1$ error term, RHO was estimated to be 0.0003. Finally, we also considered the possibility that the adjustment cost function was non-separable and/or nonlinear by adding real wages (w/p) and/or Q^2 to the equations. The coefficients of the additional variables were, however, generally insignificant.

[20] The rather fast "speed of reaction" in the final specification is consistent with the descriptive data analysis presented above.

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The results shown in Table I are encouraging and enlightening. All Q and Z coefficients are clearly significantly positive with *average* elasticities ranging from 0.34 to 0.55 for Q and 0.40 to 0.65 for Z. In other words, all of the estimates are noticeably superior to the estimates of a traditional q-type investment function. The diagnostic tests reported at the bottom of Table I were considered to test the three specifications against each other. The F-test is applied to determine if separate intercepts are required. For (79,318) degrees of freedom and a 5 percent significance level, the critical F-value is $1.32 < 4.50$, so we reject the null hypothesis that all intercepts of the 80 firms' investment functions are the same. Table I also summarizes the Breusch/Pagan and the Hausman tests. At the 5 percent significance level the critical value for the LM statistic is $\chi^2\,(1) = 3.84$, so we clearly reject the null hypothesis $\sigma_u^2 = 0$. Finally, the chi-squared H-statistic also weighs in favour of the random coefficients model.[21] The elasticities in the preferred equation suggest that a 10 percent increase in the valuation ratio (Z-score variable) resulted *on average* in a corresponding 4.6 (4.9) percent change in the investment rate.[22]

Finally, we present additional evidence that probes somewhat deeper into the ways in which lower Z-score values influence investment spending. The test uses the Z values to identify firms that should be less likely, and more likely, to face bankruptcy and information-based constraints. We then estimate equation (34) *separately* for both sub-samples of firms. The 80 firms are split into the two groups according to their 1983 Z-score value. The most solvent 25 firms are placed in the *group H,* and the remaining 55 firms are assigned to the less solvent *group L.*[23] The typical firms of groups H and L are different in asset size. The average capital stock measure for the firms in *group H* is 0.45 times as large the average capital stock for those firms in *group L.* This implies that the chosen classification scheme does *not* simply pick up a size effect.

The regression analysis conducted with the sample split confirms the theoretical considerations. Z has a much more pronounced effect on invest-

[21] This superiority of the random coefficient model is in line with recent research analysing the small-sample properties of various panel data estimators. When considering the choice between fixed or random u_i *Taylor* 1980 has shown that even in moderately sized samples ($T \geq 3$, $N - K \geq 9$; $T \geq 2$, $N - K \geq 10$) the *GLS* estimator has smaller variances.

[22] When re-estimating the models excluding the outlier company which is apparent in Figure I and II, again the random coefficient model was the preferred specification and the estimated coefficients (t-values in parantheses) for Q_t and Z_t were 0.35 (4.1) and 0.51 (5.2), respectively.

[23] This sample splitting is the methodology adopted in recent empirical work on this topic, notably *Cantor* 1990, *Fazzari/Hubbard/Petersen* 1988 and *Whited* 1990. The finally chosen split is essentially an arbitrary cutoff point. Experimentation with other methods of splitting the sample (30 : 50) suggested, however, that the qualitative results presented below are not sensitive to these modifications.

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Table II

Separate Estimates of Firm Investment by Solvency Group

	Group H		*Group L*	
Variable	Fixed	Random	Fixed	Random
Constant	–	2.72	–	2.42
		(6.6)		(21.3)
Q_t	0.96	0.93	−0.04	0.19
	(4.1)	(5.5)	(0.2)	(1.8)
Z_t	0.17	0.26	0.90	0.68
	(0.5)	(0.9)	(5.0)	(5.6)
R^2	0.69	0.34	0.67	0.39
Diagnostics:	$F(24, 98) = 4.67$		$F(54, 218) = 3.79$	
	LM = 43.08		LM = 62.71	
	H = 0.19		H = 4.85	

Notes: See Table 1. The splitting of the sample is explained in the text. The regressions are based on a sample of 25 (group H) and 55 (group L) firms over five years (1983 - 1987). The fixed effects model ("fixed") includes fixed firm-effects (not reported).

ment in the L-group, consistent with the view that these firms are credit constrained and/or faced with a cost premium to external finance. Furthermore, the Q coefficients are much smaller and in case of the fixed effects model even insignificant. On the contrary, Z has virtually *no* effect upon the H-group (high-collateral) firms while the valuation ratio Q is closely correlated with investment spending. On the whole, these *a priori* expected qualitative results suggest that any attempt to understand investment spending must account for firm's differential access to capital markets, whereby the financial factor sensitivity of investment spending is probably *not* a simple monotonic function of Z.[24] Additionally, given the size distribution of firms in both groups the results contradict the popular view that firm size is the dominant factor in determining access to debt markets.

From a theoretical perspective these results are consistent with the prediction of the recent asymmetric information literature that less solvent firms have limited access to debt markets, presumably because they lack the collateral necessary to back up their borrowing.[25]

[24] With a sufficiently large panel data set, one could split the sample into even finer groups. Our sample, however, is too small to proceed in this direction.

[25] Some of the more important papers in the area include *Jensen / Meckling* 1976, *Myers* 1977 and *Sappington* 1983. Whereas these papers rely on the presence of *moral hazard* or *incentive problems,* other models using the *lemon principle* and therefore *information problems* draw similar conclusions. See *Greenwald / Stiglitz / Weiss* 1984 and *Myers / Majluf* 1984. Another class of models are those that rely on *costly monitor-*

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IV. Conclusions

To this point, our results can be summarized as follows. Although the limitations of our Z-score variable should be stressed, the foregoing discussion provides evidence that (1) investment reacts positively to Tobin's average Q and (2) firms appear to place considerable emphasis on financial factors. We therefore conclude that investment at the firm level cannot be analysed independently of the financial conditions that firms face both internally and externally.[26] We believe that more detailed studies made on the framework as introduced here will be quite worthwhile in the future.

Appendix: Data Sources and Definitions

All series which have been used in this paper are yearly and range from 1983 to 1987. The data definitions and sources are briefly described as follows:

IK = Investment Rate, calculated from the series 'Gross Investment in Plant and Equipment' and 'Capital Stock'; *Source:* Hoppenstedts "Handbuch der Deutschen Aktiengesellschaften, various years.

Q = Tobin's average valuation ratio
DEFINITION:
$Q = [LML + (\#S * PS)] / [IN + (ACP/AHP) * FA]$

Z = Altman's *Z*-Score Model Indicator
DEFINITION:
$Z = [(1.2 * WC) + (1.4 * RE) + (3.3 * PBI) + TS] / TA + (0.6 * \#S * PS) / LML$

LML = Long and Medium Term Liability; *Source:* MicroExstat

FA = Fixed Assets: *Source:* MicroExstat

IN = Inventories; *Source:* MicroExstat

#S = Number of Ordinary Shares; *Source:* MicroExstat

PS = Ordinary Share Prices; *Source:* Hoppenstedts Handbuch Deutscher Aktiengesellschaften

AHP = Fixed Assets Historical Costs; *Source:* Statistisches Bundesamt, Fachserie 18, Reihe 1.3

ACP = Fixed Assets Replacement Costs; *Source:* Statistisches Bundesamt, Fachserie 18, Reihe 1.3

WC = Working Capital; *Source:* MicroExstat

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ing of borrowers. See *Gale/Hellwig* 1985 and *Williamson* 1987. For a review of the theoretical literature as it pertains to macroeconomic issues see *Gertler* 1988.

[26] Similar results for U.S., U.K. and Japanese firms have recently been found by *Cantor* 1990, *Devereux/Schiantarelli* 1989, *Fazzari/Athey* 1987, *Fazzari/Hubbard/Petersen* 1988, *Hoshi/Kashyap/Scharfstein* 1989, *Oliner/Rudebusch* 1989 and *Whited* 1990. Interestingly, the findings tend to support the view of the Deutsche Bundesbank [see, *Deutsche Bundesbank* 1986 and 1988], while the results are not supportive to the descriptive evidence presented in *Irsch* 1985.

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RE = Retained Earnings; *Source:* MicroExstat

PBI = Profit before Interest and Taxes; *Source:* MicroExstat

TS = Total Sales; *Source:* MicroExstat

TA = Total Assets; *Source:* MicroExstat

Abstract

The paper combines the adjustment costs hypothesis of Tobin's q models with the possibility of financial constraints. The risk of financial distress leads external claimants and firms to look at indicators of solvency in deciding about investment. The basis of our empirical investigation is a panel data set of quoted West German industrial and commercial companies. The application of the model shows that firms tend to react both to changes in the valuation ratio and to variations in financial factors. The estimates therefore suggest that financial factors are a significant determinant of investment.

Zusammenfassung

In dem Papier wird ein um Finanzierungsaspekte erweitertes q-Modell der Investition aus dem Optimalkalkül eines Unternehmens abgeleitet. In der resultierenden Investitionsfunktion wird die Akkumulationsrate zusätzlich zum Tobin'schen q von Indikatoren der Zahlungsfähigkeit beeinflußt. Die ökonometrischen Schätzungen der Investitionsfunktion unter Verwendung eines mikroökonomischen Unternehmens-Panel ergeben, daß Finanzierungsaspekte zusätzlich zu Tobin's q einen signifikanten Einfluß auf die Investitionstätigkeit in der Bundesrepublik Deutschland ausüben.

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