Tobin's Q and Sectoral Investment in West Germany and Great Britain

A pooled cross-section and time-series study*

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The objective of the paper ist to examine the effects that demand constraints have on the Q theory of investment. The paper formalizes this idea in a rigorous model and derives the optimal rate of investment of a firm as a function of marginal tax adjusted Q. An exact relationship between marginal Q and average Q is also derived. Finally, the theoretical model is estimated using pooled cross-section and time-series data for West Germany and Great Britain.

1. Introduction

The Q theory of investment, which relates investment to the ratio of the market value of firms to the replacement cost of their assets, has attracted considerable attention in recent years since *Andrew B. Abel*[1] and *Hiroshi Yoshikawa*[2] have given a theoretical rationale for using Q as an investment determinant. They have shown that under the condition of perfect competition, a well-behaved production function, and the existence of convex adjustment costs Q ist the crucial variable in determining firms' investment decisions. In spite of this microeconomic foundation and appealing features, the empirical performance of the Q theory of investment, however, is generally regarded as mixed. Although Q typically enters regression equations for the rate of investment significantly, there are two main difficulties. The first is that the residuals from the estimated investment equations are often heavily correlated. This empirical result is inconsistent with the simple form of the Q theory because the standard form of the adjustment cost function used in developing the investment function implies that investment is determined solely by current Q. Second, despite the traditional simple form of the Q theory where Q is a sufficient statistic for the incentive to invest, other variables, particularly output and/or financial variables, appear to affect investment in addition to Q. These difficulties in the empirical implementa-

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[1] See *Abel* (1980).

[2] See *Yoshikawa* (1980).

tion of the Q theory have recently led to various extensions of the standard Q model. These attempts have analysed how the specification of the investment function changes if the existence of speculative bubbles in the stock markets[3], an endogenized debt policy[4], multiple capital inputs[5], gestation lags[6], and imperfect competition[7] are introduced into the underlying theoretical model of the firm. Generally, these extensions lead to investment equations with a more complicated dynamic structure than in the conventional model and the investment equations contain other explanatory variables in addition to current Q and/or lagged Q terms.

The purpose of the present paper is to assess the consequences of demand constraints in the product market for the Q theory of investment.[8] The plan of the paper is as follows: In section 2 we develop the theoretical framework which allows for rationing in the output market and an accurate modelling of the tax system. Section 3 briefly describes the data set. In the applied section 4 we develop the empirical framework and present the results of estimating the model for a sample of 12 industries/12 years in West Germany and Great Britain. Section 5 summarizes the main findings.

2. A Model for Industry Investment

The rigorous foundation of the Q theory of investment starts from the notion of a price-taking firm facing adjustment costs. The typical firm is supposed to maximize the expected present value of the firm's equity. Equity owners are assumed to require a fixed real net-of-tax rate of return r. Thus, denoting market value of equity by V, net distributions to equity by θE, and the expected rate of inflation by π, equilibrium in the equity market implies that

$$(1) \qquad (r + \pi) \; V(t) \; = \; \dot{V}(t) \; + \; \theta E(t)$$

holds at every point in time. Specifically, in the case of corporate enterprises E in (1) denotes gross distributions as defined by equation (2) and θ corrects for the different tax treatment of dividends vis-à-vis retentions in imputation or split-rate systems.[9]

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[3] See *Ueda / Yoshikawa* (1986).

[4] See *Chirinko* (1987).

[5] See *Chirinko* (1986) and *Wildasin* (1984).

[6] See *Dinenis* (1985a).

[7] See *Schiantarelli / Georgoutsos* (1987).

[8] The consequences of demand constraints have recently been discussed in *Precious* (1985).

[9] θ is $(1 - m)/(1 - \tau + \tau_d)$ for the West German split-rate system effective prior to 1977, and $(1 - m)/(1 - \tau)$ since then (m: "representative shareholder's" marginal income tax rate; τ, τ_d: corporate tax rate on retained and distributed profits respec-

Following standard practice, it is supposed that the choice of financial mix is taken independent of the investment decision, i.e. new debt $B_n(t)$ is regarded to be exogenous, and distributed profits are defined residually as surplus of sources over uses of funds, thereby ignoring new share issues:

(2) $E(t) = (1 - \tau(t)) [p(t) F[K(t), L(t)] - w(t) L(t) - i(t) B(t)]$

$+ \tau(t) D(t) + B_n(t) - \eta B(t) - p_I(t) (1 - k(t)) I(t),$

where

K	=	real capital stock, assumed to decay at exponential rate δ;
L	=	labour input;
$F(\cdot)$	=	linear-homogeneous production function with standard properties;
p, p_I	=	price of output and investment good respectively;
w	=	nominal wage rate;
D	=	sum of tax depreciation allowances on capital stock at date t;
B	=	stock of debt outstanding;
i	=	interest rate;
η	=	constant exponential amortization rate on debt;
k	=	rate of investment grant;
I	=	uninstalled gross investment.

In order to overcome a by now well-known inconsistency[10] of the traditional neoclassical theory of investment behaviour, the Q-theoretical firm is supposed to be confronted with adjustment costs. In the following we are assuming that the installation cost function takes the form of wasted capital and can be written as $\psi(I, K)$.[11] The capital accumulation constraint is then given by:

(3) $\dot{K}(t) = \psi[I(t), K(t)] - \delta K(t), \quad \psi_I > 0, \psi_{II} < 0$[12]$, \psi_K > 0$.[13]

By allowing for the possibility of disequilibria in the output market in the form of a demand constraint a second distinguishing feature vis-à-vis the Jorgenson approach besides costly capital adjustment has recently been added to the Q-theoretical model set-up.[14] This novel feature is embodied

tively). Under the present UK corporation tax system θ is $(1 - m)/(1 - s)$, where s is the rate of imputation. For the θ concept in general see *King* (1977), 47 - 53.

[10] See *Gould* (1968), 47 and *Yoshikawa* (1980), 740.

[11] See *Hayashi* (1982), 216.

[12] "... the ... installation of capital goods costs more ... the faster the capital stock is expanded" *Tobin* (1977/78), 423.

[13] "Larger firms can ... undertake a given size investment project at lower cost" *Poterba / Summers* (1983), 143.

[14] See *Precious* (1985).

here since it provides a conceivable theoretical explanation, why separate demand variables may well possess significant additional explanatory power *besides* Q in an empirical investment equation – a frequent empirical finding which remains puzzling within the standard Q-theoretical framework, where it is implied that demand influences are thoroughly captured by Q. Formally, an exogenous upper limit Y on demand for the firm's output is imposed:[15]

$$(4) \qquad\qquad F[K(t), L(t)] \leq Y(t).$$

The model assumes that the market value of equity V is maximized subject to (3) and (4), where the explicit analytic expression for V is obtained by solving (1) forward from 0 to infinity:[16]

$$(5) \qquad\qquad V(o) = \int_o^\infty \theta E(t)\, e^{-(r+\pi)t}\, dt.$$

Separating notationally those components of V which are independent of the investment path from $t = 0$ onward, thereby assuming constant expectations with respect to the elements of θ for convenience, equation (5) can be rewritten as

$$(6) \quad V(o) = \int_o^\infty \theta\,[(1-\tau)(pF-wL)-(1-k-z)\,p_I I]\,e^{-(r+\pi)t}dt + \theta A(o) - \theta B(o).$$

where

$$(7) \qquad\qquad A(o) = \int_o^\infty \tau \int_{-\infty}^o d(t-s,s)\,p_I(s)\,I(s)\,ds e^{-(r+\pi)t}\,dt.$$

denotes the present value of future tax savings due to depreciation allowances on capital acquired prior to $t = 0$[17],

$$(8) \qquad\qquad z(t) = \int_o^\infty \tau d(s,t)\,e^{-(r+\pi)s}\,ds.$$

is the discounted stream of future tax savings per DM of investment expenditures in t, and $B(o)$ is given by[18]

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[15] Nevertheless, the price-taking assumption with respect to the output market is preserved. For justification see *Precious* (1985), 576 - 577.

[16] The transversality condition imposed is $\lim_{t\to\infty} V(t)\,e^{-(r+\pi)t} = 0$.

[17] $d(t-s,s)$ is the date t depreciation allowance per DM of date s investment expenditures (i.e. for capital goods of age $t-s$).

$$(9) \qquad -B\,(o) \;=\; \int_0^\infty \; [B_\eta\,(t) - ((1-\tau)\,i\,(t)+\eta)\,B\,(t)]\,e^{-(r+\pi)\,t}\,dt\,.$$

Thus the Lagrangean for the optimization problem is

$$(10) \qquad L \;=\; \theta\,[(1-\tau)\,(pF - wL) - (1 - k - z)\,p_I\,I] \;+$$
$$+\; \lambda\,(\psi\,(I,K) - \delta K) \;+\; \mu\,[Y - F\,(K,L)]\,,$$

where λ represents the marginal increase in market value of an additional unit of installed capital, and μ is the slack variable associated with the sales constraint (4). From (10) we infer that the optimal investment and labour demand behaviour of the firm is characterized by

$$(11) \qquad \theta\,(1-\tau)\,(pF_L - w) \;-\; \mu F_L \;=\; 0\,,$$

$$(12) \qquad \lambda\,\psi_I \;=\; \theta\,(1-k-z)\,p_I\,.$$

$$(13) \qquad \dot{\lambda} \;=\; (r+\pi+\delta-\psi_K)\,\lambda \;+\; [\mu - \theta\,(1-\tau)\,p\,]\,F_K\,.$$

$$(14) \qquad \mu \geq 0;\; \mu\,[Y - F\,(K,L)] \;=\; 0\,.$$

Sufficiency of these conditions is established by the transversality condition

$$(15) \qquad \lim_{t \to \infty} \; \lambda\,(t)\,K\,(t)\,e^{-(r+\pi)\,t} \;=\; 0\,.$$

Equation (11) in conjunction with condition (14) states that if the demand constraint is binding, it is – no surprise – the level of demand for the firm's output instead of the standard neoclassical marginal productivity condition which governs the amount of labour employed, and vice versa. (13) implicitly shows that $\lambda\,(t)$ is the present value of nominal marginal net benefits flowing from the undepreciated portion of capital installed in t over its infinite lifetime-integrate (13) forward from t to infinity. Equation (12), which relates investment demand to the ratio of market value change due to an additional unit of capital installed (λ) to its tax-adjusted replacement cost $\theta\,(1-k-z)$, virtually constitutes the Q theory of investment at the enterprise level. Specifically, if $\psi\,(I,K)$ is linear-homogeneous in its arguments, (12) can be inverted to give the rate of investment.

$$(16) \qquad \frac{I\,(t)}{K\,(t)} \;=\; g\left(\frac{\lambda\,(t)}{\theta\,(1-k\,(t)-z\,(t))\,p_I\,(t)}\right) \;=\; g\,[Q_m\,(t)]\;\; g' > 0\,.$$

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[18] It is assumed that $(1-\tau)\,i = r + \pi$. For further comment on this assumption see *Willenbockel* (1988), 6.

As pointed out by Hayashi, this additional linear homogeneity assumption for $\psi(\cdot)$ is necessary in order to derive an exact relationship between marginal Q as defined in (16) and Tobin's observable average Q. Allowing for the present model's additional features of debt finance, personal taxation, and demand constraints *Hayashi's* basic proposition[19] for the standard Q model has to be modified as follows.

Consider

$$
(17) \qquad \frac{d}{dt}\left[\lambda(t)\,K(t)\,e^{-(r+\pi)t}\right] = \left[\dot{\lambda}K + \lambda\dot{K} - (r+\pi)\,\lambda K\right]e^{-(r+\pi)t}.
$$

Using (3), (11), (12), (13), and the homogenity of $\psi(\cdot)$, the RHS can be rewitten as

$$
(18) \qquad \frac{d}{dt}\left[\lambda(t)\,K(t)\,e^{-(r+\pi)t}\right] =
$$
$$
-\left[\theta(1-\tau)(pF-wL) - \theta(1-k-z)\,p_I I - \mu F\right]e^{-(r+\pi)t}.
$$

On forward integration with recourse to (15) a comparison with (6) reveals:

$$
(19) \qquad \frac{\lambda}{\theta(1-k-z)\,p_I} = Q = \frac{V+\theta B}{\theta(1-k-z)\,p_I K} -
$$
$$
-\frac{A}{(1-k-z)\,p_I K} - \frac{\int_0^\infty \mu Y(t)\,e^{-(r+\pi)t}\,dt}{\theta(1-k-z)\,p_I K}
$$

i.e. an expectation of future demand rationing drives an additional wedge besides $A/[(1-k-z)\,p_I K]$ between average tax-adjusted Q as normally defined (which is the first term on the RHS in (19)) and marginal Q. Thus, defining tax-adjusted marginal Q including dividend taxation

$$
(20) \qquad Q_1 = \frac{V+\theta B - \theta A}{\theta(1-k-z)\,p_I K}
$$

we may restate (16) equivalently

$$
(21) \qquad \frac{I(t)}{K(t)} = h\left(Q_1(t)\,;\,[Y(s)]_0^\infty\right).
$$

The distinguishing feature of (21) compared to standard formulations of the Q theoretical investment equation is the appearance of expected future demand *besides* Q as normally defined.

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[19] See *Hayashi* (1982), 218 - 220.

For convenience or lack of data, only few[20] existing empirical studies take into account all of the on principal required tax adjustments to the Q-type argument as indicated in (19). Most frequently, the tax discrimination between retentions and distributions is ignored, i.e. θ is set to unity and the Q variable becomes.

$$(22) \qquad Q_2 = \frac{V + B - A}{(1 - k - z)\, p_I\, K} .$$

If in addition tax depreciation allowances and subsidies are neglected, A, k, and z vanish and what is left is Tobin's *average Q*:

$$(23) \qquad Q_3 = \frac{V + B}{p_I\, K} .$$

Finally, sometimes for the very lack of market value data, the equity valuation must be imputed indirectly using firms' flow-of-funds statistics. If this data source contains insufficient information for the computation of actual profits tax bases, one is forced to abstract from profit taxation altogether – i.e. τ in (2) is set to zero. We will label a pre-tax valuation ratio thus derived Q_4.

3. The Development of Q by Sectors

Before turning to the econometric results several explanatory notes on the derivation of the historical Q values are in place. The construction of the West German Q time series by industry is based on balance-sheet and profit and loss account statistics for about 74.000 (in 1980) firms of *all legal forms* as compiled and published annually by the Deutsche Bundesbank. The British Q series are derived using respective information for all *quoted stock companies* as filed in the company data bank of the London Business School.[21] Both, the time period covered and the selection of industries under consideration were determined by the respective range of disaggregated Q data for Britain available.[22] In terms of the classification outlined in the previous section the time series for British industries are "Q_3 type" while the corresponding series for West Germany are – due to data constraints – of the Q_4 variety.

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[20] See *Poterba / Summers* (1983), *Dinenis* (1985a) and *Funke / Ryll / Willenbockel* (1989).

[21] The calculated UK Q series by industry were kindly placed at our disposal by Elias Dinenis (London Business School).

[22] The assignment of UK sample industries to corresponding German branches provides no insurmountable difficulties at the level of disaggregation applying here, since the UK Standard Industrial Classification (SIC(80)) is indirectly linked with the German SYPRO system via the European Communities' Industrial Scheme (N.A.C.E.). For details see Appendix A.

Clearly, from the theoretical perspective of section 2 of the paper the Q_3 and all the more the Q_4 conception remain unsatisfactory, in that essential aspects of profits taxation are neglected as compared with Q series derived along the lines suggested by equation (20) or (22). However, with regard to Appendix B, the high correlation between the Q_4 valuation ratio for West German total manufacturing constructed from this paper's data source on the one hand and the ratios Q_1 to Q_3 derived from a narrower data base consisting of German corporate firms' balance-sheet statistics[23] on the other hand indicates, that the "error" incurred by the conscious non-adjustment for profits taxation is likely to be negligible in the present context. Given the distinct construction mode of Q_4 vis-à-vis Q_3 no meaning must be attached to the absolute level differences in Q across the country samples. Instead attention should focus on the respective evolution of Q by sector over time.[24]

Descriptive time series on the Q variables used in the paper are provided for both countries for the period 1973 to 1985 in figure 1 (p. 407/408). The first observation on figure 1 is that no trend decline is apparent in most sectors in both countries. When considering the cyclical variability, however, different features appear in both countries under consideration. By and large the movement of Q exhibits a more distinct procyclical pattern in the German case. In most industries at least the recessions of 1974/75 and 1981/82 as well as the subsequent recoveries are reflected in corresponding movements of the valuation ratios. This observation does not turn over to the case of Britain in such a clear-cut manner, i.e. the Q-series for the U.K. are less cyclically sensitive.[25]

4. Empirical Analysis

According to the framework developed in section 2 of the paper the Q model to be estimated is derived from a model of a firm that maximizes the net wealth of existing shareholders when facing convex adjustment costs and output constraints. If we simplify equation (23) by making expectations of future output depend only on the *growth rate* of actual output (GY_t) and in addition extend the Q model to allow for a simple delivery lag of one period, the empirical investment equation of reference is given by

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[23] As published annually by the Statistisches Bundesamt. The data, however, are only available up to 1983. For computational details of the valuation ratios Q_1 to Q_3 derived from this source see *Funke / Ryll / Willenbockel* (1989).

[24] A detailed intra-country analysis of the performance of Q across industries is beyond the scope of the present paper. For research in this area compare *Funke* (1987) for West Germany and *v. Furstenberg / Malkiel / Watson* (1980) for the United States.

[25] In general, the British Q series exhibit less cyclical variation than their German counterparts. This result may in part, however, occur to be due to the different data base for the construction of the Q measures in both countries under consideration.
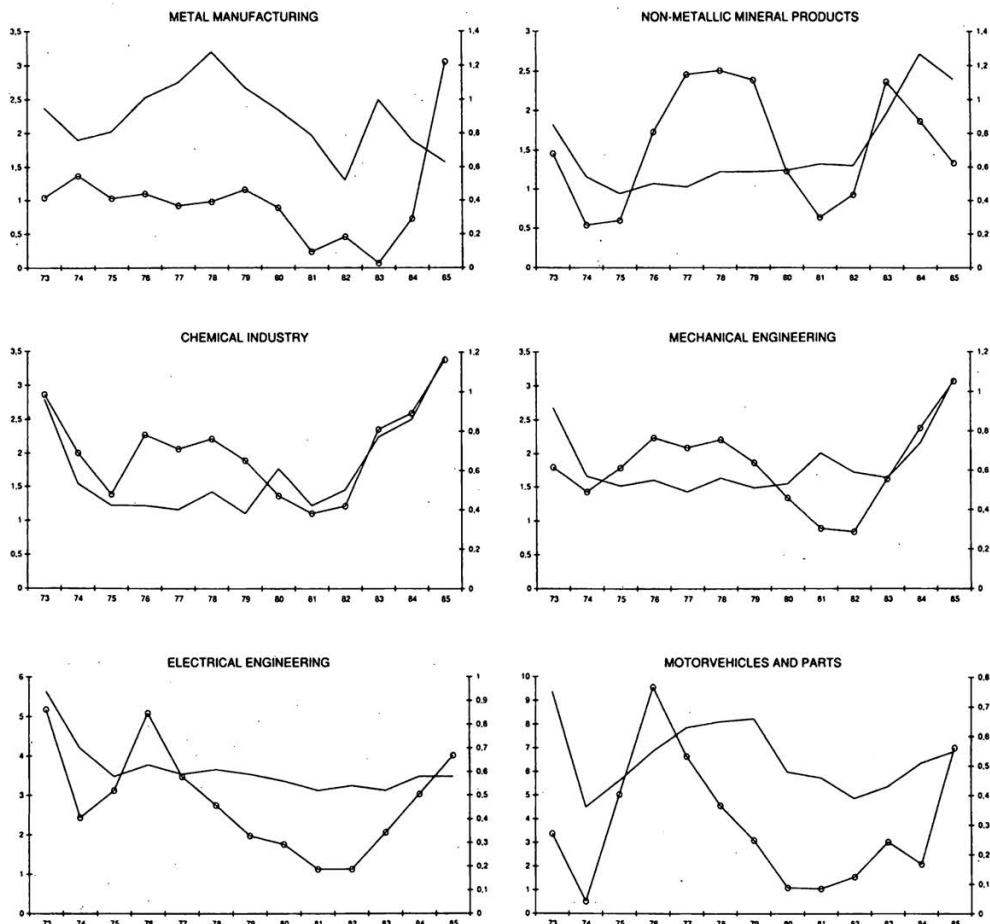
Figure 1: Q-Series by Industries   *(continued next page)*

−◯− West Germany / ——— Great Britain

$$(24) \qquad \left(\frac{I}{K}\right)_t = f\left(Q_{t-1}, GY_t\right).$$

In what follows, section 4 discusses the econometric issues involved in the estimation and analyses empirical findings. For the estimation procedure the technique of pooling cross-section and time-series data is employed. The problem, when using several years of data on a number of 12 industries to estimate equation (24), is to specify a model that will adequately allow for differences in behaviour over cross-sectional units as well as any differences
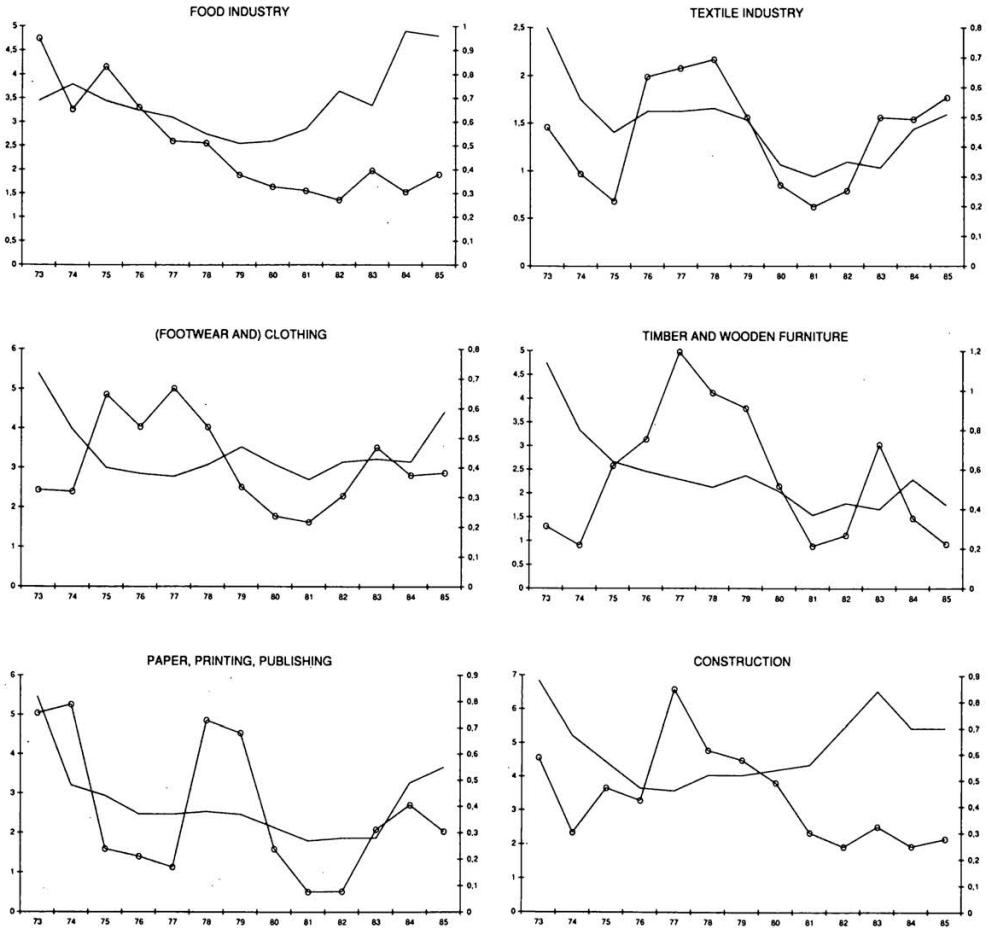
Figure 1 (continued)

in behaviour over time for a given cross-sectional unit. In general, the linear models considered can be written as:[26]

$$(25) \qquad \left(\frac{I}{K}\right)_{it} = \beta_{1it} + \sum_{k=2}^{3} \beta_{kit} X_{kit} + u_{it}$$

where $i = 1, \ldots 12$ refers to a cross sectional unit and $t = 1974, \ldots 1985$ refers to the time period. Thus $(I/K)_{it}$ is the value of the dependent variable for industry i at time t and X_{2it} (X_{3it}) is the value of Q_{t-1} (GY_t) for industry

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[26] For a survey about the formulation and estimation of static models using panel data see *Judge / Griffiths / Hill / Lee* (1980), 325 - 373.

i at time t. The stochastic term u_{it} is assumed to have the usual properties, i.e. $E(u_{it}) = 0$ and $E(u_{it}^2) = \sigma^2$. The β_{kit} are unknown coefficients and, as the subscripts indicate, for the *most general* case they can be different for different individuals and in different time periods. However, in the following *more restrictive* assumptions will be made and the following four models will be estimated and tested to decide on whether or not to pool and to estimate the pooled regressions with different degrees of pooling.

Model 1: A common intercept and common slopes

(26)
$$\left(\frac{I}{K}\right)_{it} = \beta_1 + \sum_{k=2}^{3} \beta_k X_{kit} + u_{it}$$

$$\text{RSS} = S_1; \; DF = I \cdot T - 3.$$

Model 2: Common slopes and different intercepts

(27)
$$\left(\frac{I}{K}\right)_{it} = \beta_{1i} + \sum_{k=2}^{3} \beta_k X_{kit} + u_{it}$$

$$\text{RSS} = S_2; \; DF = I \cdot T - I - 2.$$

Model 3: Common intercepts and different slopes

(28)
$$\left(\frac{I}{K}\right)_{it} = \beta_1 + \sum_{k=2}^{3} \beta_{ki} X_{kit} + u_{it}$$

$$\text{RSS} = S_3; \; DF = I \cdot T - 2 \cdot I - 1.$$

Model 4: Different intercepts and different slopes

(29)
$$\left(\frac{I}{K}\right)_{it} = \beta_{1i} + \sum_{k=2}^{3} \beta_{ki} X_{kit} + u_{it}$$

$$\text{RSS} = S_4; \; DF = I \cdot T - 3 \cdot I.$$

Model (1) suggests a total pooling; model (4) suggests no pooling at all. Model (2) is commonly referred to as the fixed coefficients dummy variable model. If one assumes that the variable coefficients are fixed the following F-tests can be used to discriminate between the four models:[27]

(30)
$$F_1 = \frac{(S_1 - S_4)/(3 \cdot I - 3)}{S_4/(I \cdot T - 3 \cdot I)} \sim F(3 \cdot I - 3, \; I \cdot T - 3 \cdot I)$$

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[27] The specification of F_4 uses the fact that the F test can be extended for conditional tests.

$$(31) \qquad F_2 = \frac{(S_2 - S_4)/(2 \cdot I - 2)}{S_4/(I \cdot T - 3 \cdot I)} \sim F(2 \cdot I - 2, \ I \cdot T - 3 \cdot I)$$

$$(32) \qquad F_3 = \frac{(S_3 - S_4)/(I - 3)}{S_4/(I \cdot T - 3 \cdot I)} \sim F(I - 1, \ I \cdot T - 3 \cdot I)$$

$$(33) \qquad F_4 = \frac{(S_1 - S_2)/(I - 1)}{S_2/(I \cdot T - I - 2)} \sim F(I - 1, \ I \cdot T - I - 2).$$

Table 1

Results of specification tests

Dependent variable is $\left(\dfrac{I}{K}\right)_{it}$

Sample period is 1974 to 1985; 12 industries

Hypothesis	West Germany	Great Britain
First model Common intercepts and slopes	$F_1 = 13{,}37$	$F_1 = 4{,}59$
Second model Common slopes and different intercepts	$F_2 = 1{,}76$	$F_2 = 1{,}31$
Third model Common intercepts and different slopes	$F_3 = 11{,}89$	$F_3 = 2{,}45$
Fourth model Different intercepts and different slopes	$F_4 = 32{,}39$	$F_4 = 10{,}58$

In a nutshell, one needs to estimate coefficients and F-statistics in order to discriminate between the different model specifications presented above.

From the four regression estimates for each country under consideration, we obtain the above F ratios corresponding to the four hypotheses:

The null hypothesis that we cannot reject at the 0.05 level of significance for both countries is hypothesis (2) – different intercepts but common slopes. One plausible interpretation of this industry specific effect is that sectors face different "normal" investment rates. The results obtained with model (2) for the sample of 12 industries and 12 years are reported in Table 2.

Table 2

Fixed coefficients dummy variable model

Dependent variable is $\left(\dfrac{I}{K}\right)_{it}$

Sample period is 1974 to 1985; 12 industries

Independent variables	West Germany	Great Britain
Constant	4,13 (15,4) [12,7]	1,09 (2,1) [1,4]
Q_{t-1}	0,17 (2,8) [1,8]	1,62 (3,3) [2,5]
GY_t	0,03 (2,3) [1,7]	− 0,02 (− 1,5) [− 1,2]
R^2	0,78	0,50

t-values are given in parantheses; heteroscedasticity consistent *t*-ratios are given in brackets; the industry dummies are not reported in the table.

In addition to the standard regression output we have calculated heteroscedasticity adjusted *t*-values[28] because the variance estimator is known to be biased when OLS is applied to a model with heteroscedastic errors.

We now proceed with the country by country results. To start with West Germany, both coefficients have the expected positive signs and are significant. The regression is therefore consistent with the above presented model and confirms the view that there is an independent effect of demand on investment. Contrary to the results for West Germany the second regression raises some doubts as to the validity of the presented fixed coefficients dummy variable model for Great Britain.

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[28] The *t*-values are computed from the heteroscedasticity consistent White-matrix, see *White* (1980).
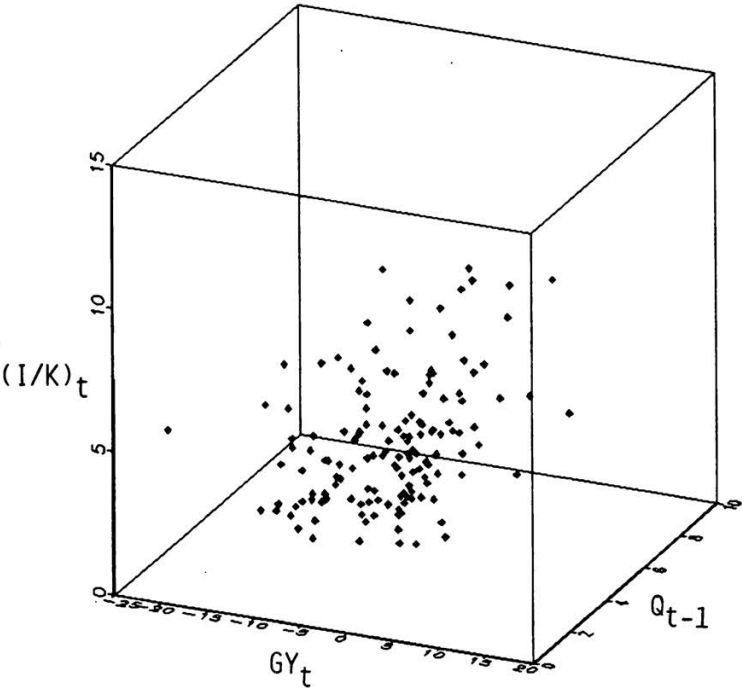
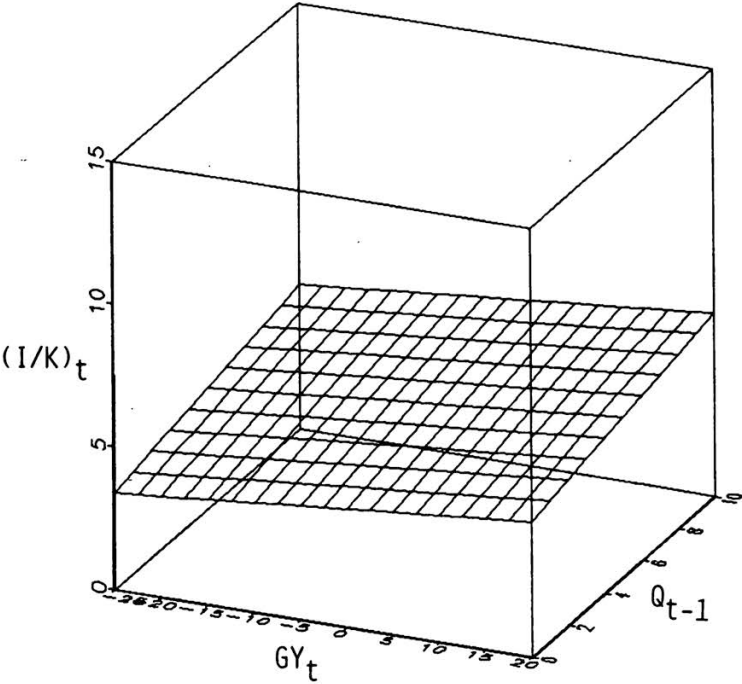Figure 2: $(I/K)_t$ against Q_{t-1} and GY_t for West Germany

Figure 3: Surface of $(I/K)_t$ against Q_{t-1} and GY_t for West Germany
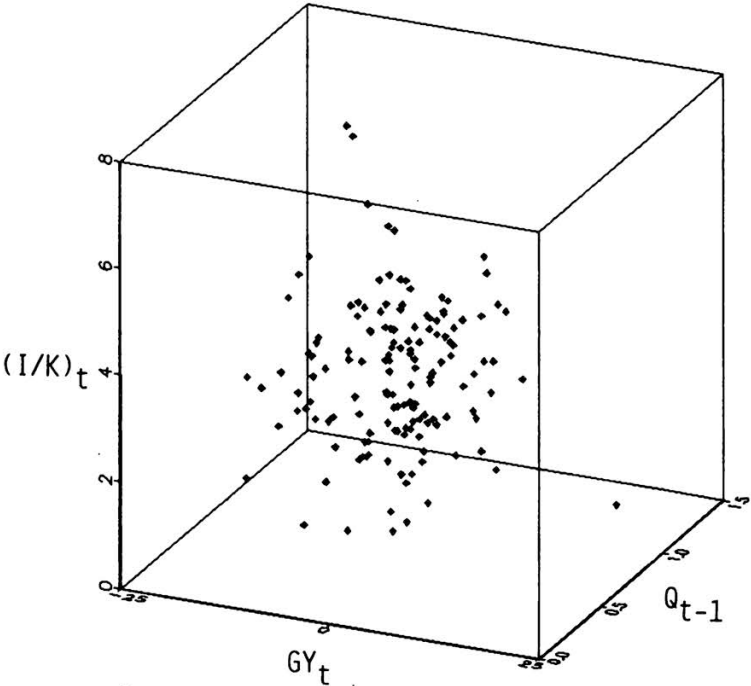according to the fixed coefficients dummy variable model

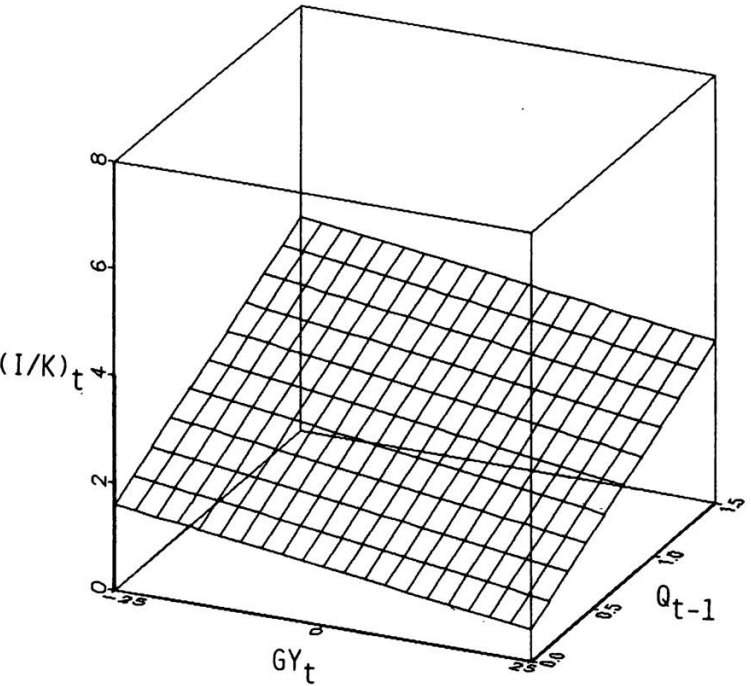Figure 4: $(I/K)_t$ against Q_{t-1} and GY_t for Great Britain

Figure 5: Surface of $(I/K)_t$ against Q_{t-1} and GY_t for Great Britain according to the fixed coefficients dummy variable model

While the coefficient of Q_{t-1} is again right signed and highly significant, the output effect comes out as a surprise; it is wrong signed and not significant at a conventional level. Furthermore the equation has a less satisfactory statistical fit. This suggests that the growth rate of output does not play an independent role on the investment rate for Great Britain.

Finally, we have compared the *static* Q model with a more general *dynamic* specification. With longitudinal data, in the presence of industry specific components in the error term, the lagged dependent variable is correlated with the disturbance. In this case, it is well known that the fixed effects estimator is biased[29] and would give rise to inconsistent parameter estimates if OLS were used. The alternative consistent estimator is *IV* applied to the model in *first differences,* using instruments dated at period $t - 2$ (and further lags).

We now turn to the results.[30] Table 3 shows that the inclusion of the lagged dependent variable is sufficient to get correct signed and strongly significant output effects for *both* countries. The lagged Q terms ΔQ_{t-1} retain their significance while ΔQ_t appears to be insignificant in both equations. At the same time the lagged investment rate itself is insignificant, however, the inclusion of $\Delta (I/K)_{t-1}$ improves the precision in the estimation of the other parameters. In sum, the results obtained with this variant do not modify previous conclusions. While demand conditions are accounted for in the Q variables, the results suggest that Q is unable to capture the full extent of this influence. Thus *Abel / Blanchard*[31] findings regarding separate effects on investment besides Q are reinforced in a combined cross-section and time-series context. To sum up, it seems that profitability and demand are the two main channels through which economic policy could influence investment. Policies influencing these two determinants simultaneously can thus only be self-enforcing

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[29] See, for instance *Nickell* (1981). A survey of time series regression models for longitudinal data with and without lagged dependent variables is contained in *Anderson / Hsiao* (1982).

[30] The "constant" has been included in the equations even though the intercept would be removed by differencing in order to control for non-zero means in the panel.

[31] See *Abel / Blanchard* (1986).

Table 3

Dynamic specification of the Q model

Dependent variable is $\Delta \left(\dfrac{I}{K} \right)_{it}$

Sample period is 1975 to 1985; 12 industries

Independent variables	West Germany	Great Britain
Constant	0,01 (0,2)	− 0,08 (− 1,3)
$\Delta (I/K)_{t-1}$	0,08 (0,7)	0,03 (0,3)
ΔQ_t	− 0,16 (− 1,3)	1,83 (1,4)
ΔQ_{t-1}	0,19 (2,0)	1,45 (1,8)
ΔY_t	0,06 (2,4)	0,05 (3,0)
R^2	0,39	0,45

Both equations were estimates by *IV*; Δ is the first difference operator; R^2 is the reduced form R^2; *t*-values are reported in parantheses.

Summary

This paper has explored the determinants of industry investment in a cross-section and time-series study for West Germany and Great Britain. The underlying Q model of investment behaviour is formulated on the basis of profit-maximizing firms which are supposed to be constrained in the product market. The model is estimated for a sample of 12 industries and 11 years (1975 - 1985). The results obtained confirm the view that lagged Q exert a significant influence on investment. Finally, a significant impact of output terms irrespective of Q was found.

Zusammenfassung

Das vorliegende Papier untersucht die Determinanten der sektoralen Investitions-tätigkeit in der Bundesrepublik Deutschland und Großbritannien mittels eines Datensatzes, der Querschnitts- und Zeitreihendaten verknüpft. In dem zugrunde lie-genden Q Modell wird die Investitionsfunktion dabei aus dem Kalkül einer gewinn-

maximierenden Unternehmung, die sich Nachfragebeschränkungen auf den Produkt-märkten gegenübersieht, abgeleitet. Die ökonometrische Schätzung der Q-theoreti-schen Investitionsfunktion erfolgt auf der Basis eines Datensatzes für 12 Industrie-zweige und 11 Jahre (1975 - 1985). Die Ergebnisse bestätigen die Modellhypothese, daß die verzögerten Q-Werte sowie Akzeleratorvariablen einen signifikanten Einfluß auf die Investitionsentwicklung haben.

Appendix A: Industrial classification

The British industries under consideration are two-digit classes. At this level of dis-aggregation the British industry grouping SIC as well as their numbering follows closely EC's "Nomenclature générale des activités économiques dans le Communautés européennes" (N.A.C.E.). The industry division ot the Bundesbank data set follows the German SYPRO ("Systematik der Wirtschaftszweige. Ausgabe 1979 (WZ 1979), Fassung für die Statistik im Produzierenden Gewerbe") classification. Relating WZ 1979 to N.A.C.E./SIC results in the industry grouping shown in the following table.

SIC/NACE No.	SIC designation	SYPRO No.	SYPRO designation	Discrepancies
22	Metal Manufacturing	27/30	Eisenschaffende Industrie	
		28	NE-Metallerzeugung	
24	Manufacture of Nonmetallic Mineral Products	25	Gewinnung und Ver-arbeitung von Steinen und Erden	SYPRO 25 excludes manufacture of glass
25	Chemical Industry	40	Chemische Industrie	SYPRO 40 excludes chemical fibres
32	Mechanical Engineering	32	Maschinenbau	
34	Electrical and Elec-tronical Engineering	36	Elektrotechnik	
35	Manufacture of Motorvehicles and Parts Thereof	33	Straßenfahrzeugbau	SYPRO 33 includes motorless road vehicles
ex 41	Food Industry	68	Nahrungsmittel-industrie	SYPRO 68 includes beverages
43	Textile Industry	63	Textilgewerbe	
45	Footwear and Clothing Industries	64	Bekleidungsgewerbe	SYPRO 64 excludes manufacture of footwear
46	Timber and Wooden Furniture	53 - 54	Holzver- und -bearbeitung	
47	Manufacture of Paper and Paper Products; Printing and Publishing	56	Papier- und Pappe-verarbeitung	SYPRO 56 excludes printing and pub-lishing
50	Construction	72 - 77	Baugewerbe	

Appendix B: Correlation Matrix

In Order to illustrate the relationship between the four Q measures defined above, a correlation matrix for Q_1 to Q_4 for West German total manufacturing for the period *1965 - 1982* is given below.

Matrix of Correlation Coefficients

	Q_1	Q_2	Q_3	Q_4
Q_1	1,000			
Q_2	0,909	1,000		
Q_3	0,964	0,916	1,000	
Q_4	0,887	0,702	0,898	1,000

Q_1:   Marginal post-tax Q measure including dividend taxation at the personal level

Q_2:   Marginal post-tax Q measure excluding dividend taxation

Q_3:   Average post-tax Q measure

Q_4:   Average pre-tax Q measure.[1]

The results of the correlation matrix show that all Q measures behave in a very similar way. This illustrates the adequacy of comparing Q series which are defined in a slightly different way for both countries.

Appendix C: Data Appendix

This section describes the calculation of the principal variables used in the econometric estimation.

Q-values for West German Industries

The construction of the various time series for Q is based on the annual balance sheet and profit and loss account data published by the Deutsche Bundesbank.[2] All published series show – due to the changes in the industrial classification – a break in the year 1980. We have therefore linked the Q series to get consistent time series for the whole sample period under consideration.

Q is calculated from the formula

$(C - 1)$ $$Q_4(t) = \frac{V(t) + B(t)}{p_I(t) K(t)}$$

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[1] Exact definitions of Q_1, Q_2 and Q_3 as well as the data sources are contained in *Funke / Ryll / Willenbockel* (1989), Q_4 has been compiled analogous to the Q series for Germany in this study.

[2] Deutsche Bundesbank „Jahresabschlüsse der Unternehmen in der Bundesrepublik Deutschland 1965 bis 1981", Sonderdruck Nr. 5 der Deutschen Bundesbank; updated figures for the years 1982 to 1985 are contained in the November issues of the „Monatsberichte der Deutschen Bundesbank".

the components of which are derived are follows:

V:

$(C - 2)$ $V(t) = \dfrac{\text{profits}(t)\text{-received interest payments}(t)\text{-depreciation expense adjustment}(t)}{\text{dividend yield}(t)}$

The market value of equity V is calculated dividing adjusted *pre-tax* profits by the industry's dividend yield.[3] The income category "received interest payments" was subtracted from profits because the denominator of Q includes *physical* assets only. Finally, profits have been adjusted for *inflation-induced* profits which arise because the accounting rules require *historic cost* to be declared. The value of the adjustment term in period t is:

$(C - 3)$ depreciation expense adjustment(t) = capital consumption$(t) \cdot \left[\left(\dfrac{p_R}{p_H} \right) \right]$

where (p_R/p_H) is the price ratio "capital consumption replacement cost/capital consumption historic cost."[4]

B: The value of debt is taken to be the sum of book values of long-term debt (maturing ≥ 4 years) and of reserve contingencies.

$p_I K$:   We define $p_I K$ as the sum of *fixed assets at replacement cost plus inventories*. Because the balance sheet data give only access to historic cost valuations of the capital stock we have compiled the value of fixed assets replacement cost by multiplying fixed assets historic cost with the price ratio "capital stock replacement cost/capital stock historic cost."[5]

Q-values for United Kingdom Industries

All valuation ratios for Great Britain are calculated from the London Business School company database EXSTAT. The Q values are defined as:

$(C - 4)$ $Q(t) = \dfrac{VOS(t) + VPS(t) + BLT(t)}{KF(t) + KINV(t)}$

where each component on the RHS is calculated by summing the respective observations by company over all companies in the industry under consideration. The company-specific elements are constructed als follows:

VOS: Market value of ordinary shares – given by the product of the annual average share price and the number of ordinary shares.

VPS: Market value preference shares – obtained by 'capitalizing' dividends on preference shares with the preference dividend yield.

BLT: Market valuation of long-term debt – derived by capitalizing interest payments on long-term loans with the U.K. debenture yield.

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[3] See Statistisches Bundesamt, FS 9, Reihe 2, various years.
[4] See Statistisches Bundesamt, FS 18, various years.
[5] See Statistisches Bundesamt, FS 18, various years.

KF, KINV: Replacement cost of net fixed capital stock and stock of inventories (be-ginnung of year) respectively. The replacement cost values are calculated on a perpetual inventory method.[6]

Other variables

Y: Index of net output (1980 = 100) by industry.[7]
I: Gross investment at constant (1980) prices.[8]
K: Gross capital stock at constant (1980) prices.[9]

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[6] For computational details regarding the conversion from book values to replace-ment values see *Dinenis / Karousos* (1988).
[7] See Monthly Digest of Statistics; Statistisches Bundesamt, FS 4, various issues.
[8] See Statistisches Bundesamt, FS 18, various issues; LBS Databank.
[9] See Statistisches Bundesamt, FS 18, various issues; LBS Databank.

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