Chapter 5

The Role of Working Capital in the Investment Process

5.1 Introduction

For investment firms rely to a large extent on internal finance especially those firms for which external finance is either too expensive or just not available. By retaining cash flows, firms accumulate the financial funds needed for investment. A considerable share of the financial assets that firms hold takes the form of socalled working capital, which consists of short term assets and short term liabilities. Working capital is needed for the day-to-day financial operation of the firm and as such is an important indicator of the liquidity of the firm.

In this chapter we investigate the sensitivity of investment in both physical capital and R&D to the presence of liquidity constraints. We assess the severity of underinvestment due to a lack of internal funds by looking at (changes in) the stock of working capital.

We derive within a formal theoretical framework of a value maximizing firm that is subject to financial constraints, the relationship between working capital and the change in the shadow value of funds. When estimating the Euler equations for investment and R&D we exploit this relationship to allow for heterogeneity in behaviour due to changes in liquidity over time. Earlier papers, e.g. by Hall (1991) and Bond and Meghir (1994), have split the sample on the basis of dividend pay-out ratios or information on share issues. We see several advantages to our procedure for measuring (changes) in the liquidity of the firm, which uses information on working capital, over other criteria. First, working capital is a continuous indicator of liquidity while share issues take place in a discrete fashion. Second dividends are not just the residual of cashflow that remains after all other (financial) decisions have been taken. Firms choose a dividend policy for a rather long period and are reluctant to deviate from it; a cut in dividends is often interpreted as a bad signal about the prospects of the firm which in turn can result in a rise in the cost of external finance. Thus dividends reflect the liquidity of the firm only to a limited extent and are less variable than working capital. However like dividends, the amount of working capital that a firm holds is determined by several (firm and industry specific) considerations and not just by investment plans. This reduces the quality of working capital as an indicator of liquidity of the firm and has implications for the econometric strategy that we employ. Moreover, working capital is the sum of various components, some of which are more under control of the firm than others. The various definitions of working capital that are encountered in the literature actually give a different picture of the liquidity of the firm.

In addition to Euler equations we estimate a version of a Q model, that allows for different investment behaviour across financial regimes. By using a different approach than others did, namely the endogenous switching regression methodology, our results add to the existing small empirical literature that focuses on the relationship between the accumulation of working capital and investment and is based on the Q model: we will split the sample by the sign of the change in working capital and test for differences between the estimates of the parameters which are obtained for the subsamples.

The sample we employ for the inference consists of data from U.S. firms in the scientific sector. This sample allows us to study investment in R&D. Furthermore as the firms in the sample are R&D intensive, they face higher cost of external finance and therefore will rely more heavily on internal funds. This feature of the sample makes it especially suitable to investigate the role of working capital in the investment process.

This chapter proceeds as follows. In section 2 we discuss the role of working capital within the firm and in particular in the investment process in more detail. In section 3 we outline the econometric framework and specify the hypotheses that we intend to test. Section 4 describes the sources of the data we used and the properties of the data by means of simple statistics. Section 5 then presents the empirical results and discusses them. Section 6 concludes.

5.2 The Role of Working Capital in the Investment Process

For operating a firm working capital is as crucial as fixed capital. It is the net amount of short term assets — current assets minus current liabilities — of the firm which gives it some latitude at several activities.

For instance, by holding inventories at various stages of the production process the firm can run larger batches and is less vulnerable to strikes, and the presence of accounts receivable on the balance sheet reflects the fact that the firm is willing to sell goods to customers that are solvent but short of cash.

Working capital is a prime measure of liquidity of the firm. Current assets include financial assets such as cash money and accounts receivable but also real assets such as inventories since it is thought that they can relatively easily be converted into cash. Current liabilities consist of (accounts) payable(s) and short term debt.

The various parts of working capital display their own patterns over the business cycle. When a firm is experiencing a negative shock to demand, its inventories of final products will generally rise. Later on, when it becomes clear that this demand shock was the beginning of a recession and the firm is in financial distress, the firm will try to shed inventories of all kinds [1], to collect accounts receivable, and try to postpone payments of debts. That is, as the recession gets worse, the liquidity of firms measured as working capital decreases as does cash flow. At the aggregate level of the manufacturing sector both in 1975 and in 1982 working capital declined sharply; some components, such as accounts receivables and inventories even fell considerably relative to sales.

The decline in working capital affects investment directly since it implies a fall in internal funds, and indirectly by raising the cost of external funds. Bernanke and Gertler (1988) and Gertler (1989) argue that the agency cost of external finance depends on the quality of the balance sheet of the firm. When its liquidity decreases or when prospects concerning future sales deteriorate, the cost of external finance rises. Eckstein and Sinai (1986) found that at the end of the recession and at the beginning of a recovery firms try to rebuild their debt capacity by accumulating short term financial assets in order to be able to borrow at acceptable rates when they need funds for investment. According to them this reliquefication characterizes a separate phase of the business cycle that precedes the period in which firms start to invest again.

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[1] A firm will also reduce inventories of materials during the recession as it will produce less.

It is conceivable that firms also save working capital in order to make sure that it can carry out an investment plan that takes years without interruption due to lack of cash.

Depending on the structure of the adjustment costs, working capital has still another effect on the investment process beyond those mentioned above. It will be used to smooth investments in the case of convex adjustment costs. If a fixed costs component dominates, investments decisions will seem irreversible. As Whited (1991) points out the height of the opportunity costs of reversing the investment decision varies with the cost of external finance which in turn depends on the availability of working capital inter alia. From the irreversability literature [2] we know that the higher the sunk costs, the longer a firm will wait to execute its investment plan ceteris paribus. Thus the size of the stock of working capital influences the timing (delay) of investment. Notice that working capital can be used for smoothing investment because it is in contrast to physical capital perfectly reversible.

The amount of working capital that firms will hold for instance in order to make sure that investment plans don't have to be interrupted depends among other things on their reputation in capital markets. For firms that are regarded as being of both high long term and high short term credit quality, Calomiris et al. (1994) find that they have lower stocks of inventories and financial working capital and in addition that these stocks are less sensitive to cash flow fluctuations. The latter finding is interpreted by them as follows. Firms of higher credit quality don't need to accumulate working capital as a buffer against fluctuations in cash flow as they can easily obtain external funds at favorable terms. Furthermore they show that given a high (long term) bond rating, only firms of large size, with low earnings variance, high cash flows and/or large stocks of liquid assets have access to the commercial paper market. The former characteristics however seem sufficient for firms to be able to issue commercial paper successfully given the fact that they have less working capital on average.

The firm controls the various components of working capital to a different extent. In general it will have more control over inventories of materials than over inventories of finished products or accounts receivable. Moreover, the bank might set a limit to short term debt or demand a minimum

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[2] See the survey of Pindyck (1991).

level of cash. As a consequence the interpretation of working capital as a measure of liquidity depends crucially on its definition. For instance high working capital defined as cash minus short term debt, might actually be a sign of low liquidity when it reflects restrictions imposed by the bank.

The empirical literature on the interaction between investment and decisions on working capital we are aware of is very limited. Whited (1991) put the reliquefication theory of Eckstein and Sinai to a test. Allowing coefficients to vary over time and controlling for demand by including output, she found that lags of working capital contributed significantly to a Q regression of investment and that in accordance with the theory investment was especially sensitive to the level of working capital [3] just after the trough of the business cycle (in 1983). Moreover when she split the sample using the criterion of whether firms have a bond rating from Moody's or not, this particular pattern in the coefficient of working capital was only found for firms of low credit quality. Fazzari and Petersen (1994) view working capital as a use of funds which is competing with fixed investment but also as a means (source) to smooth investment such that fluctuations in cash flow will not be transmitted fully to investment. Their empirical results indicate that when in addition to cash flow, the (simultaneous) change in working capital enters a Q regression model of ordinary investment, the coefficient of cash flow rises while the sign of the coefficient of the investment in working capital is negative. This should not be interpreted as evidence that investment and the change in working capital are negatively correlated. Their findings are consistent with the following interpretation. The change in working capital takes out (part of) the transitory component of cash flow such that the permanent component remains which determines investment primarily (through the liquidity effect).

In fact if a firm is liquidity constrained a positive (negative) shock to cash flow will increase (decrease) both the stock of working capital and investment. If the shock is transitory, the extent of investment smoothing determines the actual size of the change in working capital. If the shock was negative (and transitory), the firm will not reduce working capital when it has reached some minimum level necessary for operating the firm but instead reduce investment more.

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[3] Whited measures working capital as current assets minus inventories, receivables and short term debt including the current portion of long term debt.

5.3 The Econometric Framework

To study the role of working capital in the investment process, we calculate the correlations between financial working capital [4] and ordinary investment as well as R&D, and estimate reduced form and structural models to test specific theoretical assumptions concerning their interrelation. More in particular we are interested in the signs of the simple correlations between some key variables of the firm and their patterns over time. That information can throw some light on questions as to whether working capital is a (temporary) depository of funds kept to obtain external finance at lower rates or to smooth investment, that is to act as a buffer to smooth out fluctuations in cash flow (or other sources of funds), or merely a use of funds competing with investment. In the former case we expect a positive correlation between changes in working capital and changes in sales and a (slightly) positive correlation between investment and changes in working capital, while in the latter case the negative correlation that is inherent to competition (for funds in this case) dominates the relation between working capital and investment. If working capital is held for precautionary reasons, for instance in order to make sure that investment projects can be completed, changes in sales and working capital might be negatively correlated, especially when changes in sales persist over time.

The relationships between ordinary investment, R&D and changes in financial working capital are further investigated on the basis of two models that are widely used in empirical economics to explain investment: the Q model and "the Euler equation" model. They are related to each other as the first is obtained by solving the Euler equation forward. However, the way in which the expected present value of the discounted stream of marginal profits (marginal Q) is measured distinguishes the models from each other: by using information from the financial markets, expectations are measured directly rather than dealt with in an econometric way.

In sub-section 5.3.1 we derive a version of the Euler equations for physical capital and R&D that allows for changes in liquidity over time. In the next sub-section we outline an estimation strategy for Q models of investment that involves a split of the sample according to whether the liquidity of the

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[4] Below by working capital we mean financial working capital as it was measured by Whited (1991), and which will be defined formally in (3.1).

firm improves or not. In both models, liquidity is measured by the shadow value of funds, which is unobservable. However, in sub-section 5.3.1 we will establish a link between the changes in liquidity and working capital, which is instrumental for estimating both types of models. The exposition of the models, that will be used to investigate the role of working capital in the investment process, is followed by a discussion of econometric problems that have to be dealt with at the estimation stage. First we give our definition of financial working capital

$$W_t = CASH_t - STDEBT_t \tag{3.1}$$

that is, financial working capital equals cash, short term investments, and prepaid expenses less short term debt and the current portion of long term debt. Like Whited (1991), we exclude both receivables and payables from the definition. Financial working capital, as we define it, is a better variable to stratify by, because changes in inventories are determined by many (nonfinancial) considerations, such as optimization of the production process by producing in bunches for instance, and unexpected shocks in demand. Furthermore to the extent that the firm controls net receivables, they are not only used as a financial buffer but also to further sales.

5.3.1 The Euler Equations

In this subsection we derive the Euler equation models for investment and R&D and we explicitly establish their relation with working capital. The firm is assumed to maximize the expected value of the discounted stream of dividends subject to accumulation constraints on the stocks of capital and financial constraints. One constraint demands that working capital does not get below some minimum level $\underline{W}_t$. This value can be thought of as the minimum amount that is necessary to run the firm or a lower bound that is stipulated in the debt contract with the bank. The dividends D_t are given by [5]

$$\begin{aligned} D_t = {} & (1-\tau)(\Pi(K_t,G_t) - \Phi(I_t,K_t,I_t,R_t) - C(B_t,K_t,G_t)B_t - p^G_t R_t) + \\ & \Delta B_t + V^N_t - \Delta W_t - p^K_t I_t + \Delta(PAYOTH_t - RECEIV_t - INV_t) \end{aligned} \tag{3.2}$$

where $\Pi_t(.)$ is the long run profit function, $\Phi_t(.)$ the adjustment cost

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[5] We omit the subscript indicating the firm.

Table I

List of Variables

G_t	stock of knowledge (R&D) capital at the end of period t
K_t	stock of physical capital at the end of period t
R_t	R&D expenditure during period t
I_t	ordinary investment during period t
S_t	sales at the end of period t
B_t	outstanding long term debt at the end of period t
D_t	dividends paid during period t
V^N_t	new shares during period t
W_t	(financial) working capital at the end of period t
INV_t	inventories at the end of period t
$CASH_t$	cash at the end of period t
$RECEIV_t$	accounts receivable at the end of period t
$STDEBT_t$	short term debt at the end of period t
$PAYOTH_t$	accounts payable and other short term liabilities (t)

function and $C_t(.)$ the interest rate schedule. They will be specified below. τ is the corporate tax rate. Table 1 gives a list of definitions of the variables used. p^G and p^K are the real costs of knowledge and physical capital. The last term in the flow of funds constraint (3.2) containts the variables that we left out from our definition of working capital. We will assume that they do not affect the value of the firm and can be ignored in the analysis. The firm's maximization problem can now be stated as follows

$$\underset{I,R,V^N,D,\Delta B,\Delta W}{\text{Max}} \; E_t(V_t) = E_t \sum_{s=0}^{\infty} \left[1+\frac{r}{(1-c)}\right]^{-(t+s)} \left[\frac{(1-\theta)}{(1-c)} D_{t+s} - (1+\Omega_{t+s})V^N_{t+s}\right] \tag{3.3}$$

subject to (3.2) and the following constraints

$$\lambda^K_t \qquad I_t = K_t - (1-\delta^K)\, K_{t-1} \;, \tag{3.4a}$$

$$\lambda^G_t \qquad R_t = G_t - (1-\delta^G)\, G_{t-1} \;, \tag{3.4b}$$

$$\xi^B_t \qquad B_t = \Delta B_t + B_{t-1} \;, \tag{3.4c}$$

$$\xi^W_t \qquad W_t = \Delta W_t + W_{t-1} \;, \tag{3.4d}$$

$$d_t \qquad D_t \geq 0, \tag{3.4e}$$

$$v_t \qquad V^N_t \geq \underline{V}^N_t \tag{3.4f}$$

$$\eta_t \qquad W_t \geq \underline{W}_t \;, \tag{3.4g}$$

where r is the investor's required after-tax rate of return, c is the capital gains tax rate and θ is the personal income tax rate. This maximization problem assumes that when the shareholders issue new shares to the company, they must pay a premium in the form of a decrease in value of their existing shares, because of the existence of 'lemons' in the equity market (see Akerlof, 1970). The first column of (3.4) shows the current value Langrange or Kuhn-Tucker multipliers corresponding to the constraints. μ_t is the Lagrange multiplier associated with (3.2). The transition equations for B_t and W_t hold trivially but are included for the sake of completeness. Before we give the first order conditions, we specify the revenue function, the adjustment cost function and the interest rate schedule.

The long run revenue function is given by

$$\Pi(K_t,G_t) = CD(K_t,G_t) = a_t K_t^{\alpha_K} G_t^{\alpha_G} \tag{3.5}$$

Adjustment cost function

$$\Phi(I_t,K_t,I_t,R_t) = \tfrac{1}{2}\,\phi^K\,(I_t/K_t - c^K)^2\,K_t + \tfrac{1}{2}\,\phi^G\,(R_t/G_t - c^G)^2\,G_t \tag{3.6}$$

Interest rate schedule (agency cost function)

$$C(B_t,K_t,G_t) = \beta^0 + \tfrac{1}{2}\,[\beta^K + \beta^G\,K_t/G_t]\,B_t/K_t \tag{3.7}$$

The long run revenue function corresponds to a Cobb Douglas technology. As the revenue elasticities do not have to add up to one, it allows for nonconstant returns to scale and the possibility that the firm has some market power in the output market. The specification that we choose to measure the adjustment costs is ubiquitously in the literature. In the interest rate schedule the cost of debt is assumed to depend on the importance of agency costs considerations. The higher the debt, the more likely that a firm defaults. Therefore bondholders will demand a higher risk premium as debt increases. Furthermore when most of the firm's assets are intangible, it will have less collateral to offer to the bank or any other creditor that can be sold in case of a bankruptcy. Thus we expect that β^G is negative and that the other coefficients in C(.) are positive and also that $[\beta^K + \beta^G K_t/G_t]$ is positive.

The first order conditions for the control variables we are interested in I_t, R_t, V_t^N, D_t, ΔB_t, and ΔW_t are the following

$$\lambda^K_t - \mu_t[\,(1-\tau)\Phi_{It} + p^K_t\,] = 0 \tag{3.8a}$$

$$\lambda^G_t - \mu_t[\,(1-\tau)\Phi_{Rt} + p^G_t\,] = 0 \tag{3.8b}$$

$$\tilde{\mu}_t + \tilde{v}_t = (1 + \Omega_t) \quad \tilde{v}_t(V^N_t - \underline{V}^N_t) = 0 \quad \tilde{v}_{t+s} = v_{t+s}(1 + \tfrac{r}{1-c})^s \tag{3.8c}$$

$$\tilde{\mu}_{t+s} = \mu_{t+s}(1 + \tfrac{r}{1-c})^s$$

$$\tilde{\mu}_t - \tilde{d}_t = \frac{(1-\theta)}{(1-c)} \qquad \tilde{d}_t D_t = 0 \qquad \tilde{d}_{t+s} = d_{t+s}(1 + \tfrac{r}{1-c})^s \tag{3.8d}$$

$$\mu_t - \xi^B_t = 0 \tag{3.8e}$$

$$\mu_t - \xi^W_t = 0 \tag{3.8f}$$

The first order conditions for the state variables K_t, G_t, B_t, and W_t are (after eliminating λ^K_t, λ^G_t, ξ^B_t, and ξ^W_t using equations (3.8a,b,e,f))

$$(1 + \tfrac{r}{1-c})\,\frac{\tilde{\mu}_{t-1}}{\tilde{\mu}_t}\Big[\alpha^K\Pi_{t-1}/K_{t-1} + \tfrac{1}{2}\,\phi^K\,(I_{t-1}/K_{t-1})^2 - \phi^K\,I_{t-1}/K_{t-1} \tag{3.9a}$$
$$+ \beta^K\,(B_{t-1}/K_{t-1})^2 - \tfrac{1}{1-\tau}\,p^K_{t-1}\Big] + \phi^K(1-\delta^K)\,I_t/K_t + \tfrac{1-\delta^K}{1-\tau}\,p^K_t + f_i + s_t = \varepsilon_t$$

$$(1 + \tfrac{r}{1-c})\,\frac{\tilde{\mu}_{t-1}}{\tilde{\mu}_t}\Big[\alpha^G\Pi_{t-1}/G_{t-1} + \tfrac{1}{2}\,\phi^G\,(R_{t-1}/G_{t-1})^2 - \phi^G\,R_{t-1}/G_{t-1} \tag{3.9b}$$
$$+ \beta^G\,(B_{t-1}/G_{t-1})^2 - \tfrac{1}{1-\tau}\,p^G_{t-1}\Big] + \phi^G(1-\delta^G)\,R_t/G_t + \tfrac{1-\delta^G}{1-\tau}\,p^G_t + f_i + s_t = \varepsilon_t$$

$$(1\overset{+}{\textcircled{-}})(1-\tau)\;[\beta^0 + [\beta^K + \beta^G\,K_t/G_t]\,B_t/K_t]\,)\;\underbrace{(1 + \tfrac{r}{1-c}\,)}_{1/\beta}\;\frac{\tilde{\mu}_t}{\tilde{\mu}_{t+1}} = 1 \tag{3.9c}$$

$$\tilde{\mu}_{t+1} = (1 + \tfrac{r}{1-c}\,)\;[\tilde{\mu}_t + \tilde{\eta}_t] \qquad \tilde{\eta}_t(W_t - \underline{W}_t) = 0 \tag{3.9d}$$

$$\tilde{\eta}_{t+s} = \eta_{t+s}(1 + \tfrac{r}{1-c})^s$$

or

$$\mu_{t+1} = [\mu_t + \eta_t] \qquad \eta_t(W_t - \underline{W}_t) = 0 \tag{3.9d'}$$

$$d(\mu_{t-1}/\mu_t)/d\eta_{t-1} = -1/\mu_t < 0 \qquad (3.10)$$

To understand the implications of the model, we will give an interpretation of some of the first order conditions, notably those pertaining to the financial variables (3.8c,d) and (3.9c,d).

When W_t equals the lowerbound $\underline{W}_t$, the shadow value of working capital is negative. The more the operation of the firm is hampered by the constraint on working capital, the lower η_t becomes. It follows from (3.10) that when η_t decreases, next year's investment becomes more sensitive to the marginal profit of last year (the term between brackets in 3.9a,b).
Equations (3.8c) and (3.8d) give rise to (at most) four financial regimes:

1 $d > 0$ and $v = 0$: no dividends and issue of new shares
2 $d > 0$ and $v > 0$: no dividends and no new shares
3 $d = 0$ and $v > 0$: dividends and no new shares
4 $d = 0$ and $v = 0$: dividends and issue of new shares

The fourth regime is not feasible as long as $\theta > c$ and $\Omega_t \geq 0$ which was the case in the period in which the observations were collected that will be used for the inference.

Note that $(1-\theta)/(1-c) \leq \tilde{\mu}_t \leq 1 + \Omega_t$. When a firm ceases to pay dividends or starts to issue new shares, $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ drops below one and investment becomes less sensitive to last period's marginal profit. Also when the firm is in the second regime in two adjacent periods, $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ can fall below one : when the liquidity of the firm decreases, $\tilde{\mu}$ increases.

According to (3.8d) the value of a dollar inside dividend paying firms is less than a dollar, that is $\tilde{\mu}$ is at its minimum level $(1-\theta)/(1-c) < 1$. Due to tax laws, which say that the rate of personal income taxes is higher than the capital gains tax rate, funds are trapped within the firm when $(1-\theta)/(1-c) < \tilde{\mu} < 1$ (see Auerbach, 1984): it is not in the interest of the shareholders to pay dividends, although the firm does not have good investment opportunities. According to Jensen (1986) the availability of these socalled free cash flows (funds for which $\tilde{\mu} < 1$ holds) might lead to overinvestment. Only in case $\tilde{\mu} > 1$ the firm is liquidity constrained: a dollar invested in the firm would yield more than a dollar.

Equation (3.9d') suggests that the shadow price of the flow of funds constraint (3.2) (μ) remains constant (thus $\tilde{\mu}_{t-1}/\tilde{\mu}_t < 1$) when the working capital constraint was easily satisfied in period t-1. Since working capital above the minimum level $\underline{W}_t$ hardly yields any income to the firm (in fact not at all according to our model), it will be used to lower the debt burden. Even if the firm has no debt, as long as β^0 the intercept in the interest rate schedule is positive, η_t will be negative and W_t equals $\underline{W}_t$. In other words changes in W_t reflect changes in $\underline{W}_t$.

The Euler equations (3.9a) and (3.9b) cannot be estimated as they contain the unobserved ratio of shadow values $\tilde{\mu}_{t-1}/\tilde{\mu}_t$. However the other restrictions provide some information on their probable value. For example the first order condition for debt (3.9c) was exploited by Whited (1992) [6]. We will focus on (3.9d). However the shadow value of working capital constraint is also unobservable. It will be related to observables in the spirit of MaCurdy's (1981) approach [7]. We hypothesize that η depends on the value of $\underline{W}_t$ [8] . The sign of this relationship is ultimately an empirical matter, but we expect it to be negative. An (forced) increase in working capital — for example demanded by the bank — hurts more when a firm already holds a large stock of working capital (relative to its other assets) on which it earns no return, than when the initial level of working capital is relatively low. Or put differently: a dollar invested in working capital cannot be invested in, say, physical capital. As investment projects are chosen in order of their expected returns, a firm with relatively much working capital is likely to forgo a

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[6] Her approach to incorporating agency costs of debt in the model differs from our treatment. She specifies an inequality constraint on debt $B_t \leq \underline{B}_t$ and then obtains a first order condition for debt that includes the Kuhn-Tucker multiplier. To measure the unobservable KT multiplier she relates it to factors that are assumed to influence the cost of debt.

[7] In his pioneering paper he related the unobservable shadow value of the wealth constraint in a life-cycle model of consumption and labor supply to observables such as lifetime wage, initial assets et cetera.

[8] Of course it also depends on variables of which we know that they determine μ_t and μ_{t+1}. However our objective is to identify additional variables that determine the ratio μ_t/μ_{t+1} by exploiting its relation with η_t .

project with a higher return than the firm with less working capital. Or from still another perspective, the firm with much working capital has to make a profit with less physical and knowledge capital. Thus we expect that

$$d\eta_t/d(\underline{W}_t/K_t) < 0 \tag{3.11}$$

As we noted above, an entrepreneur that maximizes the value of the firm will set W_t equal to $\underline{W}_t$. By combining (3.10) and (3.11) we have found another way to measure the ratio of the shadow values of funds in two consecutive periods that can be exploited in order to estimate the Euler equations. To this end we could add the following equation to the model that can be substituted in the Euler equations for physical and knowledge capital (3.9a,b)

$$\frac{\tilde{\mu}_{t-1}}{\tilde{\mu}_t} = \vartheta_t + \delta(W_{t-1}/K_{t-1} - \overline{W_{t-1}/K_{t-1}}) \tag{3.12}$$

Note that according to the theory outlined above, $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ is positively related to the level of W_{t-1}/K_{t-1} . We included deviations from the mean in (3.12) to deal with heterogeneity among firms: for some firms (industries) the average value of W_{t-1}/K_{t-1} will be lower, for other firms (industries) it will be higher. The time dummies track aggregate changes in the liquidity of firms as far as they are not reflected in working capital.

Before we estimate the models we must deal with the individual effects. If they are correlated with RHS variables, they cause biases in the estimates. To avoid this, the individual effects (f_i) will be removed by taking differences of the equations. Since the coefficients in the Euler equations are varying over time because of the $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ factor, this is not equivalent to taking differences of the variables (see also Holtz-Eakin, Newey and Rosen (1988)).

Both in the Euler equations and in the Q model, current investment I_t/K_t (R_t/G_t) is the dependent variable. Some of the RHS variables, notably lagged investment, Q, sales and debt, are endogenous though predetermined. However after taking differences of the equations — whether they be taken vis-à-vis the first lagged equation or the most distant lagged equation or the mean of lagged equations,— the lags of these variables will be correlated with the error term. Therefore we have to rely on an instrumental variable type estimator or a Generalized Method of Moments estimator. In order to exploit as many orthogonality conditions as possible, we take first differences. Furthermore, our choice of the instruments will allow for measurement errors that follow a low order moving average process. Due to the panel structure of the data we are able to impose separate moment conditions for each period. As was pointed out by Arrelano and Bond (1991), in this manner we avoid problems due to nonstationarity of the data generating processes. Finally given the set of the instruments, the optimal weighting matrix that is used by GMM takes heteroskedasticity — both across firms and time — and the correlation structure of the errors over time into account. Since most of the correlation between errors corresponding to different firms is likely to be due to aggregate effects, we deal with this by including fixed time effects into the regression equations.

The specifcation for $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ in (3.12) has two drawbacks. First, for large changes in working capital, the value of $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ can become negative. This is conflicting with the theory. Second, the model is perhaps too parsimonious. Apart from working capital, other (unobserved) factors might affect $\tilde{\mu}_{t-1}/\tilde{\mu}_t$. Therefore we will also use an alternative specification

$$\frac{\tilde{\mu}_{t-1}}{\tilde{\mu}_t} = \exp\left(\vartheta_t + \delta\, W_{t-1}/K_{t-1} + c_i\right) \tag{3.13}$$

After inserting (3.13) in the Euler equations, we have to deal with both a multiplicative ($\exp(c_i)$) and an additive individual effect f_i. While this estimation problem can be solved in principle, we will concentrate on the case of the multiplicative effect. Chamberlain (1993) suggested a transformation of the model that yields orthogonality conditions that can be exploited by a GMM estimator. To explain his idea, we write our model succinctly as

$$d_t(y_{it},x_{it};\theta) - r_t(x_{it};\theta)\, C_i = u_{it} \qquad t = 1,\ldots,T \tag{3.14}$$

where y_{it} comprises current endogenous variables (e.g. I_t/K_t) and x_{it} includes predetermined variables. T is the last year of the sample. Let z_{it} denote the vector of instruments that are orthogonal to u_{it}. Now consider the following transformation

$$\rho_t(y_{it},x_{it};\theta) = d_t(y_{it},x_{it};\theta) - r_t(x_{it};\theta)^{-1} r_T(x_{it};\theta)\, d_T(y_{it},x_{it};\theta) \tag{3.15}$$

This is equivalent to

$$\rho_t(y_{it},x_{it};\theta) = u_{it} - r_t(x_{it};\theta)^{-1} r_T(x_{it};\theta)\, u_{iT} \tag{3.16}$$

By the fact that $E(u_{it} z_{it}) = 0$ it follows that $E(\rho_t(y_{it},x_{it};\theta)\, u_{it}) = 0$. However the latter moment condition does not include the unobservable individual effect C_i and therefore can be used for estimation. Notice from (3.17) that the GMM estimator that results, is actually based on quasi-differencing the model. As long as $r_t(x_{it};\theta)$ does not change much over time, this procedure will remove most of the additive individual effect (included in u_{it}) as well.

We conclude this sub-section by giving the estimating equations

$$\begin{aligned}(1-\delta^K)\, I_t/K_t = &- b_2^K \frac{1-\delta^K}{1-\tau} p_t^K + \left(1 + \frac{r}{1-c}\right) \frac{\tilde{\mu}_{t-1}}{\tilde{\mu}_t} \Big[b_1^K S_{t-1}/K_{t-1} \\ &- \tfrac{1}{2} (I_{t-1}/K_{t-1})^2 + I_{t-1}/K_{t-1} + b_3^K (B_{t-1}/K_{t-1})^2 + b_2^K \frac{1}{1-\tau} p_{t-1}^K \Big] + f_i + s_t + \varepsilon_t\end{aligned} \tag{3.17a}$$

$$\begin{aligned}(1-\delta^G)\, R_t/G_t = &- b_2^G \frac{1-\delta^G}{1-\tau} p_t^G + \left(1 + \frac{r}{1-c}\right) \frac{\tilde{\mu}_{t-1}}{\tilde{\mu}_t} \Big[b_1^G S_{t-1}/G_{t-1} \\ &- \tfrac{1}{2} (R_{t-1}/G_{t-1})^2 + R_{t-1}/G_{t-1} + b_3^G (B_{t-1}/G_{t-1})^2 + b_2^G \frac{1}{1-\tau} p_{t-1}^G \Big] + f_i + s_t + \varepsilon_t\end{aligned} \tag{3.17b}$$

where $\dfrac{\tilde{\mu}_{t-1}}{\tilde{\mu}_t} = \exp(\vartheta_t + \delta\, W_{t-1}/K_{t-1} + c_i)$

When the transformation due to Chamberlain is not applied, we replace c_i by $-\overline{W_{t-1}/K_{t-1}}$.

The following restrictions between the reduced form parameters and the Euler equation parameters hold

$$b_1^F = -\alpha^F/\phi^F, b_2 = 1/\phi^F \text{ and } b_3 = -\beta^F/\phi^F,\ F = G,K. \tag{3.17c}$$

5.3.2 A Q Model of Investment with Endogenous Financial Regimes

The Q type regression models that will be developed in this sub-section are based on the following relations

$$I_t/A_t = b_I I_{t-1}/A_{t-1} + b_Q Q_{t-1} + b_{INV} INV_{t-1}/A_{t-1} + b_P p^K_t + b_B B_{t-1}/A_{t-1} + b_S S_{t-1}/A_{t-1} + f_i + s_t + \varepsilon_t \tag{3.18a}$$

$$R_t/G_t = b_I R_{t-1}/G_{t-1} + b_Q Q_{t-1} + b_{INV} INV_{t-1}/A_{t-1} + b_P p^G_t + b_B B_{t-1}/A_{t-1} + b_S S_{t-1}/A_{t-1} + f_i + s_t + \varepsilon_t \tag{3.18b}$$

where $Q_t = V_t/A_t$ is "Tobin's Q" , V_t is the market value of the firm net of short term assets, and A_t is "total assets". f_i and s_t are firm and time effects, while ε_t is an error term. The exact definitions of V_t and A_t are given by

$$V_t = E_t + TB_t - ADJ_t \tag{3.19a}$$

$$A_t = K_t + G_t \text{ (in constant prices of 1987)} \tag{3.19b}$$

where $TB_t = B_t + STDEBT_t$ is total debt

E_t = ValueCOMmonShares + PREFerredSTock is the value of shares[9]

$ADJ_t = CASH_t + RECEIV_t - PAYOTH_t$

The Q models for investment are in reduced form. A lag of investment is added to capture the dynamics of investment. Inventories are included to accommodate different measures of marginal Q that are used in the literature. Debt over assets is included as a measure of agency/bankruptcy costs. Like Gilchrist and Himmelberg (1993), we think that it may be more reasonable to assume that the investment decision is made on the basis of an information set that only includes lagged values of the RHS variables (Q, S etcetera).

Using the switching regression methodology of Lee, Maddala and Trost (1979), we will test for differences in investment behaviour across two subsamples (regimes) that correspond to increases in financial working capital

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[9] The capitals in the names of the variables form the names used in the description of the dataset that we exploited, see Hall (1990a).

and decreases ($\Delta(W/A)_t \leq 0$) respectively. A close examination of the Q model suggests that this approach to testing for differences in investment behaviour due to financial considerations is more appropriate than that of Fazzari, Hubbard and Petersen, FHP for short, (1988), who classified firms as either liquidity constrained, moderately liquidity constrained, or not liquidity constrained for the whole sample period according to their dividend payout ratio [10]. However, the level of investment is determined by the change in liquidity over time rather than by the average liquidity position of a firm. In the language of our models, the ratios of the current shadow value of funds of a firm to the *future* shadow values of funds of that particular firm, rather than to the shadow values of funds of *other* firms, matter for its investment decision. From the derivation of the Q model [11], we know that the shadow value of capital equals a discounted sum of marginal profits premultiplied by the shadow values of funds μ [12]. The first order condition for investment equates the shadow value of capital λ_t to the marginal cost of investment $\mu_t[(1-\tau)p_t(\partial\Phi_t/\partial I_t) - p^I_t]$. Given λ_t, investment is determined by μ_t, p_t, p^I_t and K_t [13]. We expect that the value of μ_t in proportion to μ_{t+1}, μ_{t+2},... varies with $(W/A)_t$, just as in the Euler equation model derived in sub-section 5.3.1. Consequently, the coefficient of Q varies across the regimes and is lower when $\Delta(W/A)_t \geq 0$. Since (dis-)investment decisions with respect to working capital are taken frequently, probably several times within a year, the approach followed by FHP seems to be too rough [14].

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[10] Each category contained the same number of firms.

[11] See also chapter 1.

[12] The shadow value of capital $\lambda_t = E_t(1-\tau) \sum_{s=t}^{\infty} \left[\frac{1-\delta}{1+r/(1-c)}\right]^{s-t} \mu_s p_s \frac{\partial(\Pi_s - \Phi_s)}{\partial K_s}$. This follows from solving the Euler equation for the stock of capital forward.

[13] When the future shadow value of funds μ_s is not constant across time, the practice of substituting average Q for average Q is no longer valid. Thus the fluctuations in liquidity are a source of errors in the measurement of marginal Q.

[14] By splitting the sample by the dividend payout ratio, FHP actually divide the sample into a part for which the Q model might be valid, because the shadow value of funds is likely to be constant over time (the dividend paying

The decision to adjust the stock of working capital could be influenced by the same considerations or changes in economic circumstances as the real investment decisions. Therefore we have to consider the possibility of endogenous regime switches, which means that the error term of the model for the indicator of the regime (the sign of the change in working capital) and the error terms of the models for the decision variable of interest (e.g. R&D) that hold under the various regimes are correlated. To complete the system of equations, we have to specify a model for the change in working capital. Being without a real theory about working capital investment, we will specify a reduced form model that includes variables that are likely to be related to the change in working capital

$$\begin{aligned}\Delta(W/A)_t = {} & \gamma_W\Delta(W/A)_{t-1} + \gamma_Q\Delta Q_{t-1} + \gamma_{INV}\Delta(INV/A)_{t-1} + \gamma_{CSFL}\Delta(CSFL/A)_{t-1} + \\ & \gamma_S\Delta(S/A)_{t-1} + u_t \end{aligned} \tag{3.20}$$

where $CSFL_t$ denotes cash flows. This model can also be used to predict the regime by replacing $\Delta(W/A)_t$ by a dichotomous variable that equals one when $\Delta(W/A)_t \geq 0$ and zero elsewhere.

The endogenous switching regression model for investment that combines the specifications that hold under the two regimes reads as

$$\begin{aligned} E_t(I_t/A_t) = {} & E_t(I_t/A_t \mid \Delta(W/A)_t < 0)\ \Pr(\Delta(W/A)_t < 0) + \\ & E_t(I_t/A_t \mid \Delta(W/A)_t \geq 0)\ \Pr(\Delta(W/A)_t \geq 0) = \\ & b_1'X_t(1-\Phi(\pi'Z_t)) + b_2'X_t\Phi(\pi'Z_t) + \phi(\pi'Z_t)(\sigma_{2u}-\sigma_{1u}) \end{aligned} \tag{3.21}$$

where Z includes the explanatory variables for investment and X those for the change in working capital; b and π are the vectors comprising the corresponding coefficients. The subscripts indicate the regime. σ_{iu} denotes the correlation between the error under regime i and the error of the working capital equation. Following common practice, we assumed that the error term of the model for the regime dummy, u_t, follows a standard normal distribution $\Phi(u_t)$. This yields the probit factors $\Phi(\pi'Z_t)$ in equation (3.21). $\phi(u_t)$ is the standard normal density function.

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firms), and two other parts for which the Q model is misspecified, because the equality between marginal Q and average Q (adjusted for the current shadow value of funds) fails to hold. Adding a measure of liquidity to the Q equation does not fix the specification.

Although the framework in (3.21), that combines the specifications for the various regimes, facilitates estimation, it does not allow us to test for endogeneity of the regime switches; only the hypothesis $\sigma_{1u} = \sigma_{2u}$ can be tested.

Also note that even in the absense of correlation between the error terms, that is $\sigma_{1u} = \sigma_{2u} = 0$ (which is known in the literature as the case of exogenous regime switches), the regressors in the switching regression model (3.21) include the probit factors. The difference between the switching model and the naive model that just allows the coefficients to differ across regimes depends on the ability to predict the working capital regime; when one can perfectly discriminate between both regimes, the two models coincide. It should also be borne in mind that there is possibly a great difference between the ability of the econometrician to predict changes in working capital and the extent to which a financial manager can look ahead. Moreover, it is not clear whether a model for working capital observed at the frequency of a year makes sense. For these reasons we will consider both the (endogenous) switching regression model and the simple model that assumes perfect predictability of the regimes in the empirical section.

5.4 Sample Selection and Properties of the Data

The models outlined in section 3 will be estimated and tested with data from the Manufacturing Sector Master File from Hall (1988), which contains a subset of the Compustat data. Since our interest in working capital is mainly based on its relation to ordinary investment and R&D investment in particular, we will limit the sample to firms that have a high R&D intensity. These can be found in the scientific sector, which comprises the chemical industry, SIC 28, the computer industry, SIC 357, the electrical equipment/electronics industry, SIC 36, and the instruments industry, SIC 38. The theories discussed above identified several motives to hold working capital, some of which were connected to the financing of investment. The predictions of most of these theories can be tested best in a period that includes a recession. For instance, the reliquefication theory of Eckstein and Sinai refers to the period at the end of the recession. Therefore our investigations are based on the 1979-1984 period, although the sample we used starts earlier (in 1973) for the construction of lags and instruments.

The empirical investigation starts with an analysis of simple correlations between investment in physical and knowledge capital and financial working capital over time. Table 1 shows the development of the means of several series over time and table 2 displays the simple correlations between important variables both over time and for the whole period 1979-1984. The important facts that emerge from these tables can be summarized as follows.

Ordinary investment decreases from 1979 to 1983 significantly and then one year after the trough of the recession, it rises considerably. R&D expenditure rises over the period, although when 1979 is considered as an exception, it is nearly flat. Sales decrease during the 1980-1982 recession period as expected. While the debt-physical capital ratio declines, working

Table I

Summary Statistics

Means

	1979	1980	1981	1982	1983	1984	St.Dev.
R/G	0.153	0.166	0.175	0.168	0.175	0.174	0.009
I/K	0.151	0.150	0.148	0.133	0.127	0.164	0.010
$(S/K)_{-1}$	3.06	3.12	2.98	2.83	2.69	2.56	0.167
$\Delta S/K$	0.227	-0.0732	-0.0162	-0.165	0.0082	0.236	0.040
$(B/K)_{-1}$	0.423	0.410	0.405	0.375	0.356	0.296	0.029
$\Delta B/K^*$	0.171	1.16	-1.56	-0.942	-4.40	1.81	1.48
W/K	0.100	0.106	0.134	0.184	0.247	0.177	0.028
$\Delta W/K^*$	1.30	1.91	3.70	5.17	6.24	-4.66	1.90
$\Delta(W/K)^*$	-1.03	0.592	2.63	4.61	6.06	-4.81	2.03
WK/K	0.797	0.775	0.719	0.711	0.739	0.711	0.058
$\Delta WK/K^*$	3.99	-0.385	-1.52	0.369	3.17	0.861	1.59

* : (x 10^{-2})

ST.DEV. is average standard deviation of the means, which are computed for each period.

WK=CURRentASSeTs - ShortTermLIABilities

W =CURRentASSeTs - INV - RECEIV - STDEBT = CASH - STDEBT

Table II Simple Correlations

Corr. Period	I/K,DW/K	I/K,DS/K	I/K,DB/K	DW/K,DS/K	DW/K,DB/K	DS/K,DB/K
79	-0.1183	0.1975	0.4505	-0.6394	-0.2401	0.2133
80	-0.2798	0.3464	0.4549	-0.1880	0.0786	0.5197
81	0.0407	0.1502	-0.0481	-0.1857	-0.0653	0.2778
82	-0.1240	0.0328	0.3866	0.1001	-0.1836	0.0700
83	0.1886	0.2764	0.1027	0.0804	-0.1650	0.1932
84	-0.1531	0.3467	0.1621	-0.2765	-0.0868	0.3921
79-84	-0.0744*	0.2333*	0.2583*	-0.2091*	-0.1045*	0.3011*

Corr. Period	R/G,DW/K	R/G,DS/K	R/G,DB/G	DW/K,DS/G	DW/K,DB/G	DS/G,DB/G
79	-0.1351	0.3272	0.2640	-0.2565	-0.0539	0.2870
80	0.0150	0.4200	0.2432	-0.1633	-0.0209	0.6246
81	0.1498	0.1413	-0.0406	-0.0519	-0.0066	0.4211
82	-0.1676	0.0671	0.1726	0.0712	-0.1195	0.1665
83	0.1727	0.2875	-0.0454	0.0019	-0.1274	0.3025
84	-0.0740	0.2372	0.2357	-0.1394	0.0184	0.4123
79-84	0.0024	0.2601*	0.1666*	-0.1000**	-0.0486	0.3739*

For correlations calculated for separate years:

Critical values: 0.2089 (5%), 0.1754 (10%), based on 84 observations.

For correlations calculated over 1979-1984 period (506 obs.):

* : significant at 5% level,

** : significant at 10% level

Tests are heteroskedastic-consistent T-tests based on Seemingly Unrelated Regressions (with identity weighting) which takes the correlations between observations over time into account.

capital (W/K) actually increases during the recession years: the sharpest changes (in opposite directions) of these ratios take place just after the recession in 1983. This is followed by a movement in the opposite direction in 1984. Although this evidence already gives a clue about the possible motives for holding working capital, we will also look at the table with correlations. Changes in working capital and investment are negatively correlated with the exception of 1983. For R&D the absence of correlation with working capital could not be rejected. From the second column of table 2 we learn that both types of investment are positively correlated with an increase in sales. This could reflect a liquidity or a productivity effect. The fourth column is especially interesting for us as it displays the correlation between changes in working capital and changes in sales. In most years, with the exception of 1982 and (again) 1983, the sign is negative.

All the evidence from table 1 and 2 on the development of investment, R&D, working capital and their correlation patterns over time taken together, the following conclusions seem warranted. First ordinary investment and working capital 'compete' for the available funds. Second working capital is not a temporary depository of funds, used to smooth investment, but seems to be held for precautionary reasons: both in the cross section and in the time dimension working capital and sales are negatively correlated. Third the value of the statistics support the reliquefication theory. In 1983, the first year after the recession, the ratio of working capital to physical capital reaches its maximum, while debt to capital (B/K) drops to a minimum. Furthermore 1983 is the only year in which investment (R&D), the change in sales and the change in working capital are positively correlated. This could be interpreted as follows: the increase in funds is used for investment as usual and to improve the balance sheet, in particular the liquidity of the firm. The more the working capital of the firm rises, the cheaper financing (both internal and external) will be in the near future. This in turn makes investment tomorrow as well as today more likely. In general however (with the exception of the reliquefication period) an increase in working capital is associated with a deterioration of the (financial) condition of the firm.

5.5 Empirical Results

5.5.1 Results obtained for the Q Models

Tables 3a-3c show the regression results for Q models for ordinary investment and R&D. The instruments that were used are listed in appendix 5.A. In table 3a we included sales as a regressor to control for profitability and liquidity. Many empirical studies found that sales has explanatory power beyond Q. Some empirical studies, e.g. Chirinko and Schaller (1993), attribute this to the fact that Q as it is usually measured, namely as the stock market value of the firm over the replacement value of capital, is an imperfect indicator of profitability, which does not fully reflect fundamentals. Table 3c reports the estimates of the switching regression version of the Q model, while table 3d gives various estimation and test results for models of the regime indicator and the 'latent' variable, viz, the change in working capital $\Delta(W/A)$. First we discuss the results for the naive models shown in tables 3a and 3b.

The test results show that in most cases there is no need to include a lag of investment to capture the dynamics. Furthermore most estimates have the right sign or when not are insignificant; we will indicate the exceptions in the discussion of the results. Q does not enter the model of ordinary investment that assumes homogeneity of the parameters significantly, but sales does. However when we dropped sales from the equation, the t-value for Q rose to 2. In the case of R&D, Q performs well as an explanatory variable, while sales has nothing to add or enters with the wrong sign. The preferred measure of Q leaves out the value of the inventories from the numerator, which is plausible since it has not been included in the denominator either. Another interpretation of the results for inventories is provided by Chirinko (1994). He derives a model where Q is related to a weighted sum of various types of investment, like for instance investment in inventories and physical capital as in our model (for ordinary investment). If the gross change in inventories is proportional to its level, which seems plausible, then inventories would enter with a negative sign as they do. Debt over 'total assets', which we measured as the sum of the stocks of physical and knowledge capital, is negatively related to investment, which is in accordance with the presumption that it measures the height of marginal agency costs. The negative relation between debt and investment was also found by Long and Malitz (1985).

Table IIIa

GMM Estimation Results for Q Model

	PHYSICAL CAPITAL		R & D	
	HOMOGEN.	SPLIT BY $\Delta(W_t/A_t)>0$	HOMOGEN.	SPLIT BY $\Delta(W_t/A_t)>0$
b_I	-0.0950	0.3417	0.0333	0.0768
	(0.0764)	(0.1890)	(0.0837)	(0.1703)
b_Q	0.0121	0.0399	0.0167	0.0418
	(0.0076)	(0.0212)	(0.0048)	(0.0212)
b_{INV}	-0.0783	-0.0147	0.0042	-0.1753
	(0.0470)	(0.1198)	(0.0291)	(0.1076)
b_P	0.0196	-0.1072	-0.0107	-0.0391
	(0.0350)	(0.1437)	(0.0178)	(0.0604)
b_B	-0.1032	-0.2100	-0.0172	-0.0071
	(0.0281)	(0.0712)	(0.0357)	(0.0588)
b_S	0.0417	0.0287	-0.0111	-0.0290
	(0.0142)	(0.0395)	(0.0114)	(0.0391)
Wb_I		-0.3132*		0.2650
		(0.1112)		(0.1175)
Wb_Q		0.0059		0.0156
		(0.0121)		(0.0103)
Wb_{INV}		-0.1344		0.1665*
		(0.0747)		(0.0754)
Wb_P		0.2965		-0.0242
		(0.1267)		(0.0441)
Wb_B		-0.0957		-0.0518
		(0.0652)		(0.0534)
Wb_S		0.0754		-0.0340
		(0.0214)		(0.0149)
SARGAN	28.911	19.813	31.939	23.545
(D.F.)	(29)	(23)	(29)	(23)
DISTANCE		9.757		4.310
(D.F.)		(6)		(6)

423 obs., 90 firms, period 1979-1983. Models have been estimated in first differences. HOMOGEN. means parameter homogeneity. W* : coefficients for subsample where $\Delta(W/A) \geq 0$. Time dummies have been included. Heterosked. consistent standard errors are reported below estimates; optimal weighting matrix has been used. Sargan Test and Distance Test ~ χ^2(D.F.).

* (**) : significantly different across regimes at 5 % (10%) level

Table IIIb

GMM Estimation Results for Q Model

	PHYSICAL CAPITAL		R & D	
	HOMOGEN.	SPLIT BY $\Delta(W_t/A_t)>0$	HOMOGEN.	SPLIT BY $\Delta(W_t/A_t)>0$
b_I	-0.2187 (0.0889)	0.1752 (0.1826)	0.0046 (0.0782)	0.0109 (0.1539)
b_Q	0.0128 (0.0065)	0.0298 (0.0175)	0.0162 (0.0047)	0.0282 (0.0164)
b_{INV}	0.0233 (0.0342)	0.0512 (0.0901)	-0.0124 (0.0247)	-0.1911 (0.0761)
b_P	0.0345 (0.0347)	-0.0793 (0.1349)	-0.0136 (0.0172)	-0.0222 (0.0565)
b_B	-0.1233 (0.0326)	-0.1602 (0.0673)	-0.0225 (0.0349)	-0.0433 (0.0577)
Wb_I		-0.5024* (0.1335)		0.0100 (0.1216)
Wb_Q		0.0066 (0.0117)		0.0114 (0.0092)
Wb_{INV}		0.0074 (0.0608)		0.1057* (0.0639)
Wb_P		0.1793 (0.1076)		-0.0281 (0.0468)
Wb_B		-0.2032 (0.0643)		-0.0630 (0.0511)
SARGAN (D.F.)	29.716 (30)	22.743 (25)	32.658 (30)	27.226 (25)
DISTANCE (D.F.)		7.686 (5)		3.890 (5)

423 obs., 90 firms, period 1979-1983. Models have been estimated in first differences. HOMOGEN. means parameter homogeneity. W* : coefficients for subsample where $\Delta(W/A) \geq 0$. Time dummies have been included. Heterosked. consistent standard errors are reported below estimates; optimal weighting matrix has been used. Sargan Test and Distance Test ~ χ^2(D.F.).

* (**) : significantly different across regimes at 5 % (10%) level

To test for differences in investment behaviour between periods in which $\Delta(W/A)$ is positive or negative respectively, we employed a distance test (see for instance Newey and West, 1987). At the 10% significance level, homogeneous behaviour could not be rejected both for R&D and for ordinary investment. The estimation results for the subsamples indicate that during periods in which W/A increases, investment is less sensitive to Q as expected, but not significantly so. The significantly positive estimates obtained for the coefficients of inventories and the real investment price in the $\Delta(W/A) > 0$ subsample might be an indication of misspecification or, in the latter case, mismeasurement of the effective capital prices, because we ignored taxes and depreciation allowances.

As we discussed earlier, the endogeneity of the determinant of the regime will result in inconsistent estimates, when the estimation strategy ignores this feature of the model. Therefore we applied the switching regression methodolgy. The estimation results that we obtained for the system that includes the Q models without sales (cf. table 3b) are reported in tables 3c and 3d. First we discuss table 3d, which contains the results obtained for the models for $\Delta(W/A)$ and the corresponding dummy.

Although the explanatory variables are jointly significant according to the value of the likelihood ratio test, our probit model for the sign of $\Delta(W/A)$ is only a slight improvement over a model that only contains a constant from a prediction perspective. This finding should moderate expectations regarding the performance of the switching regression model.

Since we are using panel data, a natural question to ask is whether an individual effect should have been taken into account. However, pooling the data seems justified, as the variables are in first differences. On the other hand, this may cause the error to follow a MA(1) process. Since we actually can observe the 'latent' variable that underlies the regime dummy, we can easily test both hypotheses concerning the nature of the error term after running some simple regressions. We scaled the dependent variable and its lag, so that it looks like a continuous counterpart of the regime dummy variable and the variance of the disturbance is close to one. Note that the 2SLS and OLS estimates are similar to the ML estimates of the probit model, which already suggests that we can treat the error as a white noise process. Next we performed a test due to Godfrey (1978) for the presence of AR(1) behaviour (the individual effect) or MA(1) behaviour in the error term, which is valid when the regressors contain a lag of the dependent variable. The absence of serial correlation could not be rejected.

After computing the probability that W/A increases for each observation, we estimated (3.21). Table 3c shows the results. The reported standard errors are lowerbounds for the true standard errors. The error term of model (3.21) is $v_t + (b_1 - b_2)Z(\hat{\Phi}_t - \Phi_t) + (\sigma_{1u} - \sigma_{2u})(\hat{\phi}_t - \phi_t)$. Our formula for the covariance matrix of the estimators ignores the last two terms [15]. However, joint tests that use the 'wrong' covariance matrix cannot reject the equality of the b's and the σ's across regimes, even though the alternative hypotheses are favoured. Therefore we can conclude that our estimates of the standard errors are in most cases not significantly different from the true standard errors.

Most parameter estimates that were significantly different from zero in the naive regressions (table 3b), have become insignificant now. In the case of R&D, the coefficient of Q in the subsample where $\Delta(W/A) > 0$ is higher than in the other subsample, but not significantly. In the case of ordinary investment we find a lower coefficient of Q in the subsample where $\Delta(W/A) > 0$. Summarizing, we can say that the evidence is in agreement with the theory of sub-section 5.3.2. but it is not convincing.

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[15] One can show along the lines of Maddala (1983, appendix to chapter 8) that the difference between the true covariance matrix and the naive covariance matrix, which is based on the assumption that the error term equals v, is a positive definite matrix.

Table IIIc

GMM Estimation Results for Q Model with Endogenous Switching

	PHYSICAL CAPITAL		R & D	
	HOMOGEN.	SPLIT BY $\Delta(W_t/A_t)>0$	HOMOGEN.	SPLIT BY $\Delta(W_t/A_t)>0$
b_I	-0.2187	0.0508	0.0045	0.1839
	(0.0889)	(0.3198)	(0.0782)	(0.2527)
b_Q	0.0128	0.0801	0.0162	-0.0146
	(0.0065)	(0.0412)	(0.0047)	(0.0277)
b_{INV}	0.0233	-0.1730	-0.0124	-0.1804
	(0.0342)	(0.2061)	(0.0247)	(0.1467)
b_P	0.0345	-0.0986	-0.0136	-0.4846
	(0.0347)	(0.5200)	(0.0172)	(0.2660)
b_B	-0.1233	-0.3235	-0.0225	0.1093
	(0.0326)	(0.2161)	(0.0349)	(0.1481)
Wb_I		-0.3916		-0.2263
		(0.3401)		(0.1698)
Wb_Q		-0.0488**		0.0339
		(0.0325)		(0.0223)
Wb_{INV}		0.2134		0.1199
		(0.1773)		(0.1242)
Wb_P		0.0768		0.4239**
		(0.5186)		(0.2648)
Wb_B		0.0951		-0.1288
		(0.1706)		(0.1081)
$\sigma_{2u}-\sigma_{1u}$		0.0106		-0.3E-3
		(0.0124)		(0.0089)
SARGAN	29.716	27.431	32.658	20.927
(D.F.)	(30)	(24)	(30)	(24)
DISTANCE		1.690		11.740
(D.F.)		(6)		(6)

423 obs., 90 firms, period 1979-1983.

HOMOGEN. means parameter homogeneity. W_* : coefficients for subsample where $\Delta(W/A) \geq 0$. The probits are based on estimation results reported in table IIId. $\sigma_{2u}-\sigma_{1u}$ is the coefficient of $\phi(\hat{\pi}'Z)$, where $\phi(.)$ is the standard normal density function and $\hat{\pi}$ is the vector of estimates of the coefficients of the regressors Z used in the probit model. See also the notes to table IIIb.

Table IIId

Estimation Results for Switching Criterion

	2SLS	OLS		PROBIT ML
γ_C	-0.1486	-0.1334	π_C	-0.1924
	(0.1007)	(0.0879)		(0.0953)
γ_W	-0.6199	-0.1399	π_W	-0.1141
	(0.8569)	(0.0421)		(0.0459)
γ_I	1.7080	2.8650	π_I	2.6846
	(2.5007)	(1.2910)		(1.4768)
γ_{INV}	-3.4538	-1.5535	π_{INV}	-1.5577
	(3.4635)	(0.6596)		(0.8649)
γ_S	0.4598	0.1196	π_S	0.2830
	(0.6149)	(0.1695)		(0.2268)
γ_{CSFL}	6.6135	4.9575	π_{CSFL}	5.9500
	(3.6333)	(2.1019)		(2.3761)
$\bar{R}^2$	0.0194	0.0323	Pseudo R^2	0.0262
LM		1.682	LogL	-340.81
			$-2(\mathrm{Log}\frac{L(\hat{\omega})}{L(\hat{\Omega})})$	18.35
			% pos. obs.	50.69
			% correct pred.	57.82

423 obs., 90 firms, period 1979-1983. Models have been estimated in levels. The dependent (latent) variable is $\Delta(W/K)$. The dependent variable and its lags are normalised by the firm's average of the absolute value of $\Delta(W/K)$. The set of instruments includes most RHS variables and the second lag of $\Delta(W/K)$ instead of the first lag of $\Delta(W/K)$. pos. obs. are observations where $\Delta(W/K) \geq 0$ (regime dummy equals one). Correct pred. means that regime is predicted correctly. The likelihood ratio test statistic for joint significance of slope parameters ~ $\chi^2(5)$. The LM test for the presence of MA(1) or AR(1) errors when the regressors include a lagged dep. var. is from Godfrey (1978): $T\ \hat{e}'\hat{e}_{-1}(\hat{e}_{-1}'\hat{e}_{-1}-\hat{e}_{-1}'Z(Z'Z)^{-1}Z'\hat{e}_{-1})^{-1}\hat{e}'\hat{e}_{-1}/\hat{e}'\hat{e}$. This LM test statistic ~ $\chi(1)$. Heterosked. consistent standard errors are reported below 2SLS/OLS estimates.

5.5.2 Results Obtained for the Euler Equations

Complementary evidence on (financial) working capital as indicator of liquidity and its effects on the investment process is given by table 4, which contains the results for various versions of the Euler equations for ordinary investment and R&D. For the set of instruments used by the GMM estimator we refer again to appendix 5.A. The upper panel of table 4 shows the estimates that are valid under the assumption that no individual effects are present, and the results in the lower panel were obtained after removing the indivual effects by first differencing the models. Furthermore the right (even) columns correspond to a specification for $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ that is only based on lags of W/K, while the model underlying the left (uneven) columns also included the mean of W/K. The third panel of table 4 shows the estimation results after applying Chamberlain's transformation to get rid of a multiplicative individual effect. All the results in table 4 correspond to the exponential specification for $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ (3.14) without separate time effects ($\vartheta_t=\vartheta$). Results based on (3.13) were similar and therefore are not reported. The values for $(1-\delta^G)/(1+\rho/(1-c))$ and $(1-\delta^G)/(1+\rho/(1-c))$ were fixed at 0.78 and 0.88 respectively.

We will first discuss the estimates computed by using the nontransformed models. The results in columns (2) and (4) — which are only based on levels of W/K — are very similar to results for the models that also include the mean of W/K. In general the estimates of the δ_i's were imprecise. The value of the constant in the exponential model for $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ is close to zero, which was our prior, and the estimates for δ_2 have the right sign. Furthermore the results in columns (1) - (4) suggest that the ratio of shadow values depends negatively on the current *change* in W/K. One interpretation is that W_t/K_t (and $\overline{W}/\overline{K}$) control for an individual effect. Note that the estimates for δ_1 and δ_2 are about the same in the Euler equations for ordinary investment and R&D. This is in agreement with rational behaviour which implies that marginal investment projects of different types should earn the same return (after correcting for risk) and are undertaken by using the funds from the same source(s). In other words there is only *one* shadow value of funds which depends on the most profitable investment opportunity that the firm faces. Assuming convexity of the adjustment cost schedule, the estimates of the 'productivity parameter' (b_1) have the wrong sign.

We have performed tests from Keane and Runkle (1992) to ascertain whether individual effects — whether additive or multiplicative — are present. As the RHS variables are endogenous, their presence would destroy the consistency of the estimators used for the upper panel of table 4. The values of various test statistics on the presence of individual effects are shown in table 5. They indicate that it is important to remove additive individual effects in order to obtain consistent estimates of the technology and debt parameters. However no differences are detected between estimates based on the original model in levels and those obtained after applying Chamberlain's transformation. On the other hand the estimates obtained for the first differenced model, FD estimates for short, and Chamberlain's version of the model are different in the case of R&D. Since FD estimates are preferred over the 'levels estimates' and the 'Chamberlain estimates' are not significantly different from the latter, and moreover since the 'Chamberlain estimates' are very imprecise, we will focus in the remainder of this section on the estimates obtained after removing additive individual effects.

The estimate of the intercept δ_0 in the model for $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ in the Euler equation for physical capital is significantly less than zero. This implies that the shadow value of funds increased during the recession or in other words that the firm became more liquidity constrained. The estimates of the coefficients of W/K are individually not significantly different from zero [15]. A joint test of significance yielded the same conclusion. Since we suspected that this might be due to multicollinearity we reestimated the model after dropping W_t/K_t but δ_2 (and δ_0) remained insignificant. We also tested whether multiplicative time dummies should be included. The values for this test statistic are reported at the bottom of the second panel in table 4. They suggests that the multiplicative time dummies are missing from the model for R&D. After including the multiplicative time dummies we obtained an estimate for δ_1 (not reported here) that is significantly negative. However our model predicts that δ_2 should enter with a positive sign. In sum the evidence on the effects of working capital on investment provided by the Euler equations is rather weak.

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[15] When we used specification (3.13) for $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ we found that δ_2 was significantly positive at the 10% level.

Table IV

GMM Estimation Results for Euler Equations

	Physical Capital		R & D	
	Levels			
	(1)	(2)	(3)	(4)
ϑ	-0.0683	-0.0528	-0.0305	-0.0395
	(0.0413)	(0.0386)	(0.0220)	(0.0162)
δ_1	-0.0735	-0.1217	-0.0974	-0.0758
	(0.1168)	(0.0999)	(0.0854)	(0.0740)
δ_2	0.1926	0.1241	0.0500	0.0807
	(0.1037)	(0.0912)	(0.0754)	(0.0619)
δ_0	-0.1259		0.0496	
	(0.1134)		(0.0765)	
b_1	0.0034	0.0037	0.26E-3	0.24E-3
	(0.0020)	(0.0020)	(0.06E-3)	(0.06E-3)
b_2	0.0210	0.0145	0.0032	0.0037
	(0.0417)	(0.0321)	(0.0063)	(0.0055)
b_3	0.0053	0.0064	-0.77E-3	-0.69E-3
	(0.0082)	(0.0080)	(0.27E-3)	(0.24E-3)
SARGAN(38)	41.54	40.95	51.72	51.47
	First-Differences			
ϑ	-0.4114	-0.2990	-0.0158	-0.0274
	(0.1828)	(0.1354)	(0.0828)	(0.0786)
δ_1	-0.2423	-0.0800	-0.1579	-0.0860
	(0.1659)	(0.1053)	(0.1531)	(0.0713)
δ_2	0.0650	0.1517	-0.0504	-0.0216
	(0.1213)	(0.0964)	(0.1077)	(0.0633)
δ_0	0.5610		0.1744	
	(0.3904)		(0.3783)	
b_1	0.0344	0.0320	0.07E-3	0.04E-3
	(0.0149)	(0.0112)	(0.25E-3)	(0.23E-3)
b_2	0.1447	0.1317	0.0100	0.0124
	(0.1138)	(0.1220)	(0.0163)	(0.0156)
b_3	-0.0957	-0.1010	-0.0024	-0.0025
	(0.0408)	(0.0392)	(0.0011)	(0.0011)
SARGAN(38)	43.44	43.48	51.33	51.29
REGR. WALD(6)		68.71		233.92
T.D. WALD(5)		63.16		29.80
DISTANCE(1)	2.73	0.71	1.25	1.05
DISTANCE(5)	4.42	8.08	13.36	8.88

GMM Estimation Results for Euler Equations

First-Differences continued

LIQ. WALD(2)	4.27	3.09	1.86	1.54
LIQ+ϑ WALD(3)	6.17	6.03	1.87	1.59
m_1		-4.564		-4.240
m_2		-2.673		-0.887
m_3		2.548		1.125

Chamberlain's Transformation

δ_1	-0.4278	-0.2195
	(0.8555)	(0.1496)
δ_2	0.6900	0.0288
	(0.4124)	(0.1122)
b_1	0.2739	-0.24E-3
	(0.4017)	(1.50E-3)
b_2	-0.0166	0.1353
	(0.0872)	(0.1205)
b_3	-0.2659	0.0078
	(0.3752)	(0.0074)
SARGAN(40)	58.04	59.86
LIQ. WALD(2)	2.802	2.464

421 obs., 90 firms. period: 1980-1984; Optimal HAC weighting matrix used. Additive time dummies have been included, but multiplicative t.d. have not.

$b_1 = -\alpha^F/\phi^F, b_2 = 1/o^F$, and $b_3 = -\beta^F/\phi^F$, F = G,K.

$\tilde{\mu}_{t-1}/\tilde{\mu}_t = \exp[\vartheta + \delta_1(W_t/K_t) + \delta_2(W_{t-1}/K_{t-1}) + \delta_0(\overline{W_t/K_t})]$ in left (uneven) col.

$= \exp[\vartheta + \delta_1(W_t/K_t) + \delta_2(W_{t-1}/K_{t-1})]$ in right (even) column.

HAC standard errors below estimates; Wald tests on joint significance of nontrivial regressors and time dummies - $\chi^2(.)$; Distance tests for $\delta_1 = 0$, and $\vartheta_t = \vartheta$; m_i i=1,2,3 tests on i-th order autocorrelation - N(0,1);

When δ_0 is not restricted to zero, then Sargan test ~ $\chi^2(39)$, Liq. Wald test for $\delta_i = 0 \sim \chi^2(3)$, and Liq.+$\vartheta$ Wald test for $\vartheta = \delta_i = 0 \sim \chi^2(4)$.

Table V

Hausman Tests for Correlated Effects

Models: parameters:	1L vs 1FD	2L vs 2FD	3L vs 3FD	4L vs 4FD
$\vartheta,\delta_1,\delta_2(3)$	4.867 (0.301)	3.659 (0.301)	1.127 (0.890)	1.814 (0.612)
$b_1,b_2,b_3(3)$	8.222 (0.042)	10.666 (0.014)	8.026 (0.046)	9.348 (0.025)
$\vartheta,\dots,b_3(6)$	10.738 (0.150)	13.106 (0.041)	11.968 (0.102)	13.956 (0.030)
	1L vs Ch.T	1FD vs. Ch.T	3L vs Ch.T	3FD vs Ch.T
$\delta_1,\delta_2(2)$	1.643 (0.440)	1.973 (0.373)	0.903 (0.637)	0.408 (0.816)
$b_1,b_2,b_3(3)$	0.924 (0.820)	2.648 (0.449)	6.015 (0.111)	9.282 (0.026)
$\delta_1,\dots,b_3(5)$	2.716 (0.744)	4.535 (0.475)	8.820 (0.116)	13.323 (0.021)

Optimal HAC weighting used; p-values below values of test statistics.
The degrees of freedom of the χ^2-distribution of the test statistics shown at the intersection of columns 1 and 3, and rows 1 and 3 is one higher than indicated (4 and 7 respectively).
L is levels version of the model, FD is first differenced version and Ch.T. means that Chamberlain's transformation has been used to get rid of multiplicative individual effect. Number corresponds to column in table IV.

Table VI

ALS Estimates

	(1)	(2)	(3)	(4)
α^F	-0.2377 (0.1768)	-0.2430 (0.2097)	-0.0072 (0.0281)	-0.0031 (0.0193)
ϕ^F	6.9109 (5.4361)	7.5925 (7.0314)	100.00 (163.36)	80.65 (101.30)
β^F	0.6614 (0.5252)	0.7670 (0.6379)	0.2408 (0.3707)	0.1981 (0.2318)

421 obs., 90 firms, period: 1980-1984; HAC standard errors below estimates; Exploited restrictions: $b_1^F = -\alpha^F/\phi^F$, $b_2^F = 1/\phi^F$ and $b_3^F = -\beta^F/\phi^F$, F = G,K. The estimates of the reduced form par. are shown in columns 2FD and 4FD of table IV.

The estimates of the coefficients of the productivity term have the wrong sign. However, in the case of R&D they are insignificant. Furthermore they are in line with the estimates of the rate of return of R&D found by Hall (1993) for two important industries within the scientific sector, i.e. the chemicals industry and the electrical industry, for the 1971-1980 and 1981-1985 periods (see also table 6 below). The significantly positive estimates for the coefficients of the productivity of physical capital are clearly conflicting with the structural model. Since we are using a instrumental variable approach, the coefficients measure the effect of forecastable sales. Therefore we interpreted this finding as a liquidity effect, rather than a demand shock effect. Another problem with the results for physical capital is that the errors (after first differencing) seem to display third order autocorrelation. This finding casts doubt on the validity of the instruments although the Sargan test does not lead to rejection. The R&D equation passes the specification tests.

According to the results in table 4, debt depresses investment in physical capital and R&D. The estimates of the coefficients of debt are relatively precise. In the case of R&D, we expected that the sign of the coefficient would be determined by the 'intangibility' effect, which says that the larger the share of R&D in total assets, the higher the cost of debt finance. However, the stock of R&D in the denominator of the debt term seems to act as a proxy for total assets, or at least the part that can serve as collateral, which results in the same (negative) sign for the debt term in the R&D equation as has been found in the case of physical capital.

Finally we have calculated the values of the structural parameters that are implied by the estimates in the second panel of table 4. They can be found in table 6. The low precision of the estimates of the adjustment cost parameters spills over into the (high) standard errors of the other estimates.

Although our estimates of the liquidity parameters (δ_i's and ϑ_t's) are rather imprecise, we have also computed some statistics that desribe the development of the cross-sectionsal distribution of $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ over time. The means obtained in the case of physical capital, are considerably lower than those in the case of R&D. This could partly reflect differences in the expected rate of return.

Table VII

Cross-Sectional Distribution of $\tilde{\mu}_{t-1}/\tilde{\mu}_t$

Eq. Stat.	1979	1980	1981	1982	1983	1984
R&D Mean	0.845	0.961	0.893	0.703	0.720	0.645
R&D Std.dev.	0.238	0.241	0.214	0.130	0.181	0.151
PHY Mean	0.562	0.639	0.630	0.525	0.516	0.630
PHY Std.dev.	0.0466	0.0617	0.0529	0.0420	0.0468	0.0561

PHY is physical capital; calculations based on estimates of first-differenced versions of models that include $\delta_0,\ldots,\delta_2$ and separate time dummies in submodel for $\tilde{\mu}_{t-1}/\tilde{\mu}_t$ ($\vartheta_{78},\ldots,\vartheta_{84}$).

5.6 Conclusion

The research documented in this chapter has been aimed at measuring the effects of liquidity on investment decisions with respect to both ordinary capital and R&D. To this end we derived versions of the Q model and the Euler equation model, where the perfect capital market assumptions of Modigliani and Miller (1958) are relaxed. The models that we obtained could not be estimated right away as they contained unobservable shadow values of funds. The way we solved this problem distinguishes our research from that of others in this field: exploiting one of the other first order conditions of the value maximization problem of the firm, we established a link between the change in the shadow value of funds and the stock of working capital (relative to the size of the firm). With regard to the sign of this relationship we argued that an increase in working capital may be a measure of precaution (asked for by the bank) and therefore actually reflects a deterioration of the financial position of the firm. When estimating the Q model, we distinguished between two investment regimes defined by the sign of the change in working capital, while we inserted the relationship between the change in the shadow value of funds and working capital in the Euler equation.

The estimation results obtained for the parameters in both models were imprecise in many cases. However some findings do stand out from the tables. First Q significantly explains ordinary investment and R&D, although in the former case it does not capture the marginal profitability of capital completely since sales enters a regression significantly as well. Second, in both the Q models and the Euler equations, there is a strong negative relationship between the debt term and investment and R&D, which justifies the interpretation that it measures (part of) the marginal (agency) costs of funds. On the other hand, the coefficients of the real cost of capital are poorly estimated, although the sign is correct in most cases. This is perhaps attributable to the fact that the prices do not vary across firms but at best across industries defined at the four digit SIC level. This also means that the prices we used in the analysis do not reflect (differences in) the effective tax rate that firms face. Furthermore at the industry level, the prices will more or less display the same pattern, which rises the problem of multicollinearity given the use of time dummies.

With respect to the main focus of this chapter, measurement of liquidity effects, the evidence does not allow us to draw firm conclusions. Although the estimates of the coefficients of working capital and the differences between the regime specific coefficients of the Q's were in agreement with the predictions from the theory, they were not significant in most cases. Moreover in the Euler equations, the coefficients of the marginal productivity of capital, that is sales over the stock of capital, had the wrong sign. In fact, the Euler equation results resemble those reported in Hall (1991), where the coefficients were allowed to differ across financial regimes defined by the occurrence of dividend payments and the issue of new shares [17]. In that paper, the positive effect of sales on investment and R&D is interpreted as a liquidity effect; the fact that an instrumental variable type estimator has been used, based on instruments lagged two years, makes it unlikely that it is mainly a demand effect, since changes in demand are hardly forecastable two years ahead.

In general, we believe that the results obtained for the Euler equations are more sensitive to timing issues, mismeasurement and misspecification than the results obtained for the Q models, because the Euler equations are first order *difference equations* in de shadow value of capital λ_t, while the Q models are based on the solution of the Euler equation for λ_t, which can be obtained by *adding up* successive Euler equations. Drawing an analogy between the investment models and panel data methods, we know that going from 'levels'

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[17] See the regimes defined on page 12.

(the Q model), to 'first differences' (the Euler equations), aggravates the effects of specification errors.

We close this chapter with some suggestions for obtaining better results for both models. First we could model the change in the shadow value of funds as a joint function of working capital, change in dividend payout, and a dummy variable for the issue of new shares, and perhaps also the variables that were used by Whited (1992) to measure the height of agency costs. Second, since the Euler equations for the various stocks of capital contain the same shadow values of funds, cross equation restrictions can be imposed. Third, one could just concentrate on the Euler equation for physical capital, because that would allow the use of a much larger sample. Fourth, as mentioned above, the use of firm specific information on prices, which includes effective taxes rates, seems desirable. Finally, the switching regression version of the Q model lacks a good equation for the change in working capital. Using quarterly data and adding more lags of the explanatory variables as well as more variables that are informative about the financial position of the firm might help to obtain better results for that part of the model.

Appendix 5.A: sets of instruments

Instruments used for estimation of Q equations:

I_{t-3}/A_{t-3}, W_{t-3}/A_{t-3}, B_{t-3}/A_{t-3}, Q_{t-3}/A_{t-3} , INV_{t-3}/A_{t-3} , p^I_{t-2}/p_{t-2},
p^I_{t-3}/p_{t-3}, and time dummies
R_{t-3}/G_{t-3}, W_{t-3}/A_{t-3}, B_{t-3}/A_{t-3}, Q_{t-3}/A_{t-3} , INV_{t-3}/A_{t-3} , p^R_{t-2}/p_{t-2},
p^R_{t-3}/p_{t-3}, and time dummies

Instruments used for estimation of Euler equations:

S_{t-3}/K_{t-3}, I_{t-3}/K_{t-3}, $INTeReST_{t-3}/K_{t-3}$, $DEPREC_{t-3}/K_{t-3}$, p^I_{t-3}/p_{t-3}, p^I_{t-4}/p_{t-4},
B_{t-3}/K_{t-3}, V_{t-3}/K_{t-3}, W_{t-3}/K_{t-3}, and time dummies.
S_{t-3}/G_{t-3}, R_{t-3}/G_{t-3}, $INTeReST_{t-3}/G_{t-3}$, $DEPREC_{t-3}/G_{t-3}$, p^R_{t-3}/p_{t-3}, p^R_{t-4}/p_{t-4},
B_{t-3}/G_{t-3}, V_{t-3}/G_{t-3}, W_{t-3}/K_{t-3}, and time dummies.

V_t is defined in (3.19a) as $E_t + TB_t - ADJ_t$ (net value of the firm)

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