Does Science Make a Difference?
Investment, Finance and Corporate Governance in German Industries

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Abstract

The purpose of this paper is to examine whether the degree of liquidity constraints varies systematically across firms engaged in activities reflecting very different knowledge conditions. In particular, we compare the extent of liquidity constraints in science-based firms with non science-based firms. This distinction is important because science-based firms generally fit the characteristics of market failure identified by Kenneth Arrow in that they are based on economic activity which is uncertain, characterized by asymmetric knowledge and is non-exclusive. Based on a panel data base of German firms we find evidence suggesting that science does make a difference. However, the way in which it does make a difference is surprising and suggests that cash flow may play a dual role in financing science-based firms.

1. Introduction

Just within several decades tremendous advances have been made regarding knowledge about the functioning of capital markets. Starting with Stiglitz and Weiss (1981), a wave of theoretical studies argued that capital markets are different from other markets because of the roles that risk and uncertainty play. A second wave of empirical studies established that, in fact, there is considerable evidence suggesting the financing constraints do exist, and that they are shaped by characteristics specific to the firm. However, most of these studies do not look at the role that the industry environment plays in liquidity constraints. This oversight may be crucial, it is the knowledge conditions underlying different industries that may result in liquidity constraints in the first place. As Kenneth Arrow (1962) pointed out in his seminal article, the knowledge conditions underlying an industry vary systematically across industries. Some industries are more characterized by the fundamental knowledge conditions resulting in liquidity constraints – uncertainty and knowledge asymmetries – while by contrast, in other industries knowledge is relatively certain and symmetric.

The purpose of this paper is to examine whether the degree of liquidity constraints varies systematically across firms engaged in activities reflecting very different knowledge conditions. In particular, we compare the extent of liquidity constraints in science-based firms with non science-based firms. This distinction is important because science-based firms generally fit the characteristics of market failure identified by Arrow (1962) in that they are based on economic activity which is uncertain, characterized by asymmetric knowledge and non-exclusive. Based on a panel data base of German firms we find evidence suggesting that science does make a difference. However, the way in which it does make a difference is surprising and suggests that cash flow may play a dual role in financing science-based firms

2. Why Should Science Make A Difference?

One of the reasons why the sources of severity of liquidity remain ambiguous is that, “The investment literature has been schizophrenic concerning the role of financial structure and liquidity constraints” (Chirinko, 1993, p. 1902). As Fazzari, Hubbard and Petersen (1988, p. 141) point out, “Empirical models of business investment rely generally on the assumption of a ‘representative firm’ that responds to prices set in centralized security markets. Indeed, if all firms have equal access to capital markets, firms’ responses to changes in the cost of capital or tax-based investment incentives differ only because of differences in investment demand.” According to this view, the financial structure of a firm does not play an important role in investment decisions, since the firm can costlessly substitute external funds for internal capital. Under the assumption of perfect capital markets, firm-specific investment decisions are generally independent of the financial condition of the firm.

The assumption of perfect capital markets has, of course, been rigorously challenged. Once capital markets are no longer assumed to be perfect, external finance can also no longer be assumed to be a perfect substitute for internal capital. An implication of this view is that the availability of internal finance, access to new debt or equity finance, and other financial factors may shape firm investment decisions. Stiglitz and Weiss (1981) pointed out that, unlike in most other markets, the market for credit is exceptional in that the price of the good – the rate of interest – is not necessarily at a level that equilibrates the market. They attribute this to the fact that interest rates influence not only demand for capital but also the risk inherent in different borrowers. As the rate of interest rises, so does the riskiness of borrowers, leading suppliers of capital to rationally decide to limit the quantity of loans they make at any particular interest rate. Most potential lenders have little information on the managerial capabilities or investment opportunities of such firms and are unlikely to be able to screen out poor credit risks or to have control over a borrower's investments. If lenders are unable to identify the quality or risk associated with particular borrowers, Jaffe and Russell (1976) show that credit rationing will occur. This phenomenon is analogous to the lemons argument advanced by Akerlof (1970). The existence of asymmetric information prevents the suppliers of capital from engaging in price discrimination between riskier and less risky borrowers.

Scholars responded to the theories predicting liquidity to be constrained with a wave of empirical studies.[1] Almost all of the empirical work has followed the seminal article by Fazzari et al. (1988) and inferred the existence of liquidity constraints on the basis of the regression coefficient of the firm's cash flow on investment, typically measured as investment divided by total assets. A regression coefficient that is equal to zero (or one in logs) is interpreted as reflecting a perfect capital market and therefore no liquidity constraints, since external capital is a perfect substitute for internal capital. By contrast, a regression coefficient that is significantly greater than zero (or one in logs) is interpreted as indicating that external finance is not a perfect substitute for internal finance, and therefore that firms are liquidity constrained.

[1] See Schiantarelli (1996) and Weigand (1998) for surveys and discussion.

The most recent firm-level studies test for the presence and impact of financing constraints on the basis of *a priori* firm-specific factors. These studies have generally followed the seminal paper by Fazzari et al. (1988), who linked firm-specific characteristics, namely dividend payout and firm size, to the impact of cash flow on investment. Subsequent studies have elaborated on the impact of cash flow on investment by investigating further firm-specific variables. In particular, finance constraints have been found to exist for non-dividend paying firms (Fazzari et al., 1988; Fazzari and Petersen, 1993; Bond and Meghir, 1994; Gilchrist and Himmelberg, 1995; Hubbard et al., 1995), small firms (Gertler and Gilchrist, 1994; Himmelberg and Petersen, 1994; Petersen and Rajan, 1994; Gilchrist and Himmelberg, 1995), young firms (non-mature firms) (Hubbard et al., 1995), growing firms (Binks and Ennew, 1996), leveraged firms (Whited, 1992), non-bank affiliated firms (Hoshi et al., 1991; Binks and Ennew, 1995 and1997; Ennew and Binks, 1995), firms without bond rating (Whited, 1992 and Gilchrist and Himmelberg, 1995), and firms with high-asset specificity (Worthington, 1995). This growing literature provides compelling empirical evidence that (1) external finance is constrained under certain conditions and (2) liquidity constraints vary systematically with firm-specific characteristics

Why should science make a difference? As Stephan (1996) and Dasgupta and David (1994) emphasize, firms engaging in science-based activities are typically associated with a greater degree of uncertainty, or *hyper-uncertainty*, and *hyper-knowledge asymmetries*, about the potential economic value of their investments. As Arrow (1962) pointed out, more than most other economic goods, the production of new economic knowledge generally suffers from three source constituting market failure –

indivisibilities and monopoly, uncertainty, and externalities. The first source of market failure emanates from the propensity for knowledge to be a discrete rather than a continuous commodity. As a result, both economies of scale and scope are often associated with the production of knowledge (Mueller and Tilton, 1969). The second source of market failure involves the extraordinarily high degree of uncertainty inherent in new economic knowledge. While virtually every economic good is subject to uncertainty, almost none is exposed to the degree of risk involved in science-based new technologies. There are two additional elements of uncertainty inherent in innovative activity that are not present in other goods. The first is in the realm of production. How a new good can be technically produced is typically shrouded in uncertainty. The second involves marketing the product. Whether a demand for the new product exists is not known. Even if the knowledge can result in a new product, it is not at all clear that the product can be profitably sold. Knowledge leading to a new economic good can be produced, but there is no guarantee that the new knowledge is economic knowledge.

The third source of market failure stems from the public good nature and non-exclusive externalities inherent in science-based economic activity. The production of knowledge does not preclude other economic agents from applying that knowledge for economic gain. It is difficult to delineate and enforce property rights to newly created knowledge. The externalities associated with the production of new knowledge make it difficult for firms undertaking such activities to appropriate the economic returns accruing from their investment.

Because firms engaged in science-based activity are subject to *hyper-uncertainty*, *hyper- knowledge asymmetries*, as well as *non-exclusivity* it that might be expected that they experience a greater degree of liquidity constraints imposed upon them by traditional lending institutions than do non-science based firms. This would predict an even greater regression coefficient of cash flow on investment.

However, there are compelling reasons to suspect that in science-based firms cash flow serves a second and crucial economic function – as a signal of the firm's viability and success. The theory of noisy selection introduced by Jovanovic (1982) argues that new firms do not know whether the idea upon which their new firm is launched is viable in the market or not. Rather, they discover the viability of the idea through the process of learning from the firm's actual post-entry performance. By analogy, as a result of the hyper-uncertainty, hyper-knowledge asymmetries, and potential non-exclusive nature of a science-based firm's investment activities, it is more difficult to evaluate the expected value of a science-based firm than a non science-based firm. Cash flow, however, does signal firm success and viability. As Arrow (1962) and later Sah and Stiglitz (1986) point out, the cost of acquiring a signal to learn about the underlying economic performance in the presence of uncertain, asymmetric knowledge, is nontrivial. Thus, by serving as a signal that the firm is being positively selected in the market process, cash flow may actually make it easier to attract external finance. The dual function of cash flow in science-based firms leads us to predict that the impact of cash flow on investment will actually be weaker in science-based firms, due to the signaling effect of cash flow for firms whose economic activity is based on hyper-uncertainty, hyper-knowledge asymmetries and potential non-exclusivity.

A second important direction of the literature has been devoted towards identifying the impact that corporate governance has on the extent of financing constraints. Because they reduce the transaction cost and agency costs associated with knowledge asymmetries, different modes of corporate governance have been predicted to alleviate liquidity constraints. For example, Bond et al. (1997) hypothesize that bank ownership of firms is a governance mechanism in Germany that alleviates liquidity constraints. She compares the impact of cash flow on investment between bank-owned and non bank-owned firms and finds that the non-bank affiliated firms experience greater liquidity constraints.

A different dimension of corporate governance involves the management of firms. We would expect that owner-managed firms would experience a lower degree of liquidity constraints due to the ability of the owners to reduce uncertainty and asymmetries. This impact should be greater in science-based than in non science-based firms.

3. Measurement

To estimate if the liquidity constraints of science-based firms differ from non science-based firms, we apply a data set of 344 German firms from the mining and manufacturing industries. The data base comes from 30 different two-digit industries (SYPRO). Most of these companies have the legal form of stock corporations (*Aktiengesellschaften*). In addition to stock corporations, there are also some limited liability corporations (GmbH companies), as well as limited commercial partnerships, for which balance sheet data were available. Balance sheet data are taken from the annual reports of the firms, while secondary sources were consulted for identifying owners, share distribution, composition of managing and supervisory boards.[2] Annual observations are available for each firm between 1991 and 1996, making it possible to construct a pooled, cross-section panel data set.

We use these data to estimate the regression model:

$$
\begin{aligned}
I_{it} = {} & b_1 CF_{it} + b_2 \Delta_t Sales_i + b_3 \Delta_t WC_i + b_4 \Delta_t B_i + b_5 OWNCONC_{it} + \\
& b_6 OWNCONC_{it} \times OWNMAN_i + b_7 OWNCONC_{it} \times FOREIGN_i + \\
& b_8 SIZE_{it} + b_9 H_{ijt} + m_{it}
\end{aligned}
\qquad (1)
$$

The subscript *i* and *t* denote individual firms and time periods respectively, Δ is the first-difference operator. *I* is the log of a firms's annual expenditures for tangible investment scaled by total assets. *CF* denotes the log of cash flow (operating income plus depreciation charges) scaled by total assets.[3] Δ *Sales* is the log change in real sales. Nominal sales have been deflated by the GDP deflator (1991 prices). Δ *WC* is the log of the year-to-year change in working capital scaled by total assets.[4] Δ *B* is the log change in the ratio of bank loans to total capital. *OWNCONC* is the log of the aggregated share in a firm's outstanding capital held by the largest five shareholders. *OWNCONC* × *OWNMAN* and *OWNCONC* × *FOREIGN* are *OWNCONC* interacted with the location of ownership, namely ownership by individuals or families or foreigners. *OWNMAN* is a dummy that takes on 1 if the owner is an individual or a family (equity interest at least 25%, no other large shareholders) that is represented on either the board of managers or the supervisory board, otherwise it is zero. *FOREIGN* is a dummy variable that takes on the value of 1 if

[2] The sources used are Commerzbank's, Wer gehoert zu wem?, Hypobank's *Wegweiser durch deutsche Aktiengesellschaften*, and Hoppenstedt's *Boersenfuerhrer*.
[3] We added 1 to original values to avoid negative values before taking logs.
[4] We added 5 to original values to avoid negative values before taking logs.

the firm is owned by foreigners (equity share of more than 50%), otherwise it is zero. *SIZE* is absolute firm size, measured as the log of total employment. As an indicator of the degree of supplier concentration we use the Herfindahl index, *H*, at the two-digit industry level (SYPRO classification). The subscript *j* denotes the two-digit industry in which the respective firm *i* is classified.

The elasticity of investment with respect to cash flow is reflected by the coefficient b_1. If capital markets are imperfect and investment opportunities are controlled for, we would expect that $b_1 > 0$. Many studies in the literature control for investment opportunities by including Tobin's Q in the estimating equation. Unfortunately, in this study Tobin's Q cannot be constructed because of the relatively large number of non-quoted firms (152) in our sample. In order to control for investment opportunities, we instead use the log of the change in real sales. We would expect $b_2 > 0$. An important qualification is that these proxy measures may introduce measurement bias. Studies have typically identified both the average *Q* and sales growth as being less than perfect indicators of investment opportunities.[5] To the extent that the regression coefficient is biased, a positive estimated coefficient of cash flow coefficient may then simply indicate shifts in investment demand and future profitability and not necessarily that external finance is being constrained. An important solution to this problem was suggested by Fazzari and Petersen (1993). They point out that a firm confronted by liquidity constraints typically deploys working capital to smooth investment relative to cash flow shocks if adjusting tangible or R&D investment entails

[5] See Chirinko (1993) who discusses the issue of a misspecification of empirical investment models in greater detail.

higher costs than adjusting the difference between current assets and current liabilities. They recommend including the change in working capital, measured as change in the difference between current assets and current liabilities to separate the informational part of cash flow from its liquidity role. Therefore, if a firm is finance constrained, we would expect an inverse relationship between investment and change in working capital, $b_3 < 0$. If a change in working capital which tends to be positively correlated with profits or sales should also have a positive coefficient in the investment equation, or $b_3 > 0$, this would suggest that cash flow signals investment opportunities.

There are two possible sources to finance investment – internal cash flow and external finance. If banks play a crucial role in investment financing and bank loans are readily available at acceptable cost we would expect that an increase in the ratio of bank borrowing to total capital is positively related to investment, $b_4 > 0$. However, if capital markets are imperfect not every investment project with a positive net present value will attract external finance. In particular, asymmetric information may cause an inverse investment-borrowing relationship. This means that in order to service their debt, highly leveraged companies may have to cut investment so that $b_4 < 0$ may result. However, if banks as large creditors function as an alternative corporate governance mechanism and are better and more effective in monitoring than shareholders $b_4 > 0$ may result even under asymmetric information.

We use the degree of ownership concentration and the identity of owners as indicators of the potential range of corporate governance, or the tightness of control over the firm exercised by the actual owners. If large shareholders are better able to exercise control and thus reduce agency conflicts with managers as well as with external capital providers ownership concentration might have a positive impact on investment.[6] The variable *OWNCONC* measures the impact of ownership concentration on investment for firms that do *not* have individuals, families or foreigners as dominating owners. For this group of firms we assume that is hired managers rather than actual owners who exercise control. Here conflicts arising from the separation of ownership and control that affect investment decisions may be expected. A positive coefficient, $b_5 > 0$, would imply that the presence of a few large shareholders fosters tangible investment because of closer monitoring. However, a coefficient $b_5 < 0$ may indicate that in these "manager-controlled" firms hired managers do not use free cash flow for tangible investment but for non-investment pet projects, perks etc.[7] The coefficients on the interaction variables measure the difference in the impact of ownership concentration on investment between the presumably manager-controlled firms and the firms that seem to be under more direct control of their owners. Significant positive differences would indicate that the identity of owners and their direct involvement in managing the firm positively matters for investment.

A large literature dating back to Schumpeter (1942) argues that firm R&D is positively related to firm size and the degree of market concentration. This is because of the increased ability of firms with market power to appropriate the returns accruing from their investments in new knowledge. Therefore, we would expect firm size and market concentration to have a positive impact on investment. By contrast, market power and

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[6] See the recent surveys of Short (1994) and Shleifer and Vishny (1997) on corporate governance and firm performance.
[7] See Jensen (1986) for further discussion of management discretion.

large size may cause managerial and organisational slack so that funds are misused for pet projects rather than invested in productive assets. We thus might find an inverse relationship between concentration and investment.

In sum, under a regime of financial constraints we would expect $b_1 > 0$, $b_2 > 0$ and $b_3 < 0$ to be statistically significant. In addition, if bank loans are more readily available than other forms of external finance because monitoring by banks is effective we should find $b_4 > 0$. If governance structures affect investment decisions b_5, b_6 and/or b_7 should be significantly different from zero. The impact of firm size and market concentration is indeterminate a priori.

To allow for unobserved heterogeneity across firms and time periods such as systematic variations in the user cost of capital or bias due to the non-random character of sample selection we assume error terms m_{it} in Eq. (1) to be represented by

$$m_{it} = a_i + l_t + n_{it}, \tag{2}$$

where a_i are fixed (time-invariant) firm-specific parameters, l_t refer to time-specific (firm-invariant) effects and $n_{it} \sim \text{iid}\left(0, s_n^2\right)$ denote white noise disturbances. Due to this formulation of the error term we estimate regression equation (1) by the Least Squares Dummy Variable estimator, also known as Within-OLS estimator.[8]

[8] See Baltagi (1995) on estimators for static panel data models. Since measurement error concerning cash flow is at issue, an instrumental variable approach like GMM (Hansen 1982, Griliches and Hausman 1986, Arellano and Bond 1991) would seem to be the more appropriate estimation technique. However, the instrumenting technique calls for a long enough time series to render GMM estimation feasible. Unfortunately, our time series is rather short and additional degrees of freedom are consumed by constructing change rates etc. We have thus opted for the Within-estimator.

4. Results

[Table 1 about here]

Table 1 compares the means and standard deviations of all of the variables defined in the previous section between the science-based firm and non-science based firms. Firms are classified as being science-based if they are in chemicals, including pharmaceuticals and biotechnology, machinery, electronics, including information technology & software development, motor vehicles, optics, including laser technology, and aerospace. A careful study by Beise and Licht (1996) identified these industries as having the highest share of innovating firms, firms with R&D budgets, and firms with in-house R&D laboratories. Of the 344 firms in the data base, 204 are classified as science-based firms and 140 are classified as being non-science based firms. Table 1 indicates that the tangible ratio is significantly smaller in the science based industries, 6.4 percent, than in the non science-based industries, 8.4 percent. This presumably reflects a greater reliance on intangible assets than on tangible assets in the science-based firms. On average, firms in the science-based industries tend to be larger, as measured by employment. The mean annual rate of change in employment was negative in both science and non-science based industries. However, employment downsizing in the science-based industries was significantly less severe. The mean share of bank loans in total capital was significantly lower for firms from science-based industries than from non science-based industries. This may reflect higher uncertainty and a greater reliance on secrecy.

The share of bank loans has decreased significantly more for the science-based firms than for non-science based firms. This is consistent with the long-term observations by C. Weigand (1998) of a shift away from bank financing in Germany. The share of working capital, which can be used to smooth investment (Fazzari and Petersen, 1993; and Weigand, 1998), is significantly greater for science-based firms. There is no statistical difference in the means regarding ownership concentration, the cash flow ratio, change in working capital, sales growth, and market concentration between the science-based and non science-based firms.

[Table 2 about here]

Table 2 compares the means of the variables for listed and non-listed companies, both for science and non-science based firms. Most strikingly, for both the science-based firms and the non science-based firms, the mean investment ratios do not differ between the listed and non-listed groups. Neither the mean cash flow ratios nor the working capital ratios are different between the two groups for the science-based firms. However, the listed science-based companies are significantly larger and ownership is significantly less concentrated. For the non-science based firms the mean cash flow ratio and the working capital ratio are significantly higher for the listed companies than for the non-listed companies.

The regression results from estimating the model for the entire sample of 344 firms, the 204 science-based firms, and for the 140 non-science based firms, and for the 140 non-science based firms are shown in Table 3. The positive and statistically significant coefficient of cash flow, considered together with the significantly negative coefficient on the change in working capital, suggests that German firms are subject to liquidity constraints. However, the regression coefficient is significantly smaller for the science-based firms than for the non science-based firms, suggesting that science-based firms are not as liquidity constrained as are there non-science counterparts.

[Table 3 about here]

Interestingly, the coefficient on the change in bank loans is significantly positive for science-based as well as non-science based firms. This means that additional bank finance is available for investment spending even if liquidity constraints seem to present. However, the positive impact of bank loans on investment is smaller in science-based industries. Taken together, this result may support the view that banks act as effective monitors but are more conservative in granting loans to R&D intensive firms.

The positive and statistically significant coefficient of ownership concentration, when the firm is owner-controlled, suggests that owner-managed firms provide a governance structure that mitigates liquidity constraints. While this variable is statistically significant for science-based firms, it is non significant for non-science based firms, suggesting that the corporate governance structure of owner-managed firms is a mechanism for alleviating liquidity constraints in science-based firms but not in non science-based firms.

The coefficient of market concentration is statistically significant for the science-based firms but not for the non science-based firms. This suggests the Schumpeterian view that market power influences investment for science-based firms but not for non-science based firms.

Firm size has a weakly significant impact on investment in the full sample and for science-based industries as expected from a Schumpeterian perspective. Firm size has been identified in the asymmetric information literature as an important characteristic that can be linked to liquidity constraints. In particular, Fazari et al. (1988) found that the degree of liquidity constraints tend to be negatively related to firm size. To examine the impact of firm size on the extent of liquidity constraints, we divide the data base further into sub-samples of large and small firms, where small firms are defined as having fewer than 500 employees.[9] The regression results for large firms are shown in Table 4 and for small firms in Table 5.

[Tables 4 and 5 about here]

In both Tables 4 and 5 the coefficients of Cash Flow are statistically greater for non-science based firms than for science-based firms. This is consistent with the results shown previously in Table 3 and suggests that cash flow serves as an important signal indicating market success in science-based firms. The difference between these two coefficients is greater for small firms than for large firms. This indicates that the role of cash flow as a signal of success may actually be more important for smaller firms, which tend to be younger, than for larger enterprises, which tend to be older and more established.

As in Table 3, we find that bank loans tend to be available for investment independent of the firm size class.

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[9] The definition of a small firm as having fewer than 500 employees, while conforming to government definitions, is arbitrary. Future work should examine how the determinants of liquidity constraints vary systematically as firm size changes.

Ownership concentration apparently has no statistical impact in larger firms except for the foreign-controlled firms. This holds for large science-based firms as well as large non science-based firms. However, the degree of ownership concentration is negatively related to investment for manager-controlled firms in science-based but not in non-science based industries. The impact of ownership concentration, however, is clearly positive when the small science-based firm is owner-controlled. This suggests that management by owners is an important corporate governancee mechanisms for small firms that are science-based but not for non science-based small firms.

After splitting the sample according into larger and smaller firms, differences in firm size affect investment spending only in the subset of larger firms in science-based industries but not in the subsets of larger firms in non science-based industries or smaller firms as a whole.

Finally, market concentration has no impact on investment for both the science-based and non science-based large firms. However, for small firms, the degree of market concentration has a positive impact on investment for science-based firms but not for non science-based firms. This is reminiscent of the finding by Acs and Audretsch (1988) that innovative activity is greater in concentrated industries, but that it is small-firm innovative activity and not large-firm innovative activity that tends to rise as market concentration increases.

5. Conclusions

Since Alan S. Blinder (1988, p. 196) lamented, “A few years ago, in revising my graduate course reading list, I looked for some modern literature on liquidity constraints and investment. There was none,” scholars have responded with a series of compelling studies providing convincing evidence that liquidity constraints exist and that they vary according to the characteristics of the firm. While a theoretical literature has emerged arguing that the core reason for financing constraints is uncertainty and asymmetric information, however, empirical studies have not systematically examined whether the degree to which liquidity constraints exist vary across industries characterized by different degree of uncertainty and knowledge asymmetries.

In this paper we have explicitly focused on how financing constraints vary according to the knowledge conditions underlying the industry. In particular, we compare the extent of liquidity constraints between science-based and non-science based industries. Science-based firms are characterized by the three types of market failure identified by Arrow, and would be expected to experience a greater degree of financing constraints. The evidence suggests that the most widely-used measure of liquidity constrations – the impact of cash flow on investment – has in fact a greater impact on external finance in non-science based firms than in science-based firms. While this result may be surprising at first glance, it should be emphasized that internal finance serves a dual role in science-based firms. It provides not just a source of finance but it also serves as a signal of market success and viability under conditions of hyper-uncertainty, hyper-knowledge asymmetries, and potential non-exclusivity. Since these underlying knowledge conditions are generally more pronounced for small and new science-based firms than for their larger, more established counterparts (Audretsch, 1995), it is not surprising that the difference is even more pronounced. While the literature on imperfect capital markets has demonstrated that liquidity constraints exist, future research should extend the findings of this paper and focus on the way in which systematic differences across industries systematically influence the extent of liquidity constraints.

Table 1 *Summary Statistics*

Variables	Mean Std. dev. Full sample	 Science-based firms	 Non science-based firms
Investment expenditures / total assets (in per cent)	7.24 5.44	6.44 4.66	8.39 6.23
Sales (in millions DM)	3,472 10,356	4,066 11,958	2,608 7,349
Sales growth (in per cent)	–1.15 22.55	–0.86 22.01	–1.57 23.33
Employment	11,492 34,862	13,799 42,368	8,130 18,787
Employment growth	–1.94 19.56	–0.86 22.01	–2.84 22.05
Ownership concentration (Herfindahl index)	6,801 3,483	6,825 3,514	6,766 3,440
Cash flow / total assets (in per cent)	10.65 10.61	10.05 9.86	11.52 11.56
Bank loans / total assets (in per cent)	16.39 15.45	15.15 14.95	18.21 15.98
Change in (Bank loans / total assets) (in per cent)	–6.97 90.76	–10.05 100.36	–2.47 74.43
Working capital / total assets (in per cent)	31.04 19.68	33.89 19.43	26.87 19.30
Change in (Working capital / total assets) (in per cent)	–0.19 10.26	–0.07 9.72	–0.03 11.02
Supplier Concentration (Herfindahl index)	555 698	480 685	665 703
Number of firms	344	204	140

Table3 *Investment, Finance and Corporate Governance: Science-based versus Non Science-based firms*

Dependent variable: ***Investment***			
Independent variable:	Estimated Coefficients		
	Full sample	Science-based firms	Non science based firms
Cash Flow	1.1901*** (4.03)	0.9507** (2.14)	1.4000*** (3.66)
Δ *Sales*	0.3223** (1.97)	0.5555*** (2.72)	0.1215 (0.58)
Δ *Working Capital*	–0.8892*** (5.54)	–0.8595*** (3.64)	–0.9149*** (4.20)
Δ *Bank Loans*	0.0455*** (3.34)	0.0328** (2.09)	0.0810*** (3.04)
Ownership Concentration	–0.0593** (2.03)	–0.0888* (1.89)	–0.0318 (1.04)
Ownership concentration in owner-managed firms	0.3226** (2.00)	0.4387*** (2.88)	0.0946 (0.23)
Ownership concentration in foreign-owned firms	0.4246** (2.39)	0.1169 (0.36)	0.4292* (1.75)
Firm Size	0.2275* (1.75)	0.2998* (1.82)	0.1905 (0.96)
Market Concentration	0.2125 (1.28)	0.5605*** (2.72)	–0.4097 (1.41)
Adj. R squared	0.66	0.70	0.59
Number of firms	344	204	140
Observations (pooled)	1720	1020	700

Notes:

Within-OLS-regression, balanced panels with 344 (204, 140) fixed firm- and 5 time-specific effects (coefficients not reported). All estimates heteroskedasticity-consistent, absolute t-ratios in parentheses.

* significant at the 10% level (two-tailed test)
** significant at the 5% level (two-tailed test)
*** significant at the 1% level (two-tailed test)

Table 4 *Large Firms in Science-based versus Non Science-based Industries*

Dependent variable: *Investment*			
Independent variable:	Estimated Coefficients		
	All larger firms	Science-based larger firms	Non science based larger firms
Cash Flow	1.0807*** (3.22)	0.9378* (1.92)	1.1727*** (2.73)
∆ *Sales*	0.2151** (1.97)	0.4555*** (2.65)	0.0899 (0.42)
∆ *Working Capital*	–0.8720*** (5.06)	–0.9378*** (3.25)	–0.8190*** (4.21)
∆ *Bank Loans*	0.0376*** (2.66)	0.0258* (1.68)	0.0658** (2.19)
Ownership Concentration	–0.0193 (0.80)	–0.0244 (0.63)	–0.0272 (0.99)
Ownership concentration in owner-managed firms	0.1389 (0.93)	0.1878 (1.61)	0.0598 (0.15)
Ownership concentration in foreign-owned firms	0.5982** (2.26)	0.1566 (0.48)	0.7396** (2.09)
Firm Size	0.2630* (1.94)	0.3059* (1.82)	0.2504 (1.31)
Market Concentration	0.1183 (0.77)	0.2546 (1.32)	–0.2089 (0.85)
Adj. R squared	0.68	0.72	0.56
Number of firms	290	174	116
Observations (pooled)	1450	870	580

Notes:

Within-OLS-regression, balanced panels with 290 (174, 116) fixed firm- and 5 time-specific effects (coefficients not reported). All estimates heteroskedasticity-consistent, absolute t-ratios in parentheses.

* significant at the 10% level (two-tailed test)
** significant at the 5% level (two-tailed test)
*** significant at the 1% level (two-tailed test)

Table 5 *Small Firms in Science-based versus Non Science-based Industries*

Dependent variable: ***Investment***			
Independent variable:	Estimated Coefficients		
	All small firms	Science-based small firms	Non science-based small firms
Cash Flow	1.7178*** (2.86)	1.2892** (2.35)	1.7985** (2.23)
Δ *Sales*	0.6252* (1.72)	0.6420* (1.68)	0.4433 (0.67)
Δ *Working Capital*	–0.8957*** (2.49)	–0.4557** (2.31)	–1.3266 (1.59)
Δ *Bank Loanst*	0.0908** (2.17)	0.1101* (1.73)	0.1245 (1.63)
Ownership Concentration	–0.7596*** (2.21)	–0.9911** (2.05)	0.0424 (0.16)
Ownership concentration in owner-managed firms	1.9191*** (3.22)	2.0073** (2.96)	10.3360 (0.84)
Ownership concentration in foreign-owned firms	0.7069* (1.81)	0.7565 (1.48)	– –
Firm Size	0.1629 (0.54)	0.4389 (1.32)	–0.3707 (0.64)
Market Concentration	0.4109 (0.56)	1.8171** (2.19)	–0.9081 (0.74)
Adj. R squared	0.59	0.60	0.58
Number of firms	54	30	24
Observations (pooled)	270	150	120

Notes:

– – No coefficient estimated because there were no foreign-owned companies in the sub-group of non science-based small firms.

Within-OLS-regression, balanced panels with 54 (30, 24) fixed firm- and 5 time-specific effects (coefficients not reported). All estimates heteroskedasticity-consistent, absolute t-ratios in parentheses.

* significant at the 10% level (two-tailed test)
** significant at the 5% level (two-tailed test)
*** significant at the 1% level (two-tailed test)

References

AKERLOF, G.A. (1970): The Market for 'Lemons': Quality Uncertainty and the Market Mechanism, *Quarterly Journal of Economics* 84, 488-500.

ACS, Z.J. and AUDRETSCH, D.B. (1989): Innovation in Large and Small Firms: An Empirical Analysis, *American Economic Review* 78, 678-690.

ARROW, K. (1962): Economic Welfare and the Allocation of Ressources for Invention, in Nelson, R.R. (ed.): *The Rate and Direction of Inventive Activity*, Princeton: Princeton University Press.

ARELLANO, M. and BOND, S. (1991): Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations, *Review of Economic Studies* 58, 277-297.

AUDRETSCH, D.B. (1995): *Innovation and Industry Evolution*, Cambridge, MA: MIT Press.

BALTAGI, B.H. (1995): Econometric Analysis of Panel Data, New York et al.: Wiley.

BEISE, M. and LICHT, G. (1996): Innovationsverhalten der deutschen Wirtschaft. Beitrag zur „Erweiterten Berichterstattung zur technologischen Leistungsfaehigkeit Deutschlands“ im Auftrag des Bundesministeriums fuer Bildung, Wissenschaft, Forschung und Technologie, Zentrum fuer Europaeische Wirtschaftsforschung ZEW, Mannheim.

BINKS, M.R. and ENNEW, C.T. (1995): Bank Finance for Growing Small Businesses, in Buckland, R. and Davis, E.W. (eds.): *Finance for Growing Enterprises*, London, New York: Routledge.

BINKS, M.R. and ENNEW, C.T. (1996): Growing Firms and the Credit Constraint, *Small Business Economics* 8, 17-25.

BINKS, M.R. and ENNEW, C.T. (1997): The Relationship Between UK Banks and their Small Business Customers, *Small Business Economics* 9, 167-178.

BLINDER, A.S. (1988): Financing Constraints and Corporate Investment: Discussion and Comments, *Brookings Papers on Economic Activity*, 196-200.

BOND, S., ELSTON, J., MAIRESSE, J. and MULKAY, B. (1997): A Comparison of Empirical Investment Equations Using Company Panel Data for France, Germany, Belgium, and the UK, Working Paper No. 5900, National Bureau of Economic Research.

BOND, S. and MEGHIR, C. (1994): Dynamic Investment Models and the Firm's Financial Policy, *Review of Economic Studies* 61, 197-222.

CHIRINKO, R. (1993): Fixed Business Investment Spending: Modeling Strategies, Empirical Results, and Policy Implications, *Journal of Economic Literature* 31, 1875-1911.

DASGUPTA, P. and DAVID, P.A. (1994): Toward a New Economics of Science, *Research Policy* 23, 487-521.

ENNEW, C.T. and BINKS, M.R. (1995): The Provision of Finance to Small Businesses: Does the Banking Relationship Constrain Performance?, *Journal of Small Business Finance* 4, 57-73.

FAZZARI, S.M., HUBBARD, G.R. and PETERSEN, B.C.(1988): Financing Constraints and Corporate Investment, *Brookings Papers on Economic Activity*, 141-195.

FAZZARI, S.M. and PETERSEN, B.C. (1993): Working Capital and Fixed Investment: New Evidence on Financing Constraints, *RAND Journal of Economics* 24, 328-342.

GERTLER, M. and GILCHRIST, S. (1994): Monetary Policy, Business Cycles and the Behavior of Small Manufacturing Firms, *Quarterly Journal of Economics* 109, 309-340.

GILCHRIST, S. and HIMMELBERG, C.P. (1995): The Role of Cash Flow for Investment, *Journal of Monetary Economics* 36, 541-572.

GRILICHES, Z. and HAUSMAN, J. (1986): Errors in Variables in Panel Data, *Journal of Econometrics* 31, 93-118.

HANSEN, L. (1982): Large Sample Properties of Generalized Method of Moments Estimators, *Econometrica* 50, 1029-1054.

HIMMELBERG, C.P. and PETERSEN, B.C. (1994): R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries, *Review of Economics and Statistics* 76, 38-51.

HOSHI, T. and KASHYAP, A. and SCHARFSTEIN, D. (1991): Corporate Structure, Liquidity and Investment. Evidence from Japanese Industrial Groups, *Quarterly Journal of Economics* 27, 67-88.

HUBBARD, R.G., KASHYAP, A.K. and WHITED, T.M. (1995): Internal Finance and Firm Investment, *Journal of Money, Credit, and Banking* 27, 683-701.

HUGHES, A. (1997); Finance for SMEs: A UK Perspective, *Small Business Economics* 9, 151-166.

JAFFE, D. and RUSSEL, T. (1976): Imperfect Information, Uncertainty, and Credit Rationing, *Quarterly Journal of Economics* 90, 651-666.

JENSEN, M.C. (1986): Agency Costs of Free Cash Flow, Corporate Finance and Takeovers, *American Economic Review* 76, 323-329.

JENSEN, M.C. and MECKLING, W. (1976): Theory of the Firm: Managerial Behavior, Agency Costs, and Capital Structure, *Journal of Finanicial Economics* 3, 305-360.

JOVANOVIC, B. (1982): Selection and Evolution of Industry, Econometrica 50, 649-670.

PETERSEN, M. and RAJAN, R. (1994): The Benefits of Lending Relationships: Evidence from Small Business Data, *Journal of Finance* 49, 3-37.

PETERSEN, M. and RAJAN, R. (1995): The Effect of Credit Market Competition on Lending Relationships, *Quarterly Journal of Economics* 110, 407-443.

SAH, R. and STIGLITZ, J.E. (1986): The Architecture of Economic Systems: Hierarchies and Polyarchies, Americam Economic Review 76, 716-727.

SCHIANTARELLI, F. (1996): Financial Constraints and Investment: Methodological Issues and International Evidence, *Oxford Review of Economic Policy* 12, 90-108.

SCHUMPETER, J. (1942): *Capitalism, Socialism and Democracy*, New York: Harper&Row.

SHLEIFER, A. and VISHNY, R.W. (1997): A Survey of Corporate Governance, *Journal of Finance* 52, 737-783.

SHORT, H. (1994): Ownership, Control, Financial Structure, and the Performance of Firms, *Journal of Economic Surveys* 8, 203-249.

STEPHAN, P. (1996): The Economics of Science, *Journal of Economic Literature* 34, 1199-1235.

STIGLITZ, J. and WEISS, A. (1981): Credit Rationing in Markets with Imperfect Information, *American Economic Review* 64, 851-866.

WEIGAND, C. (1998): *Der Einfluss der Bankkreditvergabe auf den Unternehmenswettbewerb*, Hamburg: Kovac.

WEIGAND, J. (1998): Innovation, Investment, and Corporate Finance, in Mueller, D.C. et al. (eds.): *Competition, Efficiency, and Welfare*, Dordrecht: Kluwer.

WHITED, T. (1992): Debt, Liquidity Constraints, and Corporate Investment: Evidence from Panel Data, *Journal of Finance* 47, 1425-1460.

WILLIAMSON, O.E. (1988): Corporate Finance and Corporate Governance, *Journal of Finance* 43, 567-591.

WORTHINGTON, P. (1995): Investment, Cash Flow, and Sunk Costs, *Journal of Industrial Economics* 43, 49-61.

Summary Statistics

es	Mean Std. Dev.							
	Science-based Industries				Non Science-based Industries			
	Listed firms		Non-listed firms		Listed firms		Non-listed firms	
	Large	Small	Large	Small	Large	Small	Large	Sm
ent expenditures / total assets (in per cent)	6.85 4.13	4.61 4.31	6.18 4.60	6.96 6.93	8.59 5.36	7.71 6.26	8.07 5.81	9.3 6.2
millions DM)	6,021 15,425	131 210	3,340 8,984	148 249	4,003 10,404	99 67	2,062 3,291	35 72
owth (in per cent)	–0.41 17.04	3.33 20.61	–2.40 26.78	1.06 20.53	–1.07 24.30	–4.60 15.68	–1.60 19.96	–1 34
nent	20,706 55,851	279 146	11,122 29,520	237 140	12,751 26,374	324 114	6,309 7,922	25 13
nent growth	–0.21 14.80	3.57 28.46	–4.21 14.39	3.17 29.46	–1.00 26.48	–3.97 16.88	–4.60 18.98	–3 11
hip concentration (Herfindahl index)	4,869 3,435	6,061 3,619	8,779 2,324	8,350 2,659	4,917 3,421	6,213 3,008	8,507 2,556	8,8 1,9
w / total assets (in per cent)	10.10 8.84	10.84 12.06	9.52 10.50	11.75 9.90	12.03 10.13	13.31 13.41	10.27 10.99	12 17
ans / total assets (in per cent)	18.03 13.83	20.10 17.83	10.75 14.33	17.42 16.05	17.99 14.56	18.96 14.58	16.65 16.20	25 20
in (Bank loans / total assets) (in per cent)	–0.44 57.78	–4.75 120.75	–22.47 132.46	–4.84 72.38	–0.03 66.54	4.48 58.33	–7.77 75.94	1.9 10
capital / total assets (in per cent)	33.09 15.79	39.88 22.35	34.14 20.70	32.42 26.58	28.20 16.52	31.76 24.65	25.33 19.74	22 23
Concentration (Herfindahl index)	478 691	285 191	545 775	315 201	806 843	450 404	529 486	73 78
of Firms	91	65	83	17	62	11	54	13