Chapter 1: Financial constraints for investors and the speed of adaptation: Are innovators special?

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Abstract:

This paper uses a large panel of survey data on German firms in the manufacturing sector to analyse the effects of financing constraints for investors in general and for innovative firms in particular. Survey data with information on financing conditions are potentially a valuable tool that avoids the Kaplan and Zingales (1997) critique on the use of cash flow sensitivities for the identification of financial constraints. Using the autumn and the spring wave of the Ifo Institute's Investment Tests (IT) during the years 1988-1998, we create a panel with information on investment, innovation activity and financing conditions. Financial constraints affect the *distribution of investment over time* in a fundamental way. Following a shock, the adjustment of a constrained firm is slower and less spiky. After developing this argument theoretically building on Schworm's (1980) model of optimal investment under financial constraints, we use it to test the empirical content of our survey data by means of an error correction model of investment activity. Our results indicate that constrained firms in fact do react more slowly, but that innovative firms are not especially affected. This supports an argument made by Bond, Harhoff and van Reenen (2003): In equilibrium, innovative activity will come from a group of firms that is self-selected on the basis of their being able to overcome the special difficulties of financing innovation.

Keywords: Financial constraints, investment, innovation, dynamic panel data models

JEL-Classification: D210, D920, C230

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Introduction

By definition, innovative firms seek finance for a type of investment activity that is characterised by especially grave informational asymmetries: the item to be financed exists only in the mind of the firm manager.[1] On the other hand, innovative activities, if successful, create monopoly profits and will open a rich and reliable source of internal finance that makes the firm less dependent on external finance in the future. The history of Microsoft might be regarded as a case in point. In Germany, too, the innovation activity of many large firms is based on the regular income from past successes. Furthermore, firms are able to specialise in innovative activity, developing a reputation for economically successful R&D. Thus there is ample reason to suspect that financing problems of innovating firms will differ from those of non-innovators.

It is conceivable that the specific problems of financing innovation will also depend on the financial system. Allen and Gale (2000) argue that a bank-based system may be better and more efficient at financing ordinary investment, ie investment in areas where a large amount of experience has been gained, because of the economies of scale in information acquisition achieved by delegation to an intermediary. Financing innovation or investment in a new industry, however, makes it necessary to cope with diversity of opinion. Financial intermediaries are hierarchical and therefore ill-suited to deal with this aspect of innovation, whereas unintermediated (equity) markets may be better suited. On the other hand, as financing innovation entails an extreme form of informational asymmetry, the value of a long-term relationship between a bank and its client may be especially high in this context.

This paper is part of a larger research effort, based on panels of survey data, which aims to compare the significance of financial constraints for firm behaviour in bank-based Germany and the capital market-based United Kingdom. These two European countries

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[1] See, for example, Hall (2002). The point was made as early as 1962 by Kenneth Arrow, already explicitly using a moral hazard argument.

seem especially well suited for investigating the relative performance of bank-based and market-based systems, as other important features of the economies, such as income and the level of economic activity, industrial structure, economic history and many socio-economic institutions, are broadly similar. Important results are contained in Chapter 2 of this thesis.

In many important respects, our work builds on Bond, Elston, Mairesse and Mulkey (2003), who compare the role of financial factors for investment in Belgium, France, Germany and the United Kingdom, and more specifically on Bond, Harhoff and van Reenen (2003) who were the first to undertake a detailed and careful microeconometric comparison of firm investment behaviour in Britain and Germany, focussing on innovation. Both studies use the cash flow sensitivity of investment demand to identify financial constraints. The latter paper comes to intriguing and provocative results, which are

> ... easily summarised: Cash flow matters for the fixed investment of British firms, but not for German firms. In neither country does cash flow appear to be important for the flow of R&D spending. In Britain cash flow matters more for the fixed investment decisions of non-R&D firms than it does for R&D firms, and there is a significant correlation between cash flow and whether or not a firm performs R&D. (p 38)

This suggests that British firms are facing a higher difference between the costs of external and internal finance than their counterparts in Germany. As a possible reason for the seeming absence of financial constraints, the authors point to higher ownership concentration in Germany and to the *Hausbank* system, which both may contribute to mitigating problems of asymmetric information. The fact that investment behaviour of innovators in Britain seems to be less affected by financing constraints than investment of non-innovators is explained by the endogeneity of activities in a competitive environment: “The R&D performing firms in the UK are a self-selected group who choose to make long-term commitments to R&D programmes, partly on the basis that they do not expect to be seriously affected by financial constraints.”

Using an extremely large panel of accounting data for German firms from the Deutsche Bundesbank’s Balance Sheet Statistics, von Kalckreuth (2003b) and Chirinko and von Kalckreuth (2002, 2003) establish clear evidence for the existence of financial constraints in Germany, too, by comparing cash flow sensitivities of firms with a good rating and with a bad rating. These results are cross-checked by comparing the overall sensitivity of firms with respect to the user cost of capital. Yet it is true that, in comparison with other European countries (Italy, France and Spain), cash flow sensitivity in Germany does seem to be very low: see Chatelain, Hernando, Generale, von Kalckreuth and Vermeulen (2003a, 2003b). Furthermore, small firms do not seem to be especially affected by financing constraints. Low cash flow sensitivity of German firms has been detected previously by Bond, Elston, Mairesse and Mulkay (2003). So it seems quite possible that there was something special about financing conditions in Germany during the 1990s.

All of the aforementioned studies, including our own, are based on evaluating the role of internal finance for investment demand. The neo-classical point of departure for studying the interaction between the financial sphere and factor demand is provided by the theorem of Modigliani and Miller (1958). With perfect capital markets, the value of a firm is independent of its financial structure, and the decisions on factor demand and financing can be separated. The former will depend only on "real" factors such as production technology, installation costs, and current and future values of capital-good prices, interest rates and demand.

With imperfect capital markets, however, the access of firms to external finance may differ depending on the importance of information asymmetry and agency problems. These problems create a wedge between the costs of external finance and the opportunity costs of internal finance. As the sources of finance are no longer perfect substitutes, the amount of internally generated funds can matter to the investment decision.

Since the work of Fazzari, Hubbard and Peterson (1988), the predominant approach to the investigation of the role of financial factors has been an indirect one. A sub-sample of firms is classified as being financially constrained according to some *a priori* criterion. The analysis starts with the observation that, for financially constrained firms, the liquidity generated internally is a relevant explanatory variable for investment demand, whereas in the "pure" case of a financially unconstrained firm it is not. Fazzari, Hubbard and Peterson proceed to estimate separate investment equations and then test whether the current cash flow is of higher importance for the investment demand of the firms deemed to be especially constrained, compared to the rest of the sample. Thus the effect of financial constraints is identified by the "excess sensitivity" to current cash flow.

In the meantime, this approach has been forcefully criticised. Kaplan and Zingales (1997) state that there is no theoretical reason why – in a comparison between firms – a larger cost differential between internal and external finance might lead to a higher cash-flow sensitivity, as opposed to just comparing the extreme cases of a constrained firm and an absolutely unconstrained one. A non-monotonic relationship between the cost differential and excess sensitivity is perfectly conceivable.[2] On the other hand, it has been shown theoretically that, under certain conditions, cash flow terms can be significant even in the absence of financial constraints.[3] Ultimately, there is a pervasive missing variable problem. Cash flow is a close relative to profit, a summary measure of all that is important for a firm, and it is useful in predicting future values of variables relevant to the current investment decision.[4] Bond and Cummins (2001), as well as Bond, Klemm, Newton-Smith, Syed and Vlieghe (2004), attack the problem by constructing a measure for Tobin's average Q based on analysts' earnings forecasts. This synthetic measure drives out cash flow from the investment equation, casting severe doubt on the ability of cash flow sensitivity to measure financial constraints.

In our paper, we use a direct approach by relying on explicit statements by the firms themselves. We are able to explore the micro data base of the Ifo Institute's Investment Test (*Investitionstest,* IT) for the manufacturing sector in western Germany during the years 1988 to 1998. During these eleven years, the autumn wave yields 25,643 observations on a total of 4,443 firms, with 2,331 firms per year on average. Apart from its size and coverage, the data set has three important characteristics that are relevant to our problem. First, it contains many small firms, on which very little information is available from micro data sets based on quoted companies. Although large firms are clearly over-sampled, almost 50% of the IT observations refer to firms with fewer than 200 employees, and 19.5% of the firms have fewer than 50 employees. Second, firms report on their innovation behaviour. They state whether or not a product innovation was achieved during the past year and whether or not it was fundamental in a technological sense. Third, the data set contains information on financial constraints that firms face in

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2 The discussion was continued in Fazzari, Hubbard and Peterson (2000) and Kaplan and Zingales (2000).
3 See the models by Abel and Eberly (2003), Cooper and Ejarque (2001), and Gomes (2001).
4 This argument is developed formally in Appendix B of Chirinko and von Kalckreuth (2003).

their investment decisions. Notably, a number of firms (around 26.2% of respondents) explicitly state that their investment demand is limited by the cost and/or the unavailability of finance. Although part of this may be due to the workings of the classical interest rate channel, these aggregate effects can be eliminated by the use of time dummies, focussing on differential changes in time.

A subset of respondents explicitly claims to be constrained, and in a sense, this is exactly what the bulk of the empirical literature on financial constraints tries to prove by comparing cash flow sensitivities. However, it needs to be examined whether they have told the truth, ie whether or not there is informational content in their assertions. There are at least three reasons for a relationship between financing conditions and investment behaviour to be present in the data. First of all, evidently, a positive relationship might result from financial constraints curtailing the firm's investment spending. Second, financial constraints are clearly endogenous and may result from expansion plans of the firm proper. Simply speaking: the more a firm wants to spend, the more financial obstacles it will find. This in isolation would make for a negative relationship. Finally, respondents might try to rationalise their investment behaviour ex post: A shock in investment demand might "cause" statements on financial condition not via a credit supply schedule, but by the urge of the respondents to give reasons for their investment behaviour.

We therefore need to see whether the pattern of answers corresponds to what might theoretically be expected in a financially constricted environment. We want to focus on the distribution of investment over time as an essential feature of financial constraints. Given a shock, an unconstrained investor can adapt rapidly, or even instantaneously if adaptation costs are unimportant. The bulk of investment spending will take place in the first few periods, and there may be a spike in the first period. If the investor is financially constrained, however, marginal costs of finance will increase with the amount of spending, possibly to infinity. In such a setting, the investor has to equalise marginal costs of finance and the marginal value of new investment in each period. After an initial debt-financed increase in the capital stock that leads to a worsening of the financial position, the firm needs internal finance to continue the expansion and to repair balance sheets gradually. Thus, the adaptation process will be spread over time. In short: *money buys time!* This crucial difference in the adaptation dynamics can be used to identify financially constrained firms, or better, whether a subset of supposedly constrained firms really is, without having to take recourse to cash flow sensitivities. To the best of our knowledge, this method of validating survey information – and more generally *a priori* claims on certain subgroups to be financially constrained – is new to the literature.

The rest of this paper is organised as follows. Section 2 briefly describes a model of investment under financial constraints focussing on adaptation dynamics which is more fully developed in Appendix A. Section 3 presents the data set. Section 4 investigates the informational content of the survey information. The analysis proceeds in three steps. A simple fixed-effects regression of log investment on the "factors influencing investment" from the survey indicates that there is indeed a strong contemporaneous relationship between these factors and investment. Step two starts from a simple error-correction model and then uses the information on financing conditions as firm-specific and time-varying proxies for the costs of finance. Using GMM methodology, we show that the financing conditions variables keep their predictive content when we exclude contemporaneous correlation using predetermined instruments. This shows that the informational content of the financing conditions information clearly goes beyond a mere "justification effect", and it corrects for reverse causality via the marginal costs of finance schedule. Step three, finally, is a structural test on whether the financing conditions information corresponds to our model of how financial constraints condition the pattern of investment. We also want to know whether innovative firms are different from non-innovators. Our preliminary results indicate that financially constrained firms do indeed adapt more slowly, with a distribution of investment over time that puts less mass on the first periods. Innovative firms, however, do not seem to differ at all from non-innovative firms in this respect. Section 5 concludes. Appendix A contains a formal model of optimal investment under financial constraints, focussing on the adjustment dynamics. Appendix B explains the mechanics of the error correction model (ECM), and Appendix C gives further details on the data.

2 Optimal investment under financial constraints

We want to develop clear-cut predictions on how financing constraints condition the time profiles of investment and financing, under what circumstances firms are likely to report external financing problems, and in what respect the profiles might differ when there is an innovative investment project to be financed. We set up a small but analytically well tractable model of optimal capacity adjustment under financial constraints; the details can be found in Appendix A.

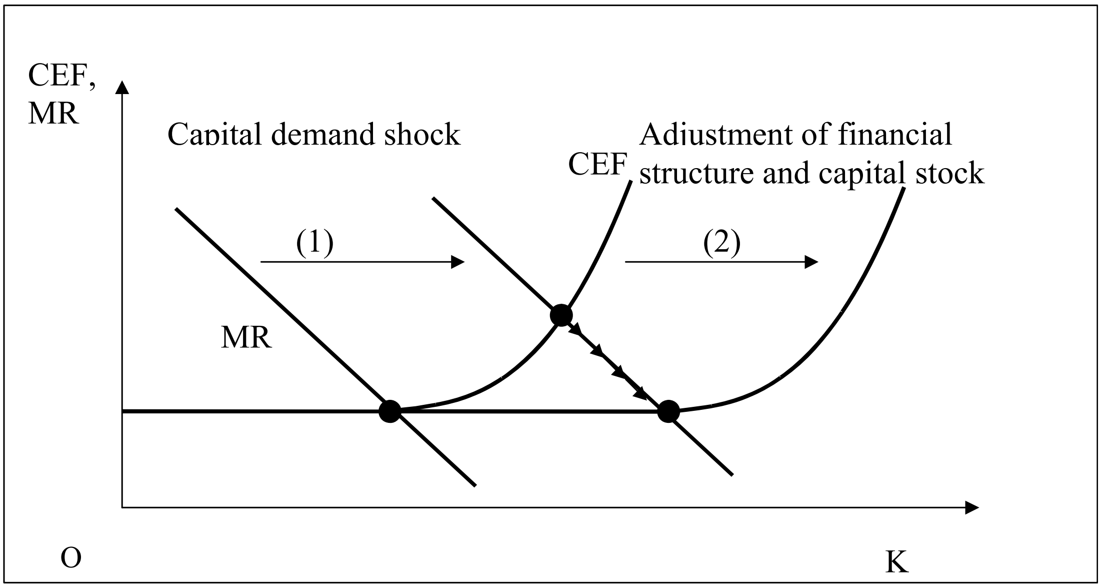
In our model, internal and external finance are not perfect substitutes. The firm is financially constrained in two respects: It has no access to new equity, and it can raise debt finance only at financing costs that are an increasing function of credit volume. Time is continuous. As observed investment behaviour on the firm level is characterised by large spikes, we do not want to use the device of assuming convex adjustment costs, thereby smoothing out investment behaviour. Instead, we assume that the stock of real capital can "jump", ie discretionary changes are possible. Given a shock, we want to see how large the *initial investment* is, how it is *financed*, and what the *adjustment process* looks like. We want to understand how this pattern is conditioned by the extent of financial constraints. Ultimately, we want to arrive at a testable hypothesis on the financing of innovative investment.

As a point of departure, we use the model of Schworm (1980). Schworm investigates investment and financing behaviour of a firm that can neither borrow nor sell new shares. In the last section of his paper he extends his analysis to a firm that has access to credit, and shows that the general results he has derived earlier remain intact. As we want to look at capacity adjustment, we specialise his analysis by assuming that prices are constant all along the adjustment path and that there is a positive capacity gap at the beginning that needs to be bridged. Compared to Schworm's more general analysis, this limitation yields richer predictions and makes the description analytically simpler. Our way of solving the optimisation problem is not much related to Schworm's approach, and he does none of our comparative dynamic exercises.

Our model not only permits discrete jumps, but also predicts spikes in the investment behaviour as a generic outcome. When the shock occurs, the firm will try to make a discrete adjustment of its capital stock, using cash holdings from retained earnings. If equity is insufficient to finance the new target capital stock entirely, the firm will use debt finance and adjust only partially. A discrete increase of the capital stock takes place, but it is incomplete. Financial constraints spread the rest of the adjustment process over time. Firms use the current internal revenue as a means of financing further expansion and of reducing debt finance at the same time. The adjustment process is finished when the target capital stock has been reached and the initial credit is paid back. In a sense, financial constraints take the place of adjustment costs in the standard model, impeding instantaneous adjustment.

It is possible to condense the dynamics of the model into a single diagram. In Figure 1, the decreasing schedule represents marginal return of investment, whereas the increasing schedule with the flat portion depicts the costs of finance. Given a profitability shock, indicated by arrow (1), the financially constrained firm will immediately invest up to the point where the costs of external finance, CEF, are equal to marginal profitability of investment. The difference between marginal profitability and the costs of finance in the steady state winds up a "clockwork". The firm retains profits, indicated by arrow (2), expanding equity base and physical capital at the same time. The "clock" winds down, along the falling schedule that depicts marginal returns of investment, until dynamic equilibrium is reached again.

Figure 1: The clockwork



The second part of our analysis investigates how the time profile of capital accumulation and financial status depends on initial equity, the size of the project to be financed and the severity of financial constraints. The results are quite intuitive. Low equity means that a firm will have to go deeper in debt at the outset, investing less real capital.

The adjustment process is spread over a longer time: the firm is "slower". With respect to size, we make an important distinction. If the entire maximisation problem, *including* initial equity, is amplified, the adjustment process of the larger firm will simply be a blown-up image of the adjustment process of a smaller firm: both processes will be of the same duration. If, however, the initial equity is fixed and only the size of the project varies, the firm with the larger project will have higher marginal financing costs at the outset and take longer to manage adjustment.

The effect of varying the intensity of financial constraints is straightforward. A severely constrained firm will take up less debt, make a smaller initial investment and nevertheless have higher marginal financing costs at the outset of adjustment compared with a less severely constrained firm. The more constrained firm needs more time to complete the adjustment process.

With respect to the financing of innovations, we can build on our preceding analysis. We take as given the technology and the market value of equity. Therefore, the main feature of an innovative investment is the importance of informational asymmetry: the innovative firm is likely to be subjected to more severe financial constraints.[5] However, as pointed out by Bond, Harhoff and van Reenen (2003), it is possible that innovators and non-innovators differ systematically in the amount of initial equity they have at their disposal. Even so, a clear prediction remains: If innovators face a steeper ascent of their external finance premium schedule, their investment will be financed to a higher degree from retained earnings than an equally sized non-innovative investment. Aghion, Bond, Klemm and Marinescu (2004) give a short summary of other aspects that might affect the financing of innovative firms. For a comprehensive review see Hall (2002).

3 The data

Since the mid-1950s, the Ifo Institute in Munich has been surveying the investment intentions of German firms in industry, trade and services. The participants of the Investment Test (*Investitionstest,* IT), represent around 50% of the turnover generated by firms with 20 employees and more; see Oppenländer and Poser (1989). The micro-data of the IT have been used by Ploetscher and Rottmann (2002) and by Ploetscher (2001) for a bivariate ordered probit estimation of investment and financing constraints, without, however, using the survey information on financial conditions. Funke, Maurer, Siddiqui and Strulik (1998) include this information in a reduced form investment model using six waves of the Investment Survey, but they interprete them as indicating expected changes in factor prices. There is also important related work by Smolny and Winker (1999) on employment adjustment and financing constraints, and Smolny (1999) on innovation and investment. These two papers use Investment Test data from the years 1980-1992. Smolny (1999) concentrates on innovation, but also estimates a reduced form equation for the ratio of investment and sales. Smolny and Winker (1999) use data on financing constraints obtained from merging another survey, the Innovation Test, to the IT. They focus on employment adjustment, stating that constrained firms should be less able to finance complementary investment, their wage bill, or short-run adjustment costs (like paying overtime) than unconstrained firms. Their econometric models are static and do not refer to the speed of adjustment in the same way as it is done in this paper.[6]

We are able to use the complete subset for western Germany within the eleven years 1988 to 1998. The sample is subject to entries and exits. During those eleven years, the autumn wave yields 25,643 observations on a total of 4,443 firms, with 2,331 firms on a yearly average. The IT is carried out twice a year. The Spring Survey collects data on the sector, the number of employees, sales, investment in the two previous years, buildings and equipment separately, as well as investment planned for the current year. Furthermore, the test contains data on investment motives, capacity growth, the importance of rented capital goods and the share of external financing. Besides some of the same information, the Autumn Survey also reports whether or not firms have achieved a product innovation, see the text of the question as given below. The year 1988 saw an important change: at the initiative of the European Commission, the Autumn Survey also asks for factors influencing investments. For the present and the following year, investors are asked to state which factors are influencing their investment activity posi-

[5] See Hall (2002).

[6] Among other things, Smolny and Winker (1999) estimated ordered probit regressions for employment changes, an OLS regression for employment growth as well as an ordered probit equation for variations in working time (overtime working, short time working) using financing constraints as an explanatory variable,

tively or negatively, and how strong this influence is. The text of the question is also given below. Information on financing conditions comes from the answers that relate to the second factor.

Question 4 [Autumn survey]: Innovations in 1999

	yes	no
• In 1999, we introduced **new** products into the market (or will do so)	□	□
• If so, were these **fundamental** innovations regarding		
- the level of technology	□	□
- the use of our products (opening new markets)	□	□

Question 5 [Autumn survey]: Factors influencing investment in 1999-2000

In 1999-2000 our investment in western Germany was/is being positively/adversely affected by the following factors: (Please refer to the explanatory notes on the reverse of the accompanying letter.)

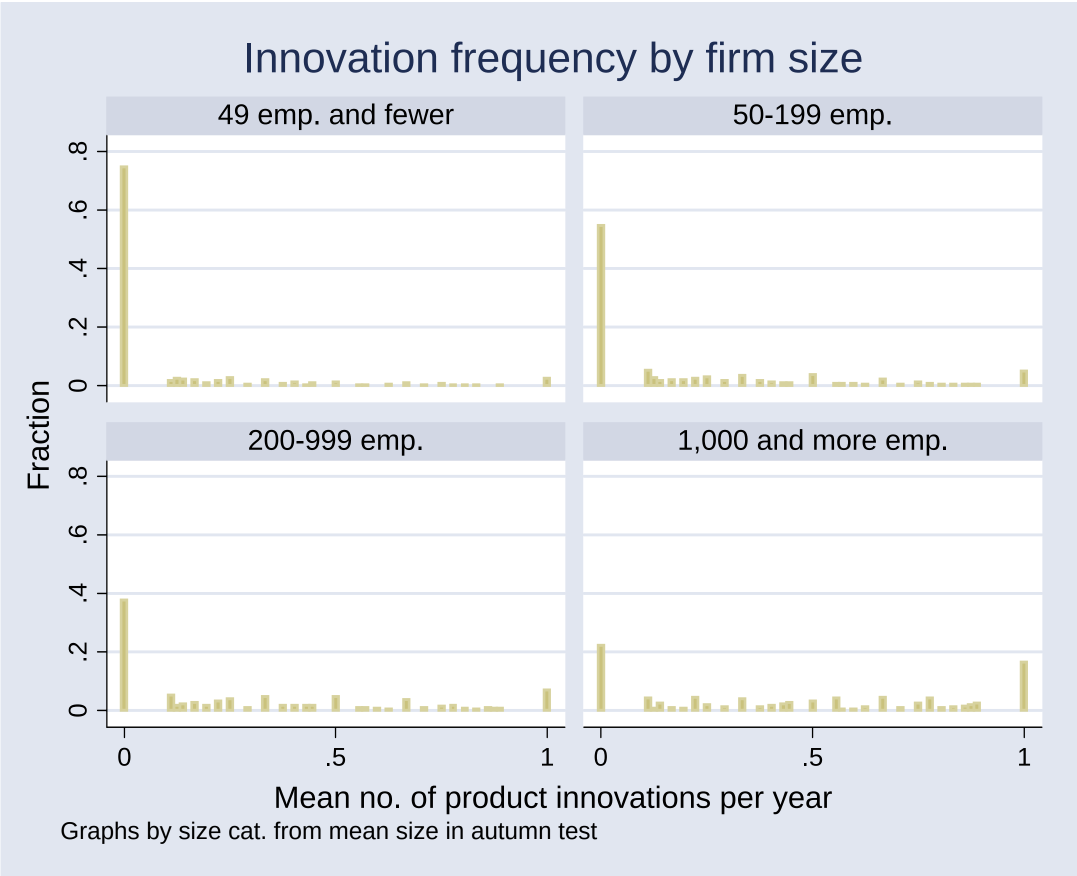
	1999					2000				
Factors	Very stimu-lating	Stimu-lating	No influ-ence	Lim-iting	Very limi-ting	Very stimula-ting	Stimu-lating	No influ-ence	Limi-ting	Very limi-ting
Sales conditions / expectations										
Availability / costs of finance										
Earnings expectations										
Technical develop-ment										
Acceptance of new technologies										
Basic economic policy conditions										
Other factors, namely ...										

We need to distinguish innovations from mere routine product variations. Therefore we count a positive response to the first part of survey question 4 only if the activity is qualified as a “fundamental innovation regarding the level of technology” in the second part of the question.

When calculating firm-specific mean numbers of innovations per year, a clear size dependence emerges. Figure 2 depicts innovation frequency according to size categories: 49 and less, 50-199, 200-999, and 1,000 and more. Most of the small firms (73%)

never innovate during their life in the sample; their median number of innovations is zero. The distribution of innovations is highly skewed to the right. Within the second size category, slightly more than half of the firms never innovates (55%). The share of firms with no innovation observed decreases further to 38% and 22% for the third and the fourth size categories. For the two large size categories we can observe a second mass point at a value of 1: a certain number of firms will innovate *every* year. With the largest size category their relative frequency, 17%, is about as large as that of firms that never innovates.

Figure 2: Mean number of product innovations by size category



To a large degree, this size dependence is a simple effect of aggregation. If ten small firms that innovate with a low frequency, say once in every 10 years, merge to form one big company, and the innovation behaviour of the newly formed subdivisions is independent and stays the same, then the company as a whole will report with a probability of 65.2% that it has achieved at least one innovation in a given year. But the standards of what a "fundamental" innovation is may also change with size. We therefore divide the firms into "innovators" and "non-innovators" depending on whether their mean number of innovations is at least equal to the size-specific average. Because the distribution for smaller firms is extremely skewed, less than 50% of the firms are considered as innovators in the basic sample: it is 25.2%, 34,1%, 39.8% and 48.0% of firms in the different size classes, ranging from the smallest to the largest, and 38.8% on average.

Innovation activity may clearly be endogenous with respect to firm-specific financing conditions. Following Bond, Harhoff and van Reenen (2003), we therefore generate a product innovator status indicator on the basis of a sectoral classification. This is the innovation indicator used for all regressions. To the degree that the sector classification is able to take account of the basic market conditions, it yields information on what a firm should do (but possibly is not able to do). Thirty sectors according to a 2-digit SYPRO classification are grouped as innovative or not innovative depending on whether the share of innovators is at least 50%. The resulting classification is intuitive, with the exception of "manufacture of aircraft and spacecraft", a sector that is classified as non-innovative. This sector enters into the estimations with no more than 9 strings of observations. A description of the sectoral structure and the innovator status for the final sample on which the GMM estimations are performed can be found in Table C1 in Appendix C. Table C2 breaks the sample up into size classes and (sector-specific) innovator status. The size differentials are even larger than for the firm-specific innovator status described above.

4 Estimation and results

4.1 Estimation strategy

Our analysis proceeds in three steps. First, we look at the relationship between investment and contemporaneous financing conditions. We specify a reduced-form model by taking the wording of Question 5 seriously: "In 1999-2000 our investment in western Germany was/is being positively/adversely affected by the following factors: ...". Respondents are asked to decompose their investment decision into various factors. If we assume a multiplicative structure and if the perceived magnitude of a change in investment is scaled by the size of the variable, we can write:

$$\log I_{i,t} - \log I_i^* = z(1)_{it} + z(2)_{it} + ... + z(k)_{it} . \quad (1)$$

Here, I_i^* is some "normal" or steady state investment, specific to the firm. This equation can also be derived as a first order Taylor approximation around the steady state from a more general equation,

$$\log I_{it} = f[\ x(1), x(2), x(3), x(4), x(5), \dots\ ] .$$

The z(·) are functions of the underlying primitive determinants x(·). In the IT, the z(·) are "sales conditions/expectations", "availability/cost of finance", "earnings expectations, "technical development", "acceptance of new technologies", "basic economic conditions" and a catch-all named "other factors". It has to be noted that respondents are not asked for the value of the underlying determinant, but for the *effect* it has on investment, ie its value weighted by its impact on the investment decision. This is different from the usual regression situation: it amounts to giving the explanatory variable weighted by its coefficient. One implication is that in a linear regression, the coefficients on the answers should be the same, at least for a given firm. The size of the coefficient will indicate the *scaling*, ie what magnitude of influence will be considered as "strong" or "moderate".

As it is, equation (1) can be estimated without further ado as a static fixed-effects panel regression. This will give us a feeling for the strength of the linear relationship between the various factors, specifically financing conditions, and investment demand. In order to separate out the user cost effects of aggregate interest rate changes, we use time dummies as additional regressors.

However, this estimation does not allow us to discriminate between the three sources of correlation indicated in the introduction: (a) financing conditions influencing investment via the cost of external finance, (b) investment influencing financing conditions because the financing premium is an increasing function of the investment volume, and (c) the "justification effect" that may spring from respondents trying to rationalise their behaviour *ex post*.

In a second step, we therefore estimate a model that uses the information on financing conditions as a proxy for the costs of finance and treats them as a part of the user costs of capital. Estimating this dynamic model using GMM methods allows us to filter out the effects (2) and (3): it can show us whether there is a price effect of financing conditions on investment demand.

Following the lead of Bond, Elston, Mairesse and Mulkay (2003) and of Bond, Harhoff and van Reenen (2003), we use an error-correction model based on a static linear neo-classical demand equation. The equation is derived in Appendix B; its general form is

$$\frac{I_{i,t}}{K_{i,t-1}} = a_1 \frac{I_{i,t-1}}{K_{i,t-2}} + b_0 \Delta \log S_{i,t} + b_1 \Delta \log S_{i,t-1} + c_0 \Delta \log UC_{i,t} + c_1 \Delta \log UC_{i,t-1}$$

$$+ s \cdot \{\log K_{i,t-2} + k_1 \log S_{i,t-2} + k_2 \log UC_{i,t-2}\} + u_{i,t} \ . \qquad (2)$$

Here, $I_{i,t}$ is the level of capital expenditure of firm i in year t, and $K_{i,t-1}$ is the real capital stock carried over from the end of the previous period. Real sales in period t are denoted by $S_{i,t}$, and the difference of the logs is approximately equal to the growth rate. $UC_{i,t}$ are the user costs of capital; they are permitted to have a firm-specific component. The coefficients are all linear functions of the parameters for an autoregressive investment model with distributed lags (ADL); see the derivation in Appendix B, in particular equation (B4).

The term s in the second line is the error-correction coefficient; it should be negative. The term in curly brackets ought to be zero in the long run for the long-term relationship between capital, user costs and sales to hold. The equation is usually estimated using $\log\left(K_{i,t-2}/S_{i,t-2}\right)$ instead of $\log K_{i,t-2}$ as level term, and we follow this convention. This affects the interpretation of $\log S_{i,t-2}$: its coefficient will now reflect possible increasing or decreasing returns, and omitting the variable will impose constant returns. The latent term $u_{i,t}$ is supposed to have the following two-way error component structure:

$$u_{i,t} = \varphi_i + \lambda_t + \zeta_{i,t} \ , \qquad (3)$$

with φ_i firm specific, λ_t time specific and $\zeta_{i,t}$ uncorrelated, but possibly heteroscedastic.

We assume financial conditions to affect the "neo-classical" user costs UC' as defined by Hall and Jorgenson (1967) and others by a mark-up:

$UC_{i,t} = UC'_{i,t} * g[FC_{i,t}]$,

where g[.] is an increasing linear function of the financing conditions. Taking logs makes this a sum. If possible idiosyncratic shocks to UC’ are uncorrelated with the variables we use as predetermined instruments, UC' can be relegated to the error term defined in (3). and we can plug levels and first differences of our financing conditions indicator into the place of the user costs term log UC.

This dynamic equation will be estimated using both the Arellano and Bond (1991) GMM estimator that uses moment conditions generated from the equation in first differences and the combined dynamic panel estimation as proposed by Arellano and Bover (1995) and Blundell and Bond (1998). As the combined dynamic estimation is able to make use of a larger set of moment conditions, more recent instruments and more observations, it is the preferred method for efficiency reasons if the econometric preconditions for its use are satisfied.[7]

This second step of our analysis models financial conditions as a part of the user costs of capital. This approach can show us whether predetermined changes in financing conditions influence investment demand, but it is agnostic about the form this influence takes. Is a financing constraints model the right theoretical framework to explain these effects?

Our third step addresses the results of the theoretical discussion in Section 2. Financing constraints have been shown to slow down the adaptation speed of firms and make their reaction during the first periods less immediate. We test this prediction by comparing the adaptation behaviour of firms which are predominantly financially depressed by their own assessment with the adaptation speed of firms that do not claim to be financially constrained. In order to do so, we need a model that allows us to determine when shocks occur and how large they are. To this end, we will continue to use equation (2) as an econometric model, but in a different way: the user cost terms will now be entirely absorbed into the error term, and we focus on the speed of adaptation for constrained and for unconstrained firms.

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[7] Von Kalckreuth (2003a), pp 185-189 gives a brief account of the estimation principle and the use of GMM estimators in an autoregressive investment equation with distributed lags.

The user cost model referred to above as step 2 is not suitable for a comparison between sub-groups, as respondents were asked to give their answers in terms of the effect a given factor has on investment. If the scaling of effects does not differ between sub-groups, this would lead us to expect similar-sized coefficients, no matter how different the subgroups are. However, with a structural model in hand, we can compare innovative and non-innovative firms by checking whether the impact of bad financing conditions on the speed of adjustment is stronger or weaker for innovative firms, compared with their non-innovative counterparts – a difference-in-difference approach.

The framework of analysis of step three therefore needs two different sample splits. We want to distinguish innovators from non-innovators, and financially constricted firms from unconstrained ones. The former will be done as explained in the last sections: innovator status is decided by the sector of a firm, identifying innovation intensive sectors by the share of firms that innovate frequently. The latter is achieved by calculating an average of financing conditions over a string of observations. Integers 1 to 5 are attributed to the categories "very stimulating", "stimulating", "no influence", "limiting", "very limiting", and the firms' mean outcomes are computed. We use two cutoff values for qualifying a firm as constrained. According to criterion 1, it is constrained if the mean grade is worse than the median of outcomes. Criterion 2 uses a 65% quantile.

This procedure is open to criticism because of potential endogeneity. Although we implicitly observe the size of the shock, it may still be that, at the firm level, random costs of adaptation will trigger financing constraints, which may also result in slow adaptation speed for firms that are classified as financially constrained. However, we want to make the fullest possible use of the financing conditions statements. The endogeneity problem is at the centre of the analysis in step two, where we test whether the relationship between financing conditions and investment survives the use of predetermined instruments. In future work, we will check the robustness of our results in step three by the use of predetermined criteria. At the current stage, we have to keep in mind the alternative interpretation outlined above.

4.2 Results

Table 1 shows the distribution of financing conditions for the largest possible sample of firms that results when all waves of the autumn survey are merged.[8] A firm is categorised as a product innovator if its mean number of reported product innovations is higher than the size-specific mean; see the discussion in Section 3. Generally, more than half of the firms (56.2%) state that financial conditions are having "no influence". A share of 17.1% of the firms see their financing conditions as "limiting" for investment, for 9.1% they are "very limiting". 17.5% of investors state that their financial conditions are either "stimulating" or "very stimulating", with the last answer being a rare exception (3.6%). The distribution of answers to the financing conditions question does not differ perceivably between innovators and non-innovators. If we could assume that the two groups do not differ in the way they scale changes in their financing conditions in terms of their impact on investment, this would represent important *prima facie* evidence against the hypothesis that financing conditions differ according to innovator status. For the UK, Aghion, Bond, Klemm and Marinescu (2004) report a non-linear relationship: the debt/asset ratio of innovative firms (firms with positive R&D expenditure) actually seems to be higher on average, compared to the non-R&D performers; however, the debt/asset ratio will decrease with growing R&D expenditure.

Table 2 shows the dependence on external finance, as given by the share of gross investment financed externally: all sorts of debt finance plus new equity. The share is gross of repayments of existing credits. For innovators, non-innovators and the entire sample, the average share of external finance is tabulated against the five financing conditions categories. Interestingly, there is a U-shape in the marginal distribution. Average use of external finance is high (0.317) when financial conditions are "very stimulating". The average share decreases to 0.267 when the conditions are just "stimulating", and reach a trough for the "no influence" category, at 0.149. With financial conditions being regarded as "limiting", the share goes back up to 0.266, and with "very limiting" conditions the share reaches 0.309, almost as high as on the other extreme of financing conditions. It is straightforward to speculate that the "stimulating" group takes on a high share of external finance *because* the opportunity seems good, whereas the two "limiting" groups feel depressed *as a consequence* of their high credit needs. And again: no difference is visible between innovators and non-innovators, either in their average share of external financing (0.201 for innovators against 0.205 for non-innovators), or in the conditional means.[9]

For our panel data analysis (both static and dynamic), we limit ourselves to consecutive strings of observations that can be checked for consistency. If there is a large jump in the contemporaneous number of employees and the data on past employment do not fit the data on contemporaneous employment in earlier observations, we assume that an M&A event has taken place and intertemporal consistency is destroyed. For the (static) reduced form fixed effects model based on the factors for investment, we use the longest uninterrupted string of observations for each firm. The sample for GMM estimations is additionally subject to a mild trimming as a means of outlier control. Each consecutive string of observations then enters as a separate unit into the dynamic panel regressions. The final model is estimated with 11,608 observations on 1,742 units, generated by 1,684 firms. More details on the regression variables, the construction of the capital stock variable and outlier control can be found in Appendix C.

Table 3 gives the results of our fixed effects estimation that was described as the "first step" of the empirical analysis. The dependent variable is the log of investment, transformed to the deviation of investment from its firm-specific average. This is equivalent to estimating equation (1) with a firm-specific intercept. Prior estimation has shown that the significance and contribution of the factors "acceptance of new technologies", "basic economic policy conditions" and "other factors" is quite low: very often these factors are not evaluated at all. Therefore, the analysis is limited to the factors *sales conditions*, *availability/costs of finance*, *earnings expectations* and *technical development*. These factors are highly significant, and they are able to "explain" a lot of variation: An R^2 of 10.2% in an estimation with micro-data is not small when all the explanatory variables are categorical dummies. In all cases, the baseline category is "very stimulating",

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[8] The answers for Question 4 on innovation are part of the data set only from 1990 on. It is therefore not possible to construct an innovation indicator based on mean innovation activity for all firms with information on financing conditions.

with the coefficients therefore yielding the effect of deviations from the positive extreme. All coefficients therefore can be expected to be negative. As may also be expected, the absolute size of the coefficients increases as the categories worsen, with insignificant permutations within the coefficients of the “technical development” factor. Comparing coefficients for given categories *between* factors does not show large differences: specifically, the coeffficients for sales conditions and for financial conditions are rather similar. This is consistent with the respondents scaling their answers with the effect that a given factor variation has on investment.

As already explained, with the fixed effects results in hand, it is impossible to separate the three possible interaction mechanisms between the statements on factors for investment and observed investment expenditure. In order to prepare the estimation of the cost of finance model as the second step or our analysis, we estimate a simple form of the error correction model without time varying financing conditions. This is equivalent to absorbing the entire user cost variation into the multiple component error term (4), as has been done by Bond, Elston, Mairesse, Mulkay (2003), Bond, Harhoff and van Reenen (2003) and several other authors. The results are shown in Table 4. The dependent variable is the investment rate $I_{i,t}/K_{i,t-1}$. The Arellano-Bond (1991) estimation of the equation in first differences, Column (1), fares well: the level term $\log(K_{i,t-2}/S_{i,t-2})$ is strongly significant, with a speed of adjustment of -0.258. The lagged sales term is insignificant, meaning that this estimation does not reject constant returns. With a coefficient of –0.101, the autoregressive term $I_{i,t-1}/K_{i,t-2}$ is of moderate importance, and neither the Sargan-Hansen test nor the test on autocorrelation of second order in the residuals of the differenced equation reject the specification. In order to be able to use more recent instruments, we try the combined dynamic panel estimator proposed by Arellano and Bover (1995) and Blundell and Bond (1998), the so-called GMM system estimator. It combines the moment conditions generated by the equation in first difference with moment conditions from the equation in levels. Our first attempt using all first differences lagged once as instruments for the level equation fails: the Sargan test strongly rejects this set of instruments. Alternately eliminating one of the variables from the set of instruments shows that the problem lies with the once-lagged difference of real sales,

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9 With the large number of observations, a formal χ^2 test would surely be significant. But economically,

$\Delta\log S_{i,t-1}$. Column (3) shows the systems estimation when this variable is not included into the set of instruments for the level equation. Both the Sargan statistic and the AR(2) test are innocent. The number of observations is clearly higher than with the first difference estimation (8,125 against 6,383). With 0.159, the speed of adjustment is somewhat smaller than shown in column (1), and the log $S_{i,t-2}$ term becomes positive and significant, indicating increasing returns. The size of that coefficient, however, remains moderate.

In the rest of the paper, we will use the same type of instrumentation all over: levels lagged 2-4 of all explanatory variables for the Arellano-Bond (first difference) estimator, and in addition all the first differences lagged once, except $\Delta\log S_{i,t-1}$, for the level equation in the systems estimation. Details can be found in the notes at the bottom of each table.

Table 5 shows GMM first difference estimations of equation (2) with categorical financial conditions variables included. The indicator variable $finneut_{i,t}$ assumes a value of 1 if respondents state that financing conditions have had “no influence” on their investment. The dummy $finbad_{i,t}$ is set equal to 1 if the respondent considers financing conditions as “limiting” or “very limiting”. The baseline category (omitted in the regression) is given by the answers “stimulating” or “very stimulating”. The financing conditions, at least the category $finbad_{i,t}$ for financial limitations, shows clear negative effects that are significant, both economically and statistically. The long-run impact of a worsening of financial conditions from one of the two stimulating categories to one of the two limiting categories on the capital stock can be calculated as a decrease by 17%; see the derivation in Appendix B, especially equation (B3). However, financial conditions are correlated with sales conditions, and it may well be that the realised sales terms that enter in equation (2) do not sufficiently control for sales expectation. It is therefore worthwhile to also include terms related to sales expectation into the error correction equation, constructed in exactly the same way as the financing conditions terms described above. In so doing, all the financing constraints terms lose their significance, whereas the indicator formed from the two limiting categories of sales expectations becomes significant, although only at the 10% level for the long-run effect.

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the patterns are virtually indistinguishable.

We estimate the same two equations using the systems estimator; see Table 6. For these estimations, the financing terms keep their significance when the sales term is added. However, it has to be noted that the estimated speed of adjustment is very low (in Column (2) the capital-sales ratio becomes even insignificant). Calculating the long-run effects of a worsening of financing conditions thus becomes unreliable.[10] Furthermore, in comparison with the first difference estimator, both specification tests are worse. The Sargan-Hansen statistic drops to p-values of 0.030 and 0.088, and the Lagrange Multiplier Test for second order correlation of the differenced residuals assumes p-values of 0.081 and 0.038. This, too, casts doubt on the validity of the additional instruments.

All in all, the results of the second step of our analysis seem to be consistent with an interpretation of the financing condition statements as indicating variations of costs of finance that are partly predetermined. The interdependence of investment expenditure and statements on financing conditions demonstrated in the course of step 1 is not all due to a possible "justification effect". However, as yet, we have not been able to show convincingly that the financial constraints indicator contains information which goes beyond sales expectations. Admittedly, this is a hard test, as internal finance and the creditworthiness of a manufacturer will be conditioned quite closely by sales and expected sales. But one might see a certain parallel here to the results obtained by Bond and Cummins (2001): when they include the profit forecasts of professional analysts in their investment equation, the cash flow term in their Q-equation becomes insignificant.

The last part of our empirical analysis is therefore dedicated to investigating the implications of financial constraints in a more specific way, by comparing the speed of adjustment of financially constrained and unconstrained firms. In Tables 7 – 10, this is done separately for the entire sample ("All firms"); the innovators, as defined by the status of their sectors; and the non-innovators. In these tables, all explanatory variables of a simple error correction model without time dependent financing conditions variables enter both with their level and interacted with a dummy variable that indicates whether a given firm is classified as financially constrained; the same is also true for the time dummies. This way, we can compare the size of any coefficient between the un-

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[10] Applying eq. (B3) to Column (1) of Table 6 yields a whopping 66% long-term decrease in the capital stock when financing conditions switch permanently from one of the stimulating categories to one of

constrained and the constrained firms. Our main focus will be the speed of adjustment, the coefficient of the capital-sales ratio, but we will also look at the coefficients that indicate the size of the short-term reaction. Bloom, Bond and van Reenen (2007) investigate the influence of uncertainty on the adaptation dynamics. Testing the hypothesis that uncertainty slows down the sensitivity of firms with respect to economic incentives, they also use an error correction model. However, unlike us, they concentrate on the short-run dynamics only.

The analysis is done using both the GMM first difference estimator (Tables 7 and 8) and the GMM system estimator (Tables 9 and 10), and for two ways of defining a financially constrained firm. In Tables 7 and 9, a firm is considered as constrained if the average financial conditions indicator calculated as described in Section 3 is worse than the median. Tables 8 and 10 report the results of a sample split with a more stringent cut-off value given by the 65% quantile of the indicator.

The results can be summarised relatively briefly. The first difference estimation using the wide cutoff-point (median) shows the financially constrained firms to adjust more slowly, although the difference between the adjustment speed parameter (shaded grey) is significant at the 10% level only for the innovators. It is interesting to also look at the differential coefficients for sales growth $\Delta \log S_{i,t}$, which reflect the differences in the immediate response to a shock. As predicted by our model, those coefficients are all smaller for the constrained companies, but none of these differences is significant.

With the stricter cut-off value in a GMM first difference estimation (Table 8), the significant difference in the adjustment speed of innovators disappears. The innovators, however, have a lower short-term response when they are constrained. Using the GMM system estimator with the wide definition of financial constraints (Table 9) we again obtain a lower adjustment speed for the constrained firms, although none of the differences is significant. The same is true for differences in the short-term reaction: they have the predicted signs, without being significant.

This changes dramatically if the more efficient GMM system estimator is used on a sample split with the more stringent classification (Table 10). For the entire sample, as

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the limiting categories. At the given stage, it is certainly too early to subscribe to this result.

for both subgroups, the adjustment speed of financially constrained firms is significantly lower (though only at the 10% level for the innovators). Numerically, the differences in adjustment speed seem to be very similar across sub-groups, there does not seem to be a difference in differences. Also the differences in the short-term reactions broadly are as predicted by the model. The fact that the main difference in the short-term reaction seems to be in the second period, not in the first, runs counter to the prediction of our model, but may be due to our instruments being less informative for the contemporaneous variables than for the first lag.

This last set of estimations gives evidence that the speed of adjustment is systematically lower when the firm is financially constrained. For the other sets of estimations, the pattern was more or less as predicted, but the differences were not significant. Finally, looking at the last set of regressions, we cannot detect any clear difference between innovators and non-innovators with respect to the impact of financing constraints on their speed of adjustment; the estimations are almost identical.

5 Conclusions

Our results are consistent with an economic environment where financial constraints do indeed play a role, but in which innovative firms are not affected worse than non-innovators. The most plausible explanation for the latter part of the statement is the argument made by Bond, Harhoff and van Reenen (2003): In an industry equilibrium where financial constraints play an important role, innovative activity will come from a group of firms that is self-selected on the basis of their being able to overcome the special difficulties of financing innovation – large firms, financially healthy firms, old firms that have had the chance to build a reputation and a steady flow of internal finance, and firms with strong relations to a financial intermediary. It will be illuminating to investigate this further.

Our results are preliminary and will be extended in future work. However, they already show that survey data can meaningfully be used in the analysis of financial constraints. Steps 2 and 3 of our empirical analysis give evidence that financial constraints play an active role in Germany. There seem to be firm-specific time variations in the financing costs that have an effect on investment demand, which is not easily explained in the context of a Modigliani-Miller world.

Survey data have to be validated. It is not *a priori* clear that the answers of the respondents bear any relationship with the theoretical concepts the analyst may have in mind. We have proposed a validation scheme that concentrates on the *temporal pattern* of firm activity under financing constraints. This validation method can be used with other type of survey data, too. Chapter 2 of this thesis uses duration analysis on qualitative data to test whether financially constrained firms take longer to escape capacity restrictions. But the strategy can also used for the diagnosis of financial constrains in other type of data, such as balance sheet information, creating a real alternative for the embattled cash flow sensitivity method.

Appendix A: Optimal capacity adjustment under financial constraints

A1 The model

An overview of the model, its aims and results has been given in Section 2. Consider a firm that is a price taker on the factor market and uses capital to produce a single good, with decreasing returns. The firm has no access to new equity, but it may hold bonds and use credit finance. Let K_t be real capital and B_t positive or negative bond holdings, with $B_t < 0$ implying net debt. Revenue (net of labour costs) is given by a strictly increasing, strictly concave function of real capital:

$$y_t = F(K_t), \qquad F' > 0, \qquad F'' < 0 .$$

Total profit, π_t, is given as the sum of net revenue and financial cash flows:

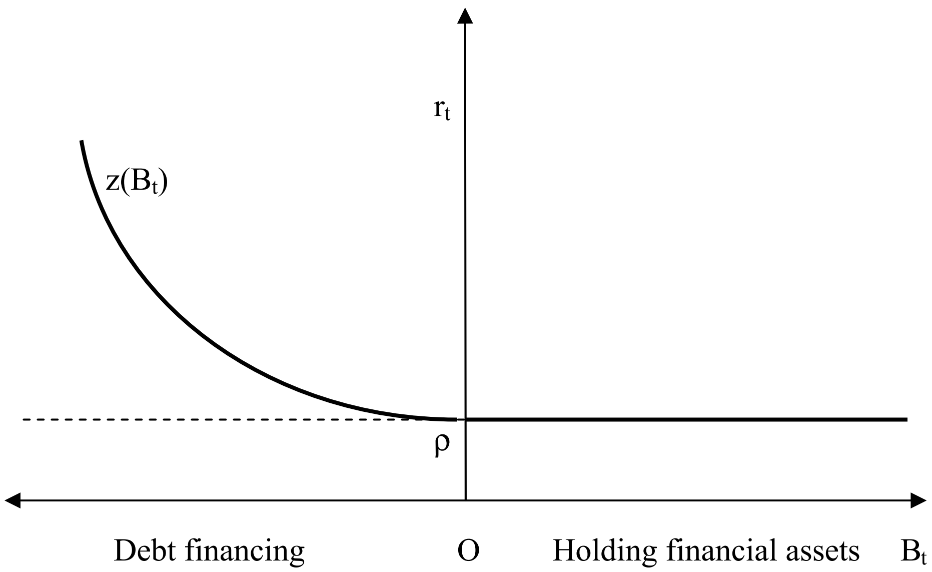
$$\pi_t = F(K_t) + r_t B_t,$$

where

$$r_t = \rho + z(B_t) .$$

The interest rate r_t has two components: an exogenous short-term rate ρ, and an external finance premium that is a continuous function of total debt. For $B \geq 0$ this finance premium is zero; for $B < 0$ it is positive, strictly decreasing and strictly convex, as shown in Figure A1:

Figure A1: External financing costs function



The function is not necessarily defined for all $B < 0$. To accommodate quantitative restrictions,[11] we allow that there might be some B^{min} such that $z(B_t) \rightarrow \infty$ for $B_t \rightarrow B^{min}$. Furthermore, we want to assume $F'(0) > \rho$, so that the project is economically meaningful. The balance sheet identity is given by

$$E_t = K_t + B_t \,.$$

Equity E_t is given by the sum of real capital and the (correctly signed) financial status. Additional capital can be financed by retained earnings or by debt. The firm's payout, ie dividend payments, is

$$\varphi_t = \pi_t - \dot{K}_t - \dot{B}_t \,.$$

Funds from current operation can be used, apart from paying dividends, for financing capital expenditure and bond acquisition or debt repayment. The last two items therefore are retained earnings, ie additions to equity:

$$\dot{E}_t = \dot{K}_t + \dot{B}_t \,.$$

Equity is a continuous variable that can only be changed by retaining earnings. The variable cannot "jump": there are no new shares, and dividends cannot become negative. Real capital, on the other hand, is allowed to jump. If there is a discrete change in capital stock, there has to be an equivalent change in financial status, in order to maintain the balance sheet identity:

$$\Delta K_t = -\Delta B_t \,.$$

The opportunity costs of equity to shareholders are given by rate ρ, which is the rate of return on their alternative investment. The firm maximises the value of its payout:

$$V = \int_0^{\infty} e^{-\rho t} \, [\pi_t - \dot{E}] \, dt \,.$$

Time starts at t=0, when, because of a change in technology or the financial environment, a need of adjustment arises. Equity in t=0, E_0, is given by the values of real capital, K^-, and financial status, B^-, immediately before the shock. The optimal values B*

[11] Quantitative constraints of the Stiglitz-Weiss (1981) type where $z(B_t)$ may converge to a finite number for $B_t \rightarrow B^{max}$ could also be adapted. In the control problem to be described next, this type of constraint would generate boundary solutions, yet without posing special problems.

and K* for financial status and real capital, if both could freely be chosen and financed by new equity, are given by the static first-order conditions:

$$\partial\varphi/\partial B = \partial\varphi/\partial K = \rho ,$$

yielding

$$B^* \geq 0 \text{ and } \quad F'(K^*) = \rho .$$

We want to model the time path of capacity expansions. Therefore we will generally assume that the inherited capital stock K^- is smaller than K*. In order to reach the new equilibrium, the firm has to acquire new capital. We may distinguish two cases:

Case 1: $E_0 \geq K^*$: Net financial assets, B^-, are sufficient to bridge the gap between the value of inherited capital stock, K^-, and the target capital stock, K*. The firm can therefore immediately jump into the new equilibrium. The necessary additions to the capital stock can be financed from free funds at opportunity costs of ρ. This is equivalent, of course, to the situation in which there are no financial constraints with respect to new equity or debt finance.

Case 2: $E_0 < K^*$: Net financial assets B^-, are insufficient to finance the targeted net addition to the real capital stock. The firm cannot jump into the new equilibrium. Buying $\Delta K = K^* - K^-$ on the spot would raise the opportunity costs of finance to $\rho + z(E_0 - K^*)$, whereas marginal revenue from the use of capital would be only ρ.

The following analysis assumes $K^* > K^-$ and Case 2, ie we look at expansion under financial constraints. It is easy to see that dividends will be zero as long as either $B < 0$ or $K < K^*$. In this case using the funds for paying back debts or aquiring additional capital is more profitable that the alternative investment with rate of return ρ. In steady state, the rates of return on both assets, bonds and real capital, are equal to ρ. An arbitrage argument ensures that steady state must be reached for both assets simultaneously. If $B = 0$ while $K < K^*$, a small credit financed addition to the capital stock would enhance current profits in a similar way as a more rapid pace of debt repayment at the cost of capital accumulation could do if $B < 0$ and $K = K^*$.

In the following, we want to convert our infinite horizon problem into one with a finite, but variable time horizon. By adding and subtracting in the integrand $\pi^* = F(K^*)$, the net revenues from producing output in steady state, we can write:

$$V = \int_0^\infty e^{-\rho t} [\pi_t - \dot{E} - \pi^*] \, dt + 1/\rho \, \pi^* .$$

Let T be the time when the steady state is entered. We can mechanically split the integral

$$\int_0^\infty e^{-\rho t} [\pi_t - \dot{E} - \pi^*] \, dt \quad = \int_0^T e^{-\rho t} [\pi_t - \dot{E} - \pi^*] \, dt \quad + \quad \int_T^\infty e^{-\rho t} [\pi_t - \dot{E} - \pi^*] \, dt .$$

Let us consider the components on the right-hand side. For $t < T$, all profits are retained, such that $\pi_t - dE_t/dt = 0$ in the integrand of the first term. Inside the second integral, for $t \geq T$, payouts are given by $\varphi_t = F(K^*) + \rho B = \pi^* + \rho B$. Thus we can write the maximand:

$$V = 1/\rho \, \pi^* - \int_0^T e^{-\rho t} \pi^* \, dt \; + \int_T^\infty e^{-\rho t} (\rho B - \dot{E}) \, dt .$$

The first term on the right-hand side is the capital value of net revenue if the steady state capital stock is in place at t=0. If this is not the case, the second term gives the net losses of dividends due to retention until the target capital stock is reached. And the third term is the value of the firm's financial activities after time T. By withholding profits further, the firm can accumulate bonds which will generate interest income in the future. But the interest rate for positive bond holdings is ρ, the discount rate. As the firm enters the steady state with B=0, the value of these activities is zero.

Because the first and the third terms are constants, it suffices to maximise the second component, which is the correctly signed loss of payouts due to adjustment:

$$V' = -\int_0^T e^{-\rho t} \pi^* \, dt \; .$$

It is obvious that maximising V′ is equivalent to minimising time T needed to reach the steady state and have access to the net revenue π*. To this end, however, the firm has to accumulate additional equity, namely the difference $K^* - E_0$.

A2 Solving for dynamic equilibrium

In control theoretic terms, we have the following problem:

$$\max_B V' = -\int_0^T e^{-\rho t} \pi^* \, dt ,$$

subject to $\dot{E}_t = \pi(K_t,B_t)$,

$\pi(K_t,B_t) = F(K_t) + [\rho + z(B_t)]\cdot B_t$,

$K_t = E_t - B_t$,

$E_0 = K^- + B^-$, with $K^* > E_0$,

$K_T = K^*$, with $F'(K^*) = \rho$,

$B_T = 0$,

T free .

Unlike Schworm (1980), we use equity E_t as our state variable. This seems more natural in our setting, as capital stock and financial status are allowed to jump, whereas equity is restricted to evolve continuously. By substitution, we can eliminate K_t from our problem. The only control variable then is B_t, which determines K_t for any given state E_t. The terminal condition could also be written as $K_T = K^*$ and $B_T \geq 0$, implying $E_T \geq K^*$. But the building up of equity is time consuming, as the pace of accumulation is limited by current profits. Therefore, the time minimal path fulfils the condition without slack, implying $E_T = K^*$ with $B_T = 0$.

As a means of deriving the necessary conditions for an optimal control provided by Pontryagin's Maximum Principle,[12] we write the Hamiltonian function:

$$H(t, E_t, B_t) = -e^{-\rho t}\,\pi^* + \lambda_t\,\pi(E_t - B_t, B_t)\ .$$

The necessary conditions for an optimal control path, the "canonical equations", are:

$$\max_B H = -e^{-\rho t}\,\pi^* + \lambda_t\,\pi(E_t - B_t, B_t) \text{ with } t \in [0,T]\ , \qquad \text{(A1)}$$

$$\dot{E}_t = \pi(E_t - B_t, B_t)\ , \qquad \text{(A2)}$$

$$\dot{\lambda}_t = \partial H/\partial E_t = -\lambda_t\,\pi_K(E_t - B_t, B_t)\ , \qquad \text{(A3)}$$

$$H(T) = 0\ . \qquad \text{(A4)}$$

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[12] The following necessary conditions are treated extensively by Seierstad and Sydsaeter (1987), Kamien and Schwarz (1991) and Chiang (1992).

Here, π_K marks the derivative of the profit function with respect to K, ie marginal revenue. As B_t is unbounded and H is concave in B_t, the value of B_t maximising H given (E_t, λ_t, t) is characterised by the necessary condition for an inner solution:

$$\lambda_t [\pi_K(E_t–B_t, B_t) – \pi_B(E_t–B_t, B_t)] = 0 . \quad (A5)$$

We will proceed to show that λ_t is positive throughout. From the transversality condition (A4) we get:

$$H(T) = –e^{-\rho T} \pi^* + \lambda_T \pi(E_T–B_T, B_T) = 0 .$$

As $\pi(K_T, B_T) = \pi^*$ by definition, this yields:

$$\lambda_T = e^{-\rho T} > 0 . \quad (A6)$$

The terminal value of λ is equal to the value of one unit of equity at time T, evaluated at t = 0, and it is positive. By recursion, this must be true everywhere along the optimal path, as the motion of λ is governed by the differential equation (A3), or

$$\dot{\lambda}_t/\lambda_t = – \pi_K(E_t–B_t, B_t) < 0 . \quad (A7)$$

In (A5), the term in brackets must therefore be zero along the entire solution path.

The structure of the solution is now plain:

1) The fundamental Euler equation,

$$\pi_K(E_t–B_t, B_t) = \pi_B(E_t–B_t, B_t) , \quad (A8)$$

has to hold at every single point of the time path, also and especially at the starting value. For every given E_t, the firm chooses B_t in such a way as to maximise $dE/dt = \pi(E_t\text{-}B_t,B_t)$.

2) In conjunction with optimal debt B_t at t=0, the Euler equation immediately yields the optimal initial capital stock. If $K^- = K^*$ does not hold, this will entail a jump in real capital.

3) As $\pi(E_t–B_t, B_t)$ is strictly concave in B_t, the value of the control variable B_t given E_t is unique. Therefore the entire time path for (E_t, B_t) is uniquely determined until the steady state is reached.

4) Along the optimal path, the value of B_t can be traced by differentiating the Euler equation:

$$\pi_{KK}\dot{E}_t - \pi_{KK}\dot{B}_t + \pi_{KB}\dot{B}_t = \pi_{BK}\dot{E}_t - \pi_{BK}\dot{B}_t + \pi_{BB}\dot{B}_t .$$

Given the additive structure of the profit function, the cross derivatives are all zero, and

$$\dot{B}_t = \pi_{KK} /(\pi_{KK} + \pi_{BB})\, \dot{E}_t \;>\; 0 .$$

Outside the steady state, B_t is negative, but strictly increasing. As

$$0 < \pi_{KK} /(\pi_{KK} + \pi_{BB}) < \; 1 ,$$

a positive and possibly varying fraction of total profits is used to pay back debts, the rest – also a strictly positive fraction – will be invested in additional real capital:

$$\dot{K}_t = \dot{E}_t - \dot{B}_t = \pi_{BB} /(\pi_{KK} + \pi_{BB})\, \dot{E}_t \; > 0 .$$

Along the path that leads to equilibrium, the firm continually grows, paying back debts at the same time.

5) This means that $K < K^*$ and $B < 0$ for all $t \in [0,T]$, and therefore $\pi_K > \rho$. As $-\pi_K$ is the rate of decrease of λ, and $e^{-\rho T}$ its terminal value, the initial value of λ is strictly greater than 1 if the steady state is not reached immediately.

A3 Interpretation and sensitivity analysis

Whereas the case of no binding financial constraints implies a discrete jump into the new equilibrium, expansion under financial constraints is distributed over time, with current profits filling the gap between E_0 and the new target capital stock bit by bit. This involves myopically maximising current profits, choosing B_t (and K_t) in such a way that the additional revenue generated by an additional unit of capital is equal to the additional financing costs, also with respect to the changing costs of existing debts.

It is worthwhile to note that the optimisation problem can be rewritten in a simple way as a time optimal problem:

$$\min_{B} V' = T ,$$

subject to $\int_0^T \dot{E}_t \, dt = K^* - E_0$, $\qquad \dot{E}_t = \pi(E - B_t, B_t)$.

Let T* be that optimum. The optimal time path $[B_t, E_t]$ will also solve the dual problem:

$$\max_B \int_0^T \dot{E}_t \, dt , \quad \text{subject to} \quad \dot{E}_t = \pi(E - B_t, B_t), \qquad T^* \text{ fix.}$$

The solution to these problems will select B_t at each moment in such a way that the current profit is maximised. This will not only maximise the current contribution dE_t/dt to the objective function, but it will also increase maximal profits in the future.

Figure A2 exemplifies solution paths for the variables K_t, E_t and B_t. In order to prepare our sensitivity analysis, it is instructive to look at the solution in the (K,B) space. The Euler equation (A8) requires that at each point in time, the marginal productivity of capital be equal to the marginal costs of financing,

$$\pi_B = \rho + z(B_t) + z'(B_t)\, B_t ,$$

the latter being comprised of both direct costs given by the interest rate $r_t = \rho + z(B_t)$ and indirect costs given by the changing costs of existing finance. Given the assumptions on $\pi(K_t, B_t)$, isoprofit lines are concave everywhere, possibly with a kink at $B_t = 0$ where $z'(B_t)$ may switch from zero to a positive number. The Euler equation implies that the marginal rate of substitution between the two assets, B_t and K_t, is always equal to 1.

This allows us to depict the set of points (B_t, K_t) that the firm will pass on its way to the steady state as an expansion path in (B_t, K_t) space, as shown in Figure A3.

With this expansion path, we are ready to analyse the influences of initial equity, the size of the project and the severity of the financial constraints on the accumulation path.

Figure A2: Adjustment paths for capital stock, equity and financial status

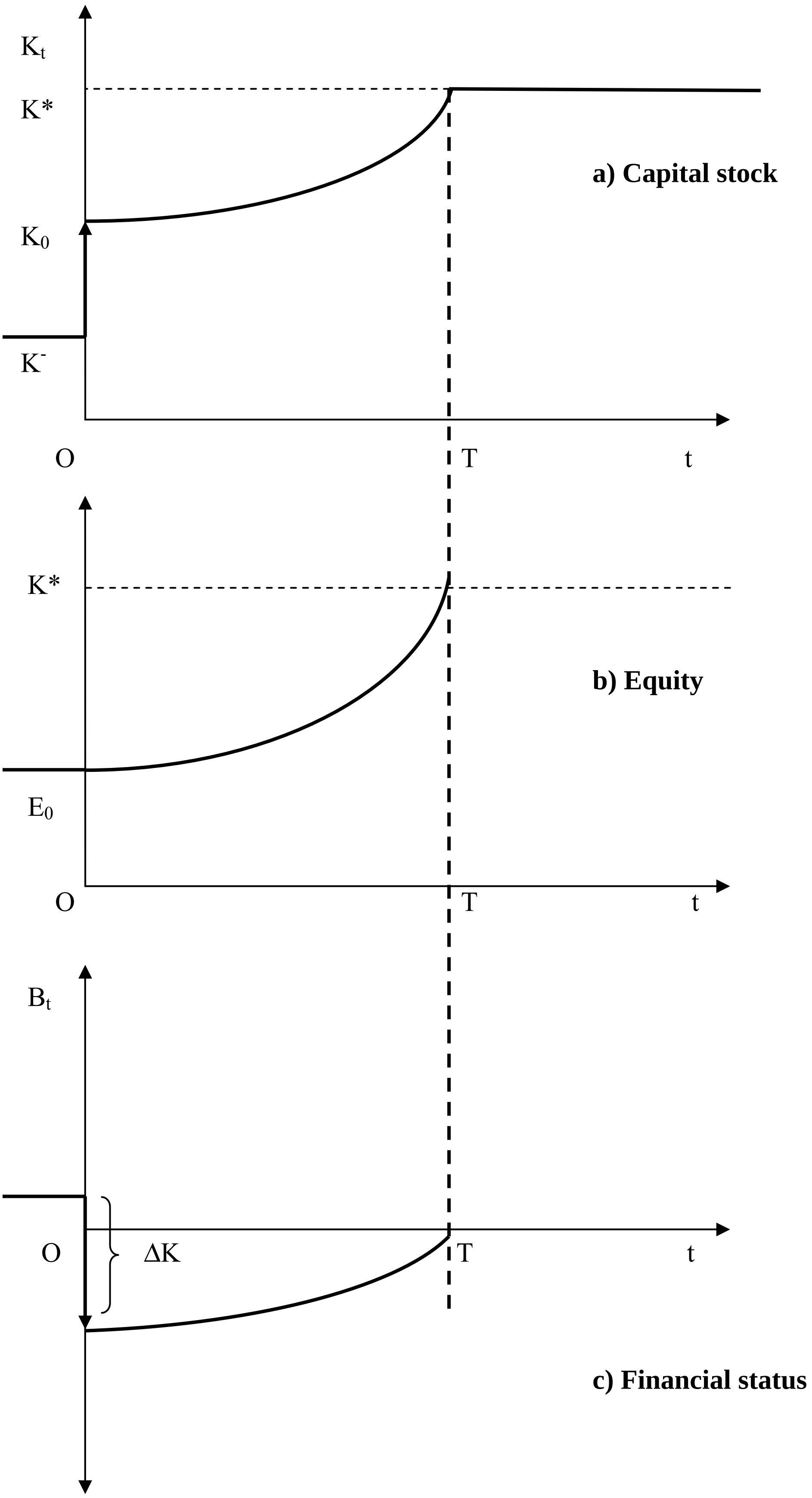
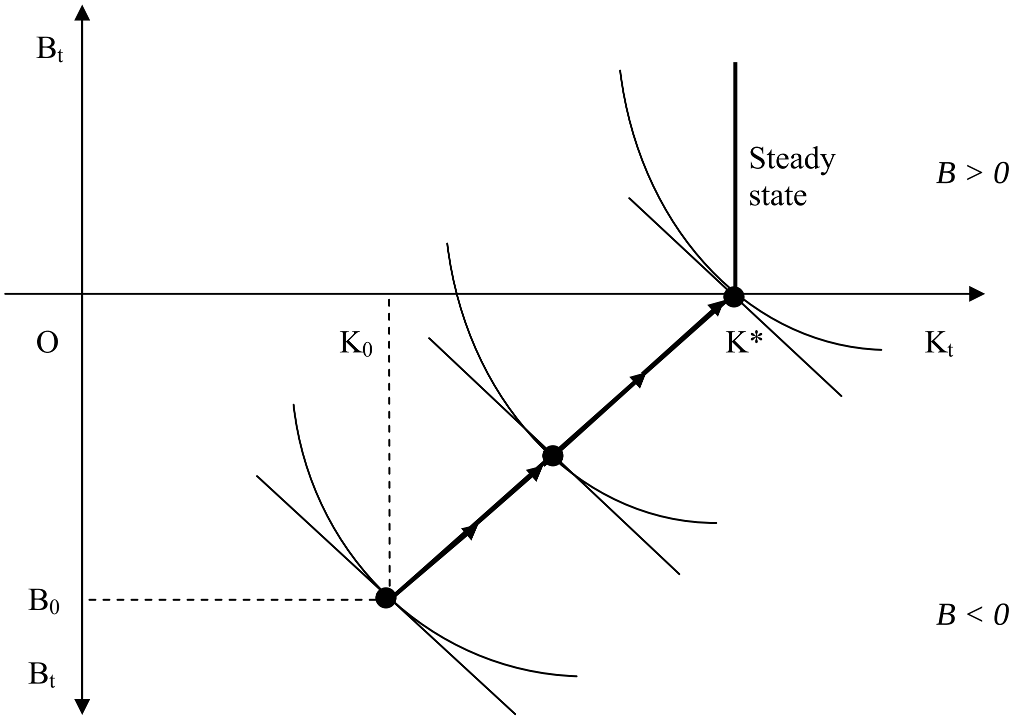


Figure A3: Phase space analysis



A3.1 The role of initial equity

The terminal state is independent of equity. Initial capital and initial financing are determined by the marginal condition:

$$\pi_K(E_0 – B_0, B_0) = \pi_B(E_0 – B_0, B_0) .$$

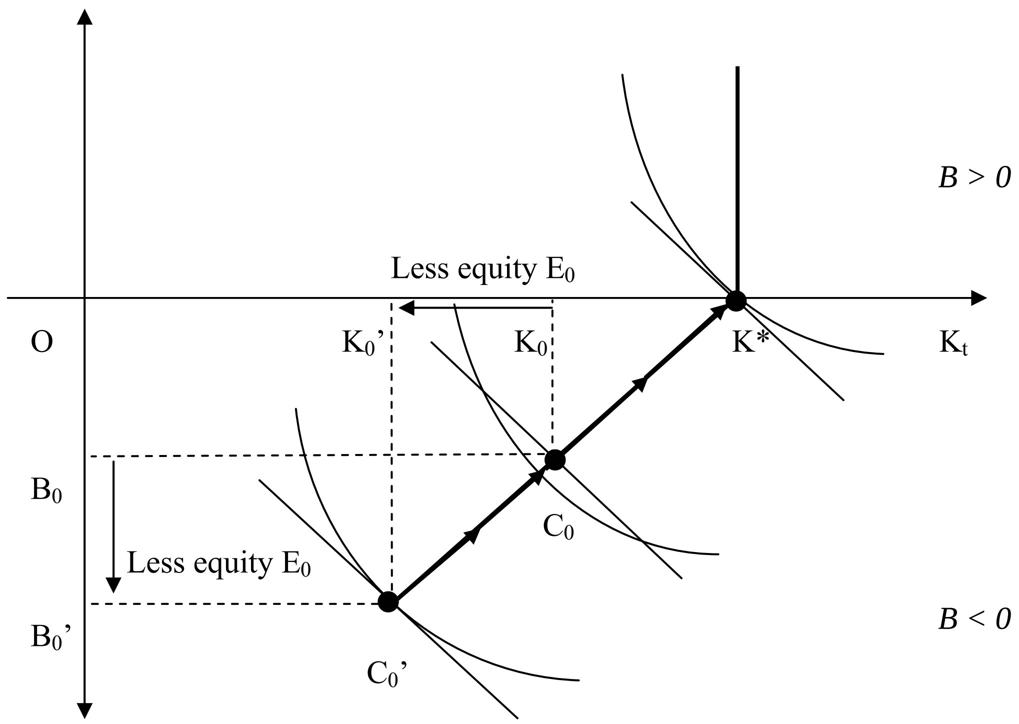
Differentiating yields (remember that the cross derivatives are zero):

$$dB_0/dE_0 = \pi_{KK} /(\pi_{KK} + \pi_{BB}) > 0 \text{ , and}$$

$$dK_0/dE_0 = 1 - \pi_{KK} /(\pi_{KK} + \pi_{BB}) = \pi_{BB} /(\pi_{KK} + \pi_{BB}) .$$

With the help of our state space diagram, it can easily be shown that the adaptation of a firm less well equipped with equity takes longer. The expansion path, ie the locus of points with $\pi_K = \pi_B$, is not affected by initial equity. Second, a point on the expansion path completely determines the rest of the adaptation dynamics. Thus, firms with higher and with lower equity will merely differ in what *starting point* they choose, their initial values for debt and real capital.

Figure A4: The significance of initial equity



Our exercise above has shown us that the starting point of a firm with much equity is nearer to the terminal state than the starting point of a firm with little equity. Consequently, the low equity firm takes longer to adapt: it has to "walk the additional mile", as depicted in Figure 4, spending a positive time ΔT accumulating enough profits to reach the point where the better equipped firm was able to start. From that point on, the behaviour of both firms is identical.

A3.2 The effect of project size

Project size can be modelled best by looking at *reduplications* of technology. Imagine that instead of being limited to one market using one production site, the firm is able to serve s markets, using s production sites. The aggregate operating profit then is given by

$$y = G(K) = s \cdot F(K/s)$$

Let a firm with s = 1 use capital K*. If a firm with s = c , c > 1 uses capital c·K*, it will have exactly the same marginal productivity and exactly c times the revenue of that other firm:

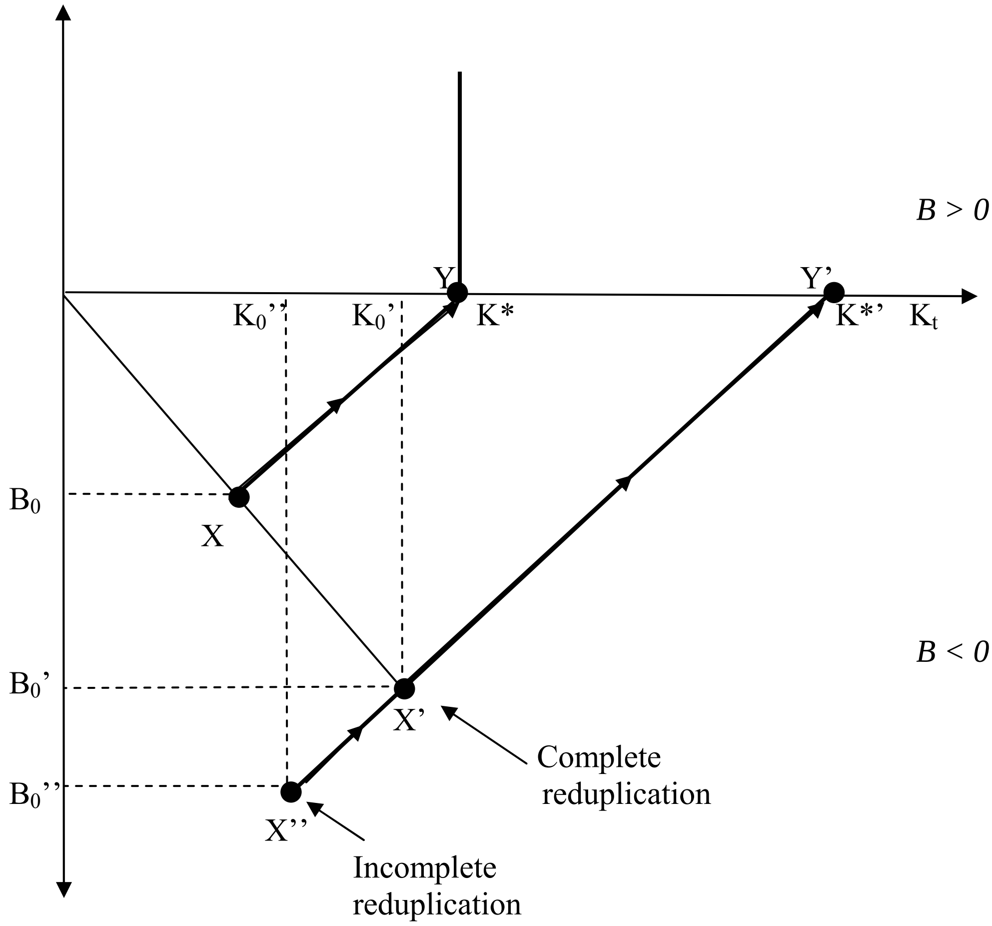
$$\partial G/\partial K \big|_{K=cK^*} = cF'(cK^*/c)\cdot 1/c = F'(K^*) .$$

Given ρ, the steady state capital stock of the "larger" firm (the firm with s = c) will therefore be c times the capital stock of the benchmark firm with s = 1.

In order to model financial costs, we want to specialise the external finance premium function, assuming that it depends on the ratio of initial equity to debt. The profit function is then

$$\pi(K_t, B_t, s) = G(K_t) + [\rho + z(B_t/E_0)] \cdot B_t .$$

Figure A5: The effect of project size



For methodical reasons, we will look at two situations: first a variation of size in unison with a concurrent variation of initial equity: a "complete reduplication"; and second, a variation of project size alone, with given equity: a "partial reduplication". The complete reduplication setting is essentially equivalent to looking at s identical firms trying to close their capacity gaps: the individual firm optimising problem, as discussed above, is blown up by the factor s, and adaptation will take exactly as long as in the benchmark case. The partial reduplication setup means that the ratio of target capital to initial equity is higher for larger sized projects. This amplifies the significance of financial constraints and slows down the adaptation process.

In the first case (complete reduplication), the profit function is:

$$\pi(K_t, B_t, s) = s \cdot F(K_t/s) + [\rho + z(B_t/sE_0)] \cdot B_t ,$$

with E_0 the equity of a benchmark firm. By substitution, we see immediately that

$$\pi_K(s \cdot K_t, s \cdot B_t, s) = \pi_K(K_t, B_t, 1) \text{ , and}$$

$$\pi_B(s \cdot K_t, s \cdot B_t, s) = \pi_B(K_t, B_t, 1) \text{ .}$$

The expansion path for the larger firm will therefore be just a blown up version of the basic diagram. Initial capital and initial debt will be s times higher, and the same is true for profits at each point in time. The target capital stock, being also s times higher, will be reached in exactly the same time. In Figure A5, where the comparison is depicted, the larger firm walks down the expansion path X'Y' instead of XY.

Now the partial reduplication case, with E_0 invariant, is easy to handle. The expansion path itself is identical with the complete reduplication case. However, initial capital is lower: only E_0 instead of $s \cdot E_0$. We have already investigated what difference this makes: the firm will use less capital initially and going deeper in debt at the same time than in the complete reduplication case. Adaptation takes longer: the firm has to go "the additional mile" from X'' to X' in Figure A5, the point where the firm in the complete reduplication case was able to start.

A3.3 The severity of financial restrictions

In order to look at variations in the external finance supply schedule, we will parameterise it as

$$r_r = \rho + \gamma \, z(B_t).$$

A higher γ means a higher interest rate for $B_t < 0$, when the firm is in debt. A value of γ=0 is the borderline case of no financial constraints at all. We can write the current profit function as:

$$\pi(K_t, B_t, \gamma) = F(K_t) + [\rho + \gamma\, z(B_t)] \cdot B_t.$$

The steady state capital stock remains unaffected by γ, as it is given by $F'(K^*) = \rho$. With respect to initial capital and initial debt, it can easily be shown that both are lower. Differentiating the Euler equation for t = 0 as above, we obtain:

$$dB_0/d\gamma \;=\; -\,\pi_{B\gamma}/(\pi_{KK} + \pi_{BB}) > \;0\;, \text{ and}$$

$$dK_0/d\gamma \;=\; \pi_{B\gamma}/(\pi_{KK} + \pi_{BB}) \;< 0\;.$$

Initial indebtedness is smaller, and so is the initial capital stock.

Investigating the influence of financial constraints on the duration of adjustment involves comparing the entire adjustment paths, a task that can become analytically quite cumbersome – see Seierstad and Sydsaeter (1987), p 210 for an introduction to sensitivity analysis in optimal control problems. Fortunately, our case is relatively simple, and we can show what is intuitively clear: the effect of financial constraint on the duration of adjustment is unambiguously positive.

The program stops when the firm has bridged the gap between E_0 and the target capital stock. Duration T thus fulfils

$$\int_0^T \dot{E}_t \, dt \;= K^* - E_0\;.$$

The addition to equity is given by current profits:

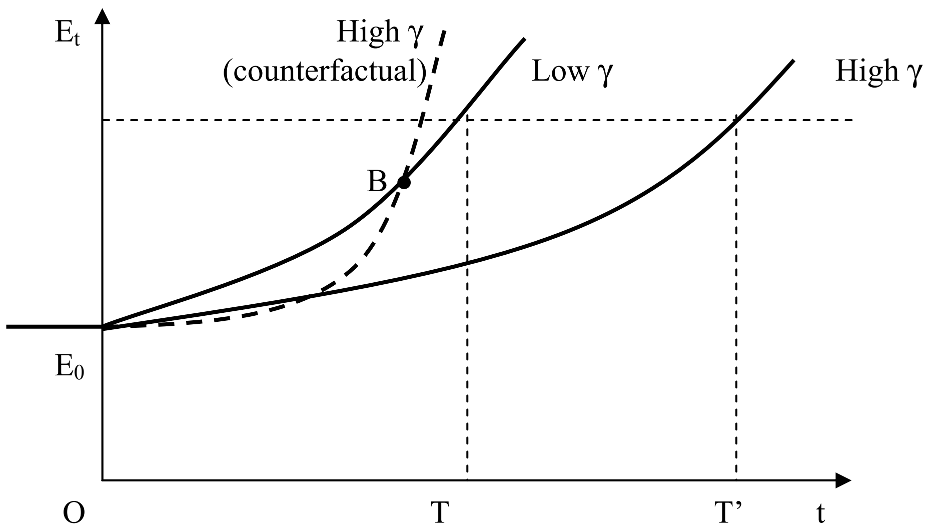
$$\dot{E}_t \;= \max_B \pi(E{-}B_t, B_t)\;.$$

As B_t is a function of the other parameters in this static optimisation problem, we can write the time derivative of E_t as a function of E_t and γ alone. From the envelope theorem we know that the direct impact of changing γ, given E_t, is simply

$$\partial\dot{E}/\partial\gamma = \pi_\gamma\,(E_t - B_t, B_t, \gamma)\;,$$

with B_t evaluated in the optimum.

Figure A6: Severe (high γ) and less severe (low γ) financial constraints



For a given E_0, accumulation starts at a lower pace when γ is higher. In the immediate neighbourhood of t=0 therefore, the accumulation path for higher γ is below the path for low γ. We will make two arguments to show that the more constrained firm takes longer to adjust. First, we will show that the disadvantaged firm can never catch up. In Figure A6 let $[E_{t,low}]$ be the time path for low γ and $[E_{t,high}]$ the time path for high γ. If the two time paths were to cross at a point such as B, then the time derivative dE_t/dt on the path $[E_{t,high}]$ in the crossing point must be larger or equal than the time derivative of the path for low γ. Yet at point B equity on both paths is the same by definition. And for a given equity, profits are strictly lower in the high γ case. This is a contradiction.

The second argument is a recursive one. In $t = 0$, as we have seen, the path $[E_{t,high}]$ starts with less capital and a lower accumulation rate. Hence in a neighbourhood of the time origin, equity will be lower in the high γ case. For positive $t > 0$, the effect on dE_t/dt consists of both the direct effect that γ has on profits and the effect of a changed E_t. As the accumulation starts with a lower rate, this effect is negative, too, reinforcing the direct effect. Thus further down the time path, these differences will accumulate. If we consider a change of γ by a small amount, $d\gamma$, the change of the accumulation rate at any point in time is given by

$$d\dot{E}_t = \pi_K \, dE_t + \pi_\gamma \, d\gamma \, .$$

This is a linear differential equation with time varying coefficients π_K and $\pi_\gamma d\gamma$, see, for example, Seierstad and Sydsaeter (1987), Appendix A4 for the rather complicated general solution. The qualitative properties, however, are simple: we know that π_K is positive and $\pi_\gamma d\gamma$ is negative everywhere. As the initial condition for t=0 is given by $dE_0=0$, the value of the left-hand side is negative all along the path. With time passing, the accumulated differential dE_t, the shortfall with respect to the baseline scenario, grows larger, as current profits are limited not only by higher financing costs, but also by lower equity. It follows directly that the more constrained firm needs longer to reach the target capital stock than a firm with a low γ.

A4 Financing innovation

When we compare innovative investment projects with simple expansion projects, we take the new production function as well as initial equity as given. In the framework of our analysis, the difference between the two types of project therefore is not technological, but relates to the degree of acquaintance with the project on the part of the creditors. An innovative project is almost by definition one where there is a huge gap between what the innovator knows (or believes to know), and what everyone else knows. This information asymmetry will lead to lemon premia on the credit market, and if it is to be bridged by extensive reporting on the side of the debtor or own research on the part of the creditor, this is costly as well. These costs will ultimately have to be borne by the debtor. Our modeling framework is one of subjective certainty on the part of the investor, but we can take information asymmetries into account by assuming a steeper external finance premium schedule for this type of investment, in the form of a higher γ.

With the results from the last paragraph, this immediately yields our first prediction: Given equity and given the ultimate size of the project, an innovative investor will be limited to a smaller initial investment, raising less finance, and paying a higher financing premium nonetheless. Compared to his non-innovative collegue, he will take longer to adjust.

However, the Ifo data do not permit us to observe initial equity. And there may be a sort of specialisation among competing firms. In our model, firms are allowed to accumulate interest bearing bonds, and the optimal financial strategy is indeterminate after adjustment has been completed. The reason is that we have focussed on the financing of one project only. However, it is possible that firms that expect innovative type of investment in the future will retain more earnings, paying smaller dividends than those who do not have this type of investment to make. Furthermore, it may well be the firms with the more patient shareholders that enter into innovative lines of business. Bond, Harhoff and van Reenen (2003) have interpreted their findings on the importance of cash flow for fixed investment in Britain an Germany in this way. When the moment comes to make the initial investment, innovative firms may display moderately low marginal financing costs and a good speed of adjustment, because they do not need much credit to start with.

Thus, if we cannot observe initial equity, there may be a selectivity issue. But we are left with one strong prediction: firms that make innovative investment must finance it to a larger extent using internal finance, given the size of the shock.

Appendix B: Deriving the basic error correction specification

This specification was invented by Charles Bean (1981), and it was introduced to the micro investment literature by Bond, Elston, Mairesse and Mulkay (2003).[13] The point of departure is the static neoclassical equation for capital demand. Using a generalised CES production function, Eisner and Nadiri (1968) derive the following linear equation from the first-order conditions of profit maximisation:

$$\log K_t = \theta \log S_t - \sigma \log UC_t + \log h_t \text{, with} \tag{B1}$$

$$\theta = \left(\sigma + \frac{1-\sigma}{\nu}\right) \text{ and } h_t = A_t^{\frac{\sigma-1}{\nu}} \cdot (\nu\alpha)^{\sigma} \text{ ,} \tag{B2}$$

where UC is the user costs of capital, A_t is productivity and σ and ν are the elasticities of substitution and scale respectively. The variable h_t depends on the time-varying terms A_t. The elasticity of capital to sales is unity ($\theta = 1$) if the production function has constant returns to scale ($\nu = 1$) or if its elasticity of substitution is unity ($\sigma = 1$), ie in the Cobb-Douglas case. A log-linear demand equation can also be derived for the case of increasing returns to scale, $\nu > 1$. If the firm is rationed on the product market, it will have to solve a cost minimisation problem. Then we have $\theta = 1/\nu$ in (B2) and h_t will be a term that depends on relative factor prices and the CES parameters.

We assume that the production possibilities are given by the capital stock at the beginning of the current period. Taking account of installation costs and short-run dynamics in the formation of expectations, we generalise the static capital-demand equation by using distributed lags:[14]

$$A(L)\log K_t = B(L)\log S_t + C(L)\log UC_t + \log h_t \text{ ,}$$

$A(L), B(L), C(L)$ being polynomials in the lag operator, not necessarily of the same degree. With the additional constraints

$$\frac{B(1)}{A(1)} = 1 \qquad \text{and} \qquad \frac{C(1)}{A(1)} = 1 \text{,}$$

[13] The discussion paper version of the latter paper was published as early as 1997.

[14] Chirinko and von Kalckreuth (2002) develop this equation explicitly by introducing delivery lags and adaptive expectations. However, as in all implicit models, the parameters belonging to the expectation formation mechanism are not separately identified.

the long-run effects of changes in the level of sales or user costs are the same as in the static model (B1) and (B2). For a lag length of two, this leads to

$$\log K_{i,t} = \alpha_1 \log K_{i,t-1} + \alpha_2 \log K_{i,t-2} + \beta_0 \log S_{i,t} + \beta_1 \log S_{i,t-1} + \beta_2 \log S_{i,t-2} +$$

$$+ \gamma_0 \log UC_{i,t} + \gamma_1 \log UC_{i,t-1} + \gamma_2 \log UC_{i,t-2}\,.$$

Subtracting lagged endogenous variables on both sides, using the approximation $\Delta \log K_{i,t} \approx \frac{I_{i,t}}{K_{i,t-1}} - \delta_i$, as well as substituting the identities:

$$\beta_0 \log S_{i,t} + \beta_1 \log S_{i,t-1} + \beta_2 \log S_{i,t-2}$$

$$= \beta_0 \Delta \log S_{i,t} + (\beta_0 + \beta_1) \Delta \log S_{i,t-1} + (\beta_0 + \beta_1 + \beta_2) \log S_{i,t-2}$$

and

$$\gamma_0 \log UCC_{i,t} + \gamma_1 \log UC_{i,t-1} + \gamma_2 \log UC_{i,t-2}$$

$$= \gamma_0 \Delta \log UC_{i,t} + (\gamma_0 + \gamma_1) \Delta \log UC_{i,t-1} + (\gamma_0 + \gamma_1 + \gamma_2) \log UC_{i,t-2}\ ,$$

we obtain the standard ECM specification for a model with two lags:

$$\frac{I_{i,t}}{K_{i,t-1}} = (\alpha_1 - 1) \frac{I_{i,t-1}}{K_{i,t-2}} + (\alpha_2 + \alpha_1 - 1) \log K_{i,t-2} +$$

$$+ \beta_0 \Delta \log S_{i,t} + (\beta_0 + \beta_1) \Delta \log S_{i,t-1} + (\beta_0 + \beta_1 + \beta_2) \log S_{i,t-2} +$$

$$+ \gamma_0 \Delta \log UC_{i,t} + (\gamma_0 + \gamma_1) \Delta \log UC_{i,t-1} + (\gamma_0 + \gamma_1 + \gamma_2) \log UC_{i,t-2} + u_{i,t}\,.$$

A latent term $u_{i,t}$ has been added. It is composed of a firm-specific constant φ_i that reflects multiplicative firm-specific productivity terms as well as the depreciation rates, a time-specific shock λ_t equal for all firms, and finally an idiosyncratic transitory shock $\zeta_{i,t}$. In this quite general specification, the data are allowed to determine the adaptation dynamics.

Using more lags will move the position of the level terms further backward. As a long-run elasticity of the capital stock with regard to user costs, one obtains:

$$\left. \frac{d \log \bar{K}}{d \log UC} \right|_{UC_t = UC_{t+1} = \ldots = \overline{UC}} = \frac{\gamma_0 + \gamma_1 + \gamma_2}{1 - \alpha_1 - \alpha_2}\ , \tag{B3}$$

and a similar expression for the sales elasticity, with the β parameters in the numerator. The long-run elasticities are non-linear functions of the parameter. Note that the numerator and denominator of this expression are given by the coefficients of the level terms. By rewriting the equation, this identity offers a possibility of neatly separating short-run and long-run dynamics:

$$\frac{I_t}{K_{i,t-1}} = (\alpha_1 - 1)\frac{I_{i,t-1}}{K_{i,t-2}}$$

$$+\beta_0 \Delta \log S_{i,t} + (\beta_0 + \beta_1)\Delta \log S_{i,t-1} + \gamma_0 \Delta \log UC_{i,t} + (\gamma_0 + \gamma_1)_1 \Delta \log UC_{i,t-1}$$

$$+(\alpha_1 + \alpha_2 - 1)\left\{\log K_{i,t-2} - \frac{\beta_2 + \beta_1 + \beta_0}{1 - \alpha_1 - \alpha_2}\log S_{i,t-2} - \frac{\gamma_2 + \gamma_1 + \gamma_0}{1 - \alpha_1 - \alpha_2}\log UC_{i,t-2}\right\} + u_{i,t}, \quad \text{(B4)}$$

again with $u_{i,t} = \varphi_i + \lambda_t + \zeta_{i,t}$. The first term in the third line is the error-correction coefficient; it should be negative. The term in curly brackets ought to be zero in the long run for the long-term relationship between capital, user costs and sales to hold. The equation very often is estimated using $\log(K_{i,t-2}/S_{i,t-2})$ and $\log S_{i,t-2}$ instead of $\log K_{i,t-2}$ and log $S_{i,t-2}$ as level terms. The coefficient of $\log S_{i,t-2}$ will then reflect possible increasing or decreasing returns, and omitting the variable will impose constant returns.

Appendix C: The sample

This section gives additional information on the sample used for the GMM estimations. Table C1 shows the industry composition and indicates the innovator status of each sector, as explained in Section 3.

Table C1: Industry composition of the ECM sample and innovator status of sectors

Sector (according to SYPRO)	**No. of Units**	**No. of Obs.**	**Prod. innov..**
Mineral oil refining	8	50	yes
Quarrying and extraction of mineral products	95	610	no
Iron and steel industry	7	45	no
Non-ferrous metal industry	26	190	no
Foundries	27	196	no
Drawing plants, cold rolling mills, secondary transf. of metals, etc.	88	566	no
Manufacture of structural metal products, rolling stock	32	203	no
Mechanical engineering	257	1,717	yes
Manufacture of road vehicles and repair of motor vehicles	50	350	yes
Shipbuilding	3	20	no
Manufacture of aircraft and spacecraft	9	60	no
Electrical engineering, repair of electrical household goods, etc.	84	555	yes
Manufacture of precision and optical instruments, clocks and watches	50	358	yes
Manufacture of tools and finished metal goods	106	734	yes
Manufacture of musical instruments, toys and games	20	114	no
Chemical industry and radioactive materials	63	434	yes
Office machinery and data processing equipment	8	55	yes
Manufacture of ceramic goods	22	149	no
Manufacture and processing of glass	25	174	no
Wood-working	68	438	no
Manufacture of wood products	92	594	no
Manufacture of pulp, paper and board	32	213	no
Processing of pulp, paper and board	55	391	no
Printing and duplication	138	916	no
Manufacture of plastic products	82	531	no
Manufacture of rubber products	15	106	no
Textile industry	93	623	no
Clothing industry	35	228	no
Manufacture of leather and leather products	30	187	no
Food and drink industry, tobacco products	122	802	no
Total	**1,742**	**11,609**	

Table C2 breaks down the sample with respect to innovator status and size.

Table C2: Size class and product innovator status

Size class (No. of employees)	Non-innovator	Innovator	Total
49 and fewer	223 83.2%	45 16.8%	268 100%
50-199	363 76.7%	110 23.3%	473 100%
200-999	394 66.0%	203 34.0%	597 100%
1,000 and more	199 49.3%	205 50.74	404 100%
Total	1,179 67,7%	563 32.3%	1,742 100%

Table C3 contains descriptive statistics for the principal regression variables: the mean, the standard deviation, the lowest and the highest values, all separately for the entire sample and for the two sub-groups. Like Table C2, it shows that firms in innovative sectors are clearly larger on average, and they also have the higher average growth rate. their average gross investment rate, however, does not differ perceptibly from the non-innovators'.

Table C3: Descriptive statistics of principal regression variables

Var.	Group	Mean	Std. Dev.	Min.	Max.
	Innovators	0.112	0.085	0	0.717
$I_{i,t/}$ $K_{i,t-1}$	Non-innovators	0.115	0.109	0	0.760
	Total	0.114	0.102	0	0.760
	Innovators	11.760	1.920	6.088	18.324
log $S_{i,t}$	Non-innovators	10.805	1.753	5.507	16.957
	Total	11.120	1.864	5.507	18.324
	Innovators	0.042	0.154	-0.638	0.658
Δlog $S_{i,}$	Nnon-innovators	0.029	0.141	-0.641	0.673
	Total	0.034	0.145	-0.641	0.673
	Innovators	10.748	1.853	5.129	17.036
log $K_{i,t-2}$	Non-innovators	9.990	1.729	5.180	16.329
	Total	10.239	1.806	5.129	17.035

Some definition and details with respect to the variables follow:

Investment ($I_{i,t}$): Additions to plant property and equipment, without acquisitions of undeveloped land. The values were taken from the spring wave, as the accounting period of most firms would be finished by the time of the survey. The values are deflated using the ratio of nominal to real investment from the national accounts.

Capital Stock ($K_{i,t}$) is computed by first estimating an initial value from sector-specific capital intensities and the firm's employment and then applying a perpetual inventory procedure with a sector-specific depreciation rate for all years following the first year for which investment data is available:

$$P^I_{j,t} K_{i,t} = (1 - \delta_j) P^I_{j,t-1} K_{i,t-1} \left(\frac{P^I_{j,t}}{P^I_{j,t-1}} \right) + P^I_{j,t} I_{i,t} \ , \qquad \text{(C1)}$$

where $P^I_{j,t}$ is a sector-specific price of investment goods, $I_{i,t}$ is real investment and δ_j the sector-specific depreciation rate.

Real Sales, $S_{i,t}$: This is sales deflated by a sector-specific index for value added.

Outlier control: The data set is trimmed in a conservative way by excluding the upper 1% percentile of $I_{i,t}/K_{i,t-1}$ and the upper and the lower 0.5% percentile of sales growth $\Delta \log S_{i,t}$ and the capital-sales ratio $S_{i,t}/K_{i,t}$. Furthermore, a string of observations is interrupted when the growth of employment between one year and the next is in the highest or lowest 3% quantiles *and* the firm's statement on employment history does not fit to the lagged emploment value. In these cases, a major M&A event was assumed, and the company is treated as a new firm.

Table 1: Frequency of innovations and financing conditions for investment

Product innovator status, relative to size-specific mean	Financing conditions for investment					
	Very stimulating	Stimulating	No influence	Limiting	Very limiting	Total
Low frequency/ none	410 3.7%	1,594 14.5%	6,117 55.7%	1.878 17.1%	986 9.0%	10,985 100,0%
High frequency	2240 3.5%	899 13.0%	3,942 57.1%	1.174 17.0%	647 9.4%	6,902 100,0%
Total	650 3.6%	2,493 13.9%	10,059 56.2%	3,052 17,1	1,633 9.1%	17,887 100,0%

Data: Ifo Investment Test, 1989-1998, autumn waves. A firm is categorised as a product innovator if its mean number of reported product innovations is higher than the size-specific mean

Table 2: Financing conditions and dependence on external finance

Product innovator status, relative to size-specific mean	Financing conditions for investment					
	Very stimulating	Stimulating	No influence	Limiting	Very limiting	Total
No innovator	0.324	0.259	0.155	0.261	0.296	0.205
Innovator	0.304	0.280	0.140	0.275	0.326	0.201
Total	0.317	0.267	0.149	0.266	0.309	0.203

Data: Ifo Investment Test, 1989-1998, autumn waves merged with spring waves. A firm is categorised as a product innovator if its mean number of reported product innovations is higher than the size-specific mean. Dependence on external finance by group is the mean share of investment financed externally.

Table 3: Fixed effects (mean deviation) estimation for the reduced form investment factor model. Dep. variable: Log of real investment

Explanatory variables	Coeff.	Std dev.	t-value
Sales exp. stimulating	-0.093	0.024	-3.91
Sales exp. neutral	-0.202	0.030	-6.62
Sales exp. limiting	-0.215	0.032	-6.67
Sales exp. very limiting	-0.357	0.038	-9.34
Fin cond. stimulating	-0.132	0.048	-2.77
Fin cond. neutral	-0.211	0.047	-4.54
Fin cond. limiting	-0.247	0.050	-4.97
Fin cond. very limiting	-0.376	0.055	-6.83
Exp. Returns stimulating	-0.030	0.026	-1.13
Exp. Returns neutral	-0.066	0.033	-1.97
Exp. Returns limiting	-0.111	0.034	-3.29
Exp. Returns very limiting	-0.222	0.040	-5.51
Technical dev. stimulating	-0.156	0.022	-7.01
Technical dev. neutral	-0.319	0.027	-12.04
Technical dev. limiting	-0.315	0.081	-3.87
Technical dev. very limiting	-0.237	0.180	-1.31
R^2 (within)		0.1019	
No. obs.		13,006	
No. firms		3,132	

Data: Ifo Investment Test, 1988-1998, autumn waves. Additional regressors: full set of time dummies (not shown). For each factor, the baseline category (omitted from the regression) is the answer “very stimulating”. The estimation was done using Stata, Special Edition, Version 8.0.

Table 4: Basic error correction model without time varying financing conditions, GMM first difference and system estimates. Dep. variable: $I_{i,t}/K_{i,t-1}$

Explanatory variable	(1) GMM first difference		(2) GMM system - all var. used as instr. in level equation		(3) GMM system - reduced set of instr. in level equation	
$I_{i,t-1}/K_{i,t-2}$	-0.101	(0.055) *	0.188	(0.027)***	0.043	(0.054)
Log $(K_{i,t-2}/S_{i,t-2})$	-0.258	(0.038)***	-0.059	(0.011)***	-0.159	(0.036)***
Log $S_{i,t-2}$	-0.052	(0.052)	0.027	(0.004)***	0.035	(0.006)***
Δlog $S_{i,t}$	0.176	(0.043)***	0.146	(0.039)***	0.170	(0.045)***
Δlog $S_{i,t-1}$	0.194	(0.048)***	0.097	(0.010)***	0.196	(0.035)***
No. obs.	6,383		8,125		8,125	
No. units	1,742		1,742		1,742	
Sargan-Hansen, p-value	0.074		0.006		0.092	
LM(2), p-value	0.344		0.112		0.227	

Additional regressors: a constant and year dummies. Column (1) reports a two-step GMM estimation of the equation in first differences, as proposed by Arellano and Bond (1991). User costs changes are subsumed into the time dummies. Instruments are the lags 2 – 4 of the undifferenced values of all regressors when feasible (ie, $I_{i,t-m}/K_{t-1-m}$, $\log S_{i,t-m}$, $\log K_{i,t-m}$, with $2 \leq m \leq 4$, where the maximum value of m is as large as possible given data availability), as well as a constant and year dummies. Column (2) reports a combined dynamic panel estimation as proposed by Arellano and Bover (1995) and Blundell and Bond (1998). This estimator combines the moment conditions generated by the equation in first differences with moment conditions from the equation in levels. For the equation in first differences, the instrumentation is as above; for the equation in levels, $\Delta I_{i,t-1}/K_{t--2}$, $\Delta \log S_{i,t-1}$, and $\Delta \log K_{i,t-1}$, as well as time dummies are used. In Column (3), estimation is as in Column (2), without using $\Delta \log S_{i,t-1}$ as an instrument for the level equation. The Sargan-Hansen statistic is a test of overidentifying restrictions proposed by Sargan (1958) and Hansen (1982). The LM(2) statistic is the Lagrange Multiplier statistic for second-order serial correlation proposed by Arellano and Bond (1991). The robust standard errors from the second step estimation with a small sample correction based on Windmeijer (2005) are in parentheses: *** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level. The estimation was done using DPD package version 1.2 on Ox version 3.30.

Table 5: Error correction model with time varying financing conditions and sales expectations, GMM first difference estimates. Dep. variable: $I_{i,t/}\,K_{i,t-1}$

Explanatory variable	(1) GMM first difference		(2) GMM first difference	
$I_{i,t-1}/K_{i,t-2}$	-0.125	(0.050)**	-0.162	(0.053)***
$\log (K_{i,t-2}/S_{i,t-2})$	-0.265	(0.036)***	-0.291	(0.040)***
$\Delta\log S_{i,t}$	0.093	(0.038)**	0.070	(0.038)*
$\Delta\log S_{i,t-1}$	0.117	(0.045)***	0.132	(0.040)***
$\log S_{i,t-2}$	-0.126	(0.048)***	-0.127	(0.046)***
$\Delta finneut_{i,t}$	-0.019	(0.024)	-0.003	(0.018)
$\Delta finneut_{i,t-1}$	-0.017	(0.020)	0.001	(0.016)
$finneut_{i,t-2}$	-0.016	(0.021)	0.005	(0.017)
$\Delta finbad_{i,t}$	-0.065	(0.024)***	-0.032	(0.021)
$\Delta finbad_{i,t-1}$	-0.048	(0.019)***	-0.019	(0.017)
$finbad_{i,t-2}$	-0.045	(0.020)**	-0.012	(0.018)
$\Delta salesneut_{i,t}$			0.008	(0.021)
$\Delta salesneut_{i,t-1}$			0.010	(0.018)
$salesneut_{i,t-2}$			0.012	(0.018)
$\Delta salesbad_{i,t}$			-0.031	(0.015)**
$\Delta salesbad_{i,t-1}$			-0.025	(0.013)*
$salesbad_{i,t-2}$			-0.025	(0.014)*
No. obs.	6,383		6,349	
No. firms	1,742		1,735	
Sargan-Hansen, p-value	0.164		0.312	
LM(2), p-value	0.461		0.607	

Additional regressors: a constant and year dummies. Both regressions report a two-step GMM estimation of the equation in first differences, as proposed by Arellano and Bond (1991). The indicator variable $finneut_{i,t}$ assumes a value of 1 if respondents state that financing conditions have had “no influence” on their investment. The dummy $finbad_{i,t}$ is set equal to 1 if the respondent considers financing conditions as “limiting” or “very limiting”. The baseline category (omitted in the regression) is given by the answers “stimulating” or “very stimulating”. The variables $salesneut_{i,t}$ and $salesbad_{i,t}$ are defined analogously to the assessment of sales expectations. For the estimation in Column (1), instruments are the lags 2 to 4 of the undifferenced values of all regressors when feasible (ie, $I_{i,t-m}/K_{t-1-m}$, $logS_{i,t-m}$, log $K_{i,t-m}$, $finneut_{i,t-m}$, $finbad_{i,t-m}$ with $2 \leq m \leq 4$, where the maximum value of m is as large as possible given data availability), as well as a constant and year dummies. In addition, lags of $salesneut_{i,t}$ and $salesbad_{i,t}$ are used. Column (3) uses also lags of $salesneut_{i,t-m}$, and $salesbad_{i,t-m}$ The Sargan-Hansen statistic is a test of overidentifying restrictions proposed by Sargan (1958) and Hansen (1982). The LM(2) statistic is the Lagrange Multiplier statistic for second-order serial correlation proposed by Arellano and Bond (1991). The robust standard errors from the second step estimation with a small sample correction based on Windmeijer (2005) are in parentheses: *** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level. The estimation was done using DPD package version 1.2 on Ox version 3.30.

Table 6: Error correction model with time varying financing conditions and sales expectations, GMM system estimates. Dep. variable: $I_{i,t}/K_{i,t-1}$

Explanatory variable	(1) GMM system estimates		(2) GMM system estimates	
$I_{i,t-1}/K_{i,t-2}$	0.147	(0.053)***	0.235	(0.038)***
log ($K_{i,t-2}/S_{i,t-2}$)	-0.088	(0.033)***	-0.026	(0.021)
Δlog $S_{i,t}$	0.111	(0.036)***	0.073	(0.035)**
Δlog $S_{i,t-1}$	0.116	(0.033)***	0.049	(0.022)**
log $S_{i,t-2}$	0.025	(0.005)***	0.021	(0.004)***
Δ$finneut_{i,t}$	-0.047	(0.021)**	-0.040	(0.018)**
Δ$finneut_{i,t-1}$	-0.036	(0.016)**	-0.030	(0.013)**
$finneut_{i,t-2}$	-0.040	(0.016)**	-0.031	(0.014)**
Δ$finbad_{i,t}$	-0.077	(0.024)***	-0.063	(0.022)***
Δ$finbad_{i,t-1}$	-0.058	(0.018)***	-0.047	(0.016)***
$finbad_{i,t-2}$	-0.058	(0.019)***	-0.046	(0.017)***
Δ$salesneut_{i,t}$			-0.037	(0.020)*
Δ$salesneut_{i,t-1}$			-0.029	(0.016)*
$salesneut_{i,t-2}$			-0.030	(0.016)*
Δ$salesbad_{i,t}$			-0.041	(0.016)***
Δ$salesbad_{i,t-1}$			-0.038	(0.012)***
$salesbad_{i,t-2}$			-0.045	(0.012)***
No. obs.	8,125		8,084	
No. firms	1,742		1,735	
Sargan-Hansen, p-value	0.030		0.088	
LM(2), p-value	0.081		0.038	

Additional regressors: a constant and year dummies. Both regressions report a two-step combined dynamic panel estimation as proposed by Arellano and Bover (1995) and Blundell and Bond (1998). The indicator variable $finneut_{i,t}$ assumes a value of 1 if respondents state that financing conditions have had "no influence" on their investment. The dummy $finbad_{i,t}$ is set equal to 1 if the respondent considers financing conditions as "limiting" or "very limiting". The baseline category (omitted in the regression) is given by the answers "stimulating" or "very stimulating". The variables $salesneut_{i,t}$ and $salesbad_{i,t}$ are defined in an analogous way from the assessment of sales expectations. Instrumentation of the differenced equation is as indicated in the notes to Table 5. For the equation in levels, $\Delta I_{i,t-1}/K_{t--2}$, $\Delta logS_{i,t-1}$, Δlog $K_{i,t-1}$, Δ$finneut_{i,t-1}$ and Δ$finbad_{i,t-1}$ are used as instruments, as well as time dummies. In addition, Column (2) uses also lags of $salesneut_{i,t-2}$, and $salesbad_{i,t-2}$ as instruments for the level equation. The Sargan-Hansen statistic is a test of overidentifying restrictions proposed by Sargan (1958) and Hansen (1982). The LM(2) statistic is the Lagrange Multiplier statistic for second-order serial correlation proposed by Arellano and Bond (1991). The robust standard errors from the second step estimation with a small sample correction based on Windmeijer (2005) are in parentheses: *** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level. The estimation was done using DPD package version 1.2 on Ox version 3.30.

Table 7: Financial constraints and the speed of adaptation using the *median* of average financial conditions as a cutoff value, GMM first difference estimates. Dep. variable: $I_{i,t}/K_{i,t-1}$

Explanatory variable	(1) GMM first difference – All firms -		(2) GMM first difference – Innovators -		(3) GMM first difference – Non-innovators -	
$I_{i,t-1}/K_{i,t-2}$	-0.249	(0.110)**	-0.527	(0.129)***	-0.171	(0.095)*
$I_{i,t-1}/K_{i,t-2}$ * *fincond*	0.038	(0.126)	0.249	(0.165)	0.004	(0.118)
log ($K_{i,t-2}/S_{i,t-2}$)	-0.374	(0.086)***	-0.608	(0.133)***	-0.312	(0.073)***
log ($K_{i,t-2}/S_{i,t-2}$)* *fincond*	0.063	(0.096)	0.245	(0.147)*	0.055	(0.089)
log $S_{i,t-2}$	-0.120	(0.105)	-0.226	(0.151)	-0.183	(0.135)
log $S_{i,t-2}$* *fincond*	-0.016	(0.117)	0.027	(0.158)	0.064	(0.150)
Δlog $S_{i,t}$	0.184	(0.109)*	0.120	(0.095)	0.077	(0.120)
Δlog $S_{i,t-1}$	0.221	(0.107)**	0.292	(0.126)**	0.103	(0.130)
Δlog $S_{i,t}$* *fincond*	-0.032	(0.115)	-0.092	(0.104)	0.065	(0.127)
Δlog $S_{i,t-1}$* *fincond*	-0.058	(0.116)	-0.143	(0.138)	0.030	(0.140)
No. obs.	6,383		2,130		4,253	
No. firms	1,742		563		1,179	
Sargan-Hansen, p-value	0.026		0.069		0.289	
LM(2), p-value	0.713		0.140		0.757	

Additional regressors: a constant and year dummies. All regressions report a two-step GMM estimation of the equation in first differences, as proposed by Arellano and Bond (1991). The dummy variable characterising a financially restricted firm is determined by attributing the numbers 1-5 to the categories "very stimulating", "stimulating", "no influence", "limiting", "very limiting" and computing the firms' mean outcome. A firm is characterised as constrained if this value is above the median for all the firms. Columns (1), (2) and (3) show estimates for all firms as well as for innovators and non-innovators separately. In each case, instruments are the lags 2 – 4 of the undifferenced values of all regressors when feasible (ie, $I_{i,t-m}/K_{t-1-m}$, $\log S_{i,t-m}$, $\log K_{i,t-m}$, with $2 \leq m \leq 4$, where the maximum value of m is as large as possible given data availability), as well as a constant and year dummies. The Sargan-Hansen statistic is a test of overidentifying restrictions proposed by Sargan (1958) and Hansen (1982). The LM(2) statistic is the Lagrange Multiplier statistic for second-order serial correlation proposed by Arellano and Bond (1991). The robust standard errors from the second step estimation with a small sample correction based on Windmeijer (2005) are in parentheses: *** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level. The estimation was done using DPD package version 1.2 on Ox version 3.30.

Table 8: Financial constraints and the speed of adaptation using the *65% quantile* of average financial conditions as a cutoff value, GMM first difference estimates. Dep. variable: $I_{i,t}/K_{i,t-1}$

Explanatory variable	(1) GMM first difference – All firms -		(2) GMM first difference – Innovators -		(3) GMM first difference – Non-innovators -	
$I_{i,t-1}/K_{i,t-2}$	-0.199	(0.083)**	-0.406	(0.122)***	-0.156	(0.081)*
$I_{i,t-1}/K_{i,t-2}$ * *fincond*	-0.083	(0.111)	0.018	(0.178)	-0.092	(0.111)
log ($K_{i,t-2}/S_{i,t-2}$)	-0.346	(0.059)***	-0.490	(0.086)***	-0.301	(0.059)***
log ($K_{i,t-2}/S_{i,t-2}$)* *fincond*	0.008	(0.082)	0.110	(0.104)	-0.004	(0.086)
log $S_{i,t-2}$	-0.140	(0.071)**	-0.161	(0.068)**	-0.189	(0.086)**
log $S_{i,t-2}$* *fincond*	-0.024	(0.101)	-0.153	(0.095)	-0.045	(0.123)
Δlog $S_{i,t}$	0.131	(0.054)**	0.111	(0.062)*	0.077	(0.062)
Δlog $S_{i,t-1}$	0.180	(0.068)***	0.285	(0.078)***	0.087	(0.077)
Δlog $S_{i,t}$* *fincond*	-0.012	(0.066)	-0.097	(0.070)	0.066	(0.077)
Δlog $S_{i,t-1}$* *fincond*	-0.014	(0.086)	-0.235	(0.090)***	0.068	(0.103)
No. obs.	6,383		2,130		4,253	
No. firms	1,742		563		1,179	
Sargan-Hansen, p-value	0.012		0.116		0.176	
LM(2), p-value	0.700		0.124		0.646	

Additional regressors: a constant and year dummies. All regressions report a two-step GMM estimation of the equation in first differences, as proposed by Arellano and Bond (1991). The dummy variable characterising a financially restricted firm is determined by attributing the numbers 1-5 to the categories “very stimulating”, “stimulating”, “no influence”, “limiting”, “very limiting” and computing the firms’ mean outcome. A firm is characterised as constrained if this value is above the 65% quantile for all the firms. Columns (1), (2) and (3) show estimates for all firms as well as for innovators and non-innovators separately. In each case, instruments are the lags 2 – 4 of the undifferenced values of all regressors when feasible (ie, $I_{i,t-m}/K_{t-1-m}$, log$S_{i,t-m}$, log $K_{i,t-m}$, with $2 \leq m \leq 4$, where the maximum value of m is as large as possible given data availability), as well as a constant and year dummies. The Sargan-Hansen statistic is a test of overidentifying restrictions proposed by Sargan (1958) and Hansen (1982). The LM(2) statistic is the Lagrange Multiplier statistic for second-order serial correlation proposed by Arellano and Bond (1991). The robust standard errors from the second step estimation with a small sample correction based on Windmeijer (2005) are in parentheses: *** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level. The estimation was done using DPD package version 1.2 on Ox version 3.30.

Table 9: Financial constraints and the speed of adaptation using the *median* of average financial conditions as a cutoff-value, GMM system estimates. Dep. variable: $I_{i,t}/K_{i,t-1}$

Explanatory variable	(1) GMM system – All firms -		(2) GMM system – Innovators -		(3) GMM system – Non-innovators -	
$I_{i,t-1}/K_{i,t-2}$	0.019	(0.086)	0.121	(0.085)	0.007	(0.077)
$I_{i,t-1}/K_{i,t-2}$ * *fincond*	0.039	(0.108)	0.071	(0.133)	0.104	(0.104)
log ($K_{i,t-2}/S_{i,t-2}$)	-0.178	(0.065)***	-0.108	(0.050)**	-0.186	(0.061)***
log ($K_{i,t-2}/S_{i,t-2}$)* *fincond*	0.045	(0.077)	0.006	(0.070)	0.116	(0.076)
log $S_{i,t-2}$	0.051	(0.016)***	0.045	(0.017)***	0.052	(0.015)***
log $S_{i,t-2}$* *fincond*	-0.027	(0.017)	-0.022	(0.019)	-0.027	(0.016)*
Δlog $S_{i,t}$	0.220	(0.098)**	0.079	(0.077)	0.170	(0.105)
Δlog $S_{i,t-1}$	0.219	(0.067)***	0.151	(0.059)**	0.224	(0.060)***
Δlog $S_{i,t}$* *fincond*	-0.044	(0.106)	-0.009	(0.090)	-0.006	(0.112)
Δlog $S_{i,t-1}$* *fincond*	-0.056	(0.076)	-0.015	(0.073)	-0.117	(0.072)
No. obs.	8,125		2,693		5,432	
No. firms	1,742		563		1,179	
Sargan-Hansen, p-value	0.186		0.038		0.731	
LM(2), p-value	0.219		0.735		0.256	

Additional regressors: a constant and year dummies. All regressions report a two-step combined dynamic panel estimation as proposed by Arellano and Bover (1995) and Blundell and Bond (1998). The dummy variable characterising a financially restricted firm is determined by attributing the numbers 1-5 to the categories "very stimulating", "stimulating", "no influence", "limiting", "very limiting" and computing the firms' mean outcome. A firm is characterised as constrained if this value is above the median for all the firms. Columns (1), (2) and (3) show estimates for all firms as well as for innovators and non-innovators separately. Instrumentation of the differenced equation is as indicated in the notes to Table 7. For the equation in levels, $\Delta I_{i,t-1}/K_{t-2}$, $\Delta \log S_{i,t-1}$, and $\Delta \log K_{i,t-1}$, are used as instruments, as well as time dummies. The Sargan-Hansen statistic is a test of overidentifying restrictions proposed by Sargan (1958) and Hansen (1982). The LM(2) statistic is the Lagrange Multiplier statistic for second-order serial correlation proposed by Arellano and Bond (1991). The robust standard errors from the second step estimation with a small sample correction based on Windmeijer (2005) are in parentheses: *** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level. The estimation was done using DPD package version 1.2 on Ox version 3.30.

Table 10: Financial constraints and the speed of adaptation using the *65% quantile* of average financial conditions as a cutoff-value, GMM system estimates. Dep. variable: $I_{i,t/}K_{i,t-1}$

Explanatory variable	(1) GMM system – All Firms -		(2) GMM system – Innovators -		(3) GMM system – Non-innovators -	
$I_{i,t-1}/K_{i,t-2}$	-0.003	(0.073)	-0.001	(0.139)	-0.021	(0.066)
$I_{i,t-1}/K_{i,t-2}$ * *fincond*	0.147	(0.110)	0.339	(0.152)**	0.118	(0.096)
Log ($K_{i,t-2}/S_{i,t-2}$)	-0.218	(0.052)***	-0.244	(0.099)**	-0.214	(0.049)***
Log ($K_{i,t-2}/S_{i,t-2}$)* *fincond*	0.166	(0.071)**	0.192	(0.102)*	0.150	(0.072)**
Log $S_{i,t-2}$	0.031	(0.010)***	0.027	(0.014)*	0.037	(0.011)***
Log $S_{i,t-2}$* *fincond*	0.000	(0.012)	-0.016	(0.015)	-0.005	(0.014)
Δlog $S_{i,t}$	0.141	(0.058)**	0.118	(0.075)	0.130	(0.062)**
Δlog $S_{i,t-1}$	0.248	(0.050)***	0.262	(0.090)***	0.247	(0.048)***
Δlog $S_{i,t}$* *fincond*	-0.039	(0.071)	-0.066	(0.086)	0.025	(0.072)
Δlog $S_{i,t-1}$* *fincond*	-0.144	(0.067)**	-0.174	(0.092)*	-0.130	(0.069)*
No. obs.	8,125		2,693		5,432	
No. firms	1,742		563		1,179	
Sargan-Hansen, p-value	0.145		0.495		0.702	
LM(2), p-value	0.210		0.662		0.300	

Additional regressors: a constant and year dummies. All regressions report a two-step combined dynamic panel estimation as proposed by Arellano and Bover (1995) and Blundell and Bond (1998). The dummy variable characterising a financially restricted firm is determined by attributing the numbers 1-5 to the categories "very stimulating", "stimulating", "no influence", "limiting", "very limiting" and computing the firms' mean outcome. A firm is characterised as constrained if this value is above the 65% quantile for all the firms. Columns (1), (2) and (3) show estimates for all firms as well as for innovators and non-innovators separately. Instrumentation of the differenced equation is as indicated in the notes to Table 9. For the equation in levels, $\Delta I_{i,t-1}/K_{t-2}$, $\Delta logS_{i,t-1}$, and $\Delta log\ K_{i,t-1}$, are used as instruments, as well as time dummies. The Sargan-Hansen statistic is a test of overidentifying restrictions proposed by Sargan (1958) and Hansen (1982). The LM(2) statistic is the Lagrange Multiplier statistic for second-order serial correlation proposed by Arellano and Bond (1991). The robust standard errors from the second step estimation with a small sample correction based on Windmeijer (2005) are in parentheses: *** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level. The estimation was done using DPD package version 1.2 on Ox version 3.30.