Financial constraints and real activity: a non-structural approach using UK survey data[1]

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1. Introduction and summary

Understanding the causes and effects of financial constraints for firms is of key importance for a variety of policy issues. In monetary transmission theory, the credit channel is supposed to condition and amplify the "neoclassical" relative price effects of interest rate changes on firm activity. Monetary policy may affect the ability of banks to finance firms (bank lending channel), or else influence firms' ability to attract external finance by affecting the value of their equity (balance sheet channel). Second, financial constraints on real activities form one crucial link that determines the real consequences of financial imbalances of various types: banking crises, asset price bubbles, or government debt. Ultimately, financial constraints due to asymmetric information are especially important for those future-oriented activities that deal with generating new knowledge: research, development and the introduction of innovative products and processes. These activities are fundamental to the long-run performance of any economic system.

For all these reasons, the study of firms' financial constraints at a micro level is a major topic on the agenda of central bank research. A recent coordinated research effort by the European System of Central Banks (ESCB) on the basis of large national balance sheet databases shows that financial constraints do seem to matter for firm investment and the monetary transmission process (see Chatelain et al (2003a) for an overview). However, unlike much of the literature on US firms, size does not seem to be a good indicator of informational asymmetries and the assorted financial constraints in European countries. Among some of the larger euro area countries - France, Germany, Italy and Spain - only Italian small firms show an excess sensitivity of investment with respect to cash flow.[3]

It is conceivable that the importance of financial constraints for the real activity of firms also depends on the financial system. Allen and Gale (2001) argue that intermediaries and markets may have different comparative advantages. A market-based system deals better with situations where innovations occur and where there is a fundamental diversity of opinion, whereas intermediaries are able to save transaction costs when a large amount of experience has been gained and things are no longer changing. The empirical patterns of financial constraints and their importance for monetary policy, financial stability and innovation and growth may therefore depend on economic institutions.

This paper is part of a larger research effort based on large 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. With respect to the United Kingdom, we are able to explore

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2 The views expressed in this paper do not necessarily reflect those of the Deutsche Bundesbank. All errors, omissions and conclusions remain the sole responsibility of the author.

3 The key results have been collected in Angeloni et al (eds; 2003): see Chatelain and Tiomo (2003) on France, von Kalckreuth (2003b) on Germany, Gaiotti and Generale (2003) on Italy, as well as Chatelain et al (2003b) for a comparative study of the euro area. On Germany, see also the study by Breitung et al (2003).

the database for the CBI *Industrial Trends Survey* (ITS), which is the most important survey for business cycle analysis in the United Kingdom. For the 11 years between January 1989 and October 1999, our cleaned unbalanced panel contains 49,244 quarterly observations on 5,196 firms. According to the CBI, the ITS represents around 33% of the total current employment within UK manufacturing.

Apart from its size and coverage, the data set has two important characteristics. First, it contains many small firms, on which very little information is available from micro data sets based on quoted companies. More than 63% of the ITS observations refer to firms with less than 200 employees. Second, the data-set contains detailed information on financial constraints that firms face in their investment decisions. Notably, a number of firms (around 20.8% of respondents) explicitly state two things: that they are constrained by the lack of either internal or external financial resources, and that these constraints have an influence on their investment behaviour.

This is exactly what the bulk of the empirical literature on financial constraints, following the seminal article by Fazzari et al (1988), tries to prove. The standard procedure in this literature is to split the sample by some criterion that a priori identifies firms as being financially constrained or unconstrained, such as size, dividend behaviour or the risk of default, and then to test whether the observed differences in investment behaviour between the two types of firm are consistent with what is to be expected from a better or worse financial standing in a situation of asymmetric information.[4] Armed with the CBI data, this complicated and very indirect procedure, heavily criticised on theoretical grounds by Kaplan and Zingales (1997, 2000), seems to be unnecessary: a subset of respondents explicitly claims to be constrained. However, it needs to be examined whether they have told the truth, ie whether or not there is informational content in their assertions. If this is the case, we have the chance to take a closer look at the interrelationship between financial constraints and investment demand.

Section 2 is dedicated to the presentation of our data set. The econometric part of the paper, Section 3, examines the informational content of our data on financial constraints. Our focus is on capacity adjustment, as the ITS data on capacity gaps, planned expansion and rates of capacity utilisation are especially rich. First, we look at the association between two types of constraints: capacity restrictions and financial constraints. Then we undertake a *duration analysis* with respect to spells of capacity constraints. Firms report whether their capacity is insufficient with respect to demand. Those firms which indicate financial constraints should take longer to close a capacity gap if there is informational content in their answers - either because they are less able to finance their investments or else because they have bigger gaps to fill. In fact, financially constrained firms do take longer to end a period of insufficient capacity. The paper ends with a conclusion in Section 4.

2. The data set

The CBI *Industrial Trends Survey* (ITS) is a qualitative survey that looks at short- and medium-term trends in the UK manufacturing and processing industries. The survey is a postal questionnaire aimed at a senior level within firms and is usually completed by either the Chairman or the Chief Executive. The CBI produces both a monthly and a quarterly survey, the latter providing more in-depth analysis. It covers a wide range of subject areas including optimism regarding the general and export business situation, investment, capacity, order books, numbers employed, output, deliveries, stocks, prices, constraints to output, export orders, competitiveness regarding the domestic, EU and non-EU market, innovation and training. The quarterly survey is the empirical basis for our analysis. Mitchell et al (2002a,b) have used the ITS micro data to show that disaggregate survey-based indicators they developed can outperform traditional aggregate indicators. The full text of the questionnaire can be found in Wood (2001).

According to the CBI, the ITS represents around 33% of the total current employment within UK manufacturing. Our research focuses on 11 years of data between January 1989 and October 1999.

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4 See, for example, Chirinko and von Kalckreuth (2002).

The cleaned, unbalanced panel contains 49,244 quarterly observations on 5,169 firms. We exclude any divisions of a company, as their information might not be truly relevant to questions regarding size or financial constraints. Furthermore, we exclude all anonymous responses because these companies cannot be tracked over time.

Apart from its size and coverage, the data set has a number of important characteristics. First, the survey consists of four employment size groups, the largest of which looks at small firms with less than 199 employees. As can be seen in Table 1, 63% of the ITS observations refer to these small firms. Second, the ITS has a wide-ranging base of firms from the UK manufacturing and processing industries; Table 2 shows the breakdown of two digit SIC codes by observation.

The question on constraints on investment is of key importance for our study. We therefore quote the exact wording here for the sake of convenience:

Question 16c

What factors are likely to limit (wholly or partly) your capital expenditure authorisation over the next 12 months?

(If you tick more than one factor, please rank in order of importance)

☐ inadequate net return on proposed investment

☐ shortage of internal finance

☐ inability to raise external finance

☐ cost of finance

☐ uncertainty about demand

☐ shortage of labour, including managerial and technical staff

☐ other

☐ n/a

Table 3 shows both the overall frequency with which firms cite a given constraint (any rank) to investment expenditure and the frequency with which this constraint was given the first rank. Firms had the opportunity to name more than one constraint on capital expenditure, but they were asked to rank the importance of their constraints. We interpret the answers to this question as information on marginal investment. For the entire sample, uncertainty about demand is the most common impediment mentioned by all firms. It is cited by most firms (55% of respondents) as a significant constraint over the time period we studied. An interpretation of these figures in the light of theory, however, has to take into account the possibility that many firms focus only on “downside risks”, such as an unanticipated decrease in demand, rather than on uncertainty in the sense of imprecise expectations. For a recent review of the microeconometric literature on investment and uncertainty see von Kalckreuth (2003a). The second most important constraint is inadequate net return, cited by 39% of firms as an important constraint. Other constraints seem to have been less important. Costs of finance were cited frequently in the early 1990s, but have been mentioned significantly less often since then.

Turning to financial issues, we see that 4.3% of firms cite inability to raise external finance as a factor likely to limit their capital expenditure over the next 12 months. However, it is also interesting to note that only 1.96% mentioned this particular factor as their foremost constraint. 18.9% of firms cite “shortage of internal finance” as an impediment to investment, and for 13.6% of firms it is the most important barrier.

For inferential purposes, it is important to know whether there is sizeable individual variation in the financing constraints data. Table 4 conditions on whether in the preceding period a firm reported either a shortage of internal finance or an inability to raise external finance, and it shows the transition to the next period. It is easy to see that the reports on financial constraints are strongly autocorrelated. Among the firms that do not report financial constraints in a given period, a share of 87.6% will not report any in the next period either, and 12.4% switch to reporting constraints. But only 36.7% of the firms that report financial constraints in one period will state that they are unconstrained next time; the remaining two thirds will claim to be still constrained. However, the state of financial constraints is far from being determined by the state in the preceding period - there is a great deal of individual movement in both directions.

3. Is there informational content in the financial constraints data?

As highlighted in the previous section, a sizeable proportion of firms in the CBI *Industrial Trends Survey* state that their investment is constrained either by insufficient internal funds or by the inability to raise external finance. These statements are interesting and potentially very rich: as we shall see below, they permit identification of the financial regime of a firm. Weighted averages of survey questions are often used for forecasting and evaluation purposes at a sectoral or macro level and in many cases turn out to be surprisingly accurate.[5] However, it is not clear a priori how well the survey responses reflect the individual economic situation of the answering firm. Therefore, we need to check the informational content of the statements on financial constraints at a micro level. In other words, we want to see whether the statements on financial constraints relate to other information in the data set in a way that is consistent with theory.

3.1 The endogeneity problem

This, however, is no easy task. Capital accumulation and financial constraints are determined simultaneously: financial constraints depend not only on the financial situation of the firm, but also on the size of the planned investment.

With complete markets and a type of uncertainty common to all agents, the net present value of a firm does not depend on the way it is financed. The Modigliani-Miller separation theorem holds that a firm's real capital allocation decision can be analysed independently of the financing decision - the structure of the asset side of the balance sheet is independent of the liability side. With asymmetric information, however, there will be a premium on external financing over and above a fair default premium which simply compensates for the fact that the debtor will not have to pay in certain states of nature. The creditor is less able than the debtor to evaluate the situation of the firm and the prospects of the investment project to be financed. The finance premium covers expected dead-weight losses caused by monitoring, costs of litigation, adverse selection and moral hazard. The important thing is that its *size depends on the financial structure of the firm*. Investment and the cost of external finance are therefore *jointly endogenous*.

Graph 1, adapted from Bernanke et al (1999), shows that the costs of external finance depend on the difference between the actual capital demand and what can be financed internally. By means of this graph, we can interpret the responses to the questions on financial constraints in terms of three regimes which are ordered in a natural way: a state of no financial constraints, a state of limited internal finance (the firm needing external finance) and a state of unavailability of external finance. If a firm states that its capital expenditure authorisations are limited by a shortage of internal finance, it is saying that it has to pay an external finance premium because the internal resources are insufficient. And if it reports that no further external finance can be raised, the firm may find itself in the regime described by Stiglitz and Weiss (1981): at a certain credit volume, the interest rate cannot be raised beyond a certain value. Then the firm is credit-rationed. Under certain circumstances, this is the equilibrium outcome of a situation where the severity of the agency problems is a function of the

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5 Mitchell et al (2002a,b) show that survey responses contain information that is useful in generating indicators of manufacturing output ahead of the publication of survey data. Furthermore, they show that disaggregate indicators for output growth can outperform traditional aggregate measures with respect to their predictive content.

interest rate itself. In the graph, the existence of such a regime would make the schedule break off at some maximum interest rate.

We see that shocks to the financial structure will affect real decisions and vice versa. In any equation describing the capital accumulation decision, the error term will be correlated with the financial constraints variable. If we had continuous variables describing the accumulation of capital, this problem could be resolved using instrumental variable techniques, such as the GMM method developed by Arellano and Bond (1991). Breitung et al (2003) explore the simultaneity between investment decision and financial conditions by estimating a VAR on a large panel of German manufacturing firms. However, instrumental variable analysis is made difficult by the fact that the ITS data on investment and expansion are qualitative: we know whether or not the firm expands or steps up investment, but not by how much.

We therefore want to test the informational content of the data on financial constraints by looking at a relationship where both lines of causality point in the same direction. To this end, we investigate the occurrence and the duration of spells of capacity constraints.

3.2 Occurrence and duration of capacity restrictions

If there are adaptation costs such as delivery lags or time to build constraints, the move to a higher desired capital stock will be spread over several periods. In order to achieve tractability, it is often assumed that marginal adaptation costs increase linearly with the size of investment.[6] Second, the external finance premium might also be an increasing function of the investment intensity. Creditors might want to give finance in instalments, cutting the project into several phases, in order to monitor feasibility and the willingness of the management to comply with the terms of the credit contract. This may induce a sequential and "evolutionary" development of a project from a smaller to a larger size even in cases where, in a world without information asymmetry, a massive parallel investment effort might have been optimal. In the extreme case, when a firm has no access to external finance, the amount of investment per period is quite simply limited by the firm's cash flow.

The ITS survey gives us information on whether or not a firm experiences capacity constraints in a given period by asking the following question:

Question 14

What factors are likely to limit your output over the next four months?

(Please leave completely blank if you have no limits to output)

☐ orders or sales	☐ skilled labour	☐ other labour	☐ plant capacity
☐ credit or finance	☐ materials or components	☐ other	

Both directions of causation between financial constraints and the expansion decision lead us to predict that a state of capacity restrictions is more probable and will be of longer duration if the respondent also reports financial constraints to investment. With a given marginal valuation of capital, a large external finance premium will induce the firm to spread investment over a longer time horizon, inducing and prolonging capacity constraints. On the other hand, with a given financial structure, a shock in the marginal valuation function will not only trigger financial constraints, but also lead to a longer adaptation process. Larger gaps simply take more time to fill. Below, we shall compare the occurrence and duration of capacity constraints for restricted and unrestricted financing, with a particular emphasis on the distinction between small and large firms. Our analysis shows that the financial constraints data actually do have informational content at the micro level.

6 See Hayashi's (1982) neoclassical micro-foundation of the Q model.

3.3 Association analysis for capacity restrictions and financial constraints

Table 5 compares the frequency of capacity restrictions for three groups of firms: those that do not seem to be limited by the lack of either internal or external finance (Group 1), those that complain about shortages of internal finance but not about inability to raise external finance (Group 2) and, finally, those that report being rationed on the market for external finance (Group 3). Whereas only 12.99% of the first group claims to be capacity restricted, the corresponding figures are 22.52% of the second group and 19.17% of the third group. The two latter groups are clearly different from the first group. We perform three statistical tests of association: the well known Pearson test, a likelihood ratio test and Fisher's exact test. Given two discrete (multinomial) variables, all three tests focus on how strongly the realised shares for one variable, conditional on the values that the other variable may take, deviates from the overall shares. Pearson's test and the likelihood ratio test are easily calculated and rely on asymptotic properties of the test statistic: for large numbers their distribution converges against the Chi(2) with $(r - 1)(s - 1)$ degrees of freedom, r being the number of rows and s being the number of columns in the contingency tables. Fisher's test exploits the exact distribution of the test statistic, but computation can take a very long time for larger tables.[7] All tests reject the null hypothesis of independence with a p-value of less than 0.0005.

It is also interesting to look at *changes* of states, as the association between the levels of the financial constraints and capacity restrictions might be the result of a special sensitivity to constraints in general on the part of the individual respondents. To put it differently: some individuals might have a special propensity to complain. Therefore we want to condition on the state of capacity restrictions in the preceding period. This examination also prepares our duration analysis: by definition, a switch from the state of not restricted to restricted initiates a spell of restricted capacity. If the restricted state is maintained, the spell goes on, and a reverse switch will end it.

Table 6 performs the three above-mentioned non-parametric association tests separately for firms that reported capacity restrictions in the preceding period and those that did not. Generally, capacity restrictions are cited much more frequently when there were restrictions in the previous quarter: whereas only 7.2% of the unrestricted firms switch to the restricted state, 53.3% of the restricted firms remain restricted. However, under both conditions the probability of capacity restrictions clearly becomes higher when financial constraints are present. Again, the three association tests mentioned above reject the null hypothesis of independence with a p-value of less than 0.0005.

3.4 The design of the duration analysis

The econometric analysis of duration data began only in the late 1970s (see Heckman and Singer (1984), Kiefer (1988) and Lancaster (1990) for overviews). Not only the statistical models, but also a good part of the terminology have been borrowed from biostatistics. The classical focus of "survival analysis" is the evaluation of survival times of human patients or animals after the contraction of a specific disease, with the aim of testing the effects of medical treatments and other factors that might potentially be of relevance. Among the economic applications have been the analysis of the duration of unemployment, for example by Steiner (1990), or of fiscal behaviour, as in the study by von Hagen et al (2001). To the best of our knowledge, the duration of capacity constraints has never been investigated before at a microeconometric level. This makes our exercise interesting and worthwhile in its own right, as capacity constraints may play an important role in the propagation of inflationary shocks.[8]

Here, we wish to consider the duration of states of restricted capacity. For a firm in this state, the probability of switching to the unrestricted state may depend on the duration that is already achieved. Such a conditioning on time is called "ageing", and the word itself makes the idea plain. Mortality among human beings is relatively high during the first months of life, and then drops sharply after a couple of years. In advanced age, mortality rises again and reaches extreme levels at the right end of the scale.

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[7] See, for example, Büning and Trenkler (1994) or any other book on non-parametric statistics.

[8] See Macklem (1997).

In order to estimate survival curves, we therefore need to have information on the time when the period of constrained capacity began. We limit ourselves to contiguous strings of observations that start with a switch of the capacity restrictions variable from zero (no capacity restrictions reported) to one (output is likely to be limited by plant capacity during the next four months). The string is interrupted if the state is left, ie the "spell" ends, or else if there is no further information on the firm. One missing survey is enough to cut the string off. For inferential reasons, we can use only those observations which are not censored immediately after entry. That is, after the initial switch from zero to one, we need at least one more consecutive observation on the firm if the string is to contain any information on duration other than that it was non-negative. The cleaned CBI survey data for the period between January 1989 and November 1999 contain 49,244 observations on 5,169 firms. In this data set, we observe 1,431 of such strings, with a total of 5,153 observations,[9] taken from 862 firms.

We need to pay special attention to three important features of our data set. First, our duration data are censored considerably. From our 1,431 cases, we observe the end of the spell 1,210 times, but in the remaining 221 spells the string is cut off by missing observations. In these cases, we know that the spell has lasted *at least* until the end of the string, and this information has to be used appropriately. Second, we have *grouped data*. We do not observe the end of the spell in continuous time, but only know that it falls in an interval between two discrete points of time. Our observations are quarterly, and the vast majority of observed periods of capacity constraints are less than four quarters. This means that the granularity of our observations is rather high, and we believe that it would not be correct to use standard models and estimation procedures which assume observed duration times to be continuously distributed in time. Third, as already stated, we are working with a *panel* of survival time data. For many firms, we observe more than one spell. These cannot be assumed to be stochastically independent, and special care has to be taken with testing procedures.

3.5 Kaplan-Meier survival curves

We start by looking at the estimated *survivor functions*. A survivor function is defined for both discrete and continuous distributions by the probability that the duration T exceeds a value t in its range, that is:

$$F(t) = P(T > t), \quad 0 < t < \infty. \tag{1}$$

For each hypothetical duration t, the survivor function gives the share of individuals with duration of t or more. In our context, the survivor function depicts the process of firms liberating themselves from capacity constraints, once they have entered into this state. It gives the mass on the *right tail* of the distribution of duration times. This is convenient, because the right tail is the important component for the incorporation of right censoring.

The Kaplan-Meier[10] (or *product limit*) estimator is a non-parametric maximum likelihood estimator of the survivor function. The estimator is given by:

$$\hat{F}_t = \prod_{j \le t} \left(1 - \hat{\lambda}_j\right), \quad \text{with } \hat{\lambda}_j = \frac{d_j}{n_j}. \tag{2}$$

The index j enumerates observed times to completion, ie time spans passed since the observational unit entered into the risk pool. We only observe firms at discrete intervals, therefore the j can be thought of as quarters. The $\hat{\lambda}_j$ are estimated probabilities for the observational unit to complete at j, given that it has reached $j - 1$, the last observed time to completion. The estimate of these conditional probabilities is obtained by dividing the observed number of completions, d_j, by the number of observational units that have neither completed nor been censored before j.

As can be seen, the survivor function is estimated recursively. The expression $(1 - \hat{\lambda})$ is an estimation of the conditional probability that an individual "survives" in the state, given that it has lasted until $j - 1$.

9 This number of observations includes the initial zero and the initial one for each string.

10 For the derivation of the Kaplan-Meier estimator as a maximum likelihood estimator, see Kalbfleisch and Prentice (2002).

The unconditional probability that the duration is at least *j* is then computed as a product of all the contemporaneous and prior conditional survival probabilities. For this estimate to be unbiased, the censoring mechanism needs to be independent; that is, the completion probabilities of non-censored and censored individuals must be identical. This will be assumed throughout below.

Table 7 not only describes termination and censoring over time, but also gives the numerical values for the survivorship and completion rates in the entire sample. The first column, time, is the number of quarters *after* the original switch from unconstrained to constrained. If, for example, the capacity state of a firm switches from unrestricted to restricted in the third quarter of 1991, then for this firm the fourth quarter of 1991 assumes the value of one. The second column gives the number of firms "at risk", for which we have information in this quarter. The third column gives the number of completions, and the fourth column the number of firms censored in this quarter, on which there is no further information thereafter. The sixth column is the estimated Kaplan-Meier survivor function, based on the estimated hazard rates in the fifth column according to equation (2). According to this estimate, about 40% of firms that start out with capacity constraints remain in this state for more than one quarter, 20% for more than two quarters, etc. After the fifth quarter, the survivor function has dropped to 6.4%. The longest observed duration is completed after 13 quarters. Completion probabilities seem to be falling, ie there is negative age dependence. The more time a firm has spent in a state of constrained capacity, the less likely it is to leave in the next quarter. The size of the sample, on which duration information is based, decreases rapidly with time. After the fifth quarter, not more than 3.7% of the original set of firms is left in the sample. It therefore seems inappropriate to draw any conclusions from survival times longer than that. The last column gives the standard deviation of the survivor function, taking into account the stochastic dependence of the duration experiences for a given firm. The standard deviations are simulated on the basis of a maximum likelihood estimation of the parameters using 20,000 replications. Numerically, they differ only very slightly from what is obtained assuming all duration experiences to be independent.

Next we wish to look at survival experiences of financially constrained and unconstrained firms. The relative sizes of the groups and some global statistics are given in Table 8. The state is measured at the *start of the spell*. As before, there are two natural ways to analytically distinguish financially constrained and unconstrained firms. First, we can group a firm as financially constrained if it reports that it has to scale down investment because of insufficient internal funds. Second, we can classify it as financially constrained if it cites either shortages of internal finance or inability to obtain external finance. The difference between the two groupings is in those 44 spells where firms cite the inability to obtain external finance as a limitation to investment, without indicating shortages of internal finance at the same time. As such a pattern is incompatible with the standard pecking order view of corporate finance under financial constraints or the natural ordering that results from costly monitoring models as shown in Graph 1, we prefer the less ambivalent first grouping. Ultimately, the answer "costs of finance" as a limit to capital expenditure might indicate the working of the classical user cost mechanism. Therefore we do not use it as a sorting criterion.

We see that the prevalence of financial limitations is clearly higher among those firms that cite capacity restrictions. Whereas 25.3% of all capacity restriction experiences are categorised as "constrained" according to the first criterion, and 28.4% according to the second criterion, the corresponding figures for the entire CBI data set are 19.0% and 20.8%, respectively.

Graph 3 depicts the results for the first criterion (shortage of internal finance) for the whole sample. The survival curves for a split along the other criterion look almost the same. The survival curve for unconstrained firms is always beneath the curve for the financially constrained firms. This means the unconstrained firms are able to complete their spell of restricted capacity faster than the constrained firms. It is convenient to point out again that there are two competing causal explanations for this difference. For a given size of capacity gap, financially constrained firms might take longer to fill it. On the other hand, firms with a huge capacity gap (and accordingly higher financing needs) might be more likely to report financial constraints. Comparing the survival curves essentially tests those two hypotheses jointly. It will be necessary to examine this difference statistically.

3.6 A proportional hazard (Cox) model of duration

In order to test the effect of financial constraints on the duration of capacity restrictions, we need to impose some structure. Let *x* be a vector of characteristics, among them an indicator variable for financial constraints at the beginning of the spell. As we have little a priori information about the underlying process, we do not want to restrict the form of the baseline survivor function that corresponds to $x = 0$. In what follows, we explicitly recognise (1) that duration is distributed continuously over time, and (2) the measurement of the capacity restrictions for a given unit is taken at discrete intervals (quarters), $j = 1, 2, \dots k$.[11] Let $\lambda(t, x_i)$ be the *hazard* for a unit with characteristics x_i at time t, defined as:

$$\lambda(t,x) = \lim_{h \to 0} P\left(t \le T < t + h \mid T \ge t, x_i\right) / h \tag{3}$$

The hazard is the instantaneous rate at which spells are completed by units that have lasted until time t, defined in the same way as a mortality rate in demographics or a failure rate in the statistical theory of capital stock dynamics. We want to assume that the characteristics x relate to the hazard rate in a proportional fashion:

$$\lambda(t,x) = \lambda_0(t) \cdot \exp(x_i'\beta), \tag{4}$$

with β being a vector of coefficients that needs to be estimated. The hazard ratio between an individual with characteristics x_i and the baseline case is given by $\exp(x_i'\beta)$, which is approximately $1 - \beta$ for small β. The hazard ratios between two individuals with characteristics x_1 and x_0 are calculated as $\exp[(x_1 - x_0)\beta]$. Equation (4) constitutes the model of proportional hazard, developed by Cox (1972). In this setup, the baseline hazard remains completely unspecified, which is why the proportional hazard model figures among the semi-parametric approaches.

We assume that the spells of different firms are independent events and that the censoring mechanism is independent of the state of the firm. We can write the probability for the completion of a spell to be registered after j surveys as a product of conditional probabilities. This allows us to derive a likelihood function that contains β as well as further (incidental) parameters describing, for the baseline case, the conditional probability of completing in the time interval between $j - 1$ and j, given that $j - 1$ has been reached. For details, see Hosmer and Lemeshow (1999), Section 7.4, as well as Kalbfleisch and Prentice (2002), Section 5.8. The likelihood function here can be shown to be identical to that for a Bernoulli experiment with probabilities that depend on time as well as on x_i by means of a standard link function. The parameter estimates are asymptotically normally distributed. We take the panel nature of the data into account by computing robust standard errors, with clusters defined by firm identity.

Table 9 contains the maximum likelihood estimations for a Cox model with one covariate, as well as dummy variables carrying information on the sector and the time of origin of the spell. As explained above, we use two alternative definitions of financial constraints. The dummy variable *fin(1)* takes a value of one to indicate that the firm cites insufficient internal finance at the outset of the spell. The dummy variable *fin(2)* will be one if the firm cites either insufficient internal finance or inability to raise external finance. The respective classification is maintained during the entire spell.

In each cell, the first figure gives the estimated coefficients. Below, in curly brackets, this value is translated into a hazard ratio. Column 1, for example, compares the hazard rates for constrained and unconstrained firms according to our first criterion. The hazard rate of a constrained firm is exp(–0.192) times the hazard ratio of a small firm, meaning that financially constrained firms are leaving the state of restricted capacity at a rate which is only about 82.6% that of an unconstrained firm. The third figure, in round brackets, indicates the robust standard deviations, taking into account stochastic dependence between spells generated by the same firm. The last entry, in square brackets, gives the z statistic for statistical significance: under the null hypothesis of no differences, the estimated coefficient divided by its standard error is asymptotically a standard normal variate. Column 2 gives the corresponding estimates with respect to our second indicator of financial constraints, *fin*(*2*). The picture is essentially similar.

[11] The assumption of absolutely continuous time is made only for expositional convenience. A discrete time concept would not invalidate any of our results, after redefining the hazard rate in t as the conditional probability that the spell is completed in $t + 1$, conditional on it having lasted until t. It is possible to conduct duration analysis with distributions of T that have both discrete and continuous portions. See Kalbfleisch and Prentice (2002) for a systematic approach.

It may be argued that the detected differences may be sector-specific. As financial constraints may be sector-specific too, we want to control for sectoral differences in order to avoid a missing variable bias. Columns 3 and 4 repeat the estimates explained above, adding 20 dummies for two digit SIC sectors. This does not lead to a reduction of the financial constraint effects; if anything, the effect is bigger.

A third set of estimates, collected in columns 5 and 6, controls for the position in the business cycle by including dummies for the time of the start of the spell. This is done in order to account for a possible dependence of duration on the general state of the economy. In a time of depression, investors might be less inclined to close capacity gaps. At the same time, internal financial resources might be scarcer and external finance might be more difficult to obtain. In fact, adding the controls for the business cycle situation makes the size effects come out somewhat smaller, as predicted. In our preferred estimate, column 5, lack of internal financial resources lowers the hazard rate by about 18% with respect to the baseline case. The value is significant at a 1% level ($p = 0.006$).

4. Conclusions and outlook

Our association and duration analysis have shown that the CBI financial constraints data are not without informational content - as theoretically expected, financially constrained firms are more often capacity constrained and they take longer to close capacity gaps than unconstrained firms. This means we can take our survey data seriously. They indicate that financial constraints and real activity are indeed interrelated. Survey information on the ups and downs of financial constraint indicators can therefore be a valuable policy tool.

But the precise nature of that interrelationship is still open. Real investment decisions may certainly cause financial constraints, and on the other hand those financial constraints may slow down or prevent expansion plans. Further research is planned to separately identify the two directions of causation using a structural approach.

Finally, it will be interesting to take a more differentiated view. Are there subgroups (large firms, for example) for which financial constraints matter less? Are high-tech firms or innovators different from the rest? What about the importance of the state of the economy? And is it possible to analyse the role of the financial system by making international comparisons? Working with individual level survey data may be demanding, but, so the author believes, it can be highly rewarding.

Table 1

Breakdown of data set by employment size

	Employment size				
	1-199	**200-499**	**500-4,999**	**5,000 and over**	**Total**
No of firms	3,394	1,060	647	68	5,169
No of observations	31,089	10,222	6,994	939	49,244

Source: CBI, *Industrial Trends Survey*.

Table 2

Number of observations split by employment size and two digit SIC code

Two digit SIC code	Employment size				
	1-199	**200-499**	**500-4,999**	**5,000 and over**	**Total**
Coke ovens	17	6	17	0	40
Mineral oil processing	73	35	38	11	157
Nuclear fuel production	0	0	0	2	2
Extraction and preparation of metalliferous ores	35	0	0	0	35
Metal manufacturing	1,429	460	292	62	2,243
Extraction of minerals not elsewhere specified	493	60	103	9	665
Manufacturing of non-metallic mineral products	1,286	436	443	85	2,250
Chemical industries	1,191	722	641	79	2,633
Production of man-made fibres	142	8	32	1	183
Manufacturing of metal goods not elsewhere specified	3,048	651	308	6	4,013
Mechanical engineering	7,116	1,718	1,028	23	9,885
Manufacturing of office machinery and data processing	103	26	90	7	226
Electrical and electronic engineering	2,991	1,420	808	54	5,273
Manufacturing of motor vehicles and parts thereof	691	409	409	187	1,696
Manufacturing of other transport equipment	315	132	136	111	694
Instrument engineering	838	230	69	0	1,137
Food, drink and tobacco manufacturing industries part 1	473	250	420	43	1,186
Food, drink and tobacco manufacturing industries part 2	689	399	454	151	1,693
Textile industries	2,427	1,098	594	7	4,126
Manufacturing of leather and leather goods	295	63	2	0	360
Footwear and clothing industries	1,439	478	262	39	2,218
Timber and wooden furniture industries	1,258	313	154	1	1,726
Manufacturing of paper and paper products	2,854	668	489	38	4,049
Processing of rubber and plastics	1,698	563	169	22	2,452
Other manufacturing industries	188	77	36	1	302
Total	**31,089**	**10,222**	**6,994**	**939**	**49,244**

Source: CBI, *Industrial Trends Survey*.

Table 3

Investment constraints

	Inadequate net return	Shortage of internal finance	Inability to raise external finance	Cost of finance	Uncertainty about demand	Shortage of labour	Other	N/a
Any rank	38.71%	18.89%	4.30%	10.64%	54.88%	5.73%	1.76%	8.89%
Rank 1	28.14%	13.58%	1.96%	5.25%	44.51%	2.76%	1.58%	9.49%

Note: Firms ranking the constraint as a limit on capital expenditure authorisations, as a percentage of all firms, including those who did not answer the question at all. Respondents were able to give one or more responses, hence results do not sum to 100%.

Source: CBI, *Industrial Trends Survey*.

Table 4

Variability and persistence of financial constraints

	Unconstrained in *t*	Constrained in *t*	Total
Unconstrained in $t-1$	19,990 87.61%	2,826 12.39%	22,816 100%
Constrained in $t-1$	2,377 36.68%	4,103 63.32%	6,480 100%
Total	25,162 79.45%	6,510 20.55%	31,672 100%

Note: Number and share of responding firms reporting either a shortage of internal finance or inability to raise external finance as a factor likely to limit capital expenditure over the next 12 months.

Source: CBI, *Industrial Trends Survey*.

Table 5

Association of capacity restrictions and financial constraints

		Capacity restrictions		
		Not restricted	**Restricted**	**Total**
Financial constraints	Not constrained	36,121 87.01%	5,394 12.99%	41,515 100%
	Internal finance	5,012 77.488%	1,457 22.52%	6,469 100%
	External finance	780 80.83%	185 19.17%	965 100%
	Total	41,913 85.63%	7,036 14.37%	48,949 100%

Association tests

Pearson's test:	Chi2(2) = 431.39	P < 0.0005
Likelihood ratio test:	Chi2(2) = 389.00	P < 0.0005
Fisher's exact test		P < 0.0005

Note: Number and share of responding firms reporting a shortage of internal finance or inability to raise external finance as a factor likely to limit capital expenditure over the next 12 months (rows) and number and share of firms reporting plant capacity as likely to limit output over the next four months (columns).

Source: CBI, *Industrial Trends Survey*.

Table 6

Association of capacity restrictions and financial constraints conditional on state of capacity restrictions in the previous period

Case 1: No capacity restrictions in previous period

		Capacity restrictions		
		Not restricted	**Restricted**	**Total**
Financial constraints	Not constrained	20,656 93.69%	1,392 6.31%	22,048 100%
	Internal finance	3,718 89.20%	450 10.80%	4,168 100%
	External finance	1,005 88.55%	130 11.45%	1,135 100%
	Total	25,379 92.79%	1,972 7.21%	27,351 100%

Association tests

Pearson's test:	Chi2(2) = 137.18	P < 0.0005
Likelihood ratio test:	Chi2(2) = 124.07	P < 0.0005
Fisher's exact test		P < 0.0005

Case 2: Capacity restrictions in previous period

		Capacity restrictions		
		Not restricted	**Restricted**	**Total**
Financial constraints	Not constrained	1,616 49.60%	1,642 50.40%	3,258 100%
	Internal finance	385 39.29%	595 60.71%	980 100%
	External finance	97 38.49%	155 61.51%	252 100%
	Total	2,098 46.73%	2,392 53.27%	4,490 100%

Association tests

Pearson's test:	Chi2(2) = 39.47	P < 0.0005
Likelihood ratio test:	Chi2(2) = 39.76	P < 0.0005
Fisher's exact test		P < 0.0005

Note: Number and share of responding firms reporting a shortage of internal finance or inability to raise external finance as a factor likely to limit capital expenditure over the next 12 months (rows) and number and share of firms reporting plant capacity as likely to limit output over the next four months (columns).

Source: CBI, *Industrial Trends Survey*.

Table 7

Survivor function and completion probabilities for the entire sample

Time	Beg total	Completed	Net lost	Completion rates	Survivor function	Std dev
1	1,431	856	133	0.5982	0.4018	0.0138
2	442	216	43	0.4887	0.2055	0.0123
3	183	63	16	0.3443	0.1347	0.0107
4	104	40	11	0.3846	0.0829	0.0090
5	53	12	7	0.2264	0.0641	0.0082
6	34	13	4	0.3824	0.0396	0.0074
7	17	3	2	0.1765	0.0326	0.0072
8	12	3	3	0.2500	0.0245	0.0069
9	6	3	0	0.5000	0.0122	.

Table 8

Composition of subsamples

Subsample	No of experiences	Times at risk	Incidence rates
All firms	1,431	2,291	0.528
Shortage of int finance	363	625	0.467
No shortage of int finance	1,068	1,666	0.551
Shortage of int or ext finance	407	703	0.472
No shortage of int or ext finance	1,024	1,588	0.553

Table 9

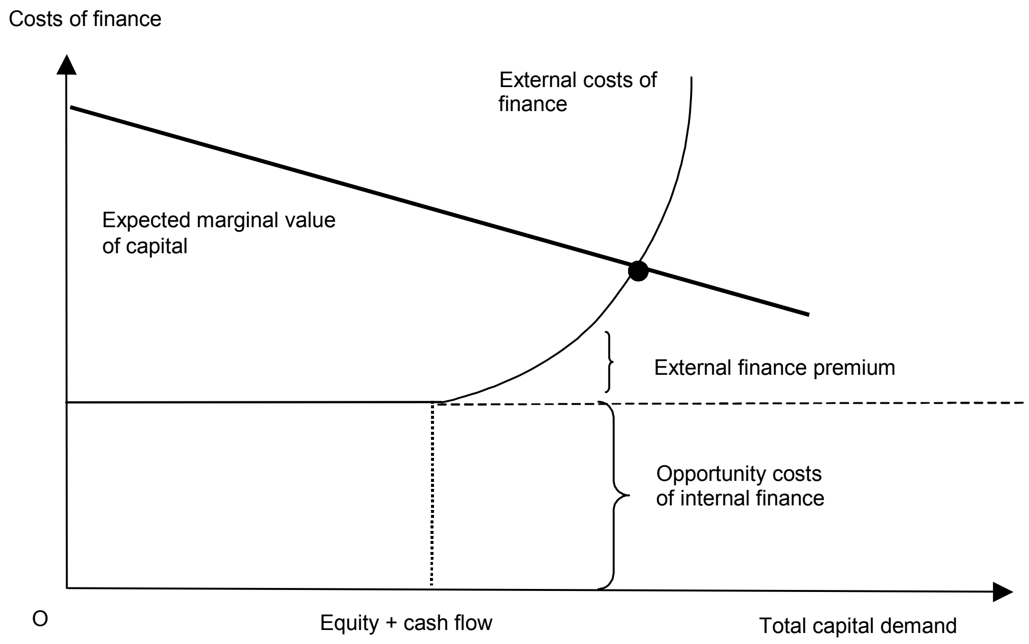
Maximum likelihood estimation of a proportional hazard model with grouped panel data

Coefficient	(1)	(2)	(3)	(4)	(5)	(6)
fin(*1*) (shortage of internal finance)	–0.192 {0.826} (0.072) [–2.65]***		–0.206 {0.814} (0.071) [–2.90]***		–0.199 {0.820} (0.073) [–2.72]***	
fin(*2*) (shortage of internal or external finance)		–0.181 {0.834} (0.068) [–2.68]***		–0.187 {0.830} (0.068) [–2.76]***		–0.172 {0.841} (0.068) [–2.54]**
Duration time dummies	9	9	9	9	9	9
Sector dummies	–	–	20	20	20	20
Dummies for time origin of spells	–	–	–	–	41	41
No of spells	1,431	1,431	1,429	1,429	1,429	1,429
No of firms	862	862	861	861	861	861
No of firm years	2,290	2,290	2,288	2,288	2,288	2,288

Note: Cox duration model with grouped data for spells of capacity constraints, estimated as a binary regression model using the complementary log-log function as link function. A spell is classified as pertaining to a financially constrained firm if, at the time when the spell starts, the firm reports financial constraints. The dummy variable *fin(1)* takes a value of one if a firm reports a shortage of internal finance in the answer to question 16c, otherwise it is zero. The dummy variable *fin(2)* takes a value of one if the firm reports either a shortage of internal finance or inability to raise external finance, otherwise it is zero. Likewise, a spell is classified as belonging to a large firm if the firm has 200 employees or more at the beginning of the spell. One observation had to be dropped because the longest duration interval (13 quarters) predicts the event perfectly. In the regressions reported in columns 3 to 6, two more observations and one sector (manufacturing of office machinery and data processing) were dropped because the sector dummy predicts the event perfectly. ** and *** indicate statistical significance at the 5% and 1% level, respectively.

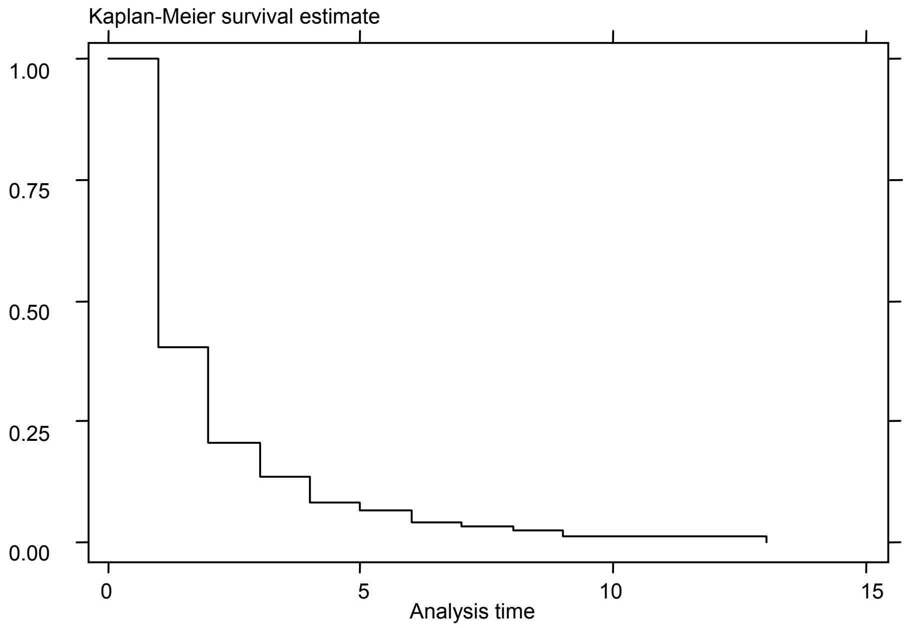
Graph 1

Capital demand and external finance premium



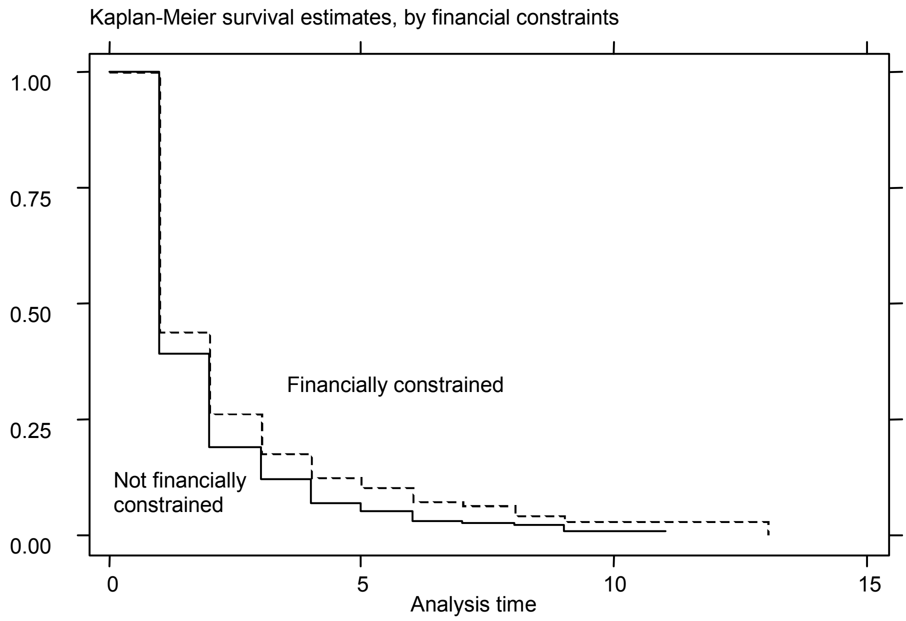
Graph 2

Kaplan-Meier estimates of the survivor function for the entire sample



Graph 3

Kaplan-Meier survival curves for financially constrained and unconstrained firms



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