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Financing Constraints and Firms' Investment Activities

by

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A dissertation submitted in partial fulfillment for the degree of dr.oceon.

at

Norges Handelshøyskole

(The Norwegian School of Economics and Business Administration)

Preface

I would like to express my gratitude to my supervisor Professor Erling Steigum Jr.. This work would never been finished without his comments, encouragement, and support throughout the whole process. The importance of our informative and clarifying discussions cannot be understated. In addition, I would like to thank Professor Jan Erik Askildsen and Professor Fabio Schiantarelli, both for their co-authorship and for constructive criticism. Their detailed comments have been of great help in the completion of this thesis. I have also benefited from insightful critiques and suggestions on previous versions of the papers by my dissertation committee, Professor Fredrik Carlsen and Professor Eilev S. Jansen.

Most of the research for this thesis was carried out at the LOS Centre, and was completed at the Department of Economics, University of Bergen. Their support is gratefully acknowledged. In addition, I would like to thank the Department of Economics at Boston College, for hosting me as a research scholar for a year. I am also indebted to present and former colleagues at these institutions for keeping my spirits up through the research period, and for the social atmosphere. Finally, a few words of thanks are addressed to my family and to all my friends that had to put up with my asocial lifestyle, absentmindedness, and complaints about data, unpleasant coefficients, and estimators.

Bergen, February 1998

Øivind Anti Nilsen

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Chapter 1

Financing Constraints and Firms' Investment Activities: Introduction and Summary

Financing Constraints and Firms' Investment Activities

Introduction and Summary

by

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February 6, 1998

* I am grateful to Erling Steigum jr. and Eilev S. Jansen for comments on an earlier draft.

1. Introduction

Over the past decade there has been great interest in the possible links between financing constraints and firms' investment activities. In the majority of the studies in this area the focus has been on investment in fixed capital. However, other real decisions have also been analyzed, such as inventory investment, research and development investment, employment demand, and pricing behavior. In this dissertation, I empirically test the output market behavior, labor demand and fixed investment, and the possible role of credit constraints for Norwegian manufacturing firms in the period from 1978 to 1991.

The volatility of investment expenditure is an important contributor to aggregate fluctuations. Therefore, understanding investment behavior and the link between investment and financial conditions have been important concerns for quite many years.[1] However, under certain conditions firms' real decisions are independent of their capital structure (Modigliani and Miller (1958)). The theorem describing this independence, known as the Modigliani-Miller (M-M) theorem, led to the neoclassical investment theory where capital market considerations were ignored (e.g. Hall and Jorgensen (1967)). The interest in the link between financial conditions and real decisions was renewed after the development of the asymmetric information literature. The fundamental insight comes from Akerlof's (1970) analysis of the "lemons" problem. According to Akerlof, asymmetric information between buyers and sellers about product quality may cause a market to malfunction. In capital markets where information is symmetric and where there is no other friction, internal and external finance (debt or equity) will be perfect substitutes. However, with asymmetric information present, firms may face "binding financing constraints", i.e. external finance (debt and equity) will be more costly than internal sources.[2] In this case, firms' investment activities will be dependent on financial conditions and access to credit markets.[3]

[1] For early empirical work, see Meyer and Kuh (1957). Fisher (1933) also argued that the poor performance of financial markets was one of the main causes of the Great Depression in the 1930s. Gertler (1988) gives a more detailed description of the evolution of the literature focusing on the links between the real and financial decisions.

[2] Other factors that may widen the wedge between the costs of external and internal finance are taxes and transaction costs.

[3] So far I have not made any distinction between capital markets and credit markets. The former includes equity and debt markets, while the latter only comprises debt markets.

Not only do frictions in the capital markets influence the investment pattern of firms. If there exists any form of irreversibility, non-convex costs attached to adjusting capital, or indivisibilities in the investment processes of firms, the adjustment path of the capital stock will be non-smooth. In standard investment models this fact is ignored. Thus, in addition to analyzing the importance of capital market imperfections for corporate investment, I will also assess the empirical importance of the two forms of departure from the standard model of investment (irreversibility and non-convexity).[4]

This chapter is organized as follows. In Section 2, the basic theory behind the cost differences between internal and external funds is given. Different investment models and their assumptions are discussed in Section 3, together with empirical evidence. Section 4 provides a description of the sample used in the other chapters of this dissertation. In the same section, a description of the Norwegian economy in the period from 1970 to 1992 is given. In Section 5, a brief overview of the research problems and the empirical findings in the following chapters are presented. Empirical findings in other studies using Norwegian firm level data are discussed in Section 6. Finally, Section 7 presents the conclusions.

2. Cost of Finance

According to the M-M theorem, the capital structure of a firm will be irrelevant for its investment decisions and other real activity decisions. It is important to note, however, that the underlying assumptions for the M-M theorem are violated in an imperfect capital market. Such violations are caused by taxes, transaction costs, asymmetric information, agency and incentive problems, and monitoring costs.[5] Consequently, there will be cost differences between external and internal finance, and different sources of funds will thus be imperfect substitutes.

First, transaction costs of issuing debt and equity, could be significant and could create a financing hierarchy. The task of issuing securities, stocks and bonds is typically performed by financial intermediaries who have sales and administration expenses. In addition, there are

[4] Hereafter I will refer to these departures from standard investment models as "technological factors".
[5] I do not assess the role of taxes since tax treatments are not considered in any of the studies in this dissertation.

legal, accounting, and printing costs. Oliner and Rudebusch (1992) refer to an American study where transaction costs consumed, on average, nearly 19 percent of the gross proceeds of small stock issues and about 14 percent of small debt issues (less than $2 million). However, transaction costs could vary with the size of the issue.

Second, information regarding a firm's investment projects, or demand shocks, will often be distributed asymmetrically between the firm and suppliers of capital. As a consequence, credit or capital markets can be described as "lemon markets," where problems of adverse selection will be present. Myers and Majluf (1984) apply the problems of information asymmetries to equity finance. In their models, external investors cannot distinguish between the quality of firms or investment projects. Every project is valued as a project of average quality. Therefore, new shareholders will demand a premium to purchase the firm's share, in order to offset losses incurred from financing lemons.[6]

Jensen and Meckling (1976) invoke a moral hazard argument to explain agency costs of debt. Managers and shareholders of a firm might have an incentive to choose risky projects as a result of their limited liability. If investments in risky projects turn out to be successful, only shareholders benefit from the increasing firm value. By contrast, if a risky project fails, bondholders bear the consequences of the failure. Since the incentives of managers and shareholders are also recognized by potential creditors in financial markets, an additional premium might be required to attract new creditors. Myers (1977) presents a model where a firm is partly debt-financed. Then managers may forgo some investment opportunities with positive net value since using debt increases the probability of bankruptcy.

Another important paper on the subject of information asymmetries in loans markets is Stiglitz and Weiss (1981). In their model, borrowers look similar to potential lenders; the riskiness of borrowers' projects is unobservable. A rise in the interest rate lowers the average borrower quality. For this reason, information asymmetries may lead to an equilibrium where the lender sets an interest rate that leaves an excess demand for credit, and where one group of borrowers will get loans while others will not, even though the borrowers look similar.

[6] Another form of agency costs occurs when managers spend excess cash flow on investment projects independent of their underlying expected profitability (Jensen (1986)). I will discuss the "free cash flow" hypothesis in Section 3.

Moreover, monitoring costs of profit outcomes and state verification may also lead to credit rationing (Williamson (1987)).

The quality of a firm's balance sheet, defined as the ratio between "collateralizeable" net worth and liabilities, is also important for access to external finance. Both monitoring costs and bankruptcy risk decrease with a strengthened balance sheet (Calomiris and Hubbard (1990)), and reduce the net gain from cheating lenders. This leads to a negative correlation between borrowers' financial "healthiness" and the premium to external funds. A negative shock in the economy leads to a decline in economic activity which in turn will worsens the financial position of the firms, thus amplifying the initial shock. This "financial accelerator" is described in Gertler and Hubbard (1988), Bernanke and Gertler (1989), and Bernanke, Gertler and Gilchrist (1995).

The transaction costs, information asymmetries, agency and incentive problems, and monitoring costs just outlined induce a wedge between internal and external funds. The availability of internal funds allows firms to undertake investment projects without resorting to more costly external financing. Thus, the investment expenditure and activity of a constrained firm will be sensitive to changes in their cash flow.

3. Tests of financial constraints in investment models

This section focuses on models that go beyond the assumption of homogeneous firms with regard to access to external finance. The increased availability of micro data sets allows the researchers to discriminate between various types of firms for which financial constraints are more important. The *a priori* classification of firms is based on observables indicating the likelihood that they will suffer from any form of capital or credit constraint. Several sample splits have been used; dividend, size, maturity, debt ratio, ownership, association with banks or industry groups, and bond rating.[7]

[7] Hubbard (1995), Schiantarelli (1996) and Fazzari, Hubbard and Petersen (1996) discuss possible problems of splitting firms into different groups according to their likelihood of facing information and incentive problems. In chapter 5 of the dissertation, a discussion of appropriate split criteria for the sample used is given.

Most of the models used in current empirical investment research have been developed under the assumption of perfect capital markets. The existence of capital market imperfections is incorporated in the empirical models by including regressors which are proxies for the availability of internal funds and /or firms' net worth. The most general form of the investment equation used in empirical panel data studies is:

$$\left(\frac{I}{K}\right)_{it} = f_i + \gamma_t + X_{it}\beta_1 + \beta_2\left(\frac{CF}{K}\right)_{it} + \varepsilon_{it} \tag{1}$$

where i denotes firm, and t denotes time. Investment in period t is denoted I, and K denotes the capital stock at time t. The vector X represents all determinants of investment, and CF/K represents the potential sensitivity of investment to fluctuations in the availability of internal funds. The firm effect, f_i, refers to all firm-specific factors that are fixed over time. The time effect, γ_t, captures factors common to all firms. A significant positive (CF/K)-coefficient, β_2, indicates sensitivity to internal funds due to the presence of credit constraints.[8] Heterogeneity in the dependence of internal funding for different groups firms (a significant larger β_2 coefficient for the assumed constrained firms) is taken as evidence of capital market imperfections or frictions.

Credit or capital constraints could also be incorporated in the maximization problem of the firm, for instance by including a non-negativity dividend restriction. This restriction prevents a firm from obtaining external funding through issuing new shares.[9] In its simplest form, the so called Euler equation of capital would be:[10]

$$-\frac{\partial D_t}{\partial I_t} = \frac{\partial D_t}{\partial K_t} - E_t\left[\frac{(1+\lambda_{t+1})/(1+\lambda_t)}{1+r_{t+1}}(1-\delta)\frac{\partial D_{t+1}}{\partial I_{t+1}}\right] \tag{2}$$

where D_t is the net cash flow or dividends in period t, E_t is the conditional expectation operator, λ_t is the non-negativity multiplier of dividend, and δ is the depreciation rate of

[8] I will return to alternative explanations of why investment and cash flow are correlated at a later point.

[9] A firm-specific debt ceiling $\overline{B_t}$ could also be included to restrict firms' access to borrowing.

[10] See the appendix for details.

capital. Equation (2) equates the cost of investing today with the marginal product of capital and the costs of postponing investment until the next period. If the dividend constraint is not binding, the non-negativity multiplier of dividend, λ_t, is zero. From equation (2), we get the result that financially constrained firms, for which $(1+\lambda_{t+1})/(1+\lambda_t) > 1$, behave as if they have a higher discount rate, i.e. there is a wedge between the marginal cost of investment today relative to investing in the next period.

One approach in testing for the existence of external finance constraints, using the methodology specified in equation (2), is to estimate the model separately for the different groups of firms. If λ_t is set equal to zero, the model will be misspecified for the assumed constrained firms, and the *goodness of fit* will be different for the constrained and unconstrained groups of firms. Another approach is to parameterize the multiplier λ_t with some variables that indicate the probability of a firm's financial distress. Finding the variables used for parameterizing to be significant is taken as evidence for the existence of capital market frictions.

Before I comment on existent empirical findings on investment and the importance of financial constraints, I will briefly discuss the two most used investment models and the assumptions underlying them. The two models are the *q* model and the Euler equation approach.[11]

The basic idea behind the *q* model is that a value maximizing firms should invest in additional units of fixed capital as long as the market value of the firm relative to the replacement value of its existing capital stock exceeds unity (Tobin (1969)). The *q* variable is used as a proxy for investment opportunities. However, marginal *q* is not measurable. Empirical studies substitute average *q*, the ratio of firm value to replacement cost of investment, for marginal *q* by hoping that average *q* still contains some information about the firm's future prospects.

[11] A more detailed description of these two approaches applied to panel data is given in Blundell, Bond and Meghir (1992). However, this description does not discuss any misspesification due to cost differences between different sources of finance. This topic is discussed in detail in Hubbard (1995) and Schiantarelli (1996). See Chirinko (1993) for a critical review of the literature on business fixed investments and the implications for public policy.

$$\left(\frac{I}{K}\right)_{it} = f_i + \gamma_t + \beta \cdot q_{it} + \varepsilon_{it} \tag{3}$$

According to Hayashi (1982) the substitution of average q for marginal q can be justified only under three conditions: perfect competition, perfect capital markets and constant returns to scale technology in production. Thus, all empirical q studies inherently suffer from the discrepancy between the two measures of q if these conditions are not fully satisfied. To control for possible capital market imperfections (i.e. credit constraints), an additional regressor, measuring the availability of internal resources, is included in the model. Then we end up with the following model:

$$\left(\frac{I}{K}\right)_{it} = f_i + \gamma_t + \beta_1 \cdot q_{it} + \beta_2 \left(\frac{CF}{K}\right)_{it} + \varepsilon_{it} \tag{4}$$

Fazzari, Hubbard and Petersen (1988), a study often referred to as the parent of all papers in this literature, used the model described in equation (4). They split their sample of American manufacturing firms according to the firms' dividend behavior. Firms with a ratio of dividends to income less than 0.1 for at least 10 out of 15 years are classified as constrained. They end up with 49 out of 422 firms in their group of constrained firms. The idea behind using the dividend behavior as a split criterion is based on the assumption that if the wedge between the costs of external and internal finance is significant, firms have to rely on the latter form of financing. The constrained firms pay low dividends to retain low-cost internal funds for financing investment projects. Holding the investment opportunities constant, they find a stronger investment-cash flow correlation for the firms that are more likely to be constrained.[12]

The findings of Fazzari, Hubbard and Petersen (1988) have been confirmed and corroborated in other studies. Some of the best known studies will be commented on briefly. A more complete overview of findings based on a data set from other countries, other split criteria, and other variations over this topic is found in Hubbard (1995), and Schiantarelli (1996).

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[12] With reference to equation 4, this means that the cash flow coefficient is larger and more significant for the assumed constrained group of firms relative to the unconstrained firms.

Belonging to some kind of business group, bank, or financial institution may reduce the information asymmetries, thus reducing transaction and asymmetric information costs. Based on data of Japanese manufacturing firms listed on the Tokyo Stock Exchange, Hoshi, Kashyap, and Scharfstein (1990) use relation to *keiretsu* groups as split criterion. Using a q model, they find that the estimated coefficients of the liquidity variables, cash flow and short-term securities, are much larger for the independent firms than for the firms belonging to a *keiretsu*. In another study, Hoshi, Kashyap, and Scharfstein (1991), they find that for firms that have loosened their ties to group banks, the effect of liquidity on investment increased significantly.

Also the study of Devereux and Schiantarelli (1990), using a sample 720 manufacturing firms in U.K., supports the hypothesis that internal finance affects firms' investment. However, their findings are ambiguous. A "standard" assumption is that the access to external funding is positively correlated with the size of the firm. Larger firms are relatively better known, and have cost advantages over small firms in financial markets. Devereux and Schiantarelli find that cash flow plays a more important role for larger firms, and they indicate that this is due to agency costs: the ownership structure in larger firms is more diverse, which tends to increase agency costs.

Oliner and Rudebush (1992) try to reveal whether it is the existence of asymmetric information, agency costs, or transaction costs which is responsible for the financing hierarchy.[13] Using a panel of 120 U.S. firms, the authors find a sensitivity of investment to cash flow for the firms expected to suffer from severe information asymmetries. Neither transaction costs nor agency costs were related to the financing hierarchy.

Fazarri and Petersen (1993) use much of the same sample as Fazzari, Hubbard and Petersen (1988). To meet the criticism that cash flow may simply proxy shifts in investment demand, they include working capital (current assets less current liabilities) in the investment equation. The authors state that if the firms have incentives to maintain stable fixed-investment, shocks in cash flow should have only a marginal effect on fixed-investment if firms adjust their

[13] The agency cost problems are caused by the fact that managers may have incentives to make decisions which are not in the interests of the firms' stockholders and bondholders (Jensen and Meckling (1976) and Jensen (1986)).

working-capital.[14] The empirical evidence supports the hypothesis that firms use working capital to smooth out shocks in cash flow. Including working capital in the regression model, i.e. controlling for the smoothening role of working capital, nearly doubles the cash flow coefficient estimates relative to cases when working capital is omitted. They find that working capital has a negative coefficient in the regression model. This finding supports their hypothesis that working capital competes with fixed investment for a limited pool of finance, and that working capital relaxes firms' financing constraints.

Whether or not the q model is appropriate for analyzing the existence of capital market frictions and credit constraints has been questioned. One of the assumptions made in the empirical q model is that the capital market is efficient, so that all relevant information about future profitability is captured by the average q. However, if q is a poor measure of investment opportunities, then the significance of the cash flow variable might be due to its role as a proxy for market fundamentals or investment opportunities rather than liquidity. Two papers, Morck, Shleifer and Vishny (1990) and Blanchard, Rhee and Summers (1993), look at this problem and find that cash flow based proxies for fundamentals play a bigger role than q in explaining investment. Another disadvantage of using the q model is that the model requires a proper estimate of the market value of the firm. Normally, only larger firms are traded on the stock market, smaller firms (which are more likely to face binding financial constraints) are not. Estimating a Euler equation representation of firms' investment decisions is a way to get around these problems.

Among the earliest studies of firms' fixed investment with costly external finance using a Euler equation model applied to panel data is Whited (1992). Using a panel of U.S. corporation data, Whited finds that the debt ratio (measured as market value of debt relative to the market value of the firm) and interest coverage (interest expenditure normalized with the sum of interest expenditure and cash flow) both have a negative effect on firms' investments. She also splits her sample on the basis of whether the firms have a bond rating or not. The hypothesis is that bond rated firms are less likely to be credit constrained, since they have undergone more investors' scrutiny. She finds that the wedge between the marginal

[14] I will come back to the discussion of whether firms have incentives to maintain smooth fixed investment levels at the end of this section.

cost of investment today relative to investing next period is more severe for the *a priori* constrained firms.

Also Bond and Meghir (1994) analyze the firms' investment and the hierarchy of finance using an Euler equation model. They assume that the interest rate prevailing for different firms is a linear function of debt to replacement value of capital. This assumption is motivated by the fact that the probability of bankruptcy rises relative to "collateralizeable" net worth. Their empirical findings, using a panel of U.K. corporations, support the hypothesis that interest rates are increasing in firms' debt-assets ratios. They also split their sample on the basis of whether firms pay dividends in two consecutive years or not. The motivation for this split criterion is the same as given in Fazzari, Hubbard and Petersen (1988). For the firms with zero dividend payments, investment displays excess sensitivity to the availability of internal funds.

Hubbard, Kashyap and Whited (1995) also use panel data for U.S. manufacturing firms. Again, dividend behavior is used as the split criterion. For firms with high dividend payouts, a simple neoclassical model with no financing constraints fits the data. For the other group of firms, the model is rejected. The authors also parameterize the wedge between the marginal cost of investment today relative to investing next period, with cash flow. For the assumed constrained firms (low-dividend firms), cash flow is statistically significant in explaining investment. Like Devereux and Schiantarelli (1990), Hubbard, Kashyap and Whited find that size of firms is not a proper split criterion. The authors state that this might reflect the possibility that larger firms have more severe agency problems. High levels of cash flow increase managers' cash spending on less profitable investment projects. This will cause a correlation between cash flow and investment which is not caused by credit constraints.

Finally, Hubbard and Kashyap (1992) should also be mentioned, even though they do not use a panel, but rather aggregate U.S. agriculture data. One of their findings is that farmers' net equity position contributes significantly to explaining investment. This gives support to the hypothesis that the collaterals are important to outside creditors. Second, the impact of declines in net worth on the discount factor is concentrated in periods in which farmers' net worth is low. These findings are consistent with the existence of asymmetric information in the capital markets.

The finding of a correlation between internal funds and investment, together with the evidence that the sensitivity of internal funding is greater for firms which are *a priori*, deemed more likely to be constrained, supports the hypothesis of capital market frictions. However, a positive correlation between investment and internal funds need not be construed as evidence in favor of financing constraints. Competing theories exist. Cash flow may serve as a proxy for the profitability of investment projects. By focusing on the *differences* in the sensitivity of constrained and unconstrained firms, researchers hope to get around this problem. However, it may still be true that the method used in controlling for investment opportunities (including q or using the marginal profit of capital) is poorer for the assumed constrained group of firms relative to the others. Consequently, also the *differences* in the estimates of the cash flow coefficients will be misinterpreted. Additionally, there is Jensen's (1986) "free cash flow" hypothesis. Jensen pointed out that the correlation between internal finance and investment spending is caused by managers' tendency to invest in less profitable investment projects when the cash flow is increasing. It is hard to discriminate between the capital-market imperfection hypothesis and the free cash flow hypothesis.[15]

Other strategies have been used to identify shifts in cash flow which are independent of shifts in investment opportunities. Lamont (1993) examines the investment decisions of oil firms that operate in both oil-related and non-oil-related activities. He finds a positive effect of oil-related cash flow on investment in non-oil business. This lends support to the capital-market frictions role of the positive investment - cash flow correlation. Cummins, Hassett and Hubbard (1994a) and Calomiris and Hubbard (1995) use tax reforms as natural experiments to isolate exogenous shocks to firms' marginal investment opportunities. The former find that firms that proxies for internal funds provide strong explanatory power for firms that may not have easy access to capital markets. In the latter study, the investment of high-surtax-margin

[15] Oliner and Rudebusch (1992) try to discriminate between the two competing hypotheses by choosing different sample split criteria. Kaplan and Zingales (1995) also try to discriminate by using additional information such as companies' financial statements and managerial statements of firms' availability of finance. They claim that the correlation between cash flow and investment is a result of the fact that cash flow proxies for investment opportunities. However, their study has been heavily criticized (see Hubbard (1995), Schiantarelli (1996), and Fazzari, Hubbard and Petersen (1996)). The most obvious shortcoming in Kaplan and Zingales is their use of subjective managerial statements. Managers have incentives to be optimistic about their own financial situation, since this is essential information to shareholders. Kaplan and Zingales' definition of financing constraints also ignores firms' incentives to maintain debt capacity by classifying firms with unused lines of credit or cash stocks as unconstrained.

firms was sensitive to shifts in cash flow, while other firms did not display such a sensitivity of investment to internal funds. These findings indicate that internal and external funds are imperfect substitutes.[16]

The empirical literature studying effects of capital-market imperfections has relied on many of the same assumptions used in the neoclassical model. One of these assumptions is that there are convex costs attached to adjusting capital, in addition to direct investment costs. These convex adjustment costs give the firm an incentive to smooth investment over time. Another implicit assumption in the investment models is that investments are reversible. This implies that the disposal of used capital is possible, and that the price of fixed capital is the same, regardless of whether a firm chooses to purchase or sell the capital at a given point in time. In addition, the standard investment models neglect the possibility that investment projects may be indivisible, so that investment can only be changed in discrete increments.

Adjustment costs may be non-convex (see Rothschild (1971)). Furthermore, some degree of irreversibility seems to be a more realistic description of the conditions firms meet in the real world.[17] In inefficient secondary markets for capital goods, disposal of fixed capital is impossible or very costly. This inefficiency is caused by the fact that capital is firm or industry-specific. Furthermore, in a competitive industry investing in excess capacity must be looked upon as a sunk cost, since the value of the capital is the same for all plants in the industry. Finally, strategic considerations make it imperative to invest immediately to prevent the entry of a potential competitor, or to utilize a time-limited opening in a potential market. With the existence of irreversibilities, non-convexities and indivisibilities, the adjustment path of the capital stock will be non-smooth, in the sense that one may observe zero investment periods and/or lumpy adjustment, with investment activity taking the form of large adjustments concentrated in a few episodes. In addition, the existence of capital market imperfections and credit restrictions may force firms to build up internal funds sufficient to finance investment

[16] Blanchard, Lopez and Shleifer (1994) use lawsuits in which firms receive significant amounts of money to analyze whether such cash windfalls induce increased investment expenditure. For their sample, they do not find such a pattern. The dividend payout did not increase after the cash windfall either. For their sample they find the agency cost hypothesis, where managers act in their own interest, to be the most obvious explanation of firms' financing and investment decisions.

[17] See Dixit and Pindyck (1994) for an overview of models in which investments are irreversible and uncertainty about future demand and prices is present.

projects. Consequently, both technological factors and capital market imperfections give the firms incentives to have an investment pattern characterized by zeroes and lumps.

4. The Norwegian Economy with a Focus on the Manufacturing Industry

In the first part of this section, a short description of the micro data sample used in the rest of the dissertation is given. As a means of getting a broader picture of the impulses behind, and the performance of units in the available micro data set, I will also discuss general economic conditions and business cycles in the Norwegian economy. An analysis of the financial structure and profitability of the manufacturing industry, as well as the supply of loans and subsidies, is also given. A discussion of industry sector adjustments during the 1970s and 1980s completes this section.

4.1 Micro-sample Description

The empirical work in this dissertation is based on a large set of unbalanced data from Norwegian plants and firms within the manufacturing industry for the 1978-1991 period. The data are collected by Statistics Norway (The Central Bureau of Statistics of Norway). Income statement and balance sheet information is drawn from Statistics of Accounts for all firms with more than 50 employees.[18] For all firms included in Statistics Norway's Statistics of Accounts, plant level information regarding production, production costs, investment and capital stock is available from the Manufacturing Statistics. All data are annual.

Firms in which the central or local government owns more than 50 percent of the equity have been excluded from the sample. This decision was motivated by the fact that the government-owned firms may depart from the underlying assumption that managers' objective is to maximize the value of the firm.[19]

[18] In 1991 Statistics Norway changed their sampling routines, which implied that no new small firms (fewer than 100 employees) were added to the sample.
[19] These firms were excluded only from the micro sample only and not from the statistics in Sections 4.2-4.5.

At the risk of anticipating the later findings, we should be aware that firms in the micro sample are relatively large in the Norwegian manufacturing industry and their access to credit may therefore be relatively easy.[20] However, even if we find some form of financing constraints for the firms in the micro sample, the constraints may be even more evident for smaller firms which are left out.

4.2 The Norwegian Economy from 1970 to 1992: General Economic Conditions

In the period after the second world war, the Norwegian economy was characterized by minor cyclical fluctuations and steady growth. This pattern prevailed until the 1970s, after which growing instability in the world economy contributed to inflation and unemployment in the OECD countries. At the same time, oil production in the North Sea became considerably more important to the Norwegian economy. The growth rates of gross domestic product (GDP) for mainland Norway (i.e. excluding ocean transport and the petroleum sector) and OECD-Europe are given in Figure 1. From the figure we see that mainland Norway was not adversely affected by the oil price shocks in 1973-4 (OPEC I) and in 1979-80 (OPEC II) as OECD-Europe was. Nevertheless, the international recession following OPEC II influenced the Norwegian economy to some extent, especially the import-oriented industries. A unique Norwegian upturn started in 1983, and the growth in GDP was larger here than in the rest of the OECD until 1987. The liberalization of Norwegian capital markets stimulated private consumption and investment. In the deregulation period consumers and companies were able to obtain credit with hardly any security.[21]

Several factors accounted for the recession, which was characterized by reduced private consumption and investments, from 1988. The authorities had revised the economic policy in a more restrictive direction from 1986. The private sector consolidated its financial position due to high interest rates and a tax regime which no longer favored lending. Finally, over-investment in the mid-80s, together with a substantial drop in real-estate prices in the

[20] Figures from Statistics Norway's Manufacturing Statistics reveal that approximately 85 percent of firms have fewer than 50 employees.

[21] Figures (see NOU 1989:1) show that average real lending to trade and industry increased by 9.9 percent annually in the 1984-1987 period. The sector 'Financing, real estate and business services' had the largest growth in this period (26.7 percent annual growth rate). Also, 'Construction' and 'Other services' showed growth above average growth (16.3 and 16.1 percent, respectively).

following period, led to an increase in the number of bankruptcies. This, in turn, was an important factor behind the Norwegian banking crises in the late 1980s and the early 1990s.

Investment in fixed capital is given in Figure 2, showing large fluctuations in the late 1970s and throughout the '80s. In the Figure, fixed investment is disaggregated into investment in 'Manufacturing', 'Oil activity', 'Government services', and 'Other industries'. The single line in the figure gives investment for mainland Norway. The importance of 'Oil activity' increases dramatically throughout the period; it represents less than 2 percent of the total investment in 1970, and as much as 32 percent in 1992. We also see that the fluctuations are largely due to variations in 'Oil activity'. However, in the period from 1986 to 1988, there are 'Other industries' and 'Government services' that appear to generate the huge fluctuations in aggregate investment.

The rate of inflation, as measured by the consumer price index, fluctuated considerably from 1970 to 1992 (Figure 3). Early in the period inflation was high: more than 7 percent annually from 1972-1978. In this period labor costs increased significantly, and this was probably caused by the oil-price shock in 1973-4 and increased aggregate demand in the mid-'70s. High nominal wage increments affected competition negatively, especially for import-competing industries. From the second half of 1977, the authorities tried to slow down the growth in costs and prices to some extent by implementing more restrictive fiscal and monetary policies. To improve competitiveness, there was an 8 percent devaluation of the Norwegian Krone in 1978. The authorities also froze prices and wages from September 1978 throughout 1979. However, OPEC II and a tight labor market led to galloping inflation, as high as 13.8 percent in 1981. In contrast, the annual inflation rate decreased from 1981 until 1985, and when inflation began to increase again in 1986, high aggregate demand was responsible. The growth in wages and prices did not slow down again until the government regulated wage increases in 1988 and 1989. In 1992 inflation was as low as 2.3 percent and the nominal wage increase 3.2 percent.

Norway was member of the Bretton Woods system until 1971. After the breakdown of this system, the member countries of the European Economic Community (EEC) developed the

'Snake' in 1972.[22] In the same year Norway also linked the Norwegian Krone to the snake. Improvements in the Norwegian currency followed that of the Deutche Mark, and lasted until 1976. Then the first of several Norwegian devaluations took place.[23] These devaluations were caused by increased deficit on the trade balance. When the "European Monetary System" was established in 1978, Norway chose to stay out and instead used an individual basket of foreign currencies, which was meant to capture the importance of the USD for petroleum prices and the importance of the oil sector for the Norwegian economy. In 1990, Norway tied its currency to the European Currency Unit (ECU), but this change in foreign exchange policy did not lead to revaluation or devaluation. Since December 1991, Norway has had a floating rate of exchange, but the Norwegian Krone has been stable relative to the ECU. The development of the Norwegian exchange rate is shown in Figure 4. Here we see a revaluation from 1978 to 1986, caused by strong growth in costs and wages throughout this period.[24]

In 1970, 23.8 percent of the labor force was employed in the manufacturing industry. This share had fallen to 14.3 percent in 1991 (see Figure 5a). The number of persons employed was reduced from 390,000 in 1970 to 290,000 in 1991. A similar overall decline in manufacturing industry employment has also been witnessed in other industrialized countries. In the 1981-1983 period, employment in the manufacturing industry dropped significantly. In the booming period, 1984-1987, however, manufacturing employment rose again. This rise was halted by the recession starting in 1988, which induced many firms to shed excess labor. Employment in the oil industry (oil activities inclusive oil drilling) has not been very important relative to total Norwegian employment. Starting from zero in the late sixties, the number of employed persons was 16,400 in 1991 (approximately 1 percent of total employment). However, the Norwegian Directorate of Labour has calculated the number of employed persons to be 63,600 in 1991.[25] This figure includes employees in the manufacturing and maintenance of oil platforms and supply ships, pipeline transport and related activities, and suppliers of services to the basic oil industry.

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[22] The system was called 'Snake in the Tunnel' since the internal exchange rates between the EEC currencies were allowed to vary only within quite small limits, like the movements of a snake in a narrow tunnel.
[23] The last devaluation took place in 1986.
[24] More detailed information regarding Norwegian foreign exchange policy is given in NOU 1989:1 and Norges Bank Skriftserie (1995).
[25] This number comes from page 107, NOU 1992:26.

The importance of the oil industry for the Norwegian economy is also indicated in Figure 5b. In 1991, 31.8 percent of total Norwegian GDP came from this industry (117 billion krones, in 1980 prices). The share of GDP from the manufacturing industry dropped from 22.1 percent in 1970 to 12.4 in 1991.

4.3 The Norwegian Capital Market: From Regulation, through Liberalization and the Banking Crisis

The Norwegian authorities have, for most of the time since the second world war, used monetary policy and credit regulations as instruments for stabilizing aggregate demand.

One of the most important instruments in the authorities' control of the credit market was the regulation of domestic interest rates, which allowed them to be different from (lower than) the world interest rate. This was accomplished by a control of nominal interest rates charged by credit institutions.[26] Developments in interest rates are shown in Figure 6, which provides nominal and real interest rates (before tax), together with average interest rates for the manufacturing industry. As shown in the figure, the nominal interest rate increased in the 1973-1987 period. The significant jump seen in 1985 was caused by the removal of interest rate regulations that year. It is also evident that the real interest rate was negative in periods, and this was due to high inflation. From 1977 to 1979 inflation fell as a result of a price and wage freeze. When the freeze was lifted, the real interest rate dropped again. However, the real interest rate has increased steadily since 1981. In Figure 6 there are no tax-adjustments. It should be noted, however, that favorable tax-deductions on interest payments made the after-tax interest rate during the period even lower. If we focus on nominal interest rates in the manufacturing industry, calculated by dividing interest paid on the yearly average debt, we find them to be in the interval from 4 to 6 percent, with exceptions in 1988 and 1989.[27]

The low-interest-rate policy prior to 1986 resulted in an excess demand for credit. In response, the government regulated the credit supply by means of various reserve requirements, whereby banks were required to invest a large portion of their funds in

[26] In the Norwegian credit market there are several different lenders: commercial and savings banks, government lending institutions, credit and financial institutions and insurance companies, all of which serve the manufacturing industry.
[27] Source: Statistics of Accounts.

government bonds and treasury bills. Financial institutions access to foreign financial sources was also regulated. Finally, the private sector's foreign transactions were controlled by requiring a license for every new loan acquired abroad. To ensure credit to sectors and purposes prioritized by the authorities, governmental lending institutions and funds were established.[28] These institutions subsidized the industry with loans under favorable conditions, both with regard to interest rates and marginal mortgage requirements. The importance of these institutions' lending has been reduced during the 1980s, due to easier access to credit in the private credit market following liberalization.

In the 1970s new credit institutions were established, which were not subject to the same laws and regulations as the existing banks. Even though the laws were changed and regulations were broadened, the authorities found it difficult to keep up with the inventiveness in the gray credit market. The growth of the euromarket for Norwegian Krone also made it much harder to constrain the underlying market forces through quantitative credit controls. As a consequence, starting in the fall of 1983, the credit market was liberalized.

From the beginning of 1984 the supplementary reserve requirements for the banks were removed. Instead the authorities tried to control banks' lending indirectly by raising reserve requirements. The requirement that banks hold some of their assets in bonds was also removed in 1984. By the fall of 1985 the authorities no longer controlled interest rates charged by banks. Earlier, the interest rate had been regulated by means of "interest rate declarations" from the Minister of Finance (except for the period from January to September, 1978). The elimination of interest rate control was one of the factors that led to an average annual real increase in bank lending of 20 percent in 1984-1987.[29] Although deregulation mainly took place in 1984-1985, there was further liberalization in the late 1980s.[30]

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[28] Among the most important for the manufacturing industry were Industribanken (Norwegian Bank of Industry), Industrifondet (Government Industrial Fund), and Småbedriftsfondet (Government Small Business Fund) to serve the industry, and Distriktenes Utbyggingsfond (Regional Development Fund) to increase the geographical distribution of credit. All these merged into Statens Nærings-og Distriktsutbyggingsfond (Norwegian Industry and Regional Development Fund) in 1993.

[29] NOU 1992:30E, page 11.

[30] As part of the credit liberalization, banks and private financial institutions were allowed to issue bonds with maturity dates two years from the date issued in 1987. In 1990, the maturity was extended to three years. From December 1988 Norwegian joint-stock enterprises were allowed to borrow in foreign currency through a Norwegian bank. Finally, from 1989 foreigners were allowed to buy Norwegian bonds. Foreign exchange regulations was virtually ended with effect from July 1990. Also the Norwegian bond market was heavily regulated, but the regulations were removed in the deregulation period. Activity in the Norwegian stock market increased through the eighties, but was not been subject to regulation. Therefore, this market did not experience

The strong cyclical upturn in the Norwegian economy was followed by a recessionary period. The commercial banks as a group ran deficits in 1987, 1988, and 1990, and also the savings banks (as a group) ran a deficit in 1988 and 1990. Because of atypically high net interest revenues, there was an aggregate surplus in the banking sector in 1989. However, in 1989 the first Norwegian bank since the 1930's went bankrupt. The borrowing commitments of this bank were taken care of by the commercial banks' own guarantee fund (Forretningsbankenes Sikringsfond). In 1991 a governmental bank guarantee fund (Statens Banksikringsfond) was established, together with a governmental bank investment fund (Statens Bankinvesteringsfond). Using these two funds, the authorities recapitalized banks in 1991 and 1992. At the same time, they required that some of the recapitalized banks set their old equity at zero. About 80 percent of the banks' loss allocations have been related to loans to the industrial sector.[31]

4.4 Focus on the Manufacturing Industry

In this section the manufacturing industry as a group is analyzed. The analysis is based on published aggregated data from Statistics of Accounts. Relative to the previous sections, a more limited time interval is analyzed, i.e. the period from 1978-1991. The limitation of the time interval is twofold. First, there are changes in the construction of tables in the published material from Statistics of Accounts. Second, the focus is narrowed to the period for which the micro data set used in the rest of the dissertation cover.

Some remarks about the aggregate data in this part of the analysis are in order. Due to the changed sampling routines in Statistics Norway in 1991, there are some inconsistencies in the material revealed in Figures 8, 9, and 10. Also the number of companies which Tables 7-11, and 13 comprise are not identical for each year. Descriptions of the variable construction and sources used in Sections 4.4 - 4.5 are given in the appendix.

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the same deregulation as the rest of the capital market. Finally, capital controls to restrict the foreign transactions of the private sector were also subject to deregulation.

[31] A more detailed description of the Norwegian bank crisis can be found in (NOU 1992:30E) and Steigum (1992).

4.4.1 Financial structure and profitability

Due to capital market imperfections, external and internal financing will not be perfect substitutes. Differences in the taxes on dividends and capital gains will also influence the capital costs of different financial sources.[32] The Norwegian tax regime had, until 1992, made retained earnings the least expensive form of financing, while new equity was most expensive (see Berg (1992)). The tax regime was characterized by high taxes (50.8 percent of the profit), combined with several deduction possibilities, inequality of taxation between investments in financial assets and fixed assets, and distortions between different types of fixed assets. In addition, different types of ownership were treated differently. This led to a system where tax-motivated arrangements for each firm were rather profitable. The goal of the reform of 1992 was to reduce the distortion in the existing tax regime.

To get a better understanding of the development of funding and the capital structure, I have plotted the equity ratio (defined as equity normalized with total assets) in Figure 7.[33] The equity ratio has increased steadily through the sample period, from 15.4 percent in 1978 to 24.7 percent in 1991.[34] We know that equity could grow through retained profits or externally supplied equity. For the manufacturing industry, the increase in equity mainly takes place through profit from operations. This we could read out of Table 1, where the source of funds is given. From this table we see that new equity is the least important source of funds, less than 20 percent of the yearly funding, and most important in 1986. Variations in funds generated from new equity appear to be significant. In 1986 the increase in long term debt was also large. Table 1 also indicates that funds generated from operations are steadier relative to the two other sources. The revealed funding pattern is similar to funding patterns in other countries,[35] and is also consistent with the pecking-order financing hierarchy.[36]

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[32] This was the case in Norway before 1992 and will therefore also be evident during most of the sample period in this article.
[33] The equity ratio used in this paper is based on book values, i.e. the increased market value of a firm has no influence on this ratio.
[34] A more detailed analysis of the financial structure for the Norwegian manufacturing industry can be found in NOU 1995:16.
[35] See Fazzari, Hubbard and Petersen (1988, Table 1) for American manufacturing firms.
[36] See Myers (1984).

In Table 1 the application of funds is also found. Due to altered sampling routines in Statistics Norway from 1987, they are no longer able to split firms' investments in fixed assets into fixed capital investment, financial fixed assets and other fixed assets. Starting with fixed assets in total, we find (of course) much of the same pattern as we saw for investments in Figure 2. We see the investment boom in from 1984-1987. More mysterious is the large fixed asset investment in 1989, a year where there was a drop in total investments. This may be caused by investments in financial fixed assets, but we are not able to say for sure due to the sampling routines in Statistics Norway. In the 1980-1991 period we find increased investments in fixed capital, which is consistent with the picture in Figure 2. There are significant fluctuations in the change of working capital, with negative figures in the boom period. We also see that a reduction in working capital in 1989 is used to compensate for the large fixed asset investments that year.

Long-term debt is grouped into 'mortgage loans', 'bonds', 'payables to group companies' and 'other'. These figures are in shown in Figure 8.[37] Mortgage loans was relatively constant during the whole sample period, while the use of bonds increased from 1986. The latter trend could be due to the removal of quantitative regulations on bond issues for the industry that year.[38] There also seems to be some reduction of mortgage loans during the period in question. The large drop in long term loans from 1979 to 1981 is hard to explain. Long term debt (50 percent of conditional tax-free allocations included) as a percentage of total liabilities and equity dropped from 46.4 percent to 38.9 percent (1979 and 1981, respectively).

Firms may use short-term debt to offset possible reductions in internal financing during recessions. Gertler and Gilchrist (1994) find evidence from the manufacturing sector that the use of short-term debt drops at the beginning of a recession. A similar conclusion was reached by Perry and Shultze (1993). We can see some of the same pattern in our sample. Figure 9 shows that short-term debt increased during the credit liberalization period, and was reduced from 1987 to 1988. However, short-term debt increased again later, particularly from 1988 to 1989. This increase may have been due to the large fixed asset investments in that year. The composition of short-term debt has been rather constant. One exception is 1987,

[37] The figures in Figures 8, 9, and 19 and in Table 1 are all deflated with CPI.
[38] See NOU 1989:1, page 78.

when the use of financial short-term debt, i.e. bank overdrafts and building loans, was minimal.[39] It is difficult to tell why this happened. However, the nominal interest rate was very high this year and may explain some of this pattern.

The composition of current assets is found in Figure 10. Here I have split current assets into four categories. These are 'Cash, accounts', which is cash, and bank deposits; 'Trade credit' consisting of shares, receivables (except from group companies) and advances to suppliers; 'inventories'; and, finally, 'other'. Cash holdings appear to have grown since credit liberalization began, while 'trade credit' has remained fairly constant over this period. The most obvious change in current assets is that firms increased their inventories during the entire sample period. Firms may have wanted to keep their production at relatively constant levels. Such production smoothening may have been financed by a reduction of internal sources and increased debt. From Figure 10 we see that the amount of current assets was not reduced in the late 1980s. We also see that working capital (short term credit less short term debt) increased from 1987 to 1988 and stayed at the same level after this. This increase in the working capital is mainly due to reductions of other short-term debt that took place from 1986 to 1987.

Jaffee and Stiglitz (1990) mentioned that firms rationed by banks, or other external credit markets, may use trade credit instead. Looking at the trade debt in Figure 9, and trade credit in Figure 10 together, it is difficult to see any clear shifts in the use of trade credit during the sample period.

Investments in fixed capital were reduced in the late 1980s while inventories increased. A large amount of both theoretical and empirical analysis has concluded that internal finance may be crucial for investment both in fixed assets and in inventories.[40] If credit constraints are important, both investments in fixed assets and in inventory should move the same way. However, this does not seem to be the case for the manufacturing industry on an aggregate level. Carpenter, Fazzari and Petersen (1994) state that "...relatively liquid assets with low

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[39] Building loans are used to finance investment during the construction period and are repaid after this period. The loan is then normally turn into a mortgage loan.

[40] See Hubbard (1995) for an overview of the empirical research on investment and credit constraints in general. Carpenter, Fazzari and Petersen (1994) look at inventory investment and internal finance. A related analysis using Norwegian data was done by Vale (1996).

adjustment costs such as inventories should bear the brunt of temporary shocks to internal finance...." Accordingly, we would expect negative growth in inventories in the late '80s. The pattern seems to be opposite for our sample. One might thus ask whether these patterns indicate that credit constraints are not important to Norwegian firms in this latter period, or whether there are other forces leading to this behavior. At least it indicates that analysis based on micro data is necessary in order to get a better idea of what motivates investment behavior in the manufacturing industry.

To understand whether the strong upturn from 1983 to 1987 was triggered by conditions in the capital market, it may be useful to look at loans made to the manufacturing industry. Even though the evolution of the short- and long-term debt has been analyzed, the focus here is on loans from banks and credit institutions given to the manufacturing industry. The amount and yearly growth rate in loans are given in Figure 11.[41] For 1986 the annual real growth in loans to the manufacturing industry was negative. (The annual growth from 1983 to 1986 was -0.3 percent (NOU 1989:1, page 130)). Figures taken from Statistics of Accounts suggest an increase in long term debt of 22.0 percent from 1985 to 1986. Therefore, the increase of long-term debt is due to a significant growth in other liabilities, such as bearer bond loans.

Before we look at the profitability for the manufacturing sector, we need to look briefly at investment, based on figures from the National Accounts statistics. There are important differences between investment patterns, depending on whether the figures are based on the National Accounts or on the Statistics of Accounts. First, the National Accounts are based on investments made in all firms, the self-employed included. The Statistics of Accounts only includes firms with more than 50 employees.[42] Second, there are differences in the definition of investment (or gross fixed capital formation) in the National Accounts and the definition of investments used in Statistics of Accounts. Figures for the manufacturing sector in the National Accounts are not corrected for disposal of fixed assets, while the figures in Statistics of Accounts are.

[41] These numbers were taken from NOS Credit Market Statistics and deflated with CPI. For 1987 detailed figures are missing due to new reporting routines. Loans to the manufacturing sector this year were calculated by taking the average share (the share granted to this specific industry relative to the total amount of loans granted) in 1986 and 1988 (19.9 percent), and multiplying this average share by the total amount of loans granted in 1987.

[42] As already mentioned, the sampling routines in Statistics Norway were changed in 1991.

Here we concentrate on the annual investment growth for the aggregated manufacturing industry, based on figures from the National Accounts.[43] The investment figures are provided in Figure 12. The investment boom in the mid-1980s is immediately apparent. In 1988 the investment growth in the manufacturing industry was negative, though it became positive again in 1989. The annual growth from 1988 to 1989 was 8.6 percent, but this significant increase was mainly due to 'Paper and paper products' which accounted for more than 50 percent of the 8.6 percent investment increase in 1989.

Profitability is indicated in Figure 13. Both 1984 and 1985 were good in terms of profitability. In these years investment increased considerably, while (new) loans to the sector were moderate. The increased profitability was therefore used to finance the high level of investment. In 1986 investment increased even further, while profitability was reduced. This should increase the demand for credit, which the growth in long-term debt in Figure 11 shows. Increased investments, together with reduced profitability, could be an indication of easier access to credit. Throughout the period of credit market liberalization, the competition for borrowers was intensified. In this period it seems to have been fairly easy to get credit without collateral. When, in 1988, firms increased their profitability, the growth in loans was moderate, and investment was reduced, it is possible that firms had started to consolidate their positions. A similar picture applies to 1989. Profitability was lower in 1990 relative to 1989. From Figure 11 we see that the growth in loans based on figures from the Credit Market Statistics was negative in 1990, while the growth in long term debt (from Statistics of Accounts) was 2.7 percent. This is an indication that the investment increase in this year was funded by sources other than loans from financial institutions. Profitability in 1991 was at the same level as in 1990, while the investment growth again was negative. The growth in long-term debt was 5 percent, while loans to the manufacturing industry were reduced by 13 percent.

4.4.2 Subsidies

Subsidies to the manufacturing industry in Norway have been significant. Figures from the Statistics of Accounts indicate that subsidies as a share of operating profit have mainly varied

[43] Details on investments, according to the market orientation of the sectors, are given in the next section.

between 50 and 90 percent. When we see such large figures, we must keep in mind that much of the subsidies went to state/government owned companies. Also the shipbuilding industry was heavily subsidized, as it is in other countries. In Figure 14 (borrowed from the National Budget for 1995), subsidies to mining, manufacturing and private services are shown, divided into five groups. In the first group, we find 'Research and Development' together with the funding of sector-specific research centers. In group two we find several regional and urban subsidies, managed by local authorities. The subsidies managed by the previously mentioned government lending institutions and funds are found in the third group. Subsidies to the shipbuilding industry are placed in group four. Finally, group five is mainly comprised of subsidies given to government-owned companies, important for small rural communities. Figure 14 indicates that throughout the 1980s the manufacturing industry was significantly subsidized, primarily in an attempt by the authorities to reduce unemployment caused by stagnation in export-competing industries and to maintain population levels in rural areas.

4.5 Industry structure adjustments

The manufacturing industry is often split into three different sectors, depending on market orientation. These three sectors are sheltered (food and beverages, and printing), export-oriented (paper, industrial chemicals, petroleum refining, and basic metals), and import-competing (textiles, wood products, part of the chemical sector, and metal products). If we consider GDP for these three sectors, we find that the timing of the cycles is different (see Figure 15). The peaks in 1973, 1979, and 1987 are unique to the export-oriented sector, and the latter two relate to the devaluation in 1977 and 1986. The drop in GDP in the mid-1980s started as early as 1985 for the export-oriented sector, while it came one to two years later in the two other sectors. The sheltered manufacturing industry has shown the smoothest pattern, while export-oriented industries fluctuate the most.

In Figure 16 we find wages as a share of value added for the three different manufacturing sectors. First, the export-oriented industry is more capital intensive relative to the others. This sector also demonstrates the biggest fluctuations in the wage-value added ratio. Wages have been relatively high in the sheltered industries, but productivity has increased from 1980.

If we return to Figure 13, we find annual growth in investments for mainland Norway, the manufacturing industry, and the manufacturing industry spilt into sheltered, import-competing, and export-oriented industries. The fluctuations are significant, and the investment boom in the credit market liberalization period (1984-1987) is very clear. Similar to what we found for GDP, sheltered industries demonstrate the smoothest pattern. The figure also shows that investments in the export-oriented industry are the driving force behind the investment fluctuations for the aggregated manufacturing sector. Also unusual is the strong upturn in investments for the export-oriented industry in 1980. This significant investment growth may be due to improvement in the competitive conditions resulting from the government-induced price and wage freeze in 1978 and 1979, together with the devaluation of the Norwegian Krone in 1978. Investment growth is also very high for the export-oriented industries during the credit liberalization period.

The phasing-in of oil activity in the Norwegian economy crowded out export-oriented industries, especially the manufacturing industry, at the same time as there was an expansion of private and governmental services and other, more sheltered, sectors. Income from the oil industry facilitated expansionary fiscal policy to keep unemployment down, but at the same time rapid growth in aggregate demand resulted in a significant increase in wages. Increased costs contributed in turn to worsened competitive conditions for the export-competing industries. Of course, other impulses too, such as the world market prices of aluminum, and basic metals, influenced production and employment in a small open economy such as the Norwegian one. Frequent devaluations in the 1970's and 1980's were used as instruments to stabilize the Norwegian economy and to help the export-oriented industries. These instruments were used because of the relatively rigid wage-setting and the authorities' fiscal policy. The ultimate regime-shift in the foreign exchange policy, toward a fixed exchange rate policy, was a result of experiences from the earlier period. The positive effects of devaluations appear to be only temporary.

In order to slow down de-industrialization and the aggravation of the import-competing and export-oriented industries, and to maintain employment levels in the manufacturing industry, a regime characterized by significant subsidizing was developed in the 1970's. Many manufacturing companies are located in rural areas and are the corner-stones of small communities. The maintenance of population levels in rural districts has always been the primary goal of the Norwegian regional policy. Subsidizing has been one of the instruments used for this purpose.

4.6 Concluding remarks

Oil industry in Norway grew steadily in importance in the period from 1970 to 1992. The income generated from this industry made it possible to counteract the effect of the negative international economic shocks which impacted oil-importing countries. At the same time, relatively high aggregate demand resulted in substantial increases in nominal wages, which had a negative effect on competitiveness, especially for import-competing industries. The increasing oil-related activity has resulted in industry structure adjustments characterized by the aggravation of the import-competing and export-oriented industries, and the importance of the manufacturing industry has been reduced. The entire evolution of the Norwegian economy over the last twenty-five years may be seen as the effect of the Dutch Disease.[44] In this pattern, we also see the fairly heavy subsidization of the manufacturing industry.

The Norwegian capital market was heavily regulated until the beginning of the 1980s. The deregulation of the Norwegian capital markets in the '80s, and the ensuing banking crisis that began around the turn of the decade, were also important factors for the Norwegian economy. The real growth in loans from credit institutions and banks to the manufacturing industry in the deregulation period was marginal. Still, manufacturing industry seemed to increase its long term debt in this period, using sources other than loans from credit institutions. Nevertheless, the equity ratio of the manufacturing industry increased slowly during the 1980s.

5. Thesis Overview

In what follows, I give a brief overview of the rest of my dissertation where I analyze firms' output market behavior, labor demand, and investment in fixed capital. All of these various aspects of a firm's investment activities may be influenced by capital market imperfections.

[44] The term Dutch Disease refers to the adverse effects on the Dutch manufacturing industry caused by the natural gas discoveries in the 1960s. See, for example, Cordon (1984).

5.1 Markups, Business Cycles and Factor Markets: An Empirical Analysis

In this paper the cyclical variation of markups in Norwegian manufacturing industry is investigated. The analysis is based on a dynamic model of the firm. The stock of capital is assumed to be fixed, whereas labor may be costly adjustable. Credit availability is dependent on the firms' leverage, and there exists a debt ceiling for each firm. The product markets of finished goods are imperfectly competitive, enabling the firm to practice markup pricing. Markups and their variations are estimated separately for different industry sector groups. Business cycles are represented by sectoral variations in GDP.

Different assumptions can be made about interpretations of the shocks that give rise to price changes and markup variations. According to theory, the cyclical variation of price-cost margins may go in either direction over the business cycle. The model of Green and Porter (1984) provides arguments for procyclical prices and margins, while Rotemberg and Saloner (1986) is the classical theoretical reference to countercyclical fluctuations. Factor market imperfections will be crucial for the outcome. If labor adjustment costs or capital market imperfections are present, marginal costs will be increasing, and markups are more likely to vary countercyclically. In contrast, with a flexible labor market and a perfect credit market the markups are expected to be less countercyclical (or procyclical).

Most studies investigating markup fluctuations use sector level data. We argue that establishment level data will give more reliable markup estimates. This is a novel approach, since the only studies we are aware of using micro level data for analyzing markups are Klette (1993, 1994), Chirinko and Fazzari (1994), and Chevalier and Scharfstein (1994). Only the latter two papers analyze markup fluctuations.

The results do, indeed, reveal cyclicality in markups. Contrary to several American studies, we do not find evidence of countercyclicality in the markup variations. If existent, markups are procyclical. This is interesting, since the sectors studied are highly unionized. We find no evidence to suggest that the labor market behaves such as to give rise to sharply increasing marginal costs. The reason may be that the workers accept relatively stable real wages over the business cycle. They are unable to, or unwilling to, extract sufficiently additional rent during a boom. The labor adjustment costs are not of significant importance for firms when they make their optimal long term pricing and quantity decisions. Our results, to a large degree, support Nymoen (1991), who argues that this variation in real wages is not so much dependent on the labor market situation as on labor losing the battle of markups, since firms are able to set prices after wages are agreed on. The empirical evidence indicates that our way of handling the adjustment costs (with convex adjustment costs similar to those used in standard investment models) does not result in them being important.

Given the way we are modeling capital market frictions, we cannot find that they are important for the dynamic optimization of the plants. Together with the insignificant labor adjustment costs, this finding indicates that labor adjustment is less problematic for larger firms than those in our data set, due to better access to credit.

5.2 Capital Market Imperfections and Labor Demand

In this study I use Norwegian data to analyze the impact of financial factors on labor demand. With capital market imperfections, a firm's financial leverage and the availability of internal funds significantly influence real decisions. With no adjustment costs associated with hiring and firing employees, a firm would adjust its labor stock instantly in the face of sales or production shocks. Nevertheless, if adjustment costs are present, firms may want to keep employees even if production is decreasing. This labor-hoarding behavior needs funding. One could argue that compared to investment in fixed capital, investment in labor does not generate any collateral value. Therefore, credit constraints and capital market imperfections may also be important for labor demand, as well as for hiring and firing decisions.

The micro evidence given in the paper suggests that financial leverage has a negative effect on labor demand and that internal cash flow increases employment. These findings are consistent with the theory of capital market imperfections, pointing out that external and internal financial sources are not perfect substitutes. The impact of financial conditions varies over the cycles. However, the picture is ambiguous. Starting with the cash flow - capital ratio, its importance is found to vary over time, being most important in the end of the 1980s. The impact of the cash flow - capital ratio varies also, depending on whether there is a (sector specific) recession or not. However, the cash flow coefficients do not vary with the size of the firm. This fact could, of course, be explained by the nature of the sample, which includes relatively large firms only. It is also evident that the importance of cash flow does not differ between expanding, contracting plants, or plants with constant employment. This last finding contradicts the finding that the importance of cash flow varies with sector-specific demand fluctuations.

The debt to total assets ratio is found (in general) to have a negative effect on firms' demand for labor. Its importance is found to be stable over different time periods. In addition, the impact of debt ratio on labor demand does not vary over the business cycles. Finally, the results indicate, in contradiction to the theory of capital-market imperfections, that the debt-ratio has a positive effect on labor demand when plants are expanding. This finding suggests that using the debt ratio to measure the access to the capital market is not appropriate. High financial leverage rises the bankruptcy risk and therefore acts as a "warning sign" for potential creditors and investors. However, leverage may also act as an indicator of potential access to funds. These two effects would have opposite implications for the investment activities of the firms. Caution should be exercised when using the debt ratio as a proxy for access to the capital market.

5.3 Zeroes and Lumps in Investment: Empirical Evidence on Irreversibilities and Non-Convexities

The objective of this paper is to establish a few stylized facts about the pattern of capital adjustment, to discuss the implications of the empirical evidence for the shape of the adjustment cost function, and to consider the aggregate implications of the findings.

The standard model of investment is based on the assumption that there are convex costs attached to adjusting capital, in addition to direct investment costs. These adjustment costs are typically assumed to be zero at zero investment and to be symmetric around zero. In these circumstances, if investment projects are divisible, there are no "technological" reasons why one should observe frequent episodes of zero investment. Moreover, the firm has an incentive to smooth investment over time, in order to avoid paying increasing marginal adjustment costs. On the contrary, if investment is irreversible or indivisible, or when there are increasing returns on the adjustment cost technology (for instance, because there are fixed costs), the adjustment path of the capital stock will be non-smooth, in the sense that one may observe zeroes and lumps in firms' investment patterns.

The occurrence of zero investment episodes at the plant level is found to be a very important phenomenon both for equipment and buildings, particularly for the latter. Aggregating across different types of capital goods, or from plants up to firm, masks the intermittent nature of investment. Another feature at plant level is that investment is lumpy, with large expenditures concentrated in a relatively small number of periods. The degree of lumpiness is much smaller at the firm level. The overall evidence at the plant level is consistent with the existence of irreversibilities, non-convexities and indivisibilities.

Focusing on the size of the units, we find that small plants or firms are characterized by a much higher incidence of zero investment expenditure. The investment pattern of small plants is also lumpier than that for large plants. This can be explained by the existence of fixed costs that do not vary with a firm's size, and/or with the existence of indivisibilities. These differences are also consistent, in principle, with the existence of financial constraints, the severity of which is likely to be greater for smaller firms.

Finally, we estimate a discrete hazard model to determine the probability of having an episode of high investment, conditional on the length of the interval from the last high investment episode. The discrete time duration model that allows for firm specific fixed effects suggests that the probability of having an investment spike is highest in the period immediately following another spike. This is consistent with investment expenditures spanning more than one calendar year or with the presence of convex components in adjustment costs. However, in almost all cases the hazard then increases monotonically and significantly after that. This provides powerful evidence for the presence and importance of fixed components characterizing the adjustment costs technology.

When we allow the parameters of the hazard model to differ between small and large plants, we obtain the results that the hazard is increasing for both, after the first period. Moreover, the introduction of cash flow as an additional explanatory variable leads to the conclusion that the differential importance of financial constraints for small and large firms is not likely to be an explanation of the observed greater degree of lumpiness of investment for smaller units.

Finally, simulation results suggest that even in the presence of an upward-sloping hazard, changes over time in the cross-sectional distribution of the interval since the last high investment episode do not seem to help in explaining fluctuations in the aggregate frequency of investment spikes. The time pattern seems to be dominated by the effects that common macro shocks have even in the presence of a flat hazard. Thus, caution is needed in drawing aggregate conclusions from the importance of irreversibilities and non-convexities at the micro level.

5.4 Is there any credit rationing at all? Threshold estimation in an investment model

In this paper, a threshold regression technique is used to analyze whether the impact of financial constraints on fixed capital investment varies between firms with different access to external funding. By using the threshold regression technique we let the data itself determine whether a firm is financially constrained or not. Thus, we do not have to make *a priori* assumptions about the selected cutoff values of the sample-split variables.

The investment model used is based on the accelerator model with an additional cash flow term. There are two reasons why the accelerator model is chosen. Firstly, most other standard investment models are based on convex adjustment costs of capital. However, Nilsen and Schiantarelli (1997) provide evidence of non-convexities and indivisibilities in the capital adjustment process. By using the accelerator model we avoid a restrictive functional form of the adjustment costs function. Secondly, investment models based on market values of the firms, such as the q model, are not appropriate since we do not have access to such data.

The analysis is based on an unbalanced data set of Norwegian manufacturing industry firms for the period 1978-1990. The results suggest some effects of the availability of internal finance on investment when we split the sample according to the firms' size. The fact that these effects in most cases are larger for smaller firms is consistent with the theory in which information asymmetries lead to financial constraints on firms' investment spending. The results seem also to indicate that there are significant differences between various industries, differences that may be of great importance when analyzing the sensitivity of investment to internal liquidity. In addition, the results also indicate that the proportion of constrained firms move independently of the business cycles and of the deregulation of the Norwegian capital market.

However, all the results should be interpreted with some care. Firstly, the size variable may absorb other effects than cost differences between external and internal funding, such as technology and product market behavior. Secondly, when the debt-assets ratio is used as a split variable, we are not able to confirm the size-split findings. However, we point at difficulties in using the debt-assets ratio to discriminate between financially constrained and unconstrained firms. This is related to the fact that an increase in the debt-assets ratio may not only signal increased bankruptcy risk, but also improved debt-capacity. Additionally, since our measure of the debt-assets ratio is based on book values only, we believe the variable is less appropriate for our purpose. Other potential split variables are also discussed, but we do not find any other relevant split-variables in our sample. We also point at difficulties in interpreting the findings since the impact of the cash flow variable may be related to its role as a proxy for investment opportunities rather than to liquidity effects. In addition, we also discuss whether measurement problems are more important for assumedly constrained firms relative to the unconstrained, inducing a disproportionally steep cash flow coefficient for the group of constrained firms.

When we find the results to be a little ambiguous about the existence of credit constraints, these findings are in line with several other analyses on Norwegian data. These studies are discussed in the next section.

6. Studies of Norwegian Firms' Investment Activities and their Financial Conditions

There have been several recent studies on investment in fixed capital and inventories and the possible role of financing constraints. For example, Johansen (Chapter 2, 1995) analyzes the relationship between cash flow and fixed investment in single-plant and multi-plant manufacturing firms. Single-plant firms' investment seems to be more sensitive to cash flow than the investment of multi-plant firms. However, these differences disappear when size is controlled for. The findings in Johansen's analysis indicate that the significance of cash flow is due to other factors than financing constraints, such as investment opportunities. In

Johansen (Chapter 3, 1995) an Euler equation model of investment is estimated using data of manufacturing firms. The results indicate a positive relationship between a firm's marginal return to capital and its net debt ratio. Given that the debt ratio is negatively correlated with the access to external finance, Johansen's findings imply that firms with high debt ratios have higher costs of financing than other firms. However, the empirical evidence on capital market frictions is sensitive to the normalization.[45]

Inventory investments of Norwegian firms in 1992 (the year the banking crisis had reached peak) were analyzed by Vale (1996). Firms' unused lines of credit were found to have a partial positive influence on firms' inventory investment, while firms' debt to suppliers has a negative effect. These findings are consistent with the existence of capital market imperfections. In the same study, several other financial variables were tested, but found to be of no significant importance to firms' inventory investment. The size of the firms was one of the variables which proved to be of no importance for inventory investment.

Nilsen and Oguz (1995) used a q model approach, and find that cash flow has a positive effect on firms' fixed investment. The estimated cash flow coefficient was found to be significantly larger for firms with higher debt ratios relative to less indebted firms. Cummins, Hassett, and Hubbard (1994b) also used a q model approach for analyzing fixed investment, and they too found cash flow to have a positive and statistically significant effect on fixed investment.

Overall, the evidence on financing constraints is mixed. Finally, two surveys should be mentioned. A survey of 1,000 small Norwegian firms (Kvinge and Langeland (1995)) revealed that two thirds of the firms reported no problems in financing investments. In another survey among 153 larger firms (J-B International (1996)), the access to financial resources was found to have a very modest role for firms' development.[46]

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[45] Here *normalization* describes which variable is used as dependent variable.

[46] Managers may have incentives to paint an optimistic picture of the access to capital markets, since information regarding possible credit constraints may reduce the value of the firm and aggravate the access to external finance (debt or equity). Therefore, caution should be exercised when using such self-reports.

7. Conclusion

After analyzing the investment activities (in a broad sense) of Norwegian manufacturing firms, one question seems to remain: Is there any form of financing constraints for the firms in this study? The empirical findings in this study are ambiguous. For firms' output market behavior, credit constraints seem to have no importance. Moreover, when cash flow is introduced as an additional explanatory variable in explaining investment spikes for fixed capital, the variable is insignificant. The size of firms has been used in several other studies as a proxy for the access to external funding. Size is also important for the investment pattern of the firms in this study. However, it could also be that revealed size effects have nothing to do with financial constraints but rather differences in technologies and market power between small and large units.

Financial variables have an effect in explaining labor demand. The debt-to-assets ratio has a negative effect on labor demand, while the cash flow capital ratio has a positive effect. These findings are consistent with the theory of capital market imperfections and are similar to findings in other countries. Finding financial variables to be important for labor demand, and only of marginal importance for investment in fixed assets may seem contradictory. However, the background for this finding may be the collateral role of capital. Investing in labor gives no such collateralizable capital, while investing in equipment and buildings does.

One of the assumptions implicit in the models of firms' investment activities is that managers' objective is to maximize the value of the firms. This neglects possible agency problems between owners and managers. In addition, it may be the case that managers of smaller firms put less emphasis on financial planning when they make their investment decisions. These two explanations counteract the implications of imperfect capital markets, and may explain the modest role of financial conditions in parts of this analysis.

It may be argued that the data set applied in this study, with relatively large firms in a Norwegian setting, has marginal relevance for the question whether information asymmetries lead to financial constraints on firms' investment activities. Financing constraints induced by information asymmetries maybe more likely to affect smaller firms that were discarded from our sample. However, when some of our findings, which are consistent with the effects of financing constraints, appear in the chosen sample, such constraints may be even more evident among the firms left out. Thus, based on our findings we cannot reject the existence of credit constraints and that these constraints are important for firms' investments activities. However, the ambiguous role of size as indicator of access to external finance is similar to findings in other Norwegian studies and surveys. Therefore, our empirical evidence of only minor capital market imperfections in our sample should not be surprising.

Another important feature in this study has been the focus on misspecification in the standard investment models, which is related to irreversibility of investment and non-convexities in adjustment costs. The analysis reveals an investment pattern described by zeroes and lumps; a pattern that is consistent with the existence of such departures from the standard neoclassical model. Future research should consider investment models where irreversibilities, indivisibilities, and non-convexities in adjustment costs are incorporated. Additional research should also consider better ways of modeling investment opportunities, especially for smaller firms where market values do not exist, which eliminates the use of the q model. More emphasis should also be put on finding variables that are able to discriminate between financially constrained and unconstrained firms. Such variables should be able to distinguish between effects coming from differences in technologies and market power, and effects caused by differences in the access to external funding.

References

Akerlof, G. A., 1970, "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism", *Quarterly Journal of Economics* 84(3), August 1970, 488-500.

Berg, S. A., 1992, "Kapitalkostnader i Norge 1980-92", Penger og Kreditt 1992/1, 39-42 (in Norwegian).

Bernanke, B. S. and M. Gertler, 1989, "Agency Costs, Net Worth, and Business Fluctuations", *American Economic Review* 79, *14-31.*

Bernanke, B. S., M. Gertler and S. Gilchrist, 1995, "The Financial Accelerator and the Flight to Quality", *Review of Economics and Statistics.*

Blanchard, O., F. Lopez-de-Silanes and A. Shleifer, 1994, "What Do Firms Do with Cash Windfalls?", *Journal of Financial Economics* 36(3), December, 337-60.

Blanchard, O., C. Rhee and L. Summers, 1993, "The Stock Market, Profit, and Investment", *Quarterly Journal of Economics*, 108(1), 115-36.

Blundell, R., S. Bond, and C. Meghir, 1992, "Econometric Models of Company Investment", In *The Econometrics of Panel Data: Handbook of Theory and Applications*, edited by Laszlo Matyas and Patrick Sevestre, Kluwer Academic Publishers, The Netherlands.

Bond, S., and C. Meghir, 1994, "Dynamic Investment Models and the Firm's Financial Policy", *Review of Economic Studies*. 61, 197-222.

Calomiris , C. W., and R. G. Hubbard, 1990, "Firm Heterogeneity, Internal Finance, and 'Credit Rationing'", *Economic Journal*. 100, 90-104.

Calomiris , C. W., and R. G. Hubbard, 1995, "Internal Finance and Investment: Evidence from the Undistributed Profits Tax of 1936-37", *Journal of Business* 68(4), October, 443-482.

Carpenter, R., S. Fazzari, and B. Petersen, 1994, "Inventory Investment, Internal-Finance Fluctuations, and the Business Cycles", *Brookings Papers on Economic Activity 2.*

Chevalier J. A., and D. S. Scharfstein, 1994, "Capital Market Imperfections and Countercyclical Markups: Theory and Evidence", NBER Working Paper No. 4614.

Chirinko, R., 1993, "Business Fixed Investment Spending: Modeling Strategies, Empirical Results, and Policy Implications", *Journal of Economic Literature* 31(4), December, 1875-1911.

Chirinko, R. S., and S. M. Fazzari, 1994, "Economic Fluctuations, Market Power, and Returns to Scale: Evidence from Firm-Level Data", *Journal of Applied Econometrics 9*, 47-69.

Cordon, W. M., 1984, "Booming Sector and Dutch Disease Economics: Survey and Consolidation", *Oxford Economic Papers* 36, 359-380.

Cummins, J. G., K. A. Hassett, and R. G. Hubbard, 1994a, "A Reconsideration of Investment Behavior Using Tax Reforms as Natural Experiments", *Brookings Papers on Economic Activity*, 1-74.

Cummins, J. G., K. A. Hassett, and R. G. Hubbard, 1994b, "Using Tax Reforms to study Investment Decisions: An International study", mimeo, Colombia University.

Devereux, M. and F. Schiantarelli, 1990, "Investment, Financial Factors, and Cash Flow: Evidence from U.K. Panel Data", In *Asymmetric Information, Corporate Finance, and Investment*, edited by R. Glenn Hubbard, University of Chicago Press, Chicago.

Dixit, A. and R. S. Pindyck, 1994, *Investment Under Uncertainty*, Princeton University Press.

Fazzari, S. M., R. G. Hubbard, and B. C. Petersen, 1988, "Financing Constraints and Corporate Investment", *Brookings Papers on Economic Activity*, 1, 141-195.

Fazzari, S. M., and B. C. Petersen, 1993, "Working Capital and Fixed Investment: New Evidence on Financing Constraints". *Rand Journal of Economics* 24: 328-342.

Fazzari, S. M., R. G. Hubbard, and B. C. Petersen, 1996, "Financing Constraints and Corporate Investment: Response to Kaplan and Zingales". NBER Working Paper: 5462.

Fisher, I., 1933, "The Debt-Deflation Theory on Great Depressions", *Econometrica* 1, October, 337-357.

Gertler, M., 1988, "Financial Structure and Aggregate Economic Activity: An Overview.". *Journal of Money, Credit, and Banking* 20, 559-588.

Gertler, M. and S. Gilchrist, 1993, "The Role of Credit Market Imperfections in the Monetary Transmission Mechanism: Arguments and Evidence", *Scandinavian Journal of Economics 95* (1), 43-64.

Gertler, M. and S. Gilchrist, 1994, "Monetary Policy, Business Cycles and the Behavior of Small Manufacturing Firms", *Quarterly Journal of Economics* 109(2), 309-340.

Gertler, M. and R. G. Hubbard, 1988, "Financial Factors in Business Fluctuations", in *Financial Market Volatility: Causes, Consequences, and Policy.* Kansas City, MO: Federal Reserve Bank of Kansas City, 33-71.

Green E., and R. Porter, 1984, "Noncooperative Collusion under Imperfect Price Information", *Econometrica 52*, 87-100.

Hall, R. and D. Jorgensen, 1967, "Tax Policy and Investment Behavior", *American Economic Review* 67, June, 391-414.

Haltiwanger, J., and J.E. Harrington, 1991, "The Impact of Cyclical Demand Movements on Collusive Behavior", *The Rand Journal of Economics* 22, 89-106.

Hayashi, F., 1982, "Tobin's Marginal q and Average q: A Neoclassical Interpretation", *Econometrica* 50, 213-224.

Hoshi, T., A. Kashyap, and D. Scharfstein, 1990, "Bank Monitoring and Investment: Evidence from the Changing Structure of Japanese Corporate Banking Relationships", In *Asymmetric Information, Corporate Finance, and Investment,* edited by R. Glenn. Hubbard, University of Chicago Press, Chicago.

Hoshi, T., A. Kashyap, and D. Scharfstein, 1991, "Corporate Structure, Liquidity and Investment: Evidence from Japanese Industrial Groups", *Quarterly Journal of Economics,* 106 (February), 33-59.

Hubbard, R. G., 1995, "Capital-Market Imperfections and Investment", mimeo, Columbia University.

Hubbard, R. G. and A. Kashyap, 1992 "Internal Net Worth and the Investment Process: An Application to U.S. Agriculture", *Journal of Political Economy* 100(3), June, 506-34.

Hubbard, R. G., A. Kashyap and T. Whited, 1995, "International Finance and Firm Investment", *Journal of Money, Credit, and Banking* 27(3), August, 683-701.

J-B International, 1996, "J-B Documentation: Profile of Board and Management in Scandinavian Companies 1996", J-B International A/S, Copenhagen.

Jaffee, D. and J. Stiglitz, 1990, "Credit Rationing", In *Handbook of Monetary Economics*, editor B. Friedman and F. Hahn.

Jensen, M., 1986, "Agency Costs of Free Cash Flow, Corporate Finance, and Takeovers", *American Economic Review* 76(2), May, 323-29.

Jensen, M. and M. Meckling, 1976, "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure", *Journal of Financial Economics*; 3(4), Oct., 305-60.

Johansen, F., 1995, "Essays on Investment and Financing Constraints", PhD. thesis, Northwestern University, Illinois.

Kaplan, S. N. and L. Zingales, 1995, "Do Financing Constraints Explain Why Investment is Correlated With Cash Flow?", mimeo, University of Chicago.

Kashyap, A., J. Stein. and D. Wilcox, 1993, "Monetary Policy and Credit Conditions: Evidence from the Composition of External Finance", *The American Economic Review* 83: 78-98.

Klette, T.J., 1993, "Is Price Equal to Marginal Costs?", Discussion Paper No. 93, Research Department, Central Bureau of Statistics, Norway.

Klette, T.J., 1994, "Estimating Price-Cost Margins and Scale Economies from a Panel of Microdata", Discussion Paper No. 130, Research Department, Central Bureau of Statistics, Norway.

Kvinge T. and O. Langeland, 1995, "Smått, men ikke bare godt", FAFO rapport 178.

Lamont, O., 1993, "Cash flow and Investment: Evidence from Internal Capital Markets", mimeo, MIT.

Meyer, J. R and E. Kuh, 1957, *The Investment Decision*, Harvard University Press, Cambridge, USA.

Modigliani, F. and M. Miller, 1958, "The Cost of Capital, Corporation Finance and the Theory of Investment", *American Economic Review* 48, 261-297.

Morck, R., A. Shleifer, and R. W. Vishny. 1990, "The Stock Market and Investment: Is the Market a Sideshow?", *Brookings Papers on Economic Activity* 2, 157-202.

Myers, S. C., 1977, "Determinants of Corporate Borrowing", *Journal of Financial Economics* 5(2), Nov, 147-175.

Myers, S. C., 1984, "The Capital Structure Puzzle", *Journal of Finance* 39, 581-582.

Myers, S. and N. Majluf, 1984, "Corporate Financing and Investment Decisions when Firms have Information that Investors do not have", *Journal of Financial Economics* 13, 187-221.

Nilsen, Ø. A, and G. Oguz, 1995, "Financial Constraints, Capital Heterogeneity and Investment: A *q* model Approach using Norwegian Firm Level Data", LOS-Centre Working Paper 9534.

Norges Banks Skriftserie nr. 23, 1995, "Norske Finansmarkeder, Norsk Penge- og Valutapolitikk", editor B. Vale, Norges Bank, Oslo.

NOU 1989:1, 1989, "Penger og kreditt i en omstillingstid", (in Norwegian).

NOU 1992:26, 1992, "En nasjonal strategi for økt sysselsetting i 1990-årene", (in Norwegian).

NOU 1992:30E, 1992, "Report by the Commission on the Banking Crisis", The Royal Ministry of Finance and Customs, Oslo.

NOU 1995:16, 1995, "Fra sparing til egenkapital", (in Norwegian).

Nymoen, R., 1991, "Aggregate Modelling of Norwegian Unemployment and Wage-Price Inflation", chapter 6 in 'Empirical Modelling of Wage-Price Inflation and Employment Using Norwegian Quarterly Data', Norges Banks Skriftserie no. 18.

Oliner, S. and G. Rudebusch, 1992, "Sources of the Financing Hierarchy for Business Investment", *Review of Economics and Statistics* 74(4), November, 643-654.

Perry, G. and C. Schultze, 1993, "Was This Recession Different Are They All Different?", *Brookings Papers on Economic* Activity, 1:1993, 145-195.

Rotemberg J., and G. Saloner, 1986, "A Super Game Theoretic Model of Price Wars during Booms", *American Economic Review 77*, 390-407.

Rothschild, M., 1971, "On the costs of adjustment", *The Quarterly Journal of Economics* 85, November, 605-622.

Schiantarelli, F., 1996, "Financial Constraints and Investment: A Critical Review", mimeo, Boston College, 1996.

Steigum jr., E., 1992, "Financial Deregulation, Credit Boom and Banking Crisis: The Case of Norway", Discussion Paper 15/92, Norwegian School of Economics and Business Administration.

Stiglitz, J., and A. Weiss, 1981, "Credit Rationing in Markets with Imperfect Information", *American Economic Review 71*, 393-410.

St. meld. 1, 1994-1995, 1994, "Nasjonalbudsjettet", (in Norwegian).

Tobin, J., 1969, "General Equilibrium Approach to Monetary Theory", *Journal of Money, Credit, and Banking* 1(1), Feb. , 15-29.

Vale, B., 1996, "Firm's Inventory Investments, Financial Conditions and the Banking Crisis in Norway", *Working Paper 1994/4*, Norges Bank, Oslo.

Whited, T., 1992, "Debt, Liquidity Constraints, and Corporate Investment: Evidence from panel data", *The Journal of Finance* XLVII, 1425-1460.

Williamson, S.D., 1987, "Costly Monitoring, Loan Contracts, and Equilibrium Credit Rationing", *Quarterly Journal of Economics* 101, 135-145.

The Euler Equation Based Investment Model

We consider a firm whose objective is to maximize the expected present value of dividends D_{s+t}, given by

$$V_t = E_t \sum_{s=0}^{\infty} \beta_{t+s} D_{t+s} \tag{A1}$$

Here E_t denotes the conditional expectations operator, $\beta_{t+s} = \prod_{\tau=0}^{s} \frac{1}{1+r_{t+\tau}}$ is the discount factor between time t and $t+s$, and $r_{t+\tau}$ is the nominal discount rate between time $t+\tau -1$ and $t+\tau$. Dividends are defined as

$$D_t = p_t\left[F(K_t) - G(I_t, K_t)\right] - p_t^I I_t \tag{A2}$$

where

$F(.)$:	production function
$G(.)$:	adjustment cost function for capital
K_t:	capital stock
I_t:	investment
p_t:	output price
p_t^I:	price of capital goods

The firm maximizes (A1) subject to the following constraints:

$$D_t \geq 0 \tag{A3}$$
$$K_t = (1-\delta)\cdot K_{t-1} + I_t \tag{A4}$$

The first constraint is a dividend restriction which prevents a firm from external funding through new share issues. The restriction can loosely be interpreted as a premium on outside equity financing. The second restriction is the capital accumulation constraint.

The value function for the maximization problem is:

$$\begin{aligned} V_t(K_{t-1}) = \max_{K,I}(1+\lambda_t)\left[p_t\left[F(K_t) - G(K_t, I_t(K_t, K_{t-1}))\right] - p_t^I I_t(K_t, K_{t-1})\right] \\ + E_t\left[\frac{1}{1+r_{t+1}} V_{t+1}(K_t)\right] \end{aligned} \tag{A5}$$

where λ_t is the non-negativity multiplier of dividend. Combining the first order conditions for capital and investment, we get

$$\begin{aligned} (1+\lambda_t)\left[p_t\left(\frac{\partial F_t}{\partial K_t} - \frac{\partial G_t}{\partial K_t} - \frac{\partial G_t}{\partial I_t}\frac{\partial I_t}{\partial K_t}\right) - p_t^I \frac{\partial I_t}{\partial K_t}\right] \\ + E_t\left[\frac{(1+\lambda_{t+1})}{1+r_{t+1}}\left(p_{t+1}(-)\frac{\partial G_{t+1}}{\partial I_{t+1}}\frac{\partial I_{t+1}}{\partial K_t} - p_{t+1}^I \frac{\partial I_{t+1}}{\partial K_t}\right)\right] = 0 \end{aligned} \tag{A6}$$

Equation (A6) could be rearranged and written as

$$-\frac{\partial D_t}{\partial I_t}=\frac{\partial D_t}{\partial K_t}-E_t\left[\frac{(1+\lambda_{t+1})/(1+\lambda_t)}{1+r_{t+1}}(1-\delta)\frac{\partial D_{t+1}}{\partial I_{t+1}}\right] \tag{A7}$$

which is the equation (2) in Section 2 of this paper.

Data definitions and sources used in Sections 4.2-4.6, and in Figures 1-15 and Table 1

All the figures in Sections 4.2-4.6 are based on published material on aggregated data from Statistics of Accounts and National Accounts. Numbers in square brackets are codes from the Statistics of Accounts. These statistics are balance sheet figures for manufacturing industry companies with more than 50 employees. In 1991, no new small firms (fewer than 100 employees) were added in the sample due to new sampling routines used by Statistics Norway. The income statement and balance sheet used in Statistics of Accounts are found in the subsequent pages.

Average interest rates on debt: $\frac{\text{Interest paid }[2510+2520]_{\text{Accounts}}}{\text{Average liabilities }[5100+5200\ +\ 1/2\cdot 5300]_{\text{Accounts}}}$ Liabilities is book value of debt and 50 percent of Conditional tax-free allocations. Source: Statistics of Accounts.

Consumer price index (CPI). See Interest rate.

Current assets: Source: Statistics of Accounts. The current assets is split in: 'Cash, account' which is cash, and bank deposits; 'Trade credit' consist of shares, receivables (except from group companies) and advances to suppliers; 'inventories', and finally, 'other'.

Employment: Number of persons engaged. Employees and self-employed. Source: National Accounts.

Equity ratio: $\frac{\text{Equity (end of year) }[5400\ +\ 1/2\cdot 5300]_{\text{Accounts}}}{\text{Total assets (end of year) }[4500]_{\text{Accounts}}}$ Source: Statistics of Accounts.

Exchange rate index: Source: Norges Bank.

Gross domestic product (GDP): Sources: National Accounts. GDP OECD-Europe taken from OECD National Accounts.

Hourly earnings: Hourly earnings of male workers in manufacturing firms affiliated with the Confederation of Norwegian Business and Industry. Sources: Confederation of Norwegian Business and Industry and NOS Wage Statistics.

Interest rate on loans **and** ***Consumer price index***: Sources: Banking and Credit Statistics, Current Figures, and Norges Bank, Economic Bulletin.

Investment: Gross fixed capital formation. Source: National Accounts.

Loans from credit institutions and banks: Source: NOS Credit Market Statistics. These numbers are deflated with the consumer price index (CPI).

Long term debt: Source: Statistics of Accounts $[5200]_{\text{Accounts}}$. In the statistics long term debt is split into: Payables to group companies, Bearer bond loans, Mortgage loans, Liable loan-capital, and Other long-term liabilities.

Return on equity: $\frac{\text{Profit before extraord. items - taxes } [2400 + 2700 - 3300]_{\text{Accounts}}}{\text{Average equity } [5400 \ + \ 1/2 \cdot 5300]_{\text{Accounts}}}$ Equity is book value of equity and 50 percent of Conditional tax-free allocations. Source: Statistics of Accounts.

Return on fixed capital: Operating profit normalized with real capital. Source: National Accounts.

Return on total asset: $\frac{\text{Profit before extraord. items + interest paid } [2400 + 2700 + 2510 + 2520]_{\text{Accounts}}}{\text{Average total assets } [4500]_{\text{Accounts}}}$

Source: Statistics of Accounts.

Short term debt: Source: Statistics of Accounts. The short term debt is split into: 'Trade debt' which is accounts payable to suppliers, and notes payable; 'Financial short-term debt', consisting of bank overdraft and building loans; and 'Other short term debt'.

Source of funds: *Generated from operations*: Profit before year-end adjustments + ordinary and extraordinary deprecations + loss (-profit) on disposals of fixed assets - taxes and dividends. *Externally supplied equity*: Increase in equity and conditional tax-free allocations not accounted for in the income statement. *Increase in long-term liabilities*: Net increase in long-term liabilities (increase from Jan. 1 to Dec. 31) Source: Statistics of Accounts.

Subsidies: This information is given in the balance sheet. However, our Figure 14 was borrowed from the Norwegian National Budget for 1995 (St.meld. 1, 1994-1995). Source: Centre for Research in Economics and Business Administration (SNF).

Wage as share of value added: Source: Manufacturing Statistics

RESULTATREGNSKAP OG BALANSE PÅ ENGELSK. SAMMENHENG MED SKJEMA
INCOME STATEMENT AND BALANCE SHEET IN ENGLISH. REFERENCES TO THE QUESTIONNAIRE

Postnr. i skjema Item no. in the questionnaire	RESULTATREGNSKAP	INCOME STATEMENT
210	Driftsinntekter	Operating income
201	Salgsinntekter	Sales (goods and services)
202	- Offentlige avgifter	- Special government taxes (except VAT)
203	Offentlige tilskudd	Current government subsidies
204	Aktiverte egne investeringsarbeider	Own work capitalized
205	Leieinntekter, fast eiendom	Income from rent, real property
206	Provisjonsinntekter	Commission income
207	Andre driftsinntekter	Other operating income
230	Driftskostnader	Operating expenditure
211	Forbruk av innkjøpte varer	Cost of purchased goods
212	Lønninger mv.	Wages and salaries
214	Arbeidsgiveravgift til folketrygden	National insurance premium
215	Pensjonskostnader o.a. personalkostn.	Pension payments and indirect staff expenses
216	Frakt og spedisjon vedr. salget	Outgoing freight and forwarding costs
217	Husleie, tomteleie, lys og varme	Rent, lighting and heating
221	Provisjonskostnader	Commission charges
213+218+219+ 222+..+226	Diverse driftskostnader	Other operating expenses
227	Tap på fordringer	Losses on accounts receivable
228	Beholdn.endr. egentilvirkede varer	Changes in stocks of finished goods/work in process
229	Ordinære avskrivninger	Ordinary depreciation
240	Driftsresultat	Operating profit
250	Finansinntekter	Financial income
241	Utdeling på aksjer i datterselskaper	Dividends received from subsidiaries
242	Utdeling på andre aksjer og andeler	Dividends received from others
243	Renteinntekter fra konsernselskaper	Interest received from group companies
244	Andre renteinntekter	Interest received from others
245	Agio	Surplus on foreign exchange
246	Andre finansinntekter	Other financial income
260	Finanskostnader	Financial expenditure
251	Renter til konsernselskaper	Interest paid to group companies
252	Andre rentekostnader	Interest paid to others
253	Disagio	Loss on foreign exchange
254	Andre finanskostnader	Other financial expenses
270	Resultat av finansielle poster	Financial items, net
240+270	Resultat før ekstraordinære poster	Profit before extraordinary items
280	Ekstraordinære inntekter	Extraordinary income
271	Vinning ved avgang av anleggsmidler	Profit on disposals (sale etc.) of fixed assets
272	Offentlige tilskudd	Extraordinary government subsidies
273+326(+)	Andre ekstraordinære inntekter	Other extraordinary income
290	Ekstraordinære kostnader	Extraordinary expenditure
281	Tap ved avgang av anleggsmidler	Loss on disposals (sale etc.) of fixed assets
282	Nedskrivning av anleggsmidler	Extraordinary (not tax-conditioned) depreciation
284+326(-)	Andre ekstraordinære kostnader	Other extraordinary expenses
300	Resultat av ekstraordinære poster	Extraordinary items, net
310(+326)	Resultat før årsoppgjørsdisposisjoner	Profit before year-end adjustments
	Årsoppgjørsdisposisjoner	Year-end adjustments
311	Oppskrivning av anleggsmidler	Revaluation of fixed assets
312	Overført fra oppskrivningsfond	Transferred from revaluation fund
322	til oppskrivningsfond	to revaluation fund
323	Oppskrivn. til forhøy. aksjekapital	Revaluation used to writing up of share capital
320 (del part)	Overført fra distriktsutbyggingsfond	Transferred from regional development fund
320 (del)	salgsgevinster	profit on sale of fixed assets
320 (del)	kontraktsavskrivning	contract depreciation, fixed assets
320 (del)	konsolideringsfond	consolidation fund
320 (del)	øvrige skattefrie fond	other condit. tax-free allocations
330 (del)	til distriktsutbyggingsfond	to regional development fund
330 (del)	salgsgevinster	profit on sale of fixed assets
330 (del)	kontraktsavskrivning	contract depreciation, fixed assets
330 (del)	konsolideringsfond	consolidation fund
330 (del)	øvrige skattefrie fond	other condit. tax-free allocations
321	Ekstraordinære skatteavskrivninger	Extraordinary tax-conditioned depreciation
331	Økning nedskrivning varekontrakter	Increase in write-off on purchasing contracts
332	Økning lagerreserver	Increase in stock reserves
333	Skatt på formue og inntekt	Tax on property and income
340(-326)	Resultat av årsoppgjørsdisposisjoner	Year-end adjustments, net
350+370	Årsoverskudd	Annual profit
354+356-352	Avsatt til aksjekapital, reservefond	Transferred to share capital, legal reserve fund
353-351-355+ 370-554-555	Avsatt til fri egenkapital	Transferred to distributable equity
357+554+555	Utbytte o.l.	Proposed dividends etc.

Postnr. i skjema	BALANSE	BALANCE SHEET
	EIENDELER	**ASSETS**
401+..+415	Omløpsmidler	Current assets
401+402	Kasse, innskudd i bank og postgiro	Cash in hand, bank and giro account
403	Aksjer og andeler	Shares
404	Obligasjoner og andre verdipapirer	Bonds and other securities
405	Vekselfordringer	Notes receivable
406	Kundefordringer	Accounts receivable from customers
407	Kortsiktige fordringer konsernselsk.	Receivables from group companies
408+415	Andre kortsiktige fordringer	Other short-term receivables
409	Lager av råvarer og innkj. halvfabr.	Stock of raw materials, consumables
411	Lager av varer under tilvirkning	Work in process
412 a)	Lager av ferdigvarer, egentilvirkede	Stock of finished goods
412 b)	Lager av ferdigvarer, kjøpte	Stock of goods for resale
413	Forskudd til leverandører	Advances to suppliers
421+..+445	Anleggsmidler	Fixed assets
421	Aksjer og andeler i datterselskaper	Shares in subsidiaries
422	Andre aksjer og andeler	Other shares
423	Obligasjoner og andre verdipapirer	Bonds and other securities
424	Langsiktige fordringer konsernselsk.	Receivables from group companies
425+426	Lån til aksjonærer mv. og ansatte	Loans to shareholders etc. and employees
427+445	Andre langsiktige fordringer	Other long-term receivables
428	Forskudd til leverandører	Advances to suppliers
429	Patenter og liknende rettigheter	Patents and similar rights
431	Goodwill	Goodwill
432	Aktiverte kostnader	Capitalized expenditure
433	Skip og andre fartøyer	Ships
434	Andre transportmidler	Other means of transport
435	Maskiner, verktøy, inventar o.l.	Machinery and equipment
436	Bygninger og bygningsmessige anlegg	Buildings (excl. dwellings)
437	Anlegg under utførelse	Plant under construction
438+439	Grunnarealer	Land and other real property
441	Boliger (inkl. tomter)	Dwellings (incl. sites)
442	Krav på aksjeinnskudd	Unpaid share subscriptions
443	Egne aksjer	Treasury stock
450	Totalkapital	Total assets
	GJELD OG EGENKAPITAL	**LIABILITIES AND EQUITY**
501+..+516	Kortsiktig gjeld	Short-term liabilities
501	Leverandørgjeld	Accounts payable to suppliers
502	Vekselgjeld	Notes payable
503	Kassekreditt	Bank overdraft
504	Byggelån	Building loans
505+506+507	Skyldig skattetrekk og off. avgifter	Unpaid payroll taxes and indirect taxes
508+509	Påløpne lønninger mv. og renter	Accrued, not due wages, salaries and interest
511	Påløpne, ikke utliknede skatter	Accrued property and income taxes, not yet assessed
512	Forskudd fra kunder	Advances from customers
513	Avsatt til utbytte	Provisions for dividend
514	Garanti- og serviceforpliktelser	Guarantee and service commitments
515+516	Annen kortsiktig gjeld	Other short-term liabilities
521+..+526	Langsiktig gjeld	Long-term liabilities
521	Langsiktig gjeld til konsernselskap	Payables to group companies
522	Ihendehaverobligasjonslån	Bearer bond loans
523	Pantelån	Mortgage loans
524	Ansvarlig lånekapital	Liable loan-capital
525+526	Annen langsiktig gjeld	Other long-term liabilities
531+..+539	Betinget skattefrie avsetninger	Conditional tax-free allocations
532	Distriktsutbyggingsfond	Regional development fund
534	Salgsgevinster	Profit on sale of fixed assets
535	Kontraktsavskrivning	Contract depreciation, fixed assets
536	Nedskrevet på varekontrakter	Write-off on purchasing contracts
537	Lagerreserver	Stock reserves
538 a)	Anleggsreserver	Fixed assets tax reserves
539	Konsolideringsfond	Consolidation fund
531+533+ 538 b)	Øvrige skattefrie fond	Other conditional tax-free allocations
541+..+546	Egenkapital	Equity
541	Aksjekapital o.l.	Share capital and the like
542	Reservefond, tilbakeføringsfond	Legal reserve fund etc.
543	Oppskrivningsfond	Revaluation fund
544+546	Fri egenkapital	Distributable equity
550	Totalkapital	Total liabilities and equity

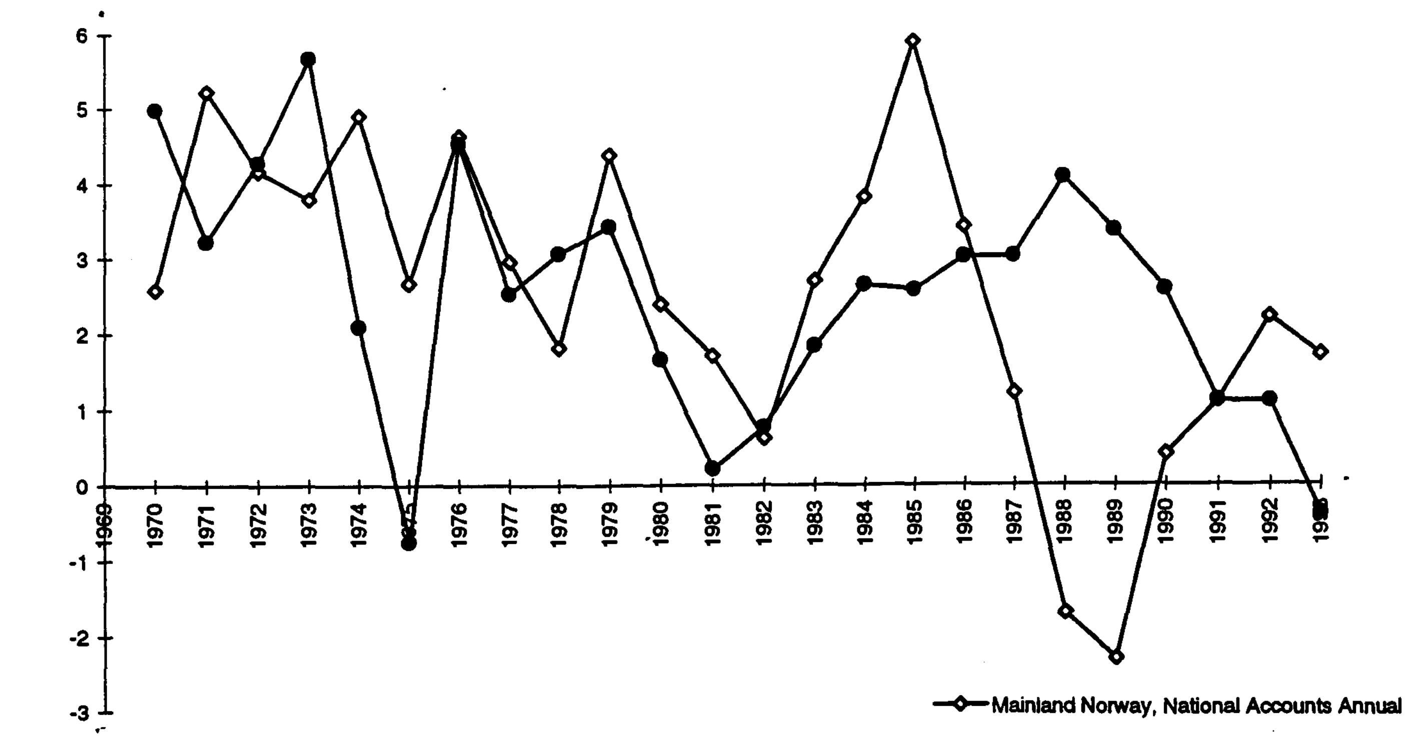

Figure 1: Gross Domestic Product, annual percentage change
Source: National Accounts and OECD National Accounts.

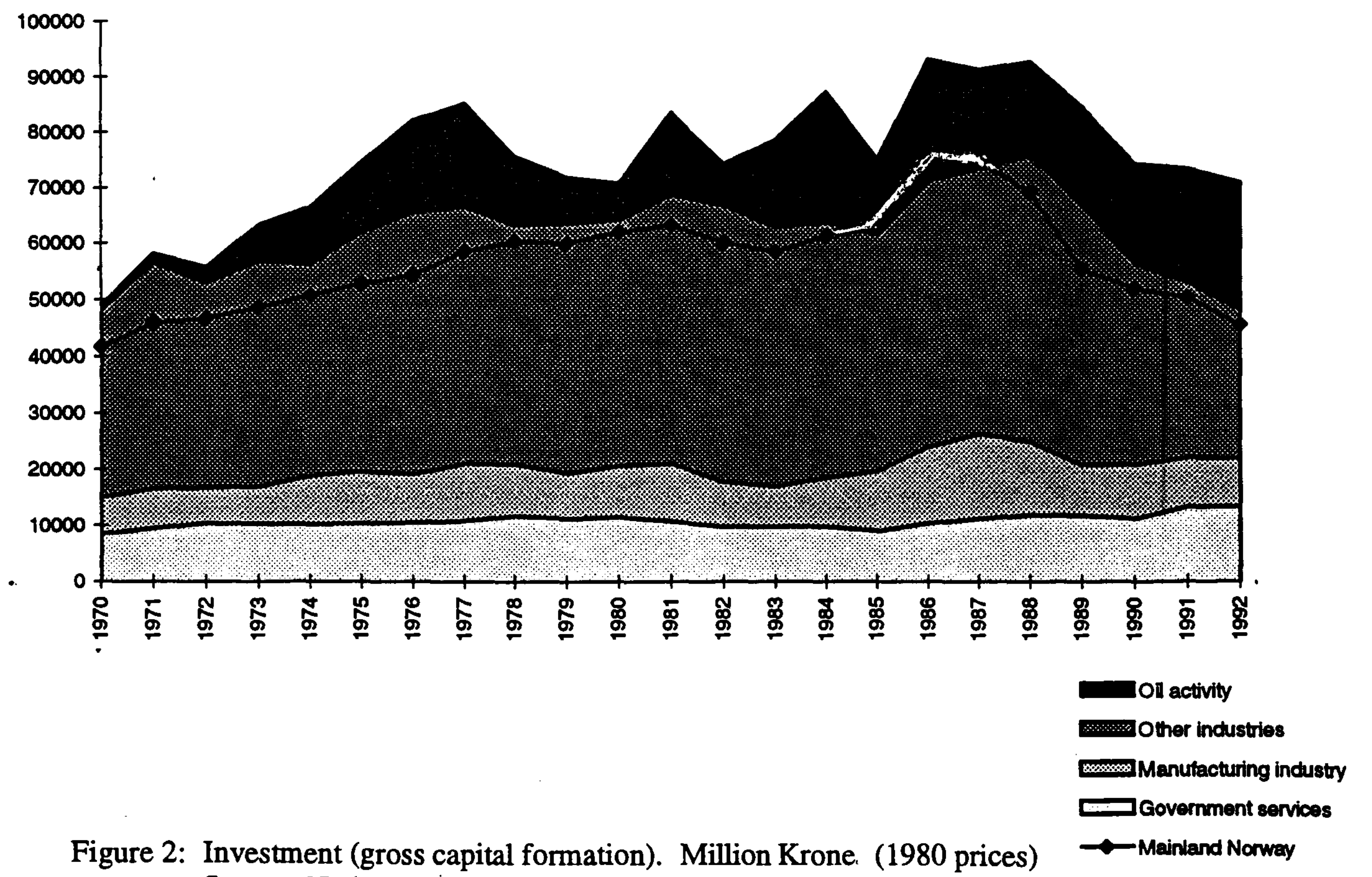

Figure 2: Investment (gross capital formation). Million Krone. (1980 prices)
Source: National Accounts

The shaded areas add up to aggregated investment in the Norwegian economy. The single line starting at 42000 is mainland Norway only, which is 'total' minus 'oil activity' and 'ocean transport'.

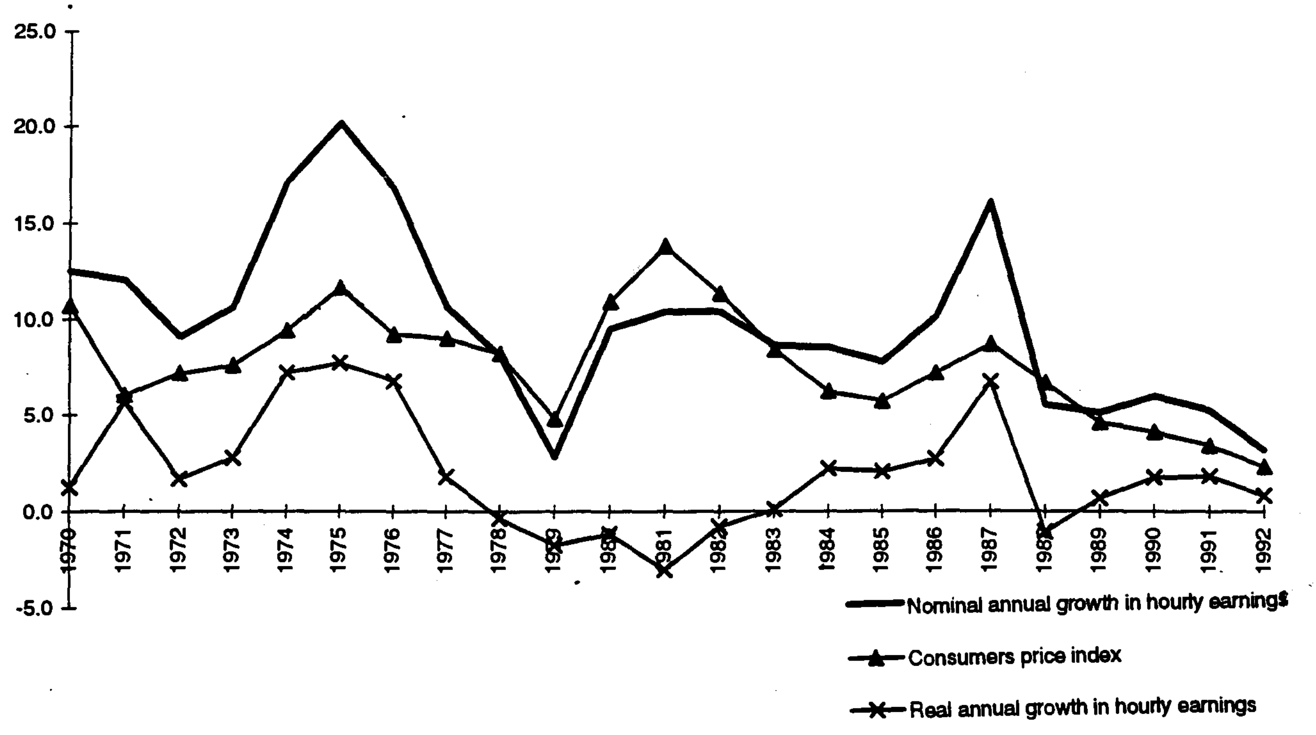

Figure 3: Annual Percentage Change in Hourly Earnings, and in the Consumer Prices Index. Sources: Confederation of Norwegian Business and Industry and NOS Wage Statistics.

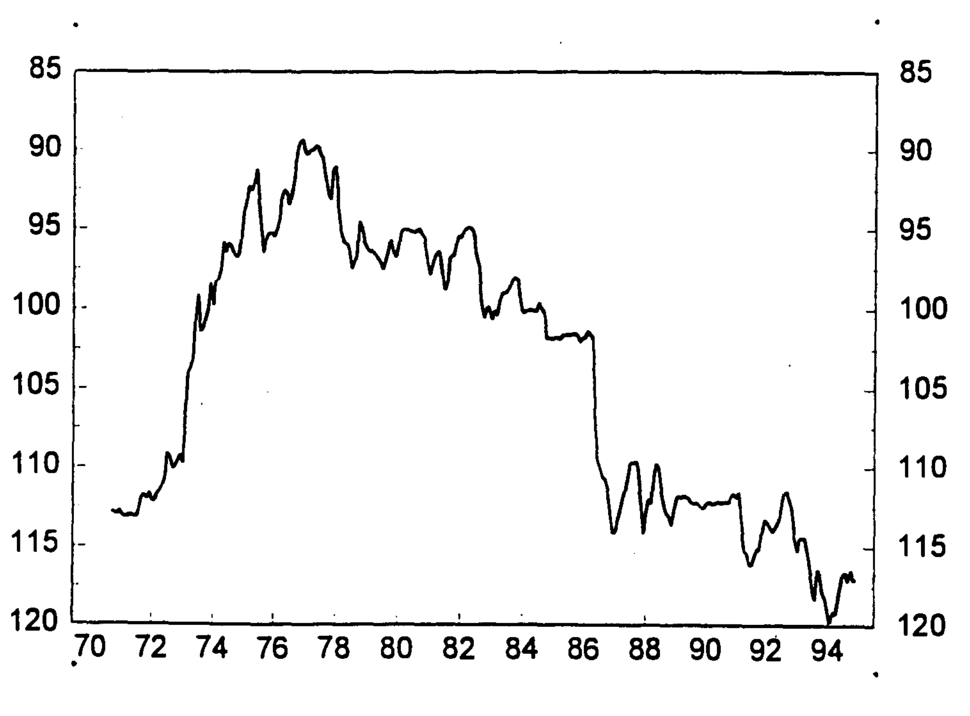

Figure 4: The Norwegian Exchange Rate.
Source : Norges Bank

The vertical axis is the Norwegian Krone relative to the basket used as the reference point until 1990. From 1990, the ECU has been used as reference.

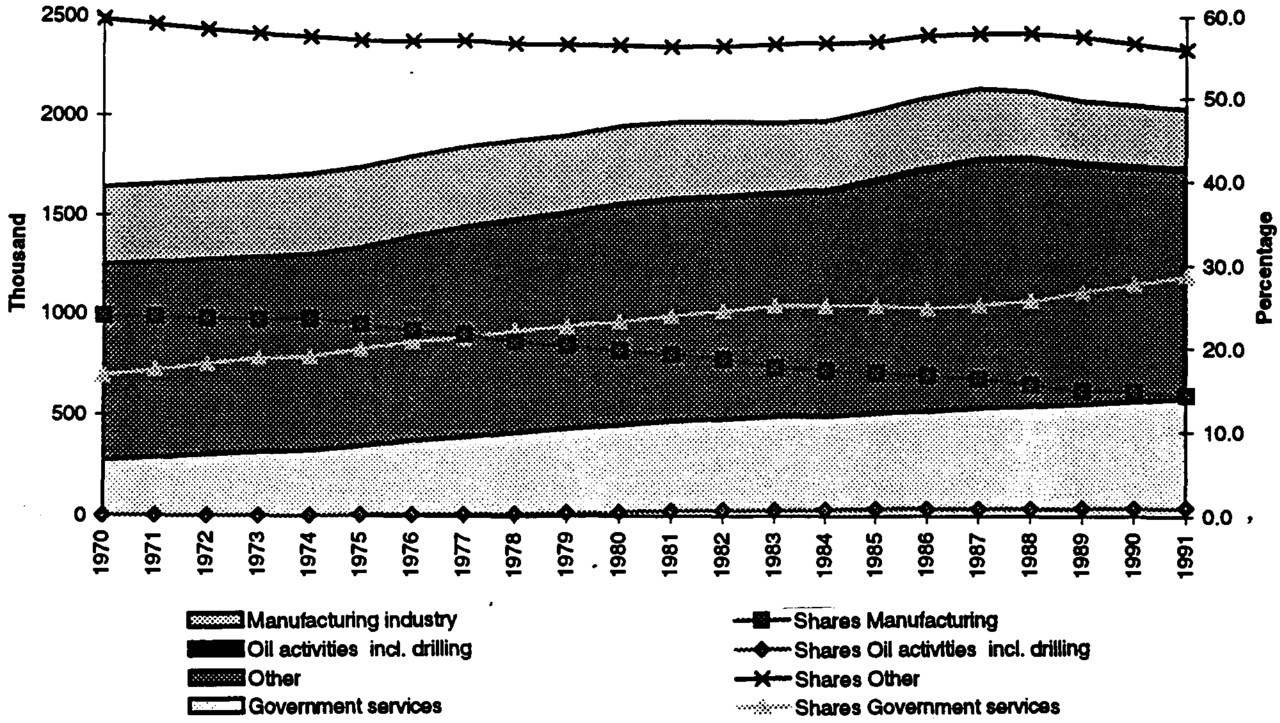

Figure 5a: Employment, absolute and relative importance of sectors.
Source: National Accounts

The shaded areas comprise total employment in Norway. The lines give the relative importance of the sectors (sectors' share of total employment).

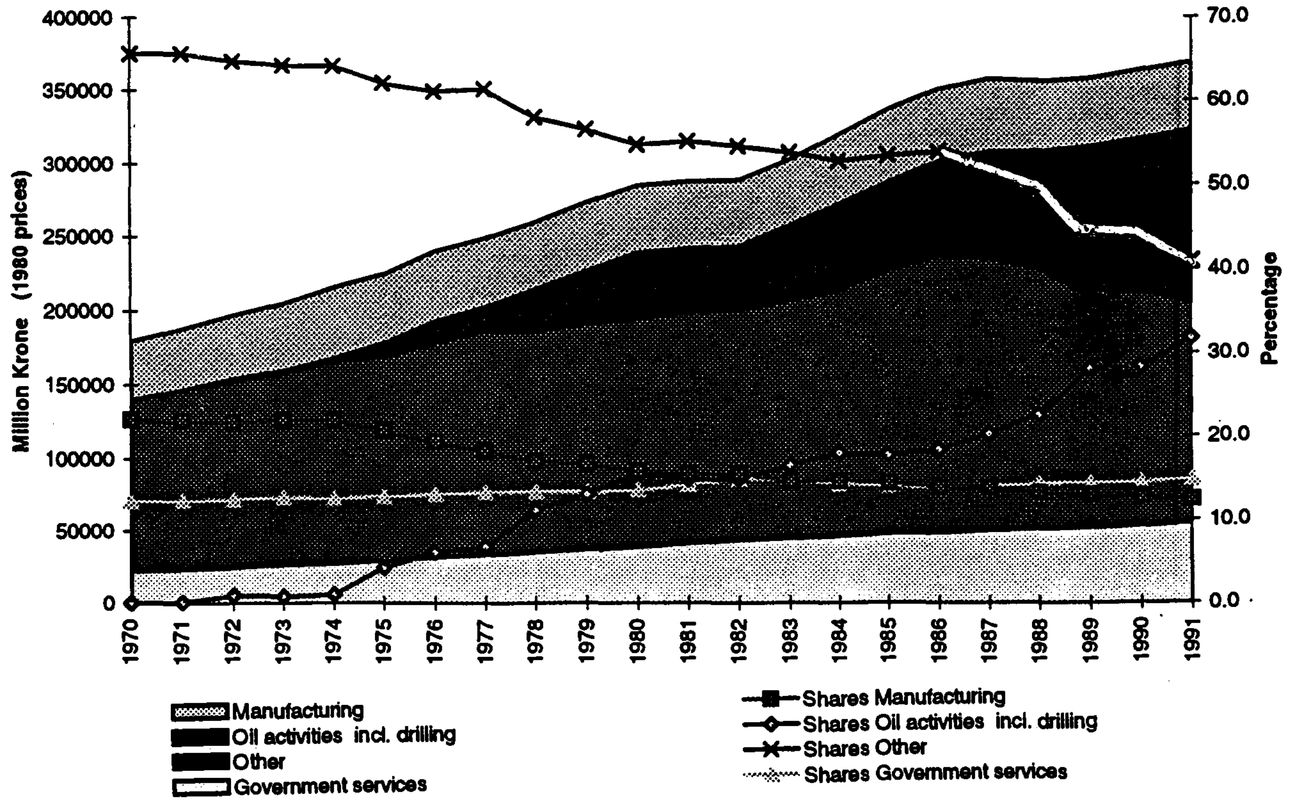

Figure 5b: Gross Domestic Product, absolute and relative importance of sectors.
Source: National Accounts

The shaded areas comprise total GDP in Norway. The lines give the relative importance of the sectors (sectors' share of total GDP).

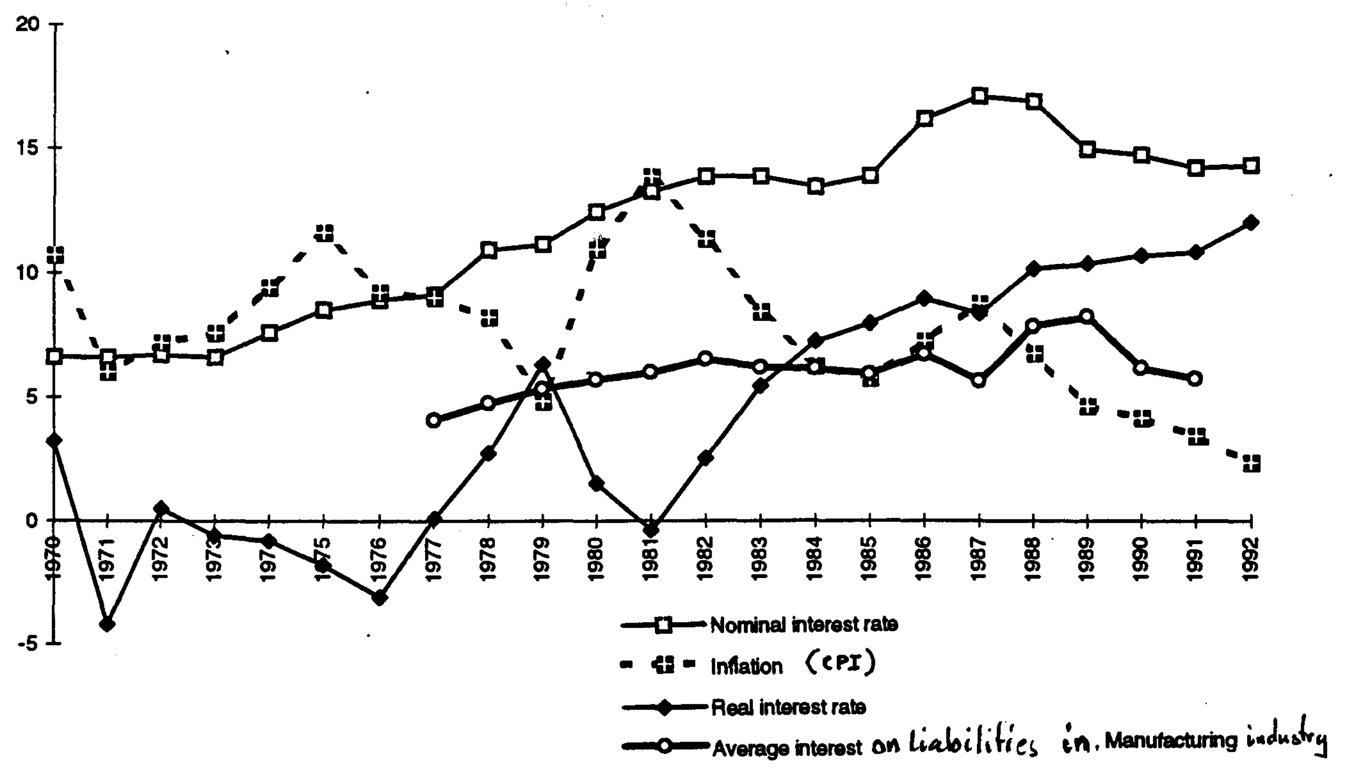

Figure 6: Interest rates and inflation (CPI).
Sources: Banking and Credit Statistics, Current Figures, Norges Bank, Economic Bulletin, and Statistics of Accounts.

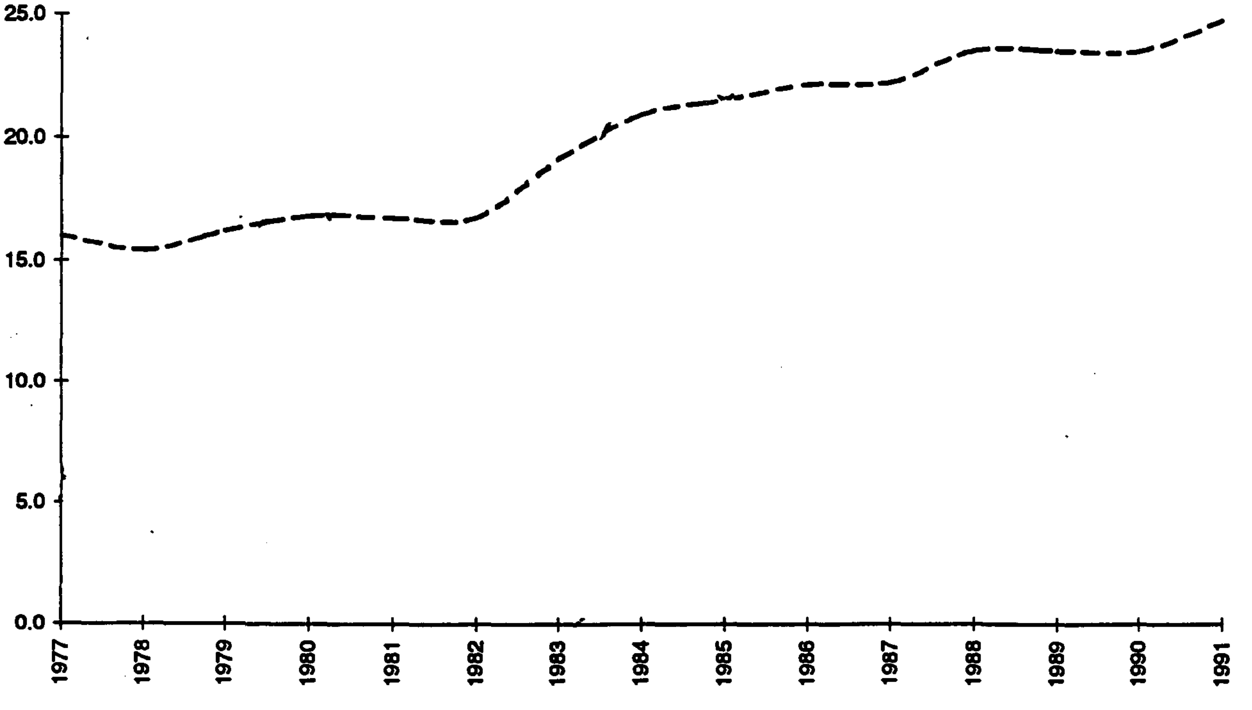

Figure 7: Equity Ratio in manufacturing industry
Source: Statistics of Accounts

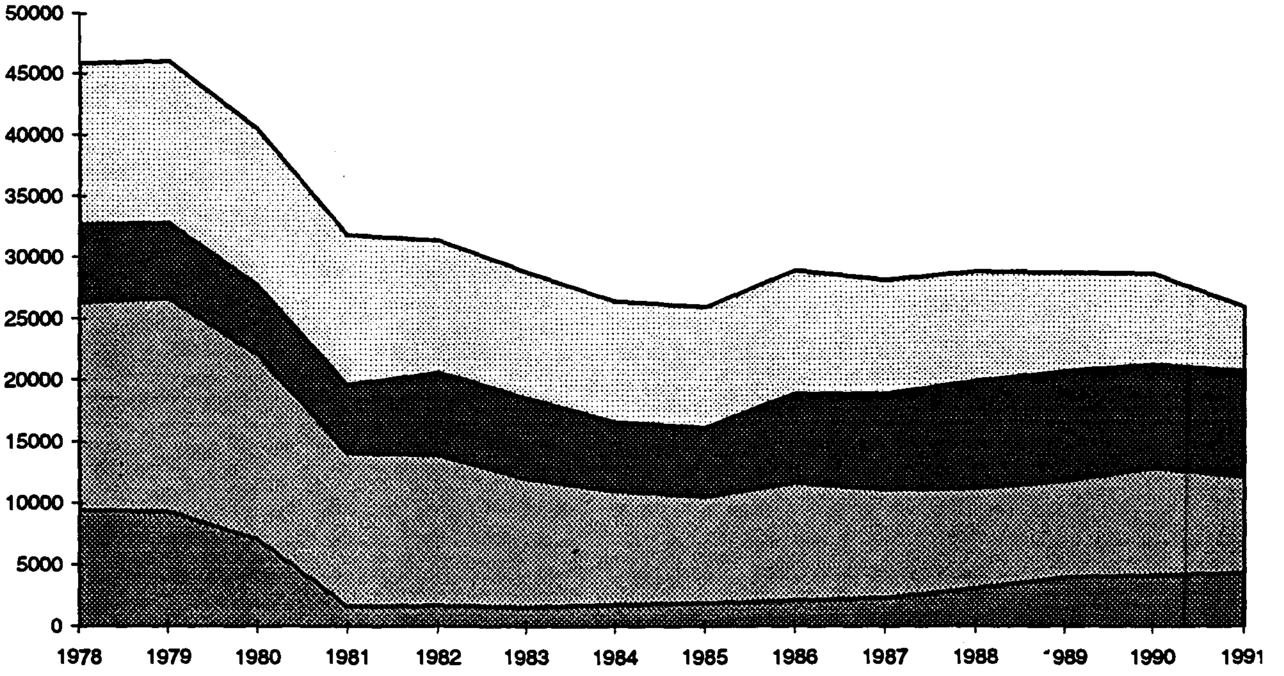

Figure 8: Composition of long-term debt in the manufacturing industry.
Million Krone (1980 prices)
Source: Statistics of Accounts

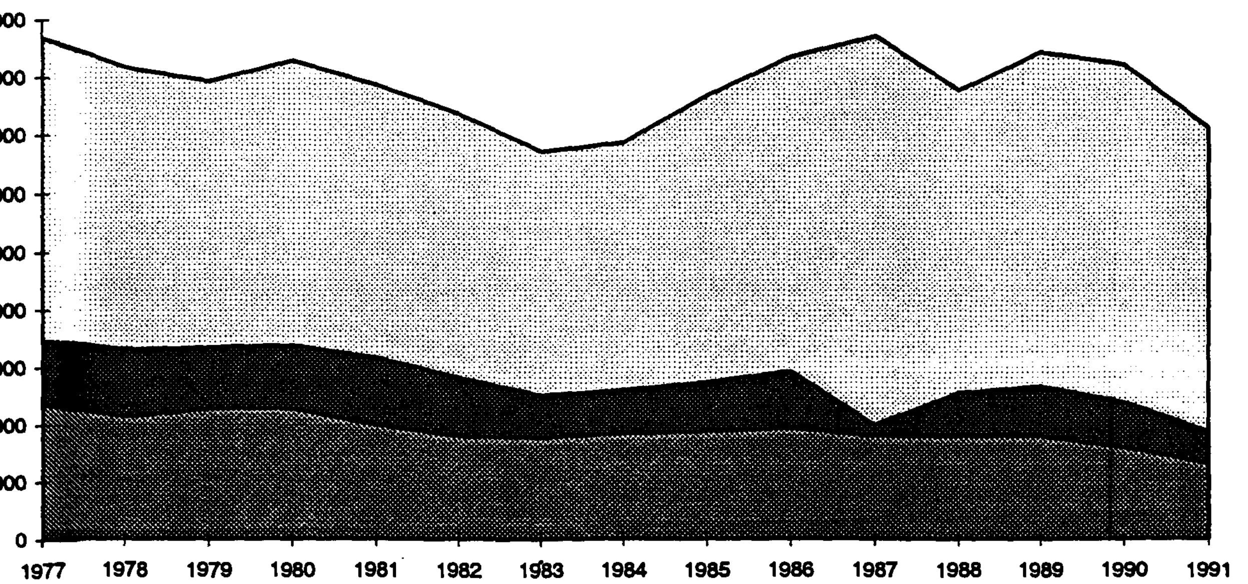

Figure 9: Composition of short-term debt in the manufacturing industry.
Million Krone (1980 prices)
Source: Statistics of Accounts

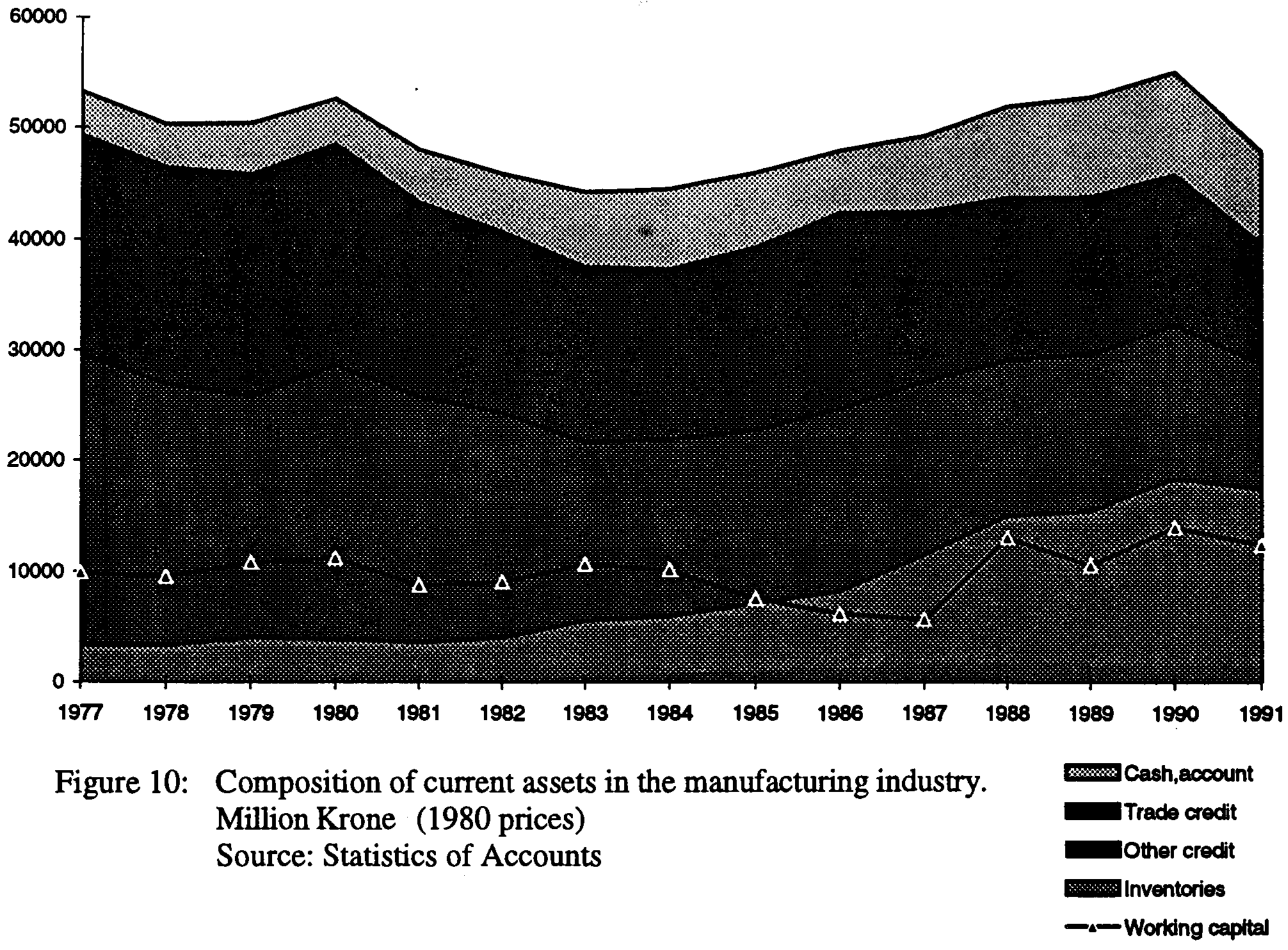

Figure 10: Composition of current assets in the manufacturing industry.
Million Krone (1980 prices)
Source: Statistics of Accounts

The shaded areas comprise current assets for manufacturing industry. The line shows working capital (inventory included) minus short-term debt.

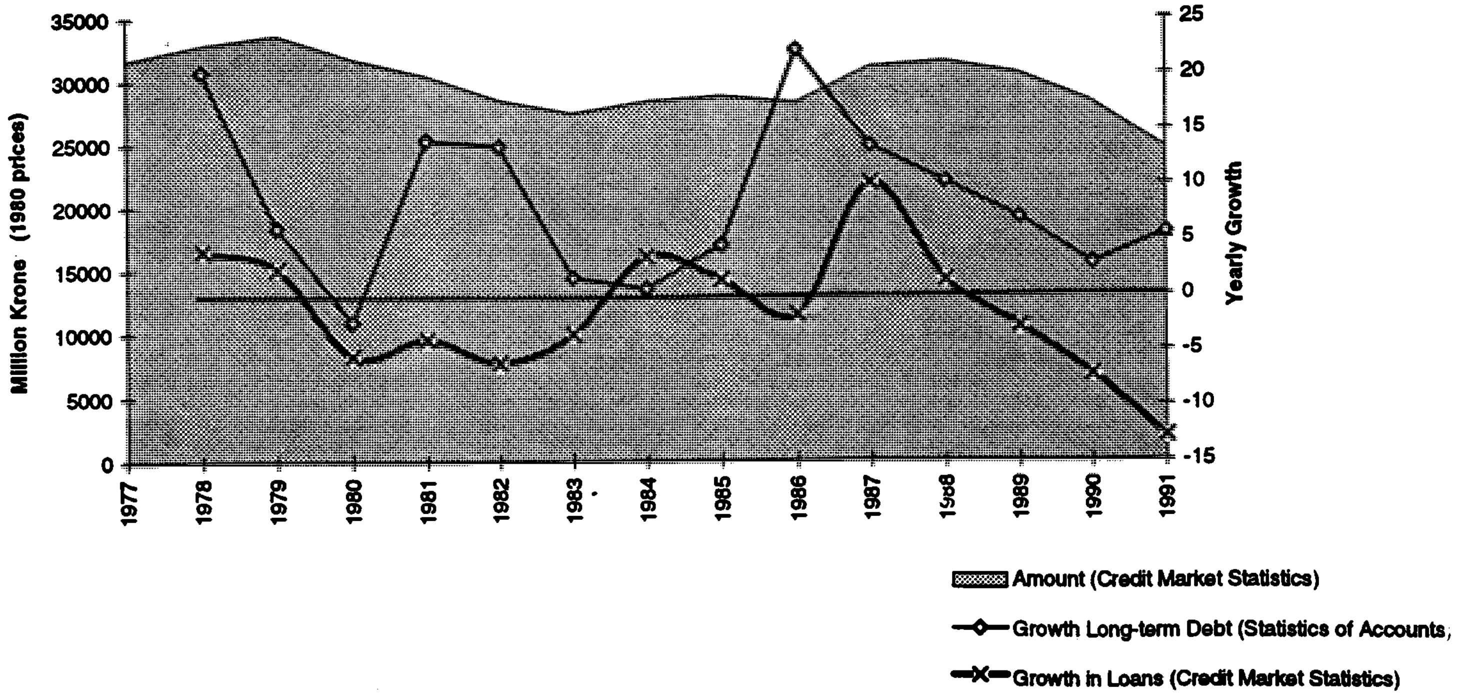

Figure 11: Loans to manufacturing industry (from credit institutions and banks) and growth in long-term debt.
Sources: NOS Credit Market Statistics and Statistics of Accounts

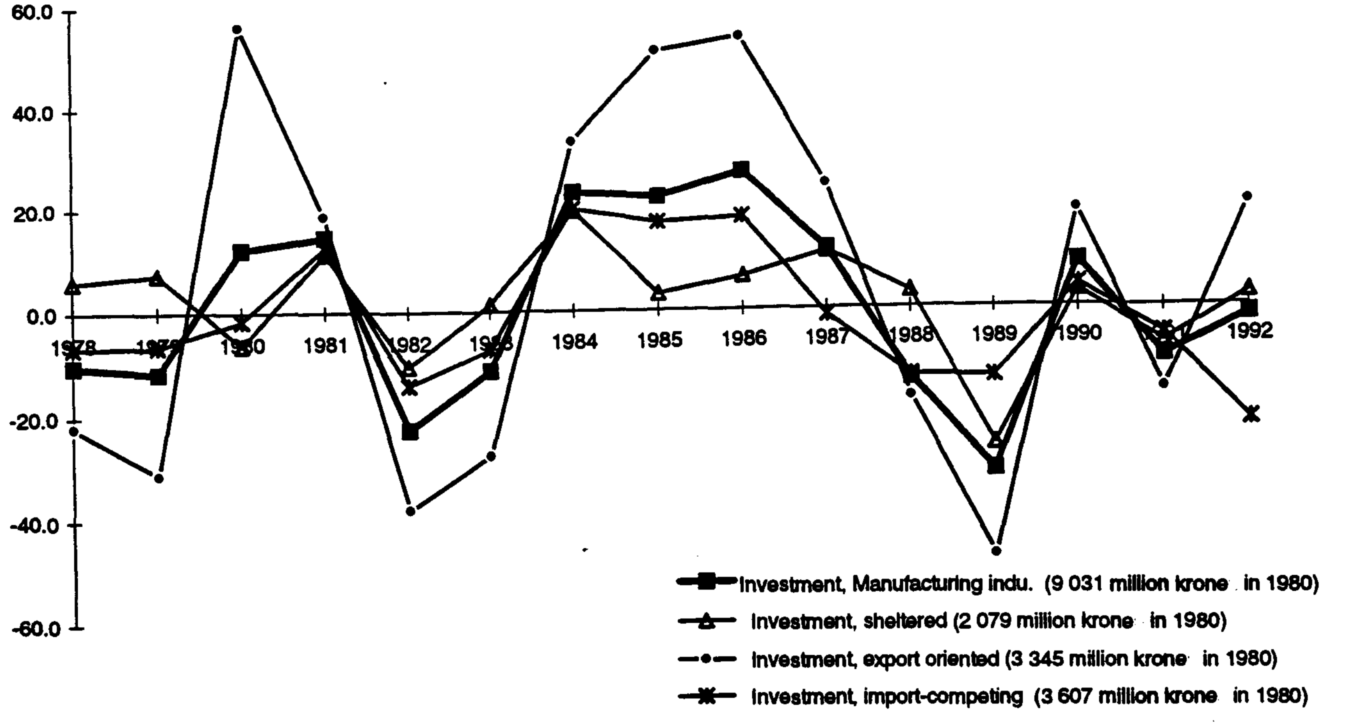

Figure 12: Investment for the manufacturing industry by sectors, annual percentage change
Source: National Accounts

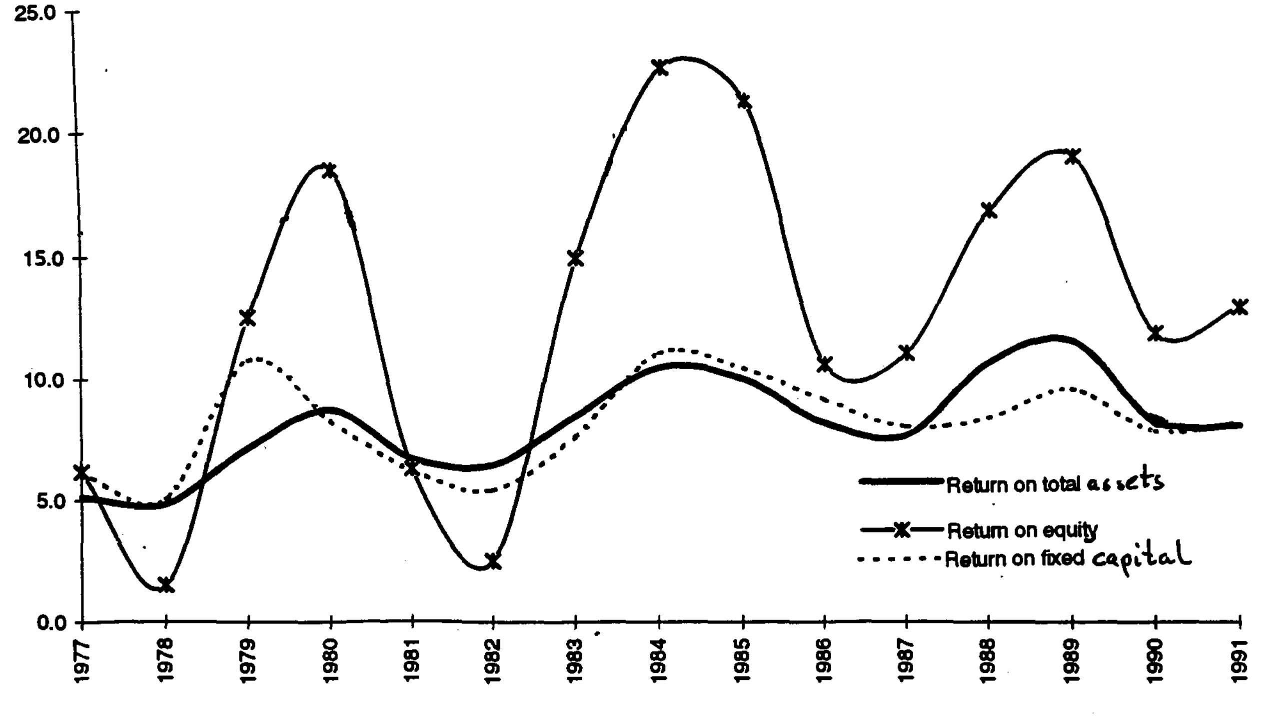

Figure 13: Profitability in the manufacturing sector as a group
Source: Statistics of Accounts

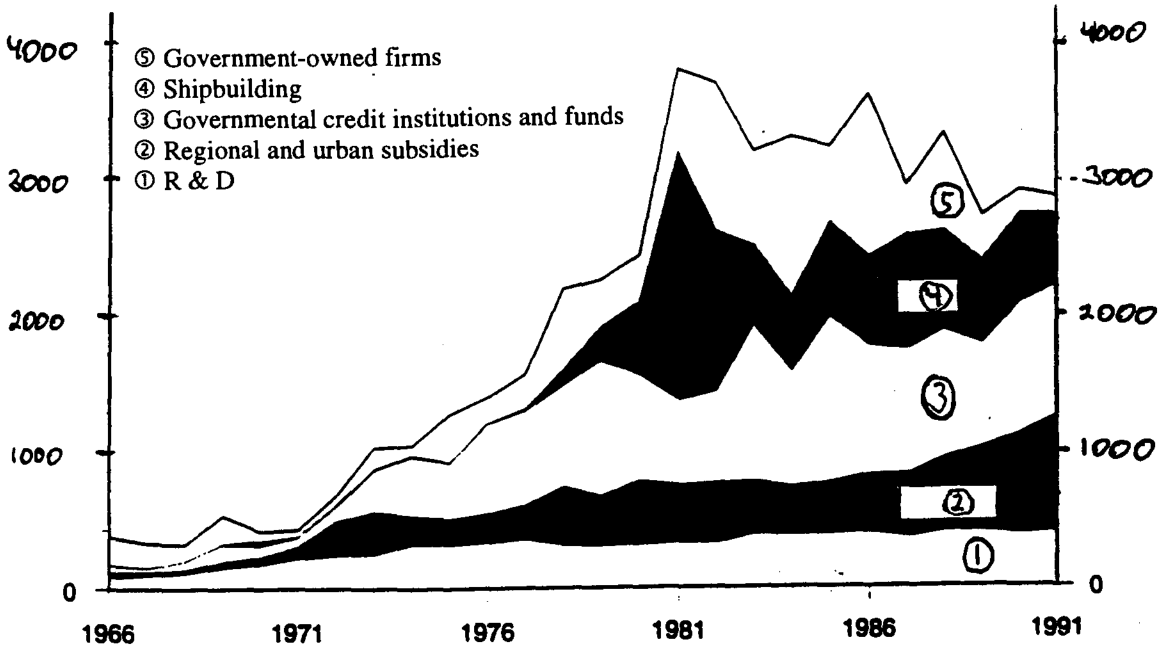

Figure 14: Subsidies to manufacturing and service industries. Millon Krone (1980 prices)
Source: National Budget for 1995, and Centre for Research in Economics and Business Administration (SNF).

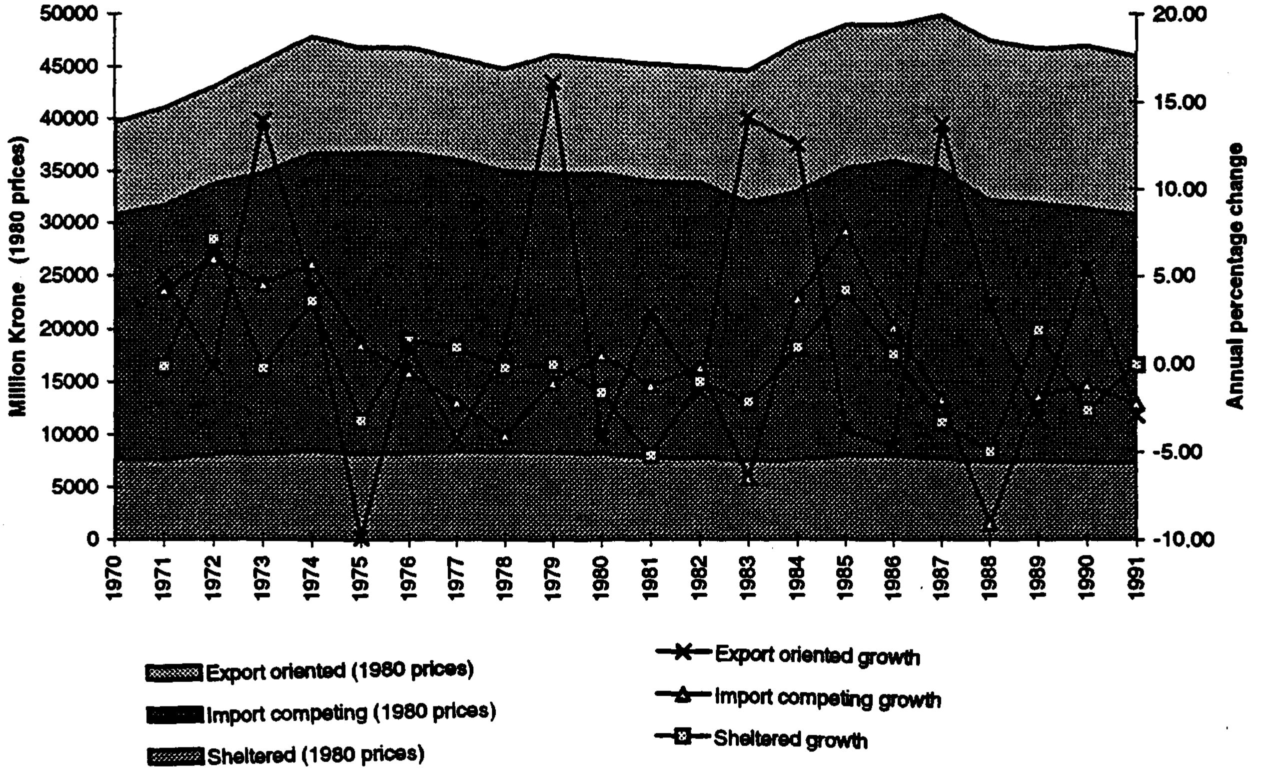

Figure 15: Gross Domestic Product in the manufacturing industry, by market orientation.
Million Krone (1980 prices)
Source: National Accounts

The shaded areas comprise GDP for the aggregate manufacturing industry. The lines are the annual growth from previous year (percentage).

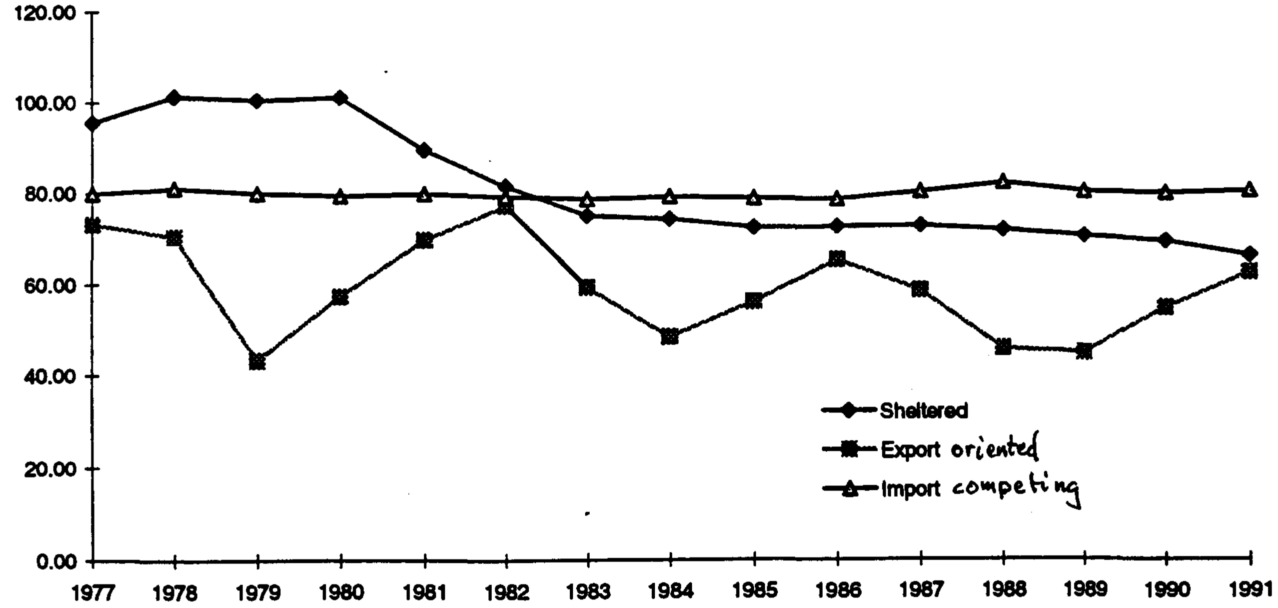

Figure 16: Wage as share of value added in the manufacturing industry, by market orientation.
Source: Manufacturing Statistics

	Source of funds			Application of funds				
	New Equity	Increase long-term	Retained earnings	Fixed assets	Fixed capital	Financial fixed assets	Other fixed assets	Working capital
1977	324.2	9159.9	4449.2	14783.1	10642.8	717.7	3422.6	-849.7
1978	567.1	7688.9	4159.9	11782.7	8276.0	-165.9	3672.5	633.3
1979	613.9	2621.5	6955.0	8392.1	6000.1	485.6	1906.4	1798.0
1980	838.6	-1036.7	7627.3	5982.5	6636.4	280.8	-934.7	1446.7
1981	485.5	3865.6	4479.0	8596.0	6633.9	656.0	1306.1	234.3
1982	1329.0	3699.4	4021.3	8041.6	4570.4	252.3	3218.8	1008.1
1983	786.3	421.1	5326.2	4355.5	3548.9	717.4	89.1	2178.2
1984	1405.2	118.1	6504.9	7568.4	4179.6	1041.0	2347.8	459.8
1985	948.1	1097.6	6171.8	10315.8	5032.7	2929.3	2353.8	-2098.2
1986	2578.6	5200.6	5097.4	13901.8	7104.0	3346.2	3451.6	-1025.2
1987	620.3	3305.8	4091.5	8355.0				-338.0
1988	1726.8	2642.6	4385.6	1836.9				6918.2
1989	511.4	1834.0	5682.5	9075.0				-1047.7
1990	1087.4	753.4	3829.7	1671.1				3999.3
1991	521.4	1346.9	4441.6	5969.3				341.1

Table 1: Source and Applications of Funds in manufacturing industry as group
Million Krones (1980 prices)
Source: Statistics of Accounts

Chapter 2

Markups, Business Cycles and Factor Markets: An Empirical Analysis

(Co-author Jan Erik Askildsen)

Markups, Business Cycles and Factor Markets: An Empirical Analysis

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November 13, 1997

Abstract

We investigate the existence of markups and their cyclical behaviour. Markup is not directly observed, rather it is given as a price-cost relation that is estimated from a dynamic model of the firm. Labour adjustment costs and financial constraints may influence on firms' production decisions. Such input factor restrictions may be interpreted as affecting the marginal costs. The induced changes in marginal costs will give rise to differences in markups between financially constrained and unconstrained firms, and also to different degrees of markup fluctuations. The markup is estimated for different sectors using firm and plant level data for the Norwegian manufacturing industry. The results indicate a frequent presence of procyclical markups but no differences between assumed constrained and unconstrained units.

JEL codes: E32, D40, D92
Keywords: Market power, business cycles, panel data, financing.

* We are grateful for comments and suggestions from F. Carlsen, Sjur D. Flåm, E. S. Jansen, T. J. Klette, E. Steigum jr., and from participants at a workshop at Norges Bank (Central Bank of Norway) May 20, 1996, the Conference of the Norwegian Economic Association in Bergen, January 1997, ESEM 1997, and EARIE 1997. The usual disclaimer applies.

1. Introduction

In this paper we investigate whether financial constraints will affect markup and its cyclicality. We estimate markups and test for their cyclicality using micro-data for plants and firms. This means that we use data at the level where decisions about production are taken. The markups are measured for different manufacturing industry sectors separately, which enables us to take detect possible sectoral differences.

Microeconomic foundations of modern macroeconomics give rise to the expectation that firms' price-cost margins will vary over the business cycle. Available empirical evidence, to a large degree from US industry sector studies, supports the case. On the other hand, theory as well as empirics are inconclusive as to the magnitude and directions of the potential cyclical movements. Furthermore, there is no clear evidence as to the sources of markup differences over time and among different types of firms. We stress the importance of considering marginal costs as well as firms' price behaviour when considering markup levels and the markup variations over the cycle.

Empirically markup pricing behaviour, which should be due to output market power, is confirmed in the seminal work by Hall (1988) on US manufacturing industry data. The theoretical underpinnings for fluctuations in markups over the business cycle are most commonly related to industrial organisation theory. Green and Porter (1984) and Rotemberg and Saloner (1986) argue in favour of respectively pro- and countercyclical markups based on different assumptions about oligopoly price setting games. Domowitz, Hubbard and Petersen (1986) stress the importance of considering price games as well as factor markets when investigating markups. Empirical studies have revealed both procyclical and countercyclical markups. Bils (1987), Galeotti and Schiantarelli (1995), Chevalier and Scharfstein (1995, 1996) and Borenstein and Shepard (1996) find evidence of countercyclical markups. Domowitz, Hubbard and Petersen (1986, 1987) and Chirinko and Fazzari (1994) tend to find more procyclical markup behaviour.

The interaction between product market competition and financial situation has been studied by Brander and Lewis (1986, 1988) and lately by Hendel (1996). According to the 'limited liability effect' financially distressed firms increase their output or reduce their output prices to generate cash. The 'strategic bankruptcy' models postulate that a rival might increase its output to increase the probability of driving a high-debt firm into insolvency. With the exception of Phillips (1995) and Chevalier and Scharfstein (1995, 1996) there are few empirical studies analysing interactions between firms' output decisions and their financial situation. Chevalier and Scharfstein combine liquidity constraints and firms' investment behaviour, including investments in market shares, and find countercyclical markups. We argue that when firms depend on adjusting factors of production between periods, such as labour, markups may be affected. A prime reason is the difficulties in providing collateral for finance of a wage bill. Therefore financial constraints may prove more severe for labour hoarding relative to investments in fixed capital. Since the capital market imperfections can be interpreted as increasing the short run production costs, markups may be reduced for the constrained firms. However, such behaviour also depends on the competitive situation in the output market. There are few studies that actually try to detect whether imperfections in the credit and labour markets will affect markups, and this paper is an attempt to add to the literature in this respect.

We argue that financial constraints and adjustments of quasi fixed factors of production will affect markups, interpreted as price relative to marginal costs. Most studies assume constant marginal costs. Our way of modelling the constraints implies that marginal costs may vary over plants. The cost differences are then related to the firms' financial positions. The reason is that in the short run potentially credit constrained firms cannot make adjustments of labour without considering its long term cost effects. With markup derived from the first order conditions, we then find that differences in access to credit or other sources of short term capital will affect the markups. We will investigate whether potentially financially constrained firms have a different markup level and experience different fluctuations in the markup compared to assumed unconstrained firms. Although several outcomes are possible as to directions of markup fluctuations, a procyclical markup is most likely. If the restrictions on short term credit are less severe during periods of high demand, we furthermore expect to see the markup fluctuate relatively more procyclically for constrained firms. We will assume that it is the firms' leverage and size that determine their financial position, in the sense that smaller firms that are highly leveraged are potentially constrained. On the other hand, if labour adjustments costs are insignificant and financial constraints do not bind, procyclicality will normally emerge given the existence of some market power. There is a potential exception. It could be the case that the elasticity of demand is highly procyclical, Bils (1987), which again is due to less collusion during booms, Rotemberg and

Saloner (1986). If such price behaviour is present, the expected procyclicality of markup will be dampened. Note in this connection that we use a standard definition of markup, which is directly related to the price elasticity. We are therefore unable to detect the actual reason for a cyclicality, and instead only find whether it moves in accordance with results emerging from a specific theoretical model.

Most of the papers investigating markup fluctuations use sector level data. One contribution of this paper is new empirical evidence on the existence and magnitude of markups and their cyclical variations by using firm and plant level data.[1] We believe that establishment level data will give more reliable markup estimates. Firstly, it allows us to correct for firm specific non-observabilities, such as productivity differences between firms, which is of importance since production technology and scale economies are relevant for firms' price setting behaviour. Aggregating up to industry level ignores these differences, and may thereby introduce biases into the estimation of the marginal costs and markups. Secondly, using plant and firm level data also have the advantage that the model is implemented at the level for which it is constructed and thereby eliminate the notion of a representative firm. This is of significance if the cost elements of importance for any markup cyclicality are firm and not industry sector specific. Such heterogeneity is captured using firm or plant level data. The effects on markups should therefore be estimated at this level of production.

We use a panel data set of Norwegian manufacturing industry covering the period 1978-1991. Financial data are available at firm level, while data on production, production costs, employment and capital are given at plant level. We present a dynamic model of the plants' decisions. This model is rather general and allows for different interpretations consistent with several price-setting configurations. The capital stock is assumed predetermined, whereas labour may be varied. The labour adjustment costs, associated with changing the level of employment from one period to the next, are modelled by a convex adjustment costs function. The going wage rate is assumed given. Competition in the product market is imperfect, enabling the firms to practice markup pricing. These markups are estimated sector wise, and are allowed to vary over the business cycles. We use sectoral variations in gross domestic product to represent business cycles. Gross domestic product may reflect demand

[1] The only studies we are aware of using micro level data for analysing markup, are Klette (1994), Chirinko and Fazzari (1994).

shocks affecting the firms' sales potentials, and thereby the firms' price setting behaviour.

The next section contains the model set up. The empirical specification is derived in section 3, and data are presented in section 4. In section 5 we report the results, and some concluding remarks are made in section 6.

2. The Dynamic Optimisation Problem[2]

The model represents a firm facing a dynamic optimisation problem. Short term price or production decisions are made in a setting which due to adjustment costs of labour and financial constraints. We make the simplifying assumption that the stock of capital is predetermined. It reflects the fact that investment is generally sunk before price decisions.[3] We note that several studies have addressed adjustment costs when investing in capital. The evidence for the existence of such adjustment costs in Norwegian firms is not clear, though. In addition, with a predetermined capital stock we avoid the problem of formalising the capital adjustment costs function, whose functional form is also unsettled.[4] Thus, investment in fixed capital is a long-run decision, and changes in the capital stock do not affect the short term price behaviour. On the other hand, we assume labour hoarding to be relevant due to costs of changing the employment levels between periods. Then contemporary and expected demand changes will effect employment and price decisions each period. However, financing short term hoarding of labour is assumed more difficult than the long term finance of real capital since servitude is ruled out and labour can hardly be used as a collateral. Still, our model is able to capture also general financial restrictions facing the firm, irrespective of why the firms may be short of finance.

We model the behaviour of a firm whose objective is to maximise the present value at the end of period $t\text{-}1$, $V_{i,t-1}$, of dividends, $D_{i,s+t}$. The subscript s and t denote time, and i denote the

[2] An appendix with more detailed derivation of the model is available from the authors upon request.
[3] It would in principle not be problematic to extend the analysis to incorporate different assumptions about capital adjustments. A problem would then be that the tax system during our period of investigation is generally considered as extremely distortive, with particular relevance for fixed capital allocation. Therefore, a detailed model of the tax system should be incorporated as well. We feel that this will obscure our analysis, and we stick to as simple a formulation as possible.
[4] See Nilsen and Schiantarelli (1997) for a discussion of capital adjustments costs for Norwegian firms.

firm.[5] The firm operates in an imperfectly competitive market. A limitation of this analysis should be noted. No assumptions are made concerning output market imperfection. The firm may operate in a monopolistic competitive market where several firms produce different brands of the same product or in an oligopoly. The model can be formally expressed as[6]

$$V_{i,t-1} = E_{i,t-1} \sum_{s=0}^{\infty} \beta_{t+s} D_{i,t+s} \tag{1}$$

Here $E_{i,t-1}$ denotes the conditional expectations operator as of time $t-1$, and $\beta_{t+s} = \prod_{\tau=0}^{s} \frac{1}{1+r_{t+\tau}}$ is the discount factor between time t and t+s, discount rate r_t reflecting the investor's opportunity cost of investing in period t. All present variables are assumed to be known to the firm with certainty whereas all future variables are stochastic. In addition, we assume that the decision-makers have rational expectations.

We assume that wages are given prior to the production decisions. The financial constraints are at the outset represented by a dividend restriction which prevents the firm from raising external funds by issuing shares to meet the owners' return claims. The non-negative dividend restriction can loosely be interpreted as a premium on external funding. Below we will extend the model to account for an explicit credit constraint.

The firm maximises (1) subject to the constraint

$$D_{i,t} \geq 0$$

Dividends are defined as

$$D_{i,t} = p_{i,t}(Y_{i,t})\left[F(\overline{K}_{i,t}, L_{i,t}, Z_{i,t}) - G(L_{i,t}, L_{i,t-1})\right] - w_{i,t}L_{i,t} - c_{i.t}Z_{i,t}$$

[5] This formulation is based on the assumption that owners and managers are risk neutral, and that managers act in the interest of the stockholders.

[6] This formulation is based on the standard capital market arbitrage condition:

$$r_t V_{i,t-1} = D_{i,t} + \left(E_{t-1}\left[V_{i,t}\right] - V_{i,t-1}\right)$$

where

$Y_{i,t} = F(\overline{K}_{i,t}, L_{i,t}, Z_{i,t}) - G(L_{i,t}, L_{i,t-1})$ = real output net of adjustment costs

$F(.)$ = concave production function

$G(.)$ = adjustment cost function for labour

$L_{i,t}$ = employment level

$Z_{i,t}$ = variable factors

$\overline{K}_{i,t}$ = predetermined, fixed capital stock

$p_{i,t}$ = output price

$w_{i,t}$ = wage cost per employee

$c_{i,t}$ = cost per unit of variable factors

Using dynamic programming, we can restate the problem in recursive form:

$$V_{i,t-1}(L_{i,t-1}) = \max_{L_{i,t}, Z_{i,t}} \left[p_{i,t}(Y_{i,t})\left[F(\overline{K}_{i,t}, L_{i,t}, Z_{i,t}) - G(L_{i,t}, L_{i,t-1})\right] - w_{i,t}L_{i,t} - c_{i,t}Z_{i,t}\right] + E_t\left[\frac{1}{1+r_{t+1}} V_{i,t}(L_{i,t})\right]$$

(2)

For the variable input factors, $Z_{i,t}$, the first order condition is given by

$$\frac{\partial Y_{i,t}}{\partial Z_{i,t}} = c_{i,t}\frac{\mu_{i,t}}{p_{i,t}} \tag{3}$$

where $\mu_{i,t} = \frac{1}{1 - \frac{1}{\varepsilon^D_{i,t}}}$ is the markup and $\varepsilon^D_{i,t} = -\frac{\partial Y_{i,t}}{\partial p_{i,t}}\frac{p_{i,t}}{Y_{i,t}}$ is the price elasticity of demand facing firm i in period t. To see the generality of the formulation, and relating it to other studies of markup cyclicality, e.g. Domowitz, Hubbard and Petersen (1986), we rewrite (3) as

$$p_{i,t}\left(1 - \frac{a_{i,t}}{\varepsilon^D_t}\left(1 + \sum_{j \neq i}\frac{\partial Y_{j,t}}{\partial Y_{i,t}}\right)\right)\frac{\partial Y_{i,t}}{\partial Z_{i,t}} = c_{i,t} \tag{3'}$$

where ε_t^D denotes the price elasticity for the industry in period t, $a_{i,t}$ is the i^{th} firm's market share, and $\frac{\partial Y_{j,t}}{\partial Y_{i,t}}$ is the conjectural variation. If there were only one firm, as it would be with monopoly or monopolistic competition, $a_{i,t}$ = 1, and $\frac{\partial Y_{j,t}}{\partial Y_{i,t}} = 0$. If so, we get the standard markup pricing expression given in equation (3). Another extreme instance is $a_{i,t} \to 0$, which yields a competitive market solution. A Cournot solution emerges when the conjectural variations are set equal to zero. Thus, our formulation can accommodate several different price games. Cost typically varies across firms, and since the production capacities are assumed predetermined, the firms may reach capacity limits and sharply increasing marginal costs at different production levels. Such cost asymmetries are probably relevant in practice but difficult to handle formally. We use our general formulation of the markup as defined from (3), addressing its different interpretations in due course. Note that our measure of markup relates to the demand elasticity. However, since it is derived from first order conditions, its level and fluctuations can be explained by cost changes as well as the firms' product market behaviour.

The first order condition for labour is:

$$\frac{p_{i,t}}{\mu_{i,t}}\frac{\partial Y_{i,t}}{\partial L_{i,t}} + E_t\left[\frac{1-\Lambda_{i,t}}{1+r_{t+1}}\frac{p_{i,t+1}}{\mu_{i,t+1}}\frac{\partial Y_{i,t+1}}{\partial L_{i,t}}\right] = w_{i,t} \tag{4}$$

where $\Lambda_{i,t} = 1 - \frac{1+\lambda_{i,t+1}^D}{1+\lambda_{i,t}^D}$ and $\lambda_{i,t}^D$ is the Lagrange multiplier associated with the dividend constraint at time t. If no dividend constraint is binding at times t and $t+1$, then $\Lambda_{i,t} = 0$, and the firm is characterised as financially unconstrained. According to equation (4) the present value of a marginal unit of labour should equal the wage cost w_{it}. Note that the first term at the left hand side equals $\frac{\partial Y_{i,t}}{\partial L_{i,t}} = \frac{\partial F_{i,t}}{\partial L_{i,t}} - \frac{\partial G_{i,t}}{\partial L_{i,t}}$, which is the increased revenue net of expenses on labour adjustments. Such adjustment affects the next period as well. The last term in the square brackets, $\frac{\partial Y_{i,t+1}}{\partial L_{i,t}} = -\frac{\partial G_{i,t+1}}{\partial L_{i,t}}$, represents the cost of postponing employment adjustment.[7] Using the laws of variance on the expectations expression, the first order condition for labour may be written as

$$\frac{p_{i,t}}{\mu_{i,t}}\frac{\partial Y_{i,t}}{\partial L_{i,t}} + E_t\left[\frac{1-\Lambda_{i,t}}{1+r_{t+1}}\right]E_t\left[\frac{p_{i,t+1}}{\mu_{i,t+1}}\frac{\partial Y_{i,t+1}}{\partial L_{i,t}}\right] + \operatorname{cov}\left(\frac{1-\Lambda_{i,t}}{1+r_{t+1}}, \frac{p_{i,t+1}}{\mu_{i,t+1}}\frac{\partial Y_{i,t+1}}{\partial L_{i,t}}\right) = w_{i,t} \tag{5}$$

Furthermore, from the rational expectation property we arrive at the following expression:

$$\frac{p_{i,t}}{\mu_{i,t}}\frac{\partial Y_{i,t}}{\partial L_{i,t}} + \left(\frac{1-\Lambda_{i,t}}{1+r_{t+1}} + e_{i,t+1}^{I}\right)\cdot\left(\frac{p_{i,t+1}}{\mu_{i,t+1}}\frac{\partial Y_{i,t+1}}{\partial L_{i,t}} + e_{i,t+1}^{II}\right) + \operatorname{cov}\left(\frac{1-\Lambda_{i,t}}{1+r_{t+1}}, \frac{p_{i,t+1}}{\mu_{i,t+1}}\frac{\partial Y_{i,t+1}}{\partial L_{i,t}}\right) = w_{i,t} \tag{6}$$

We have replaced the expectation operators with white noise expectation errors, $e_{i,t+1}^{I}$ and $e_{i,t+1}^{II}$ respectively, which are uncorrelated with any information at time t.

The standard quadratic shape of adjustment costs for labour, introduced by Holt et al. (1960), is quadratic in employment changes. However, the size of the labour stock in different plants may vary considerably. Thus, it seems more realistic to model the marginal adjustment costs linear in relative changes. The labour adjustment function can be written as

$$G_{i,t} = \frac{s}{2}\frac{X_{i,t}^2}{L_{i,t}} \tag{7}$$

where $X_{i,t} = L_{i,t} - (1-\delta)L_{i,t-1}$, and δ is a rate representing voluntary quitting which induces no direct costs (see Nickell (1986)). Assuming that $Y_{i,t} = F(K_{i,t}, L_{i,t}, Z_{i,t}) - G(L_{i,t}, L_{i,t-1})$ is homogeneous of degree $\nu_{i,t}$, using (3) and applying Euler's theorem, we get the following expression

$$\tilde{\nu}_{i,t} = \left(\nu_{i,t} - \frac{\partial F_{i,t}}{\partial K_{i,t}}\frac{K_{i,t}}{Y_{i,t}}\right) = \mu_{i,t}\frac{c_{i,t}Z_{i,t}}{p_{i,t}Y_{i,t}} + \frac{\partial F_{i,t}}{\partial L_{i,t}}\frac{L_{i,t}}{Y_{i,t}} \tag{8}$$

[7] If the firm has to take into account explicit credit limit, we get the result that financially constrained firms, for which $(1+\lambda_{i,t+1})/(1+\lambda_{i,t}) > 1$, behave as if they have a higher discount rate. More comments about this topic are given later in this section.

The parameter $\tilde{v}_{i,t}$ is interpreted as short-run returns to scale. Combining equation (6) and equation (8) yields

$$\frac{p_{i,t}}{\mu_{i,t}}\left(\tilde{v}_{i,t}\frac{Y_{i,t}}{L_{i,t}}-c_{i,t}\frac{\mu_{i,t}}{p_{i,t}}\frac{Z_{i,t}}{L_{i,t}}-s\frac{X_{i,t}}{L_{i,t}}\left(1-\frac{X_{i,t}}{L_{i,t}}\right)\right)+\frac{1-\Lambda_{i,t}}{1+r_{t+1}}\frac{p_{i,t+1}}{\mu_{i,t+1}}\cdot s\cdot(1-\delta)\frac{X_{i,t+1}}{L_{i,t+1}}+\text{cov}(.)+e_{i,t+1}=w_{i,t} \quad (9)$$

To normalise we multiply through by $\frac{\mu_{i,t}}{\tilde{v}_{i,t}}\frac{L_{i,t}}{q_{i,t}K_{i,t}}$, where $q_{i,t}$ is the price of a unit of real capital, which results in

$$\begin{aligned}
\frac{p_{i,t}Y_{i,t}}{q_{i,t}K_{i,t}} &= \frac{\mu_{i,t}}{\tilde{v}_{i,t}}\cdot\left(\frac{w_{i,t}L_{i,t}}{q_{i,t}K_{i,t}}+\frac{c_{i,t}Z_{i,t}}{q_{i,t}K_{i,t}}\right)\\
&+\frac{s}{\tilde{v}_{i,t}}\cdot\frac{p_{i,t}X_{i,t}}{q_{i,t}K_{i,t}}\left(1-\frac{X_{i,t}}{L_{i,t}}\right)\\
&-\frac{\mu_{i,t}}{\mu_{i,t+1}}\frac{s}{\tilde{v}_{i,t}}\cdot\frac{1}{1+r_{t+1}}\frac{p_{i,t+1}X_{i,t+1}}{q_{i,t}K_{i,t}}\left(1-\frac{X_{i,t+1}}{L_{i,t+1}}\right)\\
&+\frac{\mu_{i,t}}{\mu_{i,t+1}}\frac{s}{\tilde{v}_{i,t}}\cdot\frac{\Lambda_{i,t}}{1+r_{t+1}}\frac{p_{i,t+1}X_{i,t+1}}{q_{i,t}K_{i,t}}\left(1-\frac{X_{i,t+1}}{L_{i,t+1}}\right)\\
&-\frac{\mu_{i,t}}{\tilde{v}_{i,t}}\frac{L_{i,t}}{q_{i,t}K_{i,t}}\text{cov}\left(\frac{1-\Lambda_{i,t}}{1+r_{t+1}},\frac{p_{i,t+1}}{\mu_{i,t+1}}(1-\delta)\frac{X_{i,t+1}}{L_{i,t+1}}\right)+\frac{\mu_{i,t}}{\tilde{v}_{i,t}}\frac{L_{i,t}}{q_{i,t}K_{i,t}}e_{i,t+1}
\end{aligned} \quad (10)$$

Equation (10) includes a covariance term which has its origin in the first order condition for labour. It is the covariance between dividend constraints and the future marginal revenue product of labour. For an unconstrained firm, where the dividend restriction never binds, the covariance term is zero, whereas it is generally non-zero for constrained firms. Together with $\Lambda_{i,t}$, the shadow price on dividends, it represents the firm's costs of being financially constrained.

The above analysis is easily extended to explicitly consider a borrowing constraint, and the implications of the model are then more easily understood.[8] It seems reasonable that a firm may lack short-term credit to finance labour costs in particular during a slump. Assume that

[8] Stiglitz and Weiss (1981) and the extension due to Calomiris and Hubbard (1990) indicate that smaller firms without collateral are most likely to be rationed. We believe this to be of relevance for financing labour hoarding.

there is a credit ceiling $\overline{B}_{i,t}$ for each firm, in each period. This exogenous type 1 credit rationing constraint implies that the firms will receive credit up to a limit, which the firms are unable to affect. Together with the dividend constraint, $D_{i,t} \geq 0$, this ceiling prevents the firms

from external finance, both by new equity and by debt.

Define

$B_{i,t}$: actual debt

$\overline{B}_{i,t}$: debt ceiling

i_t: nominal interest rate on debt

The firm now maximises (1) subject to the following constraints:

$$D_{i,t} \geq 0$$

$$B_{i,t} \leq \overline{B}_{i,t}$$

Extending the dividend term with $..B_{i,t} - (1+i_t)B_{i,t-1}..$, and substituting accordingly in (2), which is now also maximised with respect to $B_{i,t}$, the first order condition for debt reads

$$1+\lambda_{i,t}^{D} = \lambda_{i,t}^{B} + (1+i_t)E_t\left[\frac{1}{1+r_{t+1}}\left(1+\lambda_{i,t+1}^{D}\right)\right] \tag{11}$$

Here $\lambda_{i,t}^{B}$ is the shadow value of a relaxation of the debt ceiling. If $\lambda_{i,t}^{B} = 0$, the first order condition for debt states that the value of issuing a marginal unit of new debt to finance dividend payment must equate the discounted value of repaying debt interests. If instead the debt constraint binds, there is a wedge between the residual profit, or dividend, today and the dividend expected to be paid next period. Defining $\tilde{\lambda}_{i,t}^{B} = \frac{\lambda_{i,t}^{B}}{1+\lambda_{i,t}^{D}}$, the first order condition for debt, (11), can be rewritten as

$$\left[\frac{1-\tilde{\lambda}_{i,t}^{B}}{1+i_t}\right] = E_t\left[\frac{1-\Lambda_{i,t}}{1+r_{t+1}}\right] \tag{12}$$

This expression may be substituted into equation (10):

$$\begin{aligned}
\frac{p_{i,t}Y_{i,t}}{q_{i,t}K_{i,t}} &= \frac{\mu_{i,t}}{\tilde{v}_{i,t}}\cdot\left(\frac{w_{i,t}L_{i,t}}{q_{i,t}K_{i,t}}+\frac{c_{i,t}Z_{i,t}}{q_{i,t}K_{i,t}}\right)\\
&+\frac{s}{\tilde{v}_{i,t}}\cdot\frac{p_{i,t}X_{i,t}}{q_{i,t}K_{i,t}}\left(1-\frac{X_{i,t}}{L_{i,t}}\right)\\
&-\frac{\mu_{i,t}}{\mu_{i,t+1}}\frac{s}{\tilde{v}_{i,t}}\cdot\frac{1}{1+i_t}\frac{p_{i,t+1}X_{i,t+1}}{q_{i,t}K_{i,t}}\left(1-\frac{X_{i,t+1}}{L_{i,t+1}}\right)\\
&+\frac{\mu_{i,t}}{\mu_{i,t+1}}\frac{s}{\tilde{v}_{i,t}}\cdot\frac{1}{1+i_t}\frac{p_{i,t+1}X_{i,t+1}}{q_{i,t}K_{i,t}}\left(1-\frac{X_{i,t+1}}{L_{i,t+1}}\right)\cdot\tilde{\lambda}_{i,t}^{B}\\
&-\frac{\mu_{i,t}}{\tilde{v}_{i,t}}\frac{L_{i,t}}{q_{i,t}K_{i,t}}\mathrm{cov}\left(\frac{1-\Lambda_{i,t}}{1+r_{t+1}},\frac{p_{i,t+1}}{\mu_{i,t+1}}(1-\delta)\frac{X_{i,t+1}}{L_{i,t+1}}\right)+\frac{\mu_{i,t}}{\tilde{v}_{i,t}}\frac{L_{i,t}}{q_{i,t}K_{i,t}}e_{i,t+1}
\end{aligned} \tag{10'}$$

The introduction of the debt ceiling does not change the interpretation of the model. However, it is convenient in the sense that it gives rise to several ways of parameterising the financial constraints.

Note that (10') may be rewritten as a standard first order condition with marginal revenue, $\frac{p_{i,t}}{\mu_{i,t}}$, equal to marginal costs. We then see directly that the debt constraint can be interpreted as affecting the marginal costs by shifting the marginal cost curve vertically. The more a financial constraint binds, the higher are marginal costs. However, the effect on markups can not be stated unambiguously. According to the covariance term, the firms consider the covariance between the degree of credit constraint and future marginal product of labour. The term may reasonably vary over the business cycle. It is zero for firms that are always unconstrained. Thus, it gives a reason for diverging markup levels as well as markup cyclicality between the two groups of firms.[9] These effects of the labour adjustment costs and

[9] We abstract from particular price games. However, some comments about tacitly colluded oligopoly prices should be given. Such pricing strategies are captured by the general formulation of our markup. More specifically, the shadow price of credit can be seen as affecting the relevant discount rate, see note 7. Thereby incentives for deviations are affected. Since the constraint may vary over the business cycle, so will the discount factor. This may result in the sustainable market equilibrium price varying cyclically, with reference e.g. to an oligopoly where firms play trigger strategies. If the (shadow) discount factor is reduced in recessions due to a higher shadow price of credit, firms become more myopic, the gain by deviating from a Nash equilibrium is

financial constraints on markup can be seen directly by alternatively solving (10') with respect to $\mu_{i,t}$. However, since we do not have access to price data on plant level, and since marginal costs are unobservable, we prefer the above representation since we will actually estimate the markup as it is given in (10'). The markup will be parameterised to take into consideration its variation over types of firms, and over the business cycle.

3. Empirical Specification

Several assumptions have to be made in order to estimate the model in equation (10). Firstly, as argued above, the markup may differ between constrained and unconstrained firms. Next, there may be cyclical fluctuations in markups that vary according to the same constraints. We split the sample into *a priori* assumed constrained and unconstrained firms and test for differences in markup level and its variation. Lastly, we have to find a representation of the unobservable credit constraint multiplier, which according to (10') affects the optimising behaviour.

How do financial constraints affect the markup? It should be noted that both the covariance term and the other terms involving the credit multiplier $\tilde{\lambda}_{i,t}^{B}$ are zero for the unconstrained firms. Therefore, unconstrained firms will be unaffected by the credit market situation. For the constrained firms, the term $\tilde{\lambda}_{i,t}^{B}$ is non-negative, implying a costlier adjustment for these firms. Markup should this way be lower for the firms that are constrained. The degree to which the firms are financially constrained may be time dependent. Some of the cyclicality is captured by the term cov(.) in (10'). An interpretation of the covariance term reads that if credit availability is shorter during recessions, it will in expectation contribute to increase marginal costs for constrained firms. In booms, these costs are lower if credit is then more easily available. By combining the covariance term with the first term on the right hand side in (10'), it may serve as the basis for partitioning plants into assumed constrained and unconstrained units. Thereby it strengthens the markup pro-cyclicality of constrained firms relative to unconstrained firms. We represent these effects by parameterising $\mu_{i,t}$ as

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increased. Then the sustainable equilibrium price has to decrease. A pro-cyclical markup results. Other price games may be considered, e.g. as in Chevalier and Scharfstein (1996), with the opposite outcomes.

$$\mu_{i,t} = \mu^{0Uncon}\left(1 - D_i^{Con}\right) + \mu^{0Con} D_i^{Con} + \mu^{1Uncon}\left(1 - D_i^{Con}\right)\cdot \Psi_t + \mu^{1Con} D_i^{Con} \Psi_t \tag{13}$$

where

$$D_i^{Con} = \begin{cases} 1 & \text{if plant is constrained} \\ 0 & \text{otherwise} \end{cases}$$

According to (13), the markup term consist of a constant term, μ^0, and a variable term, μ^1. The variation is related to changes in gross domestic products Ψ_t, as measured relative to the four surrounding years. In this way, the Ψ_t variable picks up the degree to which demand each year is higher or lower than the general trend. The Ψ_t variable is expressed as

$$\Psi_t = \ln(GDP_t) - \frac{1}{4}(\ln(GDP_{t-2}) + \ln(GDP_{t-1}) + \ln(GDP_{t+1}) + \ln(GDP_{t+2})) \tag{14}$$

Next, both the constant and cyclical part of markup are different for assumed constrained and unconstrained firms. The superscript *Uncon* denotes unconstrained, for which firms cov (.) and $\tilde{\lambda}_{i,t}^{B}$ in (10') are zero, while the superscript *Con* represents the constrained firms.

With this representation, constraints due to the need to finance labour hoarding are reasonably interpreted as a shift in marginal costs from constrained to unconstrained firms, and between periods of low and high demand, which directly affect the markups. Our model is expected to generate procyclical markup variations unless there are price games and conditions for tacit collusion that differ over the cycle. Potential strategic behaviour as discussed by Green and Porter (1984), Rotemberg and Saloner (1986), and Brander and Lewis (1986,1988) are all inherent in the general markup formulation of (3'), as well as a situation with collusion and constant price behaviour over the business cycle.[10] We have no means, though, to discriminate between the different hypothesis. Nevertheless, note that the countercyclical price setting behaviour discussed by Rotemberg and Saloner (1986) has to be quite strong if it is to dominate at sector level. Even if financial constraints and labour

[10] See footnote 9.

adjustment costs can be ruled out, markup is expected to be constant or procyclical for all plants with constant marginal costs. Therefore, price configurations that induce a strongly procyclical demand elasticity would have to be commonplace for countercyclicality to emerge, which is of course possible but not plausible for aggregated manufacturing industry sectors.

Whereas we assume that the effects of the covariance term is picked up by our parameterisation of the markup term, we will test for a particular formulation of the credit constraint. Following Hubbard, Kashyap and Whited (1995), we expect the constraint to bind less the higher is a firm's cash flow to its assets. The reason is that a high cash flow will make it easier to finance a quasi fixed factor like labour. Thus, for constrained firms we will use

$$\tilde{\lambda}_{i,t}^{B} = \left(\alpha^0 + \alpha^1 \frac{CF_{i,t}}{FA_{i,t}} \right) \cdot D_i^{Con} \tag{15}$$

where CF is cash flow and FA is the aggregate replacement cost of fixed assets. Both variables are measured at firm level, i.e. they are an aggregate over all plants within a firm.

A firm's classification as financially constrained or unconstrained is assumed fixed over the entire sample period. Implicitly, we are assuming that a firm cannot affect its credit limit or possibilities to attract capital by issuing new shares. One interpretation of this setting is that a firm's credit-worthiness is either fixed or changes slowly over time. By using pre-sample information for splitting the sample, we hope to reduce the endogeneity problem induced by the fact that the firm-specific term in equation (10') may be correlated with the split criteria. We use the three first observations for each plant to characterise a plant's financial position. These observations are correspondingly not used to estimate the parameters of the model. Letting our classification be fixed over the entire sample period is consistent with our hypothesis that the covariance term in (10') will be zero for the unconstrained units. Finance data are available at firm level. Even though we use plant level data when estimating markup, we assume that it is the financial position of the parent firm that is most relevant for considering a plant's financial situation. It is at the firm level that the formal accounting information to be used by external sources is reported. Furthermore, a plant belonging to a larger firm must be assumed to be able some way or other to participate in the common value of all the merged plants.[11]

We assume that small firms with a high share of debt to total assets are most likely to be rationed. A small firm may be assumed younger, and thereby have a shorter credit history to be used for consideration of its credit worthiness. Moreover, small firms may have lower collateral relative to their liabilities. In addition, informational asymmetries will make it impossible for small firms to raise capital through new shares or commercial papers. Together, these factors will make it likely that smaller firms face a larger premium on external funding. The debt ratio serves as a signal of the firm's bankruptcy risk. With a high debt ratio a firm is assumed to be less capable of serving additional debt. This problem is more severe for smaller than larger firms. We will therefore use both criteria simultaneously when considering whether a plant is characterised as constrained or unconstrained. For each industry sector to be investigated, the group of constrained units consists of plants belonging to firms with a debt-asset ratio exceeding that of the median firm, and with employment below the median. In addition, we classify firms as unconstrained if the average number of employees is greater or equal to 100 in the pre-sample period since such firms are relatively large in the Norwegian manufacturing industry. All median numbers are calculated as an average of the first three observations for each plant.

The final model to be estimated is given by (10'), with the expressions (13)-(15) substituted for $\mu_{i,t}$ and $\tilde{\lambda}_{i,t}^{B}$. We use a Taylor approximation of first order for the term $\frac{\mu_{i,t}}{\mu_{i,t+1}}$ in (10') in order to get a model that is linear is in Ψ_t:

$$\frac{\mu_t}{\mu_{t+1}} \approx 1 - \frac{\mu^{1Uncon}}{\mu^{0Uncon}}(\Psi_{t+1} - \Psi_t) + \left(\frac{\mu^{1Uncon}}{\mu^{0Uncon}} - \frac{\mu^{1Con}}{\mu^{0Con}}\right)(\Psi_{t+1} - \Psi_t) \cdot D_i^{Con} \tag{16}$$

When estimating this revised version of the model in (10'), we will include a firm specific fixed effect for each firm. The fixed firm effect can be interpreted as accounting for firm specific characteristics that are constant over the sample period. We have also included a time dummy that is meant to pick up the effect of macro shocks. The estimation is carried through separately for each sector, since we want to allow for sectoral differences in the parameters.

[11] The findings of Lamont (1993) support the assertion that it is firm level that matters for internal finance.

The econometric model is derived using Euler equations. Furthermore, we have assumed that the decision-makers have rational expectation about the future. Since the error term $e_{i,t+1}$ is correlated with the regressors, an instrumental variable estimation method is called for to ensure consistency of the estimated parameters. As long as the decisions makers' expectations are formed rationally, in the sense that the errors they make in forecasting are uncorrelated with the information they had available at the time they made their forecast, there are orthogonality conditions that can be used in a generalised method of moments (GMM) as outlined in Hansen (1982). Variables dated t and earlier which are correlated with the variables in the regression, are valid instruments. However, the set of instruments is only valid if the error term, $e_{i,t+1}$, is serially uncorrelated. The firm–fixed effects are removed by estimating the model in first-differences. This first-differencing introduces a first-order serial correlation into the model. Therefore, a first-order correlation is expected, but an absence of higher order serial correlation is essential for the consistency of the estimated parameters. The *m2* test, proposed by Arellano and Bond (1991), is employed to control for the absence of higher order serial correlation. The *m2* test is normally distributed with mean 0 and variance 1. If the *m2* test rejects the null hypothesis of no serial correlation in the first-differenced model, the instruments are correlated with the differenced error term, and the set of instruments is invalid. Further testing for the validity of the instruments is done by the *Sargan/Hansen* test. When the model is overidentified, we can test the null hypothesis that the model is correctly specified. The *Sargan/Hansen* test has a χ^2-distribution with as many degrees of freedom as overidentifying restrictions. Again, Arellano and Bond (1991) provide a complete discussion of these procedures. In our estimation, we have used all right hand side variables in levels as instruments, together with employment levels, all at dates *t-1* and earlier.[12]

The estimated coefficients from the *GMM*-estimation described above give unrestricted estimates of the deep parameters of the model expressed in equation (10'). These deep parameters of interest are μ^{0Uncon}, μ^{1Uncon}, μ^{0Con}, μ^{1Con}, $\tilde{v}$, *s*, α^0, and α^1. We make the initial assumption of constant elasticity of scale, i.e. $\tilde{v} = 1$. To find the other parameters

[12] All the GMM regression results are obtained using "DPD" for GAUSS, documented in Arrelano and Bond (1988).

from the observed estimators we use a minimum distance estimation method.[13] Denote the estimators from the regression $\hat{\Sigma}$, and the parameters of interest θ. Both of these are vectors. We may write $\hat{\Sigma} = g(\theta) + \eta$. The minimum distance estimate of θ, θ^*, is the value of θ which solves

$$\min_{\theta}\left(\hat{\Sigma} - g(\theta)\right)' A\left(\hat{\Sigma} - g(\theta)\right)$$

where A is a positive definite weighting matrix. The optimal (minimum-variance) choice of A is $A = \Omega^{-1}$ where $\Omega = Var(\hat{\Sigma})$. The asymptotic variance of $\hat{\theta}$ can be written as:[14]

$$V(\hat{\theta}) = \left(\left(\frac{\partial g(\theta)}{\partial \theta'}\right)' \Omega^{-1}\left(\frac{\partial g(\theta)}{\partial \theta'}\right)\right)^{-1}$$

Finally, to test the validity of the restrictions, we use a 'Comfac' test.[15] This Comfac test is a Wald test, which is asymptotically distributed as χ^2 with degrees of freedom equal to the number of restrictions.[16]

4. Data.

The empirical analysis is carried through at the plant level. Variables representing debt-constraints are constructed from the balance sheet of the firm to which the plant belongs.

4.1 The Sample

The empirical work is based on a large set of unbalanced data of Norwegian plants and firms

[13] The parameter results are obtained using the "Optimisation" application for GAUSS.
[14] The proof of the consistency and asymptotic normality of the minimum distance estimator can be found in appendix 3A, Hsiao (1986).
[15] This name we have borrowed form the paper of Blundell, Bond, Devereux, and Schiantarelli (1992).
[16] A more detailed description of the test could for instance be found in Greene (1993), "Econometric Analysis", 2nd edition.

within manufacturing industry for the period 1978-1991. The data are collected by Statistics Norway. Income statement and balance sheet information are provided from Statistics of Accounts for all firms with more than 50 employees during the period 1978-1990. In 1991 no new small firms (less than 100 employees) were added to sample due to new sampling routines used by Statistics Norway. For all firms included in Statistics Norway's Statistics of Accounts, plant level information about production, production costs, investment and capital stock is available from the Manufacturing Statistics.[17] All data are annual.

We include observations where the calculated man-hours worked per employee during a year are in the interval [400,2500].[18] Wage per hour is calculated by dividing the total wage bill by total man-hours worked. For the period 1978-1983 we found that the standard error of this wage variable was more than triple of what we observe for the rest of the sample period. Because of this we used the information about number of blue- and white-collar workers and excluded observations where the share of white-collar workers was higher than 0.5. To get as homogeneous a sample as possible we also excluded observations for plants where part-time employees count for more than 25 percent of the work force.

Firms in which the central or local governments own more than 50 percent of the equity have been excluded from the sample, as well as observations that are reported as "copied from previous year". This actually means missing data. In an attempt to isolate plants whose capital stock has a negligible role in production, we deleted observations where the calculated replacement value of equipment and buildings together was less than NOK 200,000 (1980 prices).[19] To avoid measurement errors of production, observations with non-positive production levels were deleted. Also observations where the employment level was 5 times larger than, or less than 1/5 of the employment previous year, were deleted. The remaining data set was trimmed to remove outlayers. Observations with ratios outside of five times the interquartile range above or below the sector specific median were excluded.[20] Finally, we included only series with at least six consecutive observations. Due to leading and lagging when constructing the explanatory variables, we loose two cross-sections. This leaves us with

[17] See Halvorsen et al. (1991) for further details.

[18] Before 1983 the registered total plant man-hours cover hours worked by blue-collar workers only. In this period man-hours worked per employee were calculated by dividing the registered man-hours by the number of blue-collar workers.

[19] Approximately £ 20,000.

[20] We used ratios for output, variable costs, and debt.

series of at least four consecutive observations.

4.2 Variable Definition and Construction

Codes in square brackets refer to variable number in the Manufacturing Statistics.

Replacement value of capital stock ($q_t K_t$): The replacement value of capital is calculated separately for equipment and buildings using the perpetual inventory formula

$$q_t^j K_t^j = q_t^j K_{t-1}^j \cdot \left(1 - d^j\right) \cdot PI_t^j + I_t^j$$

where superscript j indicates the different types of capital. Depreciation rates, d^j, are taken from the Norwegian National Accounts (0.06 and 0.02 for equipment and buildings, respectively). Also the price indices for investment, PI_t^j, are taken from the Norwegian National Accounts. When calculating the replacement value of capital, we use as a benchmark the oldest reported fire insurance value ([871] and [881] for equipment and buildings, respectively) larger than or equal to NOK 200,000, measured in 1980 prices. From these initial values we calculate the replacement value backwards and forwards, using the investment figures.[21] Finally we added together the two categories of capital. Real investment at time t in capital of type j equals purchases minus sales of fixed capital. Investments in equipment include machinery, office furniture, fittings and fixtures, and other transport equipment, excluding cars and trucks ([501]+[521]+[531]-[641]-[661]-[671]). The measure of buildings includes buildings used for production, offices and inventory storage ([561]-[601]).

Output ($p_t Y_t$): Gross production [1041], plus subsidies [291], and minus taxes [301].

Variable costs: ($w_t L_t + c_t Z_t$): Wage expenses [291] and inputs [1061].

Employees (L_t): Number of employees [131]. The change in the labour stock is defined as

[21] If the replacement value of capital became negative, it was set equal to zero. When calculating the capital stock forward it may happen that the replacement value becomes negative because of large sales of capital goods. When calculating it backwards the replacement value becomes negative if the net purchase of fixed capital is larger than the replacement value in year $t+1$.

$X_t = L_t - (1-\delta)L_{t-1}$. It is problematic to determine the quit rate, δ .We may argue that there is a lower level of quits at 2.5 per cent. This is motivated by the fact that individuals are working for approximately 40 years, implying that 2.5 percent of the labour stock in a plant is changed due to retirement. In addition, some workers voluntarily change employer. For the US, the quit rate of employees on manufacturing payrolls (Bureau of Labor Statistics (1975, 1983)) varies between 0.01 and 0.06 over the period 1940-1981. Hamermesh, Hassink and van Ours (1996) find a flow of workers from existing jobs at a rate of 0.08 for the Netherlands. For Norway, corresponding figures are at present hard to collect. However, Klette and Mathiassen (1996) find total job destruction to be 8.4 percent each year (1977-1986) in the Norwegian manufacturing industry. We find this reasonably representative, and set $\delta = 0.08$.[22]

Debt-ratio (B/TA): The book value of short-term and long-term liabilities ($[5100]_{\text{Accounts}}$ + $[5200]_{\text{Accounts}}$) normalised with total assets $[5500]_{\text{Accounts}}$.

Cash flow (CF): Profit before year-end adjustments $[310]_{\text{Accounts}}$+ depreciation $[229]_{\text{Accounts}}$+ extraordinary (not-tax-conditioned) depreciation $[282]_{\text{Accounts}}$ - tax on property and income $[333]_{\text{Accounts}}$ - profit on disposals of fixed assets $[271]_{\text{Accounts}}$ + loss on disposals of fixed assets $[281]_{\text{Accounts}}$. These numbers are normalised with the aggregate replacement value of fixed capital in all plants belonging to a firm.

Interest rates (i_t): We have used interest rates for loans with three months duration (NIBOR).

Price indices (p_t): Price indices for industry sector gross output collected from National Accounts.

Gross Domestic Product (GDP_t): The industry sector values are collected from National Accounts. The GDP_t values are annual. For sectors where the National Accounts give information at a less aggregated level than our sector specification, we have used the more detailed information.

[22] In a previous version of this paper we have tried with quit rates of 0 as well as sector specific quit rates varying from 4 to 14%, without the different assumptions dramatically affecting the results.

The plants belong to the manufacturing industry sectors (ISIC code in parentheses): Food (311), Textiles (321), Clothing (322-324), Wood Products (331), Furniture (332), Paper and Paper Products (341), Chemicals (351-352), Mineral Products (361-369), Metals (371-372), Metal Products (381), Machinery (382). Some of the plants changed sector during the sample period. We group these plants into the sector where they had their highest frequency of observations.

Before turning to the results, we present the expected signs and sizes of the parameters of interest. The non-cyclical part of the markup is assumed to be $\mu^0 \approx 1$. This implies that there is no monopolistic power. The cyclical part of the markup, μ^1, may be positive or negative. We expect a positive sign, i.e. a procyclical markup. Assume that we find $\mu^1 = 0.5$. This implies that a relative change in the (detrended) *GDP* of 6 percent increases the markup by 0.03, for instance from 1.00 to 1.03. Based on our interpretation of the effects of financial constraints, we will expect to find $\mu^{0Uncon} > \mu^{0Con}$ and $0 < \mu^{1Uncon} \leq \mu^{1Con}$. We expect the labour adjustment costs parameter $s \geq 0$ Based on other calculations of the size of adjustments costs, the parameter estimates of s are expected to be small in absolute terms. As to the debt constraint, we expect $\alpha^0 > 0$ and $\alpha^1 \leq 0$.

5. Results

All the results are given in table 1. We only report the restricted estimates revealed by the minimum distance procedure.

We start out estimating the model by allowing both the fixed and the cyclical markup term to vary between *a priori* constrained and unconstrained plants. In addition, we include time dummies. If the time dummies are jointly significant (insignificant), they are included (excluded). Knowing that our specification requires the labour adjustment costs parameter s to be positive, we reestimate the model if the empirical results are inconsistent with this assumption. If the hypotheses of equal markup terms between the two types of firms cannot be rejected, we reestimate the model imposing the restriction of similar coefficients for the two groups of plants. The final specification is named *preferred* in the table. It is also worth mentioning that for two of the sectors, Paper and Paper Products (341) and Metals (371-2), the number of constrained firms is too small for the GMM estimation procedure to work. Therefore, for these sectors we estimate the model by placing all units into the same group.

As already mentioned, we make the initial assumption of constant unit elasticity of scale. However, we are only able to relax this assumption and identify the $\tilde{\nu}$ parameter if the number of unrestricted coefficients is greater than or equal to the number of deep parameters. After the model is reduced according to the above described procedure, this turns out to be true for none of the analysed industries.

We find the fixed markup term not to deviate significantly from one in most of the industries. In Metal Products (381) we find a markup of 1.14. The fixed markup term is also greater than one in Clothing (322-4), although its significance is weak with a *t*-value equal to 1.76. For Metals (371-2), we get a very high fixed markup term. This sector includes products where Norwegian firms have a high market share on the world market, like e.g. raw aluminium. Therefore the estimate is not unreasonable. Note that for Machinery (382) the *m2* test marginally rejects the validity of the instruments. This rejection remains even after lagging the instruments *t-2* and *t-3*. For brevity sake, these results are not reported. We find a fixed markup term which is less than one in Textiles (321). This result is implausible and hard to interpret. However, the markup term is not significantly different from one. Strictly speaking, market power prevails only where markup exceeds unity. We will not rule out that some degree of market power is relevant even though strictly speaking it does not follow from our results. With a richer set of instruments and utilising more orthogonality restrictions in GMM, we believe we could get sharper estimates. However, the relatively small number of firms in our sample restricts our set of instruments. Using larger data sets, Klette (1994) finds a positive price-cost margin, to a large degree of the same magnitude as we find, for most industry groups, and he concludes that market power exists in most sectors. We believe that our tests of significance to some degree underestimate the real market power.

The cyclical markup term is significantly greater than zero in six of the analysed industries. These are Food (311), Textiles (321), Wood Products (331), Furniture (332), Chemicals (351-2), and Metals (371-2). Significantly countercyclical markups are not found in any of the analysed industries, although an insignificant countercyclicality is found in Clothing (322-4), Paper and Paper Products (341), and Mineral Products (361-9). Thus, in general the results are as expected given our model. Other empirical studies have found both procyclical and countercyclical markups. Our findings of procyclical markups correspond to the findings of Domowitz, Hubbard and Petersen (1986, 1987) and Chirinko and Fazzari (1994).

The existence of adjustments cost of labour may affect the marginal costs and therefore the markups. The labour adjustment costs parameter, s, is in general insignificant or of the wrong sign. Note, however, that the insignificant adjustment costs parameter may only be used to reject our specific adjustment costs structure, not to exclude the existence of labour hoarding as such. We refer in this connection to other studies which also tend to find relatively small adjustment costs for labour, e.g. by Burgess and Dolado (1989). A first explanation of the insignificance of the adjustment costs parameter is nevertheless that labour hoarding is not existent i.e. firms are able to adjust their labour stock without significant costs. In our formulation we have chosen convex adjustment costs. It may be the case that the labour adjustment costs are not correctly handled this way. There may e.g. be non-convexities in the labour adjustment costs (see Hamermesh and Pfann (1996)). In addition, the actual costs may be asymmetric, i.e. they differ between upturns and downturns, as analysed by Pfann and Verspagen (1989), Jaramillo, Schiantarelli, and Sembenelli (1993), and Pfann and Palm (1993). Some of this asymmetry is embedded in our formulation by the quit rate δ , which makes an adjustment of labour upwards relative more expensive than an adjustment downwards. Contrary to the relatively more expensive labour adjustments in upturns, it may instead be the case that labour utilisation or productivity is procyclical (Basu (1996)). Then firms would face relatively lower labour costs in booming periods. Even though our estimates indicate small or insignificant adjustment costs, it could still be the case that such labour hoarding exists. This kind of behaviour would induce procyclical markups. So, smaller relative labour costs in booming periods caused by labour hoarding are consistent with our findings of procyclicality in the markups.

According to industrial organisation theory, the firms' aggressiveness in their pricing behaviour may vary as aggregate demand changes. The concept of super-game perfectness explains how firms through tacit collusion will be able to charge a market price higher than the price given from a competitive equilibrium. The tacit collusion exists because of the threat of punishment from the competitors in later periods if a firm undercuts the tacit collusion price in a given period. Such co-operation may break down in downturns, Green and Porter (1984), or in booming periods, Rotemberg and Saloner (1986). We have not modelled any such price games, since we have no reasons to believe them to be systematic over several industry sectors. This does not mean that they may not be the part of the explanation of our results. However, as our model is set up, we assume that any, tacit or open, co-operation is withheld over the business cycle. For several reasonable product demand configurations this implies a procyclical markup, as we have found. We note that if demand is iso-elastic and marginal costs are constant, a constant markup will result. Therefore, for the sectors where no cyclicality is found, we cannot rule out the existence of market power.

In this paper we focus on the interaction between output decisions and credit constraints. Such constraints are likely to be more binding in recessions. Then the marginal costs will increase since necessary funding may be hard to raise, and the firms behave as though they are more myopic. The reduced markup, given constant marginal costs within a period, is also consistent with the interpretation of credit constraints as shifting the marginal cost curve. When pricing and output decisions are intertemporal investment decisions, liquidity constraints and pricing decisions are correlated. Chevalier and Scharfstein (1995) argue that capital market imperfections may lead to financing constraints which may induce reduced investments in market shares.[23] However, as pointed out by the authors, the output price and markups of liquidity constrained firms may go in either direction.

We have also tried to estimate the model with the specified parameterising of the debt-multiplier. However, our model sketched in equation (10') is based on the assumption that the s parameter is positive and significantly different from zero. When this is not the case, the debt parameters α^0 and α^1 are not identifiable. Our estimation results based on a full model where we also use the debt-multiplier parameterising, reveals insignificant α-s. Also the size of these parameters are hard to interpret. Therefore these results are not reported.

The insignificant estimates of the debt multiplier parameters are consistent with our findings of insignificant differences in the markup terms between constrained and unconstrained firms. Based on this, we may conclude that either has our parameterising of the debt

[23] See for instance Gertler (1988), Hubbard (1997) and Schiantarelli (1996) for a more detailed discussion about investment and liquidity constraints.

constraints not been successful, or it is the case that debt constraints do no present a problem for the plants in our sample. An interpretation of the results reads that the firms' financial situation does not restrict their establishments' pricing behaviour and quantity adjustments. More specifically, they are able to reduce factor use during a downturn, or, if this potential is limited, credit can be provided to finance any hoarding of labour. It should not be excluded, though, that the insignificance of the debt constraints might be due to sample selection biases. The sample used consists of plants with at least 6 consecutive observations belonging to firms with more than 50 employees. These firms are relatively large in the Norwegian manufacturing industry and their access to credit should therefore be relative easy.[24] The relatively easy access to credit may also explain why labour adjustment costs are of no significance for forward looking firms over a business cycle. Therefore, it might be the case that financing constraints are less likely for firms in our sample. Finding that financial factors influence only marginally on firms' operating behaviour, corresponds to other analyses focusing on the importance and existence of credit constraints for Norwegian firms.[25]

Some last comments about our sample split based on debt ratios are warranted. In the given sample split, we have implicitly assumed that the "debt-capacity" is the same for all firms, and that the debt-asset ratio is used as a proxy for the distance from this capacity, i.e. the debt-asset ratio is negatively related to credit limits. If, however, the debt capacity is higher for some firms, leverage acts as an indicator of better access to external funding and less credit rationing. Splitting the sample on debt ratio information may therefore be inappropriate for our investigation.

6. Concluding remarks

In this paper, we have analysed the cyclical behaviour of markups based on firm and plant level data from Norwegian manufacturing industries. The markups are estimated from a dynamic model of a firm. This way we get around the difficulties of measuring markups and marginal costs. The model is rather general and allows for different interpretations consistent with several price-setting and demand configurations. Financial constraints may prevent the

[24] Data from the Manufacturing Statistics reveal that approximately 85 percent of firms have less than 50 employees.
[25] See Nilsen and Schiantarelli (1997) for investment in fixed capital, and Vale (1996) for inventory investment.

firm from making optimal labour adjustments. The labour adjustments costs are assumed to be convex such that labour hoarding may take place.

The empirical results do reveal only a few sectors with price-cost margin higher than unity. Still we believe that markup pricing takes place. We do not reveal any sectors where the markups significantly fluctuate countercyclically. If existent, markups are procyclical. A relevant or significant labour adjustment cost parameter is found in none of the analysed industries. This can be understood by relating the results to the effects of other relevant labour market institutions. During the period of investigation it has been relatively easy for firms to temporarily lay off workers. The workers can during short term unemployment spells claim unemployment compensations that are not far below their ordinary wage rates. Lately enforced reductions in such benefits may give rise to reductions in short term lay-offs, and thereby make costly labour adjustments more relevant. There are not yet sufficient data available to study this potentially different labour market situation. The results indicate that our way of handling the adjustment costs will not result in them being important. A reason may be that there is a fixed component of adjustment costs that is relatively more important for smaller plants. If so, labour adjustment is not of significant importance for the firms that are present in our data set when they make their optimal long term pricing and quantity decisions.

In our model, finding a significantly positive labour adjustment costs parameter is essential to be able to identify the debt multiplier parameters. Since we do not find the labour costs parameter, s, to be significantly positive, it may be hard to draw any conclusions about credit constraints. However, in our model we have tried to discriminate between *a priori* constrained and unconstrained units. Our empirical results reveal that there are no differences in the markup behaviour of financially constrained and unconstrained plants. We argue that these results are due to sample selection problems. The small firms in our sample that are assumed to be constrained, are relative large in a Norwegian context.

Thus, all findings are consistent. We get procyclical markups, small adjustment costs and difficulties in revealing the existence of any credit constraints. More binding credit constraints would probably have generated even stronger procyclicality. Thus, from a macroeconomic perspective, there is a good basis for arguing that markups in Norwegian manufacturing industry are procyclical.

In future research, more emphasis should be put on finding better ways of estimating labour and capital market imperfections. Introducing non-convex or asymmetric labour adjustment costs may be warranted. Capacity and labour utilising may be important when explaining the insignificance of the labour adjustment costs parameter, and therefore other ways of modelling the demand for labour should be tried. In our formulation the adjustment costs parameter will incorporate more than only employment adjustments. We should also get around the problem of requiring the labour adjustment costs parameter to be significantly positive to be able to identify credit constraints multipliers.

References

Arrelano, M. and S.R. Bond, 1988, "Dynamic Panel Data Estimation Using DPD - A Guide for Users", Working Paper 88/15, Institute for Fiscal Studies.

Arellano, M. and S.R. Bond, 1991, "Some Test of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations", *Review of Economic Studies 58*, 277-297.

Basu, S., 1996, "Procyclical Productivity: Increasing Returns or Cyclical Utilization?", *Quarterly Journal of Economics 111*, 719-51.

Bils, M., 1987, "The Cyclical Behavior of Marginal Cost and Price", *The American Economic Review 77*, 838-55.

Blundell, R. S. Bond, M. Devereux and F. Schiantarelli (1992). "Investment and Tobins' Q: Evidence from company data", *Journal of Econometrics 51*, 233-257.

Borenstein S. and A. Shepard, 1996, "Dynamic Pricing in Retail Gasoline Markets", *Rand Journal of Economics 27*, 429-51.

Brander, J. A. and T. R. Lewis, 1986, "Oligopoly and Financial Structure: The Limited Liability Effect", *American Economic Review 76*, 956-70.

Brander, J. A. and T. R. Lewis, 1988, "Bankruptcy Costs and the Theory of Oligopoly", *Canadian Journal of Economics 21*, 221-43.

Burgess, S.M. and J.J. Dolado, 1989 "Intertemporal Rules with variable Speed of Adjustment: An Application to UK Manufacturing Employment", *The Economic Journal 99*, 347-365.

Bureau of Labor Statistics, 1975, *Handbook of Labor Statistics 1940-1959*, U.S. Department of Labor.

Bureau of Labor Statistics, 1983, *Handbook of Labor Statistics 1960-1981*, U.S. Department of Labor.

Calomiris, C. W., and R. G. Hubbard, 1990, "Firm Heterogeneity, Internal Finance, and Credit Rationing'", *Economic Journal 100*, 90-104.

Chevalier, J. A., and D. S. Scharfstein, 1995, "Liquidity Constraints and Cyclical Behavior of Markups", *The American Economic Review, Paper and Proceedings 85*, 390-6.

Chevalier J. A., and D. S. Scharfstein, 1996, "Capital Market Imperfections and Countercyclical Markups: Theory and Evidence", *American Economic Review 86*, 703-25.

Chirinko, R. S., and S. M. Fazzari, 1994, "Economic Fluctuations, Market Power, and Returns to Scale: Evidence from Firm-Level Data", *Journal of Applied Econometrics 9*, 47-69.

Domowitz, I., R.G. Hubbard, and B.C. Petersen, 1986, "Business Cycles and the Relationship between Concentration and Price-Cost Margins", *The Rand Journal of Economics 17*, 1-17.

Domowitz, I., R.G. Hubbard, and B.C. Petersen, 1987, "Oligopoly Supergames: Some Empirical Evidence on Prices and Margins", *Journal of Industrial Economics 36*, 9-28.

Galeotti M., and F. Schiantarelli, 1995, "The Cyclicality of Markups in a Model with Adjustment Costs: Econometric Evidence for U.S. Industry", manuscript.

Gertler, M., 1988, "Financial Structure and Aggregate Economic Activity: An Overview.". *Journal of Money, Credit, and Banking 20*, 559-588.

Green E., and R. Porter, 1984, "Noncooperative Collusion under Imperfect Price Information", *Econometrica 52*, 87-100.

Greene, W. H., 1993, *Econometric Analysis*, Macmillan Publishing Company, New York.

Hall, R.E., 1988, "The Relationship between Price and Marginal Cost in U.S. Industry", *Journal of Political Economy 96*, 921-47.

Haltiwanger, J., and J.E. Harrington, 1991, "The Impact of Cyclical Demand Movements on Collusive Behavior", *The Rand Journal of Economics 22*, 89-106.

Halvorsen, R., R. Jenssen and F. Foyn, 1991, "Dokumentasjon av Industristatistikkens tidsseriebase", mimeo, Statistics Norway.

Hamermesh, D. and G. Pfann, 1996, "Adjustment Costs in Factor Demand", *Journal of Economic Literature 34*, 1264-92.

Hamermesh, D. S., W. H. Hassink and J. C. van Ours, 1996, "Job Turnover and Labor Turnover: A Taxonomy of Employment Dynamics", *Annales d'Economie et de Statistique* 0(41-42), 21-40.

Hansen, L.P. 1982, "Large Sample Properties of a Generalized Methods of Moments", *Econometrica 50*, 1029-54.

Hendel, I., 1996, "Competition under Financial Distress", *Journal of Industrial Economics 44*, 309-24.

Holt, C., F. Modigliani, J. Muth and H. Simon, 1960, *Planning Production Inventories, and Work Force*, Prentice Hall.

Hsiao, C., 1986, *Analysis of Panel Data*, Cambridge University Press, Cambridge, UK.

Hubbard, R. G., 1997, "Capital-Market Imperfections and Investment", NBER Working Paper 5996.

Hubbard, R. G., A. Kashyap and T. Whited, 1995, "International Finance and Firm Investment", *Journal of Money, Credit, and Banking 27*, 683-701.

Jaramillo, F., F. Schiantarelli and A. Sembenelli. 1993, "Are Adjustment Costs for Labor Asymmetric? An Econometric Test on Panel Data for Italy", *The Review of Economics and Statistics 75*, 640-648.

Klette, T. J., 1994, "Estimating Price-Cost Margins and Scale Economies from a Panel of Microdata", Discussion Paper No. 130, Research Department, Central Bureau of Statistics, Norway.

Klette, T. J. and A. Mathiassen, 1996, "Job Creation, Job Destruction and Plant Turnover in Norwegian Manufacturing", *Annales d'Economie et de Statistique* 41-42, 97-125.

Lamont, O., 1993, "Cash flow and Investment: Evidence from Internal Capital Markets", mimeo, MIT.

Nickell, S., 1986, "Dynamic Models of Labour Demand", ch. 9 in *Handbook of Labor Economics I*, ed. by O. Ashenhelter and R. Layard, Elsevier Science Publishers.

Nilsen, Ø. A. and F. Schiantarelli, 1997, "Zeroes and Lumps in Investment: Empirical Evidence of Irreversibilities and Non-Convexities", mimeo, Boston College.

Pfann, G.A. and F.C. Palm, 1993, "Asymmetric Adjustment Costs in Non-linear Labour Demand Models for the Netherlands and UK Manufacturing Sectors", *Review of Economic Studies 60*, 397-412.

Pfann, G.A. and B. Verspagen. 1989, "The Structure of Adjustment Costs for Labour in the Dutch Manufacturing Sector", *Economic Letters 29*, 365-371.

Phillips, G. M., 1995, "Increased Debt and Industry Product Markets: An Empirical Analysis", *Journal of Financial Economics 37*, 189-238.

Rotemberg J., and G. Saloner, 1986, "A Super Game Theoretic Model of Price Wars during Booms", *American Economic Review 77*, 390-407.

Rotemberg J., and M. Woodford, 1992, "Oligopolistic Pricing and the Effects of Aggregate Demand on Economic Activity", *Journal of Political Economy 100*, 1153-1207.

Schiantarelli, F., 1996, "Financial Constraints and Investment: Methodological Issues and International Evidence", *Oxford Review of Economic Policy 12*, 70-89.

Stiglitz, J., and A. Weiss, 1981, "Credit Rationing in Markets with Imperfect Information", *American Economic Review 71*, 393-410.

Vale, B., 1996, "Firm's Inventory Investments, Financial Conditions and the Banking Crisis in Norway", Working Paper 1994/4, Norges Bank, Oslo.

Unrestricted estimates	Food (311)				Textiles (321)				Clothing (322-4)				Wood Product (331)			
Time-dummies	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
m2 (p-value)	0.148	0.135	0.122	0.126	0.526	0.483	0.534	0.457	0.460	0.715	0.269	0.608	0.410	0.314	0.332	0.201
Sargan/Hansen [df]	9.98 [9]	7.70 [6]	6.89 [6]	4.52 [4]	4.26 [9]	3.14 [6]	4.82 [6]	3.10 [4]	1.53 [9]	4.42 [6]	0.82 [6]	2.39 [4]	8.63 [9]	9.79 [6]	6.59 [6]	5.22 [4]
# Obs.	1114	1114	1114	1114	197	197	197	197	98	98	98	98	474	474	474	474
# Plants	300	300	300	300	47	47	47	47	26	26	26	26	100	100	100	100
Plants Constrained (%)	11.7	11.7	11.7	11.7	17.0	17.0	17.0	17.0	27.0	27.0	27.0	27.0	24.0	24.0	24.0	24.0
Restricted estimates																
Coefficients																
μ^0			1.0018	1.0029			0.8577*	0.8947			1.1043*	1.0967(*)			1.0564	1.0585
			(0.0136)	(0.0158)			(0.0640)	(0.0771)			(0.0524)	(0.0549)			(0.0845)	(0.0641)
$\mu^{0\,UNCON}$	1.0033	1.0045			0.8407	0.8871			1.1349*	1.1066*			1.0113	1.1228(*)		
	(0.0138)	(0.0169)			(0.0654)	(0.0851)			(0.0437)	(0.0455)			(0.1147)	(0.0732)		
$\mu^{0\,CON}$	0.9245	0.9450			0.8614	0.8434			1.1666*	1.1167**			1.1187	1.0493		
	(0.0537)	(0.0551)			(0.0729)	(0.0995)			(0.0582)	(0.0683)			(0.0885)	(0.1007)		
μ^1			0.0651*	0.0713*			0.1459(*)	0.1897*			-0.1599*	-0.0615			0.4724*	0.2915(*)
			(0.0235)	(0.0236)			(0.0839)	(0.0880)			(0.0752)	(0.1189)			(0.1857)	(0.1600)
$\mu^{1\,UNCON}$	0.0655*	0.0705*			0.1341	0.1674			-0.0687	0.0456			0.4767*	0.2486		
	(0.0240)	(0.0241)			(0.0893)	(0.0977)			(0.0836)	(0.1195)			(0.1077)	(0.1611)		
$\mu^{1\,CON}$	0.0387	0.0543			0.3559*	0.3416*			-0.1498	-0.0268			0.0031	0.0412		
	(0.0981)	(0.0956)			(0.0647)	(0.0799)			(0.0929)	(0.1032)			(0.2383)	(0.3563)		
s	0.1267		0.0988		-0.0317		-0.0234		-0.0576		-0.0723		-0.1622(*)		-0.1370	
	(0.1051)		(0.1059)		(0.0647)		(0.0809)		(0.0387)		(0.0551)		(0.0959)		(0.1388)	
$\mu^{0\,UNCON} - \mu^{0\,CON} = 0$	t = 1.42	t = 1.00			t = -0.24	t = 0.34			t = -0.35	t = -0.10			t = -0.74	t = 0.57		
$\mu^{1\,UNCON} - \mu^{1\,CON} = 0$	t = 0.27	t = 0.16			t = -2.10	t = -1.38			t = 1.03	t = 1.15			t = 1.78	t = 0.53		
Comfac [df]	1.65 [2]		1.57 [1]		4.75 [2]		2.47 [1]		9.38 [2]		5.18 [1]		1.72 [2]		0.09 [1]	
				Preferred				**Preferred**				**Preferred**				**Preferred**

* Indicates significance at the 5 % level.
(*) Indicates significance at the 10 % level.

1) Dependent variable is pY. All variables are normalised with qK.
2) For variable definitions, see text.
3) All standard errors in parentheses are robust to heteroskedasticity.
4) m2 is a test of second order serial correlation.
5) Sargan/Hansen is the Sargan/Hansen test of overidentification restrictions.
6) The Comfac statistics is a test of the non-linear restrictions imposed, going from unrestricted to restricted model
7) Instruments used are independent variables period t-1, t-2 plus employment same periods.

Table 1 : GMM estimates and initial parameters

Unrestricted estimates	Furniture (332)				Paper, Paper Products (341)†		Chemicals (351-2)				Mineral Products (361-9)			
Time-dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
m2 (p-value)	0.308	0.158	0.077	0.103	0.237	0.525	0.281	0.351	0.378	0.391	0.653	0.380	0.128	0.216
Sargan/Hansen [df]	8.77 [9]	6.32 [6]	10.72 [6]	5.25 [4]	9.40 [6]	6.10 [4]	4.33 [9]	3.36 [6]	2.53 [6]	3.43 [4]	11.67 [9]	6.00 [6]	7.81 [6]	2.44 [4]
# Obs.	165	165	165	165	366	366	272	272	272	272	359	359	359	359
# Plants	33	33	33	33	70	70	56	56	56	56	70	70	70	70
Plants Constrained (%)	33.0	33.0	33.0	33.0	3.9	3.9	14.3	14.3	14.3	14.3	22.9	22.9	22.9	22.9
					Note: To few constrained firms									
Restricted estimates														
Coefficients														
μ^0			1.2732*	1.0799	1.1947*	1.0434			1.0191	0.9904			1.0374	1.0773
			(0.0429)	(0.0528)	(0.0752)	(0.1382)			(0.0376	(0.1130)			(0.0672)	(0.0686)
$\mu^{0\,UNCON}$	0.7209(*)	0.9714					1.0105	0.9304			0.9391	1.0008		
	(0.0605)	(0.1519)					(0.0414)	(0.1291)			(0.0916)	(0.1157)		
$\mu^{0\,CON}$	1.1836*	1.1394*					1.0675	1.1053			1.0529	1.0959		
	(0.0295)	(0.0275)					(0.0535)	(0.0868)			(0.0511)	(0.0571)		
μ^1			-0.1137	0.3438*	0.2218	-0.0981			0.2294(*)	0.1997(*)			-1.9239	-0.1156
			(0.1623)	(0.1565)	(0.4155)	(0.4534)			(0.1171)	(0.1102)			(7.6100)	(0.2591)
$\mu^{1\,UNCON}$	0.7609*	0.3018					0.3067*	0.2365			0.0131	0.0029		
	(0.1861)	(0.2629)					(0.1470)	(0.1444)			(0.2546)	(0.2781)		
$\mu^{1\,CON}$	0.6079*	0.3801*					0.0732*	0.0659*			-0.0575	-0.0893		
	(0.1090)	(0.1433)					(0.0270)	(0.0291)			(0.4136)	(0.4377)		
s	-0.2701*		-0.7296*		-0.3888*		-0.3358(*)		-0.4398*		-0.0545		-0.1638	
	(0.0787)		(0.1154)		(0.1064)		(0.1756)		(0.1966)		(0.2304)		(0.2387)	
$\mu^{0\,UNCON}-\mu^{0\,CON}=0$	t = -9.95	t = -1.16					t = -1.07	t = -1.86			t = -1.07	t = -0.70		
$\mu^{1\,UNCON}-\mu^{1\,CON}=0$	t = 1.40	t = -0.50					t = 1.76	t = 1.28			t = 0.18	t = 0.22		
Comfac [df]	13.22 [2]		42.57 [1]		11.63 [1]		2.28 [2]		1.54 [1]		0.26 [2]		1.15 [1]	
				Preferred		**Preferred**				**Preferred**				**Preferred**

* Indicates significance at the 5 % level.
(*) Indicates significance at the 10 % level.

1) Dependent variable is pY. All variables are normalised with qK.
2) For variable definitions, see text.
3) All standard errors in parentheses are robust to heteroskedasticity.
4) m2 is a test of second order serial correlation.
5) Sargan/Hansen is the Sargan/Hansen test of overidentification restrictions.
6) The Comfac statistics is a test of the non-linear restrictions imposed, going from unrestricted to restricted model
7) Instruments used are independent variables period t-1, t-2 plus employment same periods.

Table 1 (cont.) : GMM estimates and initial parameters

†) For this sector, the instruments are lagged time t-2, and t-3.

Unrestricted estimates	Metals (371-2)†		Metal Products (381)				Machinery (382)			
Time-dummies	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
m2 (p-value)	0.001	0.056	0.148	0.179	0.075	0.213	0.063	0.036	0.074	0.046
Sargan/Hansen [df]	3.74 [6]	1.08 [4]	6.75 [9]	5.51 [6]	4.00 [6]	5.47 [4]	5.32 [9]	3.98 [6]	2.58 [6]	0.47 [4]
# Obs.	201	201	477	477	477	477	420	420	420	420
# Plants	35	35	110	110	110	110	97	97	97	97
Plants Constrained (%)	5.0	5.0	22.6	22.6	22.6	22.6	22.7	22.7	22.7	22.7
	Note: To few constrained firms									
Restricted estimates										
Coefficients										
μ^0	1.2204* (0.0721)	1.3206* (0.1146)			1.1760* (0.0690)	1.1425* (0.0678)			1.0196 (0.0390)	1.0490 (0.0487)
$\mu^{0\,UNCON}$			0.9162 (0.0951)	0.9177 (0.1052)			1.0327 (0.0463)	1.0420 (0.0554)		
$\mu^{0\,CON}$			1.1016(*) (0.0531)	1.1742* (0.0588)			1.0636 (0.0446)	1.0591 (0.0500)		
μ^1	0.7660* (0.2044)	0.7522* (0.1939)			0.0212 (0.1951)	0.0763 0.1580			0.1117(*) (0.0633)	0.0964 (0.0752)
$\mu^{1\,UNCON}$			0.0012 (0.2644)	0.1640 (0.2937)			0.1059 (0.0786)	0.0827 (0.1041)		
$\mu^{1\,CON}$			-0.0337 (0.1101)	0.0391 (0.1495)			0.0728(*) (0.0392)	0.0782(*) (0.0443)		
s	-1.0542 (0.6887)		-0.0499 (0.0543)		-0.1663* (0.0825)		-0.1586* (0.0595)		-0.1467 (0.0945)	
$\mu^{0\,UNCON} - \mu^{0\,CON} = 0$			t = -1.90	t = -2.36			t = -0.43	t = -0.23		
$\mu^{1\,UNCON} - \mu^{1\,CON} = 0$			t = 0.15	t = 0.52			t = 0.38	t = 0.04		
Comfac [df]	0.26 [1]		3.76 [2]		18.82 [1]		1.03 [2]		0.002 [1]	
		Preferred				Preferred				Preferred
	m2-test rejects the validity of the instruments									m2-test rejects the validity of the instruments

* Indicates significance at the 5 % level.
(*) Indicates significance at the 10 % level.

1) Dependent variable is pY. All variables are normalised with qK.
2) For variable definitions, see text.
3) All standard errors in parentheses are robust to heteroskedasticity.
4) m2 is a test of second order serial correlation.
5) Sargan/Hansen is the Sargan/Hansen test of overidentification restrictions.
6) The Comfac statistics is a test of the non-linear restrictions imposed, going from unrestricted to restricted model
7) Instruments used are independent variables period t-1, t-2 plus employment same periods.

Table 1 (cont.) : GMM estimates and initial parameters

†) For this sector, the instruments are lagged time t-2, and t-3.

Chapter 3

Capital Market Imperfections and Labor Demand

Capital Market Imperfections and Labor Demand*

by

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February 5, 1998

Abstract

In this paper, I study the influence of firm-specific financial conditions on labor demand using micro data for Norwegian plants and firms for the 1978-1991 period. The findings indicate that financial leverage has a negative influence on employment, while cash flow has a positive effect. These findings are consistent with capital market imperfections. The impact of the financial conditions varies over the cycles. The most striking results is that the financial conditions of firms are more important in recessions than during booms. Finally, there seems to be evident that when plants are reducing their labor stock, the negative effect of a high debt-to-net-worth ratio is amplified for plants of small firms, while the opposite is the case for plants belonging to larger firms. This finding illustrates the ambiguous role of the debt ratio as a proxy for the access to capital markets.

* The present paper is a revised version of a paper presented at the workshop at Norges Bank (The Central Bank of Norway) on May 20, 1996. I am grateful to E. Biørn, F. Carlsen, E.S. Jansen, E. Steigum Jr., S. Vagstad and seminar participants at the University of Bergen for comments on preliminary versions. The usual disclaimer applies.

1. Introduction

During the last decade, theoretical and empirical studies concerning the role of credit-market imperfections have shown that internal and external sources of financing are not perfect substitutes. Consequently, a firm's financial leverage and the availability of internal funds significantly influence real decisions. The basic idea is that access to external finance depends upon internal net worth. Firms have to pay a premium for external financing. This is caused by asymmetric information problems and imperfect or costly contract enforceability.[1] The external finance premium may become so high that firms find themselves credit constrained. These constraints may influence the operating behavior of the firm.

Most of the theoretical and empirical papers have paid particular attention to investment in fixed capital. In this paper, the consequences of leverage for employment decisions are studied. Investment in fixed capital is more capital-intensive relative to investment in labor. Therefore, the insufficiency of internal funding may be more important for investment in fixed capital. This should also imply that monitoring costs and information asymmetries are most severe for investment in fixed capital. With no adjustment costs associated with hiring and firing employees, a firm would adjust its labor stock instantly in the face of sales or production shocks.[2] Nevertheless, if adjustment costs are present, firms may want to keep employees even if production is decreasing. This labor-hoarding behavior must be funded. One could argue that, compared to investment in fixed capital, investment in labor does not generate any collateral value. Thus, credit constraints and capital market imperfections may also be important for labor demand, as well as hiring and firing decisions.

In this study, I use Norwegian data to analyze the impact of financial factors on employment. The sample covers the 1978-1991 period. In this period, the financial sector in Norway went through large changes. A deregulation of this sector took place in 1984-1985. In the late 1980s and early 1990s, there was a banking crisis and several large banks ran deficit and were recapitalized. In this paper, I test whether the changes in the credit market led to a structural change in the relationship between employment decisions and finance.

[1] See Gertler (1988) and Stiglitz (1992) for an overview of the financial asymmetric information literature.
[2] Of course, this is true only if we ignore legal agreements between firms and employees.

In recessions the financial "healthiness" of firms is worsened. Therefore, the impact of the financial factors may vary over the business cycles. This hypothesis is tested by constructing a sector-specific demand index to identify recessions and booms, and analyze whether the importance of the financial variables is similar over the business cycles. The size of a firm is presumed to be highly correlated with the probability of being constrained. If this is true, one implication (which is tested) would be that potential credit constraints are more severe for the employment decisions of smaller firms than larger ones. Finally, there may be asymmetries in the adjustment costs of labor, implying that the costs of hiring and firing are different. Consequently, I also analyze whether the importance of the financial variables is different for expanding firms relative to contracting ones.

This paper is organized as follows: the theoretical arguments concerning possible credit constraints and their implications for firms' employment decisions are discussed in the next section. In Section 3, empirical studies of labor demand and employment changes and the importance of financial variables are discussed. A brief description of the panel data from the manufacturing industry, together with the empirical formulation, is given in Section 4. The results are then reported and discussed in Section 5. Section 6 concludes the paper.

2. Theoretical Background

There are adjustment costs associated with changes in employment, changes resulting from hiring, training, and firing employees (Nickell (1986)). If these costs are significant, firms may want to keep employees even though production is decreasing. This labor-hoarding behavior requires funding. For this reason, firms' employment decisions depend on their access to the capital market.

If capital markets are perfect, firms' capital structure will be irrelevant for their investment decisions because external and internal financial sources are perfect substitutes (Modigliani and Miller (1958)). However, external and internal financing may not be perfect substitutes due to taxes, transaction costs, asymmetric information and incentive problems.[3]

[3] Differences in the taxes on dividends and capital gains will influence the capital costs of different financial sources. This was the case in Norway before the tax reform in 1992, and will therefore also be evident during the

In this presentation, I concentrate on the consequences of information and incentive problems. Information about the investment projects for which capital is being sought or about demand shocks will often be distributed asymmetrically between the firms and suppliers of capital. Therefore, credit or capital markets can be described as "lemon markets," where problems of adverse selection are present. In the debt market, information asymmetries may lead to an equilibrium where the lender sets an interest rate that leaves an excess demand for credit. In addition, there may also be one group of borrowers who receive loans while others do not, although the borrowers look similar (Stiglitz and Weiss (1981)). Monitoring costs of profit outcomes may also lead to credit rationing (Williamson (1987)).

Myers and Majluf (1984) explain why firms sell new equity at a discount. Managers are assumed to have better information than both shareholders and bondholders. For that reason, if a firm has profitable investment opportunities, the new shares should be bought by its own managers. Outside investors know this and will demand a premium to purchase the firm's shares, in order to offset losses incurred from financing lemons. Furthermore, Jensen and Meckling (1976) show that managers and shareholders of a firm might have an incentive to choose risky projects due to their limited liability. If investments in risky projects turn out to be successful, only shareholders benefit from the increasing firm value. By contrast, if a risky project fails, bondholders bear the consequences of the failure. Since the incentives of managers and shareholders are also recognized by potential creditors in financial markets, an additional premium might be required to attract new creditors.

Information asymmetries, monitoring costs, and the agency and incentive problems just outlined induce a wedge between internal and external funds. The availability of internal funds allows firms to undertake investment projects without resorting to more costly external financing. In addition, greater internal cash flow improves a firm's balance sheet and its net worth position. Increasing financial health will lower bankruptcy risk and thereby reduce the cost of borrowing (Calomiris and Hubbard (1990)). The ratio of loans to "collateralizeable" net worth is also important to firms, since a negative shock to net worth will increase the cost

sample period in this article. In the old tax regime, retained earnings were the least expensive form of financing, while new equity was most expensive (see Berg (1992)).

of external financing.[4] So, when a firm's debt position worsens and the threat of bankruptcy increases, investment, production and employment will be reduced (Bernanke and Gertler (1989)).[5]

The effects of capital market imperfections are asymmetric, dependent on whether there is a recession or a boom; they have more impact in recessions than booms (Gertler and Hubbard (1988)). We could also think of such asymmetries as dependent on whether firms are expanding or contracting, if the size of the firm is important for its access to the capital market. Information asymmetries will make it almost impossible for small firms or lesser-known firms to raise capital through new share issues or commercial papers. Therefore, small firms depend on banks as their primary source of financing. Gertler and Gilchrist (1993) show that small firms do not borrow to smooth the impact of declining sales. In another study, they find that inventory/sales ratios for small firms are fairly stable over the business cycle, while these ratios rise for large firms in bad times (Gertler and Gilchrist (1992)). Furthermore, Oliner and Rudebusch (1993) find evidence of the reallocation of lending toward large firms after monetary contraction. All of these results are consistent with the hypothesis that finance constraints are more severe for smaller firms.

3. Other Empirical Studies on Financial Factors and Employment Decisions

In this section, I concentrate on panel data studies analyzing financial conditions and their relevance for employment decisions.[6] Among the first to use a panel of firm-level data in labor demand models were Nickell and Wadhwani (1991). They also introduced firm-specific financial variables in their labor demand model, such as book value debt-equity ratio and market capitalization relative to capital stock. Both factors exerted a significant influence on employment. To get around the problem of measuring the market value debt-equity ratio, Nickell and Nicolitsas (1994) considered a flow equivalent measured as interest payments

[4] A magnification of an initial demand shock due to financial market imperfections is often referred to as the "financial accelerator" effect.

[5] Nickell and Wadhwani (1991) also state that bankruptcy costs are increasing in employment due to the compulsory payments due existing employees.

[6] With firm- or plant-level panel data it is possible to examine variations across firms and over time. Such data also allows the researcher to control for unobserved firm-specific characteristics (e.g. efficiency).

relative to profits. This financial variable was found to influence employment demand. Increased interest payments yielded a reduction in employment.

The two previously mentioned studies estimated a log-linear dynamic employment equation with the logarithm of employment as the dependent variable. In a German study by Frisse, Funke, and Lankes (1992), a different approach is used. Assuming that firms are maximizing the expected utility of profit, the authors derive a model in which labor demand depends on firms' degree of risk aversion, output, real wages, and debt ratio. Using panel data for large, quoted West German industrial and commercial companies, they estimate their model with labor-capital ratio as the dependent variable, and output-capital ratio, real wage, and debt ratio as explanatory variables. As opposed to models in the U.K. studies, this model does not allow any dynamics. However, interestingly enough, the debt ratio is found to have negative effects on employment in the German study.

Instead of focusing on the level of employment, Cantor (1990) analyses employment growth rates and finds a positive correlation between leverage and employment volatility. His set of U.S. firm level data for the period from 1968 to 1987 is based on the Compustat annual financial data tapes. On the basis of the debt-to-asset ratio, the total sample is split in two sub-samples. Cantor runs some simple regressions for each sub-sample, where firms' employment growth rate is the dependent variable, and current and lagged sales-capital ratio and cash flow-capital ratio are the explanatory variables. The results indicate that higher leverage increases the sensitivity of firms' employment to cash flow changes.

Moreover, using U.S. firm-level data, Sharpe (1994) finds that increased financial leverage heightens firms' sensitivity to demand shocks. He also finds that smaller firms and more highly leveraged firms are more sensitive to macroeconomic conditions and to firm-specific sales shocks. Finally, the importance of size and leverage is found to be higher in recessions than in expansions. These findings are consistent with financial market imperfections. Also the work of Calomiris, Orphanides and Sharpe (1994) (hereafter called COS) is based on the same methodology as Sharpe (1994), using leverage and size as state variables to analyze the effect of sales shocks.

In all of the above-mentioned studies, the hypothesis of symmetric labor adjustment costs has been used. This implies that the costs a firm faces when a number of new workers are hired vary in the same way as when the same number of workers is fired.[7] The appropriateness of asymmetric labor adjustment costs is analyzed by Pfann and Verspagen (1989), Jaramillo, Schiantarelli, and Sebenelli (1993), and Pfann and Palm (1993). They all find that the hypothesis of symmetric adjustment costs is rejected by their data. In addition, in the latter study, hiring costs are found to exceed firing costs for production workers, whereas firing costs exceed hiring costs of non-production workers.

I have also pointed out some differences between the different approaches. It may be argued that the theoretical foundation of the econometric models based on the English tradition is preferable. The main basis for that argument is that the links between the theoretical and the empirical models are well-founded and that the models are based on optimization of an object function, either cost minimization or profit maximizing. The dynamics in these models are also usually given by the theory. On the other hand, there are several assumptions which must be made in order to establish the empirical model, such as the form of the product function, expectation formation, and the relationship between the labor demand of workers of different skills (see Nickell (1984, 1986)). The models used by Sharpe and COS are more *ad hoc*, and the relationship to the underlying theory is weak. In the models in Sharpe (1994), there are no lagged endogenous variables, which results in a very restrictive form of employment adjustment. Moreover, there are no real wage terms or other input factors used as regressors. However, the purpose of the study -- to analyze the impact of leverage on a firm's employment responsiveness to a sales shock -- could justify the approach to a certain degree.

4. Data and Empirical Formulation

The empirical analysis in this paper is carried out at the plant level. However, the financial variables are constructed from the balance sheet of the firm to which the plant belongs, and they are, therefore firm-specific rather than plant-specific.

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[7] Of course, one could argue that asymmetries in the adjustment costs are incorporated by allowing the regressors to differ according to whether the economy, or the firm, is in a recession or a period of expansion.

4.1 The Sample

The empirical work is based on a large set of unbalanced data from Norwegian plants and firms within the manufacturing industry for the 1978-1991 period. The data are collected by Statistics Norway. The income statement and balance sheet information was taken drawn from Statistics of Accounts for all firms with more than 50 employees.[8] For all firms included in Statistics Norway's Statistics of Accounts, plant-level information about production, production costs, investment and capital stock is available from the Manufacturing Statistics.[9] All data are annual.

Observations are included where the calculated man-hours worked per employee during a year is in the interval [400,2500].[10] Wage per hour is calculated by dividing the total wage expense by total man-hours worked. For the 1978-1983 period, the standard error of this wage variable was found to be more than triple that of the rest of the sample period. Because of this, information concerning the number of blue- and white-collar workers was used and observations where the share of white-collar workers was higher than 0.5 were excluded. In order to secure as homogeneous a sample as possible, we also excluded observations for plants where part-time employees count for more than 25 percent of the workforce.

Firms in which the central or local government owns more than 50 percent of the equity have been excluded from the sample. Observations reported as "copied from previous year" are also excluded, because this actually means the data is missing. In an attempt to isolate plants whose capital stock has a negligible role in production, observations where the calculated replacement value of equipment and buildings together was less than NOK 200,000 (1980 prices) were also excluded.[11] To avoid measurement errors in production, observations with non-positive production levels were deleted, as well as observations where the employment level was 5 times larger than, or less than 1/5 of the employment level for the previous year.

[8] In 1991, Statistics Norway changed their sampling routines which implied that no new small firms (fewer than 100 employees) were added to the sample.
[9] See Halvorsen et al. (1991) for further details.
[10] Before 1983 the total registered 'man-hours' covered hours worked by blue-collar workers only. In this period man-hours worked per employee was calculated by dividing the registered man-hours by the number of blue-collar workers.
[11] Approximately 30,000 US$.

Some of the plants changed sector during the sample period. These plants are grouped into the sector where they have their highest frequency of observations. Because fixed firm effects are removed by estimating the model in first-differences, and some cross-sections are used for instrumenting, I ended up with an unbalanced panel of 10,002 observations from the period from 1981 to 1991. These observations come from 1,519 different plants and 934 different firms. Only plants with 6 or more consecutive observations are included in the final unbalanced data set. The number of observations, organized by length of the period for which they are available and observations by year, are given in Tables A1 and A2.

4.2 Empirical Formulation

To study the impact of financial factors on employment I start with the following model:

$$Y_{it} = A_i N_{it}^a K_{it-1}^b \qquad \text{(Supply)}$$

$$Y_{it} = P_{it}^{-\eta} Y_{jt}^d \qquad \text{(Demand)}$$

where

Y_{it}	- output
Y_{jt}^d	- demand index
N_{it}	- employment
K_{it-1}	- capital in the beginning of period t (in the *end* of period $t-1$)
A_i	- efficiency
η	- elasticity of demand (the markup, μ, is defined as: $\mu = \frac{1}{1-\eta^{-1}}$)
P_{it}	- product price

The subscript i denotes plant, j denotes the sector for which the plant belongs, and t denotes time. The wage is w_{it}, and the capital K_{it-1} is assumed to be predetermined. The firm is maximizing the profit; $\pi = P_{it}Y_{it} - w_{it}N_{it}$. Solving out employment, N_{it}, from its first order condition (FOC), and substituting the output price, P_{it}, from the demand equation into this FOC, leads us to a log-linear equation of the form:

$$n_{it} = -\alpha_{w0} w_{it} + \alpha_{k1} k_{it-1} + \alpha_{y0} y_{jt}^d + f_i + \gamma_t + \varepsilon_{it} \qquad (1)$$

Small letters indicate that the variables are log-transformed.[12] All α -parameters are assumed positive. The plant specific effects, f_i, refer to all those factors (e.g. efficiency) which are plant-specific but fixed over time.[13] The time dummy, γ_t, is meant to pick up the effects of macro shocks affecting all firms, such as aggregate demand shocks. The last term in equation (1), ε_{it}, is an error term, which is commented further later in this paper.

In order to be able to analyze the impact of financial pressure on the labor demand, I also add in variables related to the plants' or firms' financial situation. Here two variables are utilized, cash flow - capital ratio (named (CF/K^F)), and the debt to assets ratio (B/TA).[14] Cash flow is added in to the model to test the hypothesis of imperfect substitutability between different sources of finance. In addition, as mentioned in Section 2, greater internal cash flow improves a firm's balance sheet and thereby reduces the cost of borrowing. The debt ratio is meant to be a proxy for the likelihood of a firm's financial distress. The variable is set to capture the premium on borrowing cost or the probability of being credit rationed. The theory, in Section 2, predicts that the sign of the (CF/K^F)-coefficient will be positive, while the (B/TA)-coefficient is expected to be negative.

In empirical analyses of the dependence of investments and financial factors, it is important to control for shifts in product (or investment) demand. Neglecting this may lead to results indicating financial factors to be important. However, the significance of the financial variables may be caused by their role as proxies for investment opportunities, and not by any credit constraints that firms are exposed to.[15] Thus, it is important to identify exogenous shocks to firms' net worth that are uncorrelated with changes in investment opportunities. To control for current and expected shifts, a sector-specific product demand index, y_{jt}^d, is included in the model, together with the time dummies. In addition, plant level production variables, y_{it} and y_{it-1} are included. However, the latter variable is not exogenous.

[12] The basis of this model is similar to the model used by Nickell and Nicolitsas (1994).
[13] Note that these plant specific effects will control for sector specific fixed effects also.
[14] Note that both of the financial variables are firm-specific instead of specific to the establishment. This is based on the assumption that it is the firm, and not a specific plant, which is rationed. It also reflects the fact that all balance sheet variables are given at firm level. The superscript F of the CF/K^F - variable indicates that this is the aggregate of the capital stock of all plants within a firm. See the data appendix for details on variable definitions and construction.
[15] This problem is well known when estimating Q-models of firms' investments.

To keep the model flexible, both the dependent variable and the other explanatory variables in equation (1) are included in the empirical model, both as contemporaneous and lagged variables.[16] Labor adjustment costs justify the lagging of the dependent variable. With heterogeneous workers, but where only total employment is observable, the lag structure of the model will be more complex (Nickell (1986)). The lagging of the explanatory variables is motivated by the knowledge that these variables are unlikely to have an instantaneous impact on the demand for labor. The same is probably true for the financial variables. For instance, a firm's bankers will probably both operate and receive information, with some delay. The empirical model is then of the form:

$$
\begin{aligned}
n_{it} &= \lambda_1 n_{it-1} + \lambda_2 n_{it-2} - \alpha_{w0} w_{it} + \alpha_{w1} w_{it-1} + \alpha_{k1} k_{it-1} + \alpha_{k2} k_{it-2} \\
&+ \alpha_{d0} y_{jt}^{d} + \alpha_{d1} y_{jt-1}^{d} + \alpha_{y0} y_{it} + \alpha_{y1} y_{it-1} \\
&+ \beta_{CF_1} (CF / K^F)_{it-1} + \beta_{B_2} (B / TA)_{it-2} \\
&+ f_i + \gamma_t + \varepsilon_{it}
\end{aligned}
\tag{2}
$$

All stock variables, except the number of employees, are measured at the end of period t.[17] In order to eliminate the unobserved fixed effects, the model is first-differenced.

Some comments about the estimation method and the error term should be made. There are several reasons for using an instrument variable estimation technique (IV method). First, the presence of the lagged dependent variable in the equation calls for an IV method (Nickell (1981)). Second, some notions about the wage variable make us treat this as endogenous. The wage variable is constructed by dividing the total wage expenditure by the number of employees. This implies that our data is influenced by hours worked and by the composition of white-collar and blue-collar workers. The error term in the model includes technological shocks in addition to demand shocks that are not picked up by the time dummies or the $y_{jt}{}^{d}$ variable. These shocks will influence wages via the hours and composition effects. As a consequence, wages have to be treated as endogenous. Additionally, wages cannot be treated

[16] I have chosen to use a flexible dynamic labor demand equation model. This approach is chosen to avoid the restrictive functional form of a labor adjustment costs function. Using an Euler equation approach requires that adjustment costs are modeled explicitly. See Hamermesh and Pfann (1996) for a discussion of different adjustment cost structures.
[17] The given numbers of employees are measured as an average over the employment in February, April, June, September, and November.

as predetermined since the calendar years do not correspond to the wage-contract periods. The cash flow variable, $(CF/K^F)_{it-1}$, is also treated as endogenous. Employment changes from period $t-1$ to t may reduce the cash flow in period $t-1$ due to adjustment costs. For employment, and wage, I use as instruments the second, third, and fourth lag of these variables; n_{it-2}, n_{it-3}, n_{it-4}, w_{it-2}, w_{it-3}, w_{it-4}. For the cash flow ratio I use the second, $(CF/K^F)_{it-2}$, as instrument. Finally, y_{jt-2}^d and y_{jt-3}^d, and y_{it-2} and y_{it-3}, and $(B/TA)_{it-3}$, are all used as additional instruments.

The model is estimated using the generalized method of moments (GMM) as outlined in Hansen (1982). GMM has the advantage over the "standard" IV method that it utilizes the set of instruments optimally, (i.e. minimum asymptotic variance of the parameters of interest). The GMM estimator for a linear instrumental variable model where the firm-fixed effects are removed by estimating the model in first-differences is given by:

$$\hat{\beta} = \left(X'ZA_N^{-1}Z'X\right)^{-1} X'ZA_N^{-1}Z'y \tag{3}$$

where X is the stacked matrix of the first differenced explanatory variables and y is the stacked vector of observations on the first-differenced dependent variable. The instrument matrix Z is formed by instruments dated $t-s$, where $s \geq 2$. The weighting matrix A is used to weight the instruments optimally.

The GMM technique is a two-step procedure. In the first-step the following weighting matrix is used:

$$A_N = \left(\frac{1}{N}\sum_{i=1}^{N} Z_i'HZ_i\right) \tag{4}$$

where H is a $(N\times N)$ matrix with twos on the leading diagonal, minus ones on the first off-diagonal, and zeros elsewhere. The first-step GMM estimator is consistent but inefficient. Using the residuals from the first-step, a new weighting matrix is formed:

$$A_N = \left(\frac{1}{N} \sum_{i=1}^{N} Z_i ' \Delta\hat{\varepsilon}_i \Delta\hat{\varepsilon}_i ' Z_i \right) \tag{5}$$

This weighting matrix is substituted into the expression in equation (3) and gives a consistent and efficient GMM estimator.

The set of instruments is only valid if the error term, ε_{it}, is serially uncorrelated. By estimating the model in first-differences we introduce a first-order serial correlation (moving average) in the model. Therefore, a first-order correlation is expected, but an absence of higher order serial correlation is essential for the consistency of the estimated parameters. The one-degree of freedom test, *m2*, proposed by Arellano and Bond (1991) is employed. The *m2* test is normally distributed with mean 0 and variance 1. If the *m2* test rejects the null hypothesis of no serial correlation in the first-differenced model, the instruments are correlated with the differenced error term, and the set of instruments is invalid. Another test of the validity of the instruments is the *Sargan/Hansen* test. When the model is overidentified (more instruments than right-hand-side variables), we can test the null hypothesis that the model is correctly specified (that the moment restrictions are valid). The *Sargan/Hansen* test has a χ^2-distribution with as many degrees of freedom as overidentifying restrictions. Again, Arellano and Bond (1991) provides a complete discussion of these procedures.

5. Empirical Results[18]

I start my empirical analysis by testing the model specified in equation (2).[19] From the discussion above, I treat the following variables as endogenous; n_{it-1}, w_{it}, w_{it-1}, and $(CF/K^F)_{it-1}$.

---

[18] All the GMM regression results are obtained using "DPD" for GAUSS, documented in Arellano and Bond (1988). All the reported standard deviations of the estimated parameters are robust to heteroskedasticity.

[19] In the tables, the following transformation for the industry demand, y_{jt}^d, and plant specific sales is used (here illustrated by the industry demand index variable and coefficients);

$$\beta_{yd_0} y_{jt}^d + \beta_{yd_1} y_{jt-1}^d \Leftrightarrow \beta_{\Delta yd} \cdot \Delta y_{jt}^d + \beta_{yd} \cdot y_{jt-1}^d$$

where $\beta_{\Delta yd} = \beta_{yd_0}$, and $\beta_{yd} = \beta_{yd_0} + \beta_{yd_1}$. This allows us immediately to test the significance of the contemporaneous variable and the sum of the contemporaneous and the lagged variables.

The results are given in column (i) of Table 1. The signs of the financial variables' coefficients are as expected. These two coefficients are also significant. However, both of the capital coefficients are insignificant. In column (ii) we find the results of a model where the k_{it-2} is left out. The remaining capital coefficient is still negative and insignificant. To test whether this is caused by inclusion of the financial variables, these two variables are omitted from the model. These results are given in column (iii). Again, the capital coefficient is small, and negative. In fact, all the coefficients in column (iii) are very similar to those in column (ii). I interpret this as evidence that the inclusion of the cash flow - capital ratio, and the debt-ratio, does not introduce any extra biases in the model, relative to the specification in column (ii).[20]

For all of the regressions (i)-(iii), the *m2* test indicates that there is no serial correlation. The assumption that there is no serial correlation in the error term is essential for the consistency of the estimators. The *Sargan/Hansen*-test in regressions (i)-(iii) indicates invalidity of the instruments. As pointed out by Arellano and Bond (1991), the *Sargan/Hansen*-test has a strong tendency to reject the validity of the instruments too often in the presence of heteroskedasticity.

The model is also estimated when capital stock variables are assumed endogenous, using k_{it-2} and k_{it-3} as instruments. The results from this regression, shown in column (iv), suggest that the k_{it-1} coefficient is still insignificantly negative. Again the *Sargan/Hansen*-test still rejects the instruments. I take these two findings as evidence that treating capital as exogenous is not what leads to the small and insignificant capital coefficients.

I have also included the contemporaneous cash-flow variable, $(CF/K^F)_{it}$, and the debt ratio at the end of period $t-1$, $(B/TA)_{it-1}$, in the model specification. Both of these two variables were assumed to be endogenous, and therefore had to be instrumented. However, these two additional variables had the opposite sign of what was expected in the regression model. These findings are hard to explain and are not consistent with the theory outlined in Section

[20] The theoretical model assumes that capital should be included in the empirical model. Finding the capital coefficient to be small, sometimes even negative, could, of course, be an indication of mis-specification. However, here we focus on the financial variables and overlook the insignificance of the capital coefficient. See the appendix *Interpretation of non-financial variables* for a further discussion of the capital coefficient.

2. One possible explanation is that these two additional variables are still endogenous, even though I have tried to control for this effect by instrumenting the variables.[21] It is also worth mentioning that including these two variables does not make sense if we believe that creditors receive information of the financial condition of a firm with some delay. The financial variables are therefore unlikely to have an instantaneous impact on a firm's employment decision.

In column (v) the results of the within group estimation are given. There are significant differences for the estimated coefficients, relative to the ones given in column (ii). This is especially true for the first employment variable, e_{it-1}, and the wage variables. As we know, within groups estimation require strict exogenous regressors. Since lagged dependent variables are used as a regressor, and the wage variables will most likely be endogenous, instrument variable estimation methods are preferred. Interestingly, the result is that the cash flow coefficient is relatively unaffected whether GMM or the within groups estimation method is used.

Booms and recessions

As discussed in the theoretical section, there may be asymmetries between booms and recessions due to "the financial accelerator". Another factor that may be important when analyzing Norwegian data is the financial deregulation and the business cycles of the Norwegian economy during the eighties. Here I focus on whether deregulation and the business cycles have influenced the importance of financial variables for labor demand. Two dummy variables are constructed; $D^{84\text{-}87}$ takes the value one in the period 1984-1987 (the booming period) and zero otherwise, and $D^{88\text{-}91}$ takes the value one for the years 1988-1991 and zero otherwise. The financial variables are interacted with these two dummy variables.

[21] As already mentioned, the given numbers of employees are measured as an average over the employment in February, April, June, September, and November. The debt asset ratio is measured in the end of December the previous year (year *t-1*). Increased employment from November year *t-1* to February year *t* may induce some adjustment costs which may be financed with debt already in December year *t-1*. If this scenario is likely, employment will have implications for the debt ratio. The empirical results with a negative cash flow coefficient indicate that increased cash flow reduces the employment. However, this may be an effect of an employment increase reducing the cash flow due to labor adjustment costs.

$$
\begin{aligned}
n_{it} = \ldots &+ \beta_{CF} \cdot \left(\frac{CF}{K^F}\right)_{it-1} + \beta_B \cdot \left(\frac{B}{TA}\right)_{it-2} \\
&+ D^{84-87}\left(\beta_{CF}^{84-87} \cdot \left(\frac{CF}{K^F}\right)_{it-1} + \beta_B^{84-87} \cdot \left(\frac{B}{TA}\right)_{it-2}\right) \\
&+ D^{88-91}\left(\beta_{CF}^{84-87} \cdot \left(\frac{CF}{K^F}\right)_{it-1} + \beta_B^{88-91} \cdot \left(\frac{B}{TA}\right)_{it-2}\right) \\
&+ \cdots
\end{aligned} \tag{6}
$$

From the results in Table 2, where the specification in equation (6) is used, it is clear that the debt ratio coefficients in the two latest periods are not significantly different from the one in the first period. On the other hand, the cash flow coefficients are growing larger over time.[22] For the latest period, 1988-1991, the increased cash flow coefficients could be due to the banking crises and the general downturn in the economy. We may ask why the cash flow coefficient is insignificant and small in the initial period, and why it affects firms' operating behavior more and more over time. This pattern is reasonable if we believe that bankers became better in judging firms' creditworthiness after the deregulation of the banking sector took place. If the credit market became more competitive, it makes sense that the quality of firms' balance sheet became more important. However, there are indications that bad banking practices took place in the deregulation period, together with a credit expansion (see Steigum (1992)). On the other hand, the average annual growth in loans to the manufacturing industry was -0.3 percent in the 1983-1986 period (see page 130, NOU 1989:1), such that the manufacturing sector did not benefit from the growth in credit in the booming period. Finding the debt ratio coefficient to be stable over the analyzed period may be an indication that the credit liberalization that took place in Norway in the mid-eighties did not change firms' access to the credit market. However, this contradicts the variations in the cash flow ratio coefficients.

I also analyze whether the debt coefficient and the cash flow coefficients vary as a result of sector specific recessions. To analyze this phenomenon I have constructed a dummy variable, D_{jt}^{REC}, which is equal to one if the gross output in the sector for which the plant belongs has

[22] I have also tested whether the financial variables are statistically significant different from zero in each period. The coefficients of the financial variables in each period are (standard errors in parentheses); $(CF/K^F)_{it-1}^{81-83}$ = 0.004 (0.010), $(CF/K^F)_{it-1}^{84-87}$ = 0.098 (0.018), and $(CF/K^F)_{it-1}^{88-91}$ = 0.195 (0.043), and $(B/TA)_{it-2}^{81-83}$ = -0.108 (0.046), $(B/TA)_{it-2}^{84-87}$ = -0.106 (0.052), $(B/TA)_{it-2}^{88-91}$ = -0.134 (0.077).

decreased from year $t-1$ to year t, and zero otherwise. The new interacted cash flow variable, $D_{jt}^{REC} \cdot (CF/K^F)_{it-1}$, the new interacted debt ratio, $D_{jt}^{REC} \cdot (B/TA)_{it-2}$, and the new interacted plant specific output variable, $D_{jt}^{REC} \cdot y_{it}$, are all assumed to be endogenous. I have used the following additional instruments, $D_{jt-2}^{REC} \cdot (CF/K^F)_{it-2}$, $D_{jt-2}^{REC} \cdot (B/TA)_{it-3}$, and $D_{jt-2}^{REC} \cdot y_{it-2}$. The results from this regression are given in column (i), Table 3. Again, we find that the debt ratio coefficients are not significantly different in recessions and booms. However, the cash flow coefficients vary, conditional on whether there is a recession or not. This latest finding is consistent with what we expected; in recessions firms may depend more heavily on internal sources, and profitability becomes a more important signal to creditors.

Firms' size

Smaller firms may be more exposed to credit rationing. The existence of asymmetric information problems may be more severe for smaller firms, and internal and external sources of finance will be less perfect substitutes for one other. If this is the case, smaller firms will be more dependent on internal resources, and an increase in the debt ratio may be a more serious problem for this kind of firms. With this hypothesis as a background, we expect to find the coefficients of the financial variables to be different for small and large firms. To test whether the financial variables are of greater importance for smaller firms, I have generated a dummy variable, D_{it}^{small}, with the value one if the number of employees in the firm to which the plant belongs at time t is less than one hundred, and zero otherwise. This dummy variable is interacted with the financial variables. There may be a problem of endogeneity since several firms are single plant firms and the number of employees is the dependent variable in the regression model. Therefore, all three interacted variables are treated as endogenous. Twice lagged values of the interacted terms are used as additional instruments, $D_{it-2}^{small} \cdot (CF/K^F)_{it-2}$, $D_{it-2}^{small} \cdot (B/TA)_{it-2}$, and $D_{it-2}^{small} \cdot y_{it-2}$. In column (ii), Table 3, we find some differences in the coefficients of the financial variables between small and large firms. The cash flow coefficient is larger for smaller firms, and the debt ratio coefficient more negative. These differences indicate that asymmetric information problems may be more severe for plants of smaller firms relative to plants belonging to larger firms. However, the evidence is not conclusive, since these differences are not statistically significant. This lack of significance may be explained by the fact that the firms in the sample are relatively large, and their access to credit should therefore be relatively easy.[23] Therefore, the limit used for splitting the sample may be too high. However, lowering the limit would leave too few observations in the assumed constrained group.

Expansion and contraction

As already pointed out, there may be asymmetries in the adjustment costs of labor. Pfann and Verspagen (1989) and Pfann and Palm (1993) find that hiring costs are more important than firing costs. Using data for Norwegian manufacturing plants, Wulfsberg (1996) finds that expanding firms adjust more slowly to equilibrium than contracting firms. Here I focus on whether the importance of the financial variables is different when the employment is increasing and when it is decreasing. Credit may be harder to get when financing new projects or expanding the stock of labor. Therefore, the adjustment speed of employment could be a function of the financial conditions of the firm. To investigate this hypothesis I interact the financial variables with two dummies, D_{it}^{EXP} taking the value one if the labor stock is increased and zero otherwise, and D_{it}^{CON} equal to one if the labor stock is reduced, and zero otherwise. Again, I control for endogenity of the sample splitting criteria, thus including the following additional instruments: $D_{it-2}^{EXP} \cdot (CF/K^F)_{it-2}$, $D_{it-2}^{EXP} \cdot (B/TA)_{it-2}$, and $D_{it-2}^{EXP} \cdot y_{it-2}$, and correspondingly for contracting plants. The results of this analysis are given in column (i), Table 4. The base case is a plant having the same employment in year t and year t-1. The cash flow coefficients are statistically insignificant, and this fact is independent of whether the employment is constant, expanding or contracting. However, the largest cash flow coefficient is found when plants are contracting.

The debt ratio coefficient is negative and insignificant for the base case (constant employment). In relation to plants that are contracting, the debt ratio is significantly negative. This is what was expected; financial leverage, or debt to collateralizeable net worth, has a negative effect on employment. Surprisingly, we find the debt ratio coefficient to be significantly positive when plants are expanding. This finding is not consistent with the presence of credit rationing. One plausible explanation of this contradictory result is that

[23] Figures from the Manufacturing Statistics reveal that approximately 85 percent of firms have fewer than 50 employees.

cross-sectional leverage ratios could be positively associated with greater creditworthiness. In the given formulation I have implicitly assumed that the "debt-capacity" is the same for all firms, and that the debt-asset ratio is used as a proxy for the distance from this capacity, i.e. the debt-assets ratio is negatively related to credit limits. If, however, the debt capacity is higher for some firms, leverage acts as an indicator of greater access to external funding and less credit rationing. The two opposite roles of the debt ratio may also explain the results presented earlier in this paper, where the variation of the debt ratio coefficient between small and large firms was insignificant. To control for the possible role of the debt ratio as a proxy for debt-capacity, I construct an interacted variable $D_{it}^{Small} \cdot D_{it}^{EXP} \cdot (B/TA)_{it-2}$, where D_{it}^{Small} is equal to one if the firm is small, and D_{it}^{EXP} is equal to one if a plant is expanding. The underlying hypothesis is that high leverage is more critical for small firms relative to larger firms. The results, reported in column (ii), support this hypothesis. The coefficient of the $D^{Small} \cdot D^{EXP} \cdot (B/TA)_{t-2}$ variable is negative and strongly significant.

Interpretation of financial variables[24]

From the results presented, it is clear that financial variables exert an important influence on employment. Maintaining the model in column (ii) as the preferred specification, the short run effect of a 10 percent increase in the debt ratio yields a short-run reduction in employment of 0.9 percent. This estimate is similar to Nickell and Wadhwani's (1991) estimate (see their table II, column 3). In the long-run, a 10 percent increase in the debt ratio reduces employment by 2.4 percent. The long-run effect of 10 percent increase in the cash flow ratio yields a 1.4 percent increase in employment. These estimates make it clear that firms' financial conditions, and their access to the capital markets, are important factors for labor demand.

The cash flow coefficient was found to be larger when the sector was in a recession. It follows that when a firm responds to a negative shock by contracting, this will increase the firm's dependence on internal sources, and this dependence may force the firms to adjust their labor stock even faster. This effect is most evident for plants belonging to smaller firms, firms with less "debt-capacity", which indicates that a high debt ratio is more severe for small firms

[24] See the appendix for an interpretation of the non-financial variables.

than for larger firms. Met with an increased degree of credit rationing, firms are probably less able to expand in response to good news. For this reason, the initial impact of the shock will be amplified. All of this may be taken as evidence supporting the hypothesis of the financial accelerator.

6. Conclusion

In this study, I have investigated the impact of financial factors on labor demand. The micro evidence given in this paper suggests that financial leverage has a negative effect on labor demand and that internal cash flow increases the employment. These findings are consistent with the theoretical claim that external and internal financial sources are not perfect substitutes.

The findings indicate that the impact of financial conditions varies over the cycles. However, the picture is ambiguous. Starting with the cash flow - capital ratio, its importance is found to vary over time, being most important in the early eighties. This was a period in which the Norwegian capital markets were still regulated. The impact of the cash flow ratio varies also, dependent on whether there is a (sector specific) recession or not. However, the cash flow coefficients do not vary with the size of the firm. This fact could, of course, be explained by the nature of the sample, which covered relatively large firms only. It is also evident that the importance of cash flow does not differ between expanding plants, contracting plants, or plants with constant employment. This last finding contradicts the finding that the importance of cash flow varies with sector specific-demand fluctuations.

The debt-to-assets ratio is found (in general) to have a negative effect on firms' labor demand. Its importance is found to be stable over different time periods. In addition, the debt ratio has the same effect on employment in recessions and booms. However, the results in this study reveal that the debt ratio has a significant negative effect on labor demand when plants are contracting. Finally, the results indicate, in contradiction to the theory of capital-market imperfections, that the debt-ratio has a positive effect on labor demand when plants are expanding. This finding suggests that using the debt ratio to measure the access to the capital market is not appropriate. High financial leverage increases the risk of bankruptcy and therefore acts as a "warning sign" for potential creditors and investors. However, leverage may also act as an indicator of potential access to funds. These two effects would have opposite implications for the operation behavior of the firms. Caution should be exercised when using the debt ratio as a proxy for access to the capital market.

References

Arellano, M. and S.R. Bond, 1988, "Dynamic Panel Data Estimation Using DPD - A Guide for Users", Working Paper 88/15, Institute for Fiscal Studies.

Arellano, M. and S.R. Bond, 1991, "Some Test of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations", *Review of Economic Studies* 58, 277-297.

Berg, S. A., 1992, "Kapitalkostnader i Norge 1980-92", Penger og Kreditt 1992/1, (in Norwegian), 39-42.

Bernanke, B.S. and M. Gertler, 1989, "Agency Costs, Net Worth, and Business Fluctuations", *American Economic Review* 79, 14-31.

Bernanke, B.S., M. Gertler and S. Gilchrist, 1995, "The Financial Accelerator and the Flight to Quality", *Review of Economics and Statistics.*

Bresson, G., F. Kramarz, and P. Sevestre, 1992, "Dynamic Labour Demand Models", In *The Econometrics of Panel Data: Handbook of Theory and Applications*, edited by L. Matyas and P. Sevestre, Kluwer Academic Publishers, The Netherlands.

Calomiris, C.W., and R.G. Hubbard, 1990, "Firm Heterogeneity, Internal Finance, and 'Credit Rationing'", *Economic Journal.* 100: 90-104.

Calomiris, C.W., A. Orphanides, and S. A. Sharpe, 1994, "Leverage as a State Variable for Employment, Inventory Accumulation, and Fixed Investment", *NBER.* Working Paper No. 4800.

Cantor, R., 1990, "Effects of Leverage on Corporate Investment and Hiring Decisions", *Federal Reserve Bank of New York Quarterly Review*, Summer 1990, 15(2), 638-655.

Frisse, K., M. Funke, and F. Lankes, 1992, "Financial Structure and Labour Demand of West German Industrial and Commercial Companies: A Study of Longitudinal Data". *Jahrbucher fur Nationalökonomie und Statistik* 209(1-2), January 1992, 106-118.

Gertler, M., 1988, "Financial Structure and Aggregate Economic Activity: An Overview.". *Journal of Money, Credit, and Banking.* 20: 559-588.

Gertler, M. and S. Gilchrist, 1993, "The Role of Credit Market Imperfections in the Monetary Transmission Mechanism: Arguments and Evidence", *Scandinavian Journal of Economics 95* (1), 43-64.

Gertler, M. and S. Gilchrist, 1994, "Monetary Policy, Business Cycles and the Behavior of Small Manufacturing Firms". *Quarterly Journal of Economics* 109(2), 309-340.

Gertler, M. and R.G. Hubbard, 1988, "Financial Factors in Business Fluctuations", in *Financial Market Volatility: Causes, Consequences, and Policy.* Kansas City, MO: Federal Reserve Bank of Kansas City, 33-71.

Halvorsen, R., R. Jenssen and F. Foyn, 1991, "Dokumentasjon av Industristatistikkens Tidsseriedatabase", mimeo, Statistics Norway.

Hamermesh, D. S., G. A. Pfann, 1996, "Adjustment Costs in Factor Demand", *Journal of Economic Literature* 34(3), September, 1264-92.

Hansen, L.P., 1982, "Large Sample Properties of a Generalized Methods of Moments", *Econometrica* 50, 1029-54.

Jaramillo, F., F. Schiantarelli and A. Sembenelli, 1993, "Are Adjustment Costs for Labor Asymmetric? An Econometric Test on Panel Data for Italy", *The Review of Economics and Statistics* LXXV, 640-648.

Jensen, M., and W. Meckling, 1976, "Theory of the Firm: Managerial Behavior, Agency Costs, and Ownership Structure", *Journal of Financial Economics* 3:305-60.

Layard, R., S. Nickell and R. Jackman, 1991, *Unemployment: Macroeconomic Performance and the Labour Market*, Oxford University Press.

Modigliani, F. and M. Miller, 1958, "The Cost of Capital, Corporation Finance and the Theory of Investment", *American Economic Review* 48: 261-297.

Myers, S. and N. Majluf, 1984, "Corporate Financing and Investment Decisions when Firms have Information that Investors do not have", *Journal of Financial Economics 13*, 187-221.

Nickell, S., 1981, "Biases in Dynamic Models with Fixed Effects", *Econometrica* 49, 1417-1426.

Nickell, S., 1984, "An Investigation of the Determinants of Manufacturing Employment in the United Kingdom", *Review of Economic Studies* 51: 529-557.

Nickell, S., 1986, "Dynamic Models of Labour Demand", chapter 9 in *Handbook of Labor Economics* Volume I, edited. by O. Ashenhelter and R. Layard, Elsevier Science Publishers BV.

Nickell, S. and D. Nicolitsas, 1994, "How Does Financial Pressure Affect Firms?", mimeo, Institute of Economics and Statistics, Oxford University.

Nickell, S. and S. Wadhwani, 1991, "Employment Determination in British Industry: Investigations Using Micro-Data", *Review of Economic Studies* 58: 955-969.

NOU 1989:1, 1989, "Penger og kreditt i en omstillingstid", (in Norwegian).

Nymoen, R., 1991, "Aggregate Modelling of Norwegian Unemployment and Wage-Price Inflation", chapter 6 in 'Empirical Modelling of Wage-Price Inflation and Employment Using Norwegian Quarterly Data', Norges Banks Skriftserie no. 18.

Oliner, S. and G.D. Rudebusch, 1993, "Is there a Bank Credit Channel for Monetary Policy?", 93-8, *Finance and Economics Discussion Series*, Federal Reserve Board, USA.

Pfann, G.A. and F.C. Palm, 1993, "Asymmetric Adjustment Costs in Non-linear Labour Demand Models for the Netherlands and U.K. Manufacturing Sectors", *Review of Economic Studies 60*, 397-412.

Pfann, G.A. and B. Verspagen, 1989, "The Structure of Adjustment Costs for Labour in the Dutch Manufacturing Sector", *Economic Letters 29*, 365-371.

Sharpe, S.A., 1994, "Financial Market Imperfections, Firm Leverage, and the Cyclicality of Employment", *American Economic Review 84*, 1060-1074.

Steigum jr., E., 1992, "Financial Deregulation, Credit Boom and Banking Crisis: The Case of Norway", Discussion Paper 15/92, Norwegian School of Economics and Business Administration.

Stiglitz, J.E., 1992, "Capital Markets and Economic Fluctuations in Capitalist Economies". *European Economic Review* 36, 269-306. Alfred Marshall Lecture EEA Congress, Cambridge U.K..

Stiglitz, J.E., and A. Weiss, 1981, "Credit Rationing in Markets with Imperfect Information", *American Economic Review 71*, 393-410.

Williamson, S.D., 1987, "Costly Monitoring, Loan Contracts, and Equilibrium Credit Rationing", *Quarterly Journal of Economics* 101, 135-145.

Wulfsberg, F., 1996, "Adjustment Costs and Dynamic Labour Demand in Norwegian Manufacturing Firms", mimeo, Department of Economics, University of Oslo.

DATA APPENDIX

Variables

Codes in square brackets refer to the variable number used in the Manufacturing Statistics. Figures collected at the firm level (from Statistics of Accounts) are refereed to as $[\ ]_{\text{Accounts}}$.

Employment (N_{it}): Number of employees [131].

Wages (W_{it}): Wage expenses [291] normalized with the number of employees [131]. This expression is deflated with price indices for gross output at the 3-digit sector level for which a plant belongs. From Norwegian National Accounts.

Capital (K_{it}^{j}): The capital stock is calculated by adding together the replacement value of equipment and buildings.[25] The replacement value of capital is calculated separately for equipment and buildings using the perpetual inventory formula:

$$PI_t^j K_{it}^j = PI_{t-1}^j K_{it-1}^j \cdot \left(1-\delta^j\right) \cdot \left(1+\Pi_t^j\right) + PI_t^j I_{it}^j$$

where superscript j indicates the different types of capital. PI^j_t denotes the price of investment goods (from the Norwegian National Accounts) and Π^j_t the corresponding inflation rates between $t-1$ and t. The depreciation rates, δ^j, are also taken from the Norwegian National Accounts (0.06 and 0.02 for equipment and buildings, respectively). In the calculation of the replacement value of capital, we use the fire insurance value of the capital stock. This variable is available only for the sum of machinery, fixtures and fittings, and other means of transport, on the one hand, and for buildings used for production, on the other. For each of these types of capital we use the first reported fire insurance value ([871] and [881] for equipment and buildings, respectively) greater than or equal to NOK 200,000 in 1980 prices as a bench-mark. From these initial values, we calculate the replacement value backwards and forwards, using the investment figures.[26]

Real (fixed price) investment at time t in type j of capital equals purchases minus sales (dismissals) of fixed capital. My definition of investment in equipment includes machinery, office furniture, fittings and fixtures, and other transport equipment, excluding cars and trucks (using the codes in Manufacturing Statistics, ([501]+[521]+[531]-[641]-

[25] Other fixed assets, which are not included in my measure of capital, include vehicles, housing for employees, building for spare-time activities, sites and property.

[26] If the replacement value of capital became negative, it was set equal to zero. When calculating the capital stock forward it may happen that the replacement value becomes negative because of large sales of capital goods. When calculating it backwards the replacement value becomes negative if the net purchase of fixed capital is larger than the replacement value in year $t+1$.

[661]-[671]).[27] Investment in buildings includes buildings directly used for production, which includes also offices, and inventory storage buildings ([561]-[601]).

Cash flow (CF_{it}) The definition of cash flow is:

Operating profit $[2400]_{Accounts}$
+ depreciation $[2290]_{Accounts}$
- interest expenditure$[2510]_{Accounts}$ + $[2520]_{Accounts}$
- tax on property and income $[3330]_{Accounts}$
- dividend (proposed) $[3570]_{Accounts}$
= Cash flow

The cash flow capital rate (CF_{it}/K^F_{it-1}): The cash flow capital ratio is calculated by normalizing the cash flow in year *t* by the aggregate of the capital stock, in the beginning of the year, of all plants within a firm.

Debt (B_{it}): The book value of short-term and long-term liabilities $[5100]_{Accounts}$ + $[5200]_{Accounts}$

Total assets (TA_{it}): Total assets $[5500]_{Accounts}$ is the sum of short- and long-term liabilities, conditional tax-free allocations, and equity.

Debt Asset Ratio (B_{it}/TA_{it}): Debt normalized with total assets.

Plant specific production (Y_{it}): Gross production [1041] + subsidies [291] – taxes [301].

Demand indices (Y_{jt}^d)**:** The industry sector values of Gross Domestic Product are collected from National Accounts. These numbers are deflated with price indices for gross output from Norwegian National Accounts

The sector specification used is (ISIC code):

Food and Beverages (31)
Textiles and Clothing (32)
Wood Products and Furniture (33)
Paper, Printing and Publishing (34)
Chemicals (351-352)
Products of Petroleum and Coal (354)
Plastics (355-356)
Mineral Products (36)
Metals (37)
Metal Products and Machinery (381, 382)
Electrical Equipment (383)
Other Production (384, 385, 390)

[27] Other transport equipment includes railroads internal to the plant, funiculars, transport cranes, conveyer belts, etc.

Interpretation of non-financial variables

The employment dynamics differ from other related studies. The sum of the autoregressive coefficients in column (ii), called λ $(= \lambda_1 + \lambda_2)$, is found to be $\lambda = 0.64$, but is larger, $\lambda = 0.70$, based on the regression results in column (x). The studies of Nickell and Wadhwani (1991), and Arellano and Bond (1991) are both based on UK panel data from the manufacturing industry. The companies are quoted and are fairly large (around 6000 employees in the first study). In the first study they find $\lambda = 0.72$, and in the latter one, $\lambda = 0.68$. Based on my estimate, Norwegian manufacturing firms are facing somewhat smaller adjustment costs of labor than those in the UK. Nickell (1986) pointed out that with adjustment costs as small as a half a day's pay, the autoregressive coefficient is $\lambda = 0.42$. With flexibility in the working hours, e.g. using overtime, it would be higher. Wulfsberg (1996) studies a panel of Norwegian manufacturing plants, and finds $\lambda = 0.78$. One explanation for the deviation of my results relative to Wulfsberg, is the size of the plants in the samples. The average (median) employment per plant is 115 (71) in my study, and 40 (12) in Wulfsberg. There are several reasons why the adjustment costs, and consequently the autoregressive coefficient, may be inversely related to size. As pointed out in Section 2, smaller plants, and even more so smaller firms, may have restricted access to the credit market. They are therefore less likely to demonstrate a labor-hoarding behavior. Another possibility is that larger plants may have greater flexibility in moving workers between different production units. This will reduce the hiring and firing costs. Moreover, the fixed component of adjustment costs, if there is one, may be relatively more important for small plants. Finally, smaller units may be exposed to demand shocks with a greater variance. If this means that the occurrence of large negative shocks is more likely for small plants, this may give rise to more frequent episodes of employment adjustments. The hypothesis that the adjustment costs are smaller for larger plants is confirmed by Wulfsberg (1996).

Nymoen (1991) estimates the long-run elasticity of wage to be -0.26 based on aggregate Norwegian data. Layard, Nickell and Jackman (1991) provide an estimate of -0.42, also on the basis of Norwegian aggregate data. In UK panel data studies, the long-run wage elasticity is found to be -0.41 in Nickell and Wadhwani (1991), -0.67 in Nickell and Nicolitsas (1994, column 3, Table 1), and -0.24 in Arellano and Bond (1991, column c, Table 4). From this comparison, I find my estimate of the long-run wage elasticity in column (ii), -0.46, to be reasonable.

Industry output is used as a proxy for the demand index. The two lags of this variable are found to be significant in most of the specifications of the labor demand model even after including plant specific output variables. Evidently, firms in this study operate in an imperfect output market where there is room for markup pricing (prices higher than marginal costs). Nickell and Wadhwani (1991) also find this variable to be significant. Their coefficient estimate, Δy_{jt}^{d}, is 0.14. Using the estimate from column (ii), my estimate is 0.04. This difference may be due to variations in definitions used, or the fact that in my model also y_{jt-1}^{d} is included as a regressor.

In all the regressions the capital coefficient is found to be small, or even negative. As pointed out earlier, this may be an indication of mis-specification of the model. It may be related to my definition of the capital variable. I have used the aggregate of the replacement value of equipment and the buildings. The fire insurance values of capital are reported in the sample. One problem with the fire insurance values is that there are a lot of missing values. Therefore, I have only used the insurance values as a bench-mark when calculating the replacement value of capital.[28] When I compare the two alternative measures, I find that fire insurance values are generally larger than the replacement values based on the perpetual inventory method. Therefore, underestimation of the capital stock could still be a present phenomenon and cause the insignificant and small capital coefficients.[29]

[28] See Data Appendix for further details.

[29] Another source of biases may be that the value of machinery and buildings is only approximately 85 percent of the fixed capital in the firms (based on book values reported in the Statistics of Accounts).

Number of observations on each plant	Number of plants
6	233
7	236
8	211
9	215
10	99
11	75
12	57
13	120
14	274
	1519

Table A1: Number of plants by number of observations

	All observations	Useable observations	Belonging to Small firms	Belonging to Large firms
1978	825			
1979	880			
1980	914			
1981	952	825	256	569
1982	996	880	273	607
1983	1279	914	300	614
1984	1290	885	279	606
1985	1308	835	233	602
1986	1277	1037	259	778
1987	1209	1047	269	778
1988	1116	1066	294	772
1989	1003	1003	274	729
1990	896	896	218	678
1991	614	614	24	590
	14559	10002	2679	7323

Table A2: Observations by year
The difference between the two first columns is due to constructing lags and taking differences.

	Belonging to Small firms	Belonging to Large firms
Food and Beverages (31)	480	1751
Textiles and Clothing (32)	185	250
Wood Products and Furniture (33)	393	603
Paper, Printing and Publishing (34)	188	1186
Chemicals (351-352)	91	281
Products of Petroleum and Coal (354)	0	301
Plastics (355-356)	120	162
Mineral Products (36)	75	501
Metals (37)	55	415
Metal Products and Machinery (381, 382)	588	997
Electrical Equipment (383)	152	391
Other Production (384, 385, 390)	352	485
	2679	7323

Table A3: Number of observations, by firms'sector, and size

Independent variables	Full specification (i)	Restricted specification (ii)	Financial variables omitted (iii)	Instrumenting capital (iv)	Within groups (v)
n_{it-1}	0.6169*	0.6120*	0.6223*	0.5952*	0.5300*
	(0.0378)	(0.0381)	(0.0585)	(0.0372)	(0.0225)
n_{it-2}	0.0162	0.0163	0.0230	0.0202*	-0.0074
	(0.0103)	(0.0105)	(0.0129)	(0.0101)	(0.0138)
w_{it}	-0.3376*	-0.3354*	-0.2712*	-0.3371*	-0.4926*
	(0.0610)	(0.0613)	(0.0843)	(0.0585)	(0.0256)
w_{it-1}	0.1700*	0.1660*	0.1300*	0.1665*	0.2598*
	(0.0443)	(0.0445)	(0.0638)	(0.0430)	(0.0253)
k_{it-1}	-0.0101	-0.0117	-0.0106	-0.0198	0.0291*
	(0.0276)	(0.0235)	(0.0266)	(0.0342)	(0.0183)
k_{it-2}	0.0039				
	(0.0188)				
Δy^{u}_{jt}	0.0323	0.0325	0.0742*	0.0288	0.0282
	(0.0181)	(0.0182)	(0.0221)	(0.0175)	(0.0176)
y^{u}_{jt-1}	0.0415	0.0432	0.1012*	0.0443	0.0275
	(0.0236)	(0.0238)	(0.0292)	(0.0235)	(0.0203)
Δy_{it}	0.3194*	0.3177*		0.3405*	0.3687*
	(0.0334)	(0.0336)		(0.0302)	(0.0167)
y_{it-1}	0.1639*	0.1602*		0.1733*	0.2503*
	(0.0267)	(0.0273)		(0.0271)	(0.0174)
$(CF/K^F)_{it-1}$	0.0508*	0.0486*		0.0473*	0.0548*
	(0.0115)	(0.0112)		(0.0104)	(0.0159)
$(B/TA)_{it-2}$	-0.0810*	-0.0805*		-0.0900*	-0.1180*
	(0.0276)	(0.0271)		(0.0261)	(0.0209)
Sargan/Hansen [df]	179.7 [134]	179.3 [134]	133.4 [82]	199.3 [155]	
m2	0.005	-0.001	-0.652	-0.114	0.287

Table 1: Employment equations, basic specifications

Dependent variable: n_{it}

* indicates significance at the 5% level.

Notes: (1) All equations are estimated in first differences to eliminate the plant dummies. The regressions include time dummies. The basic estimation technique is due to Arellano and Bond (1991), and uses an IV (GMM) method. (2) All standard errors in parentheses are robust to heteroscedasticity. (3) *Sargan/Hansen* is the Sargan/Hansen test of overidentification restrictions. (4) *m2* is a test of second order serial correlation. (5) After initial differencing, n_{it-1}, w_{it}, w_{it-1}, and $(CF/K^F)_{it-1}$ are taken as endogenous. Instruments are defined in the main text.

Independent variables	Time variations (i)
n_{it-1}	0.5211*
	(0.0423)
n_{it-2}	0.0090
	(0.0109)
w_{it}	-0.3822*
	(0.0643)
w_{it-1}	0.1309*
	(0.0463)
k_{it-1}	0.0116
	(0.0251)
Δy^{d}_{jt}	0.0437*
	(0.0185)
y^{d}_{jt-1}	0.0703*
	(0.0257)
Δy_{it}	0.2132*
	(0.0464)
y_{it-1}	0.1004*
	(0.0314)
$(CF/K^{F})_{it-1}$	0.0027
	(0.0104)
$(B/TA)_{it-2}$	-0.0662*
	(0.0338)
$D^{84-87}*(CF/K^{F})_{it-1}$	0.0913*
	(0.0196)
$D^{84-87}*(B/TA)_{it-2}$	0.0093
	(0.0279)
$D^{88-91}*(CF/K^{F})_{it-1}$	0.1986*
	(0.0429)
$D^{88-91}*(B/TA)_{it-2}$	0.0077
	(0.0375)
$D^{84-87}*\Delta y_{it}$	0.1046
	(0.0556)
$D^{84-87}*y_{it-1}$	-0.0098*
	(0.0042)
$D^{88-91}*\Delta y_{it}$	0.1351*
	(0.0615)
$D^{88-91}*y_{it-1}$	-0.0197*
	(0.0056)
Sargan/Hansen [df]	161.9 [128]
m2	0.091

Table 2: Employment equations, time-specific variations

Dependent variable: n_{it}

* indicates significance at the 5% level.

Notes: As in Table 1.

Independent variables	Sector demand fluctuations (i)	Small/Large firms (ii)
n_{it-1}	0.5941*	0.5641*
	(0.0348)	(0.0372)
n_{it-2}	0.0162	0.0159*
	(0.0099)	(0.0102)
w_{it}	-0.3380*	-0.3175*
	(0.0529)	(0.0593)
w_{it-1}	0.1488*	0.1149
	(0.0426)	(0.0426)
k_{it-1}	0.0113	-0.0197
	(0.0232)	(0.0227)
Δy^d_{jt}	0.0011	0.0208
	(0.0195)	(0.0172)
y^d_{jt-1}	0.0268	0.0365
	(0.0229)	(0.0228)
Δy_{it}	0.2899*	0.2667*
	(0.0363)	(0.0404)
y_{it-1}	0.1496*	0.1465*
	(0.0263)	(0.0266)
$(CF/K^F)_{it-1}$	0.0339*	0.0137
	(0.0130)	(0.0084)
$(B/TA)_{it-2}$	-0.0861*	-0.0660
	(0.0393)	(0.0451)
$D^{REC}*(CF/K^F)_{it-1}$	0.0593*	
	(0.0130)	
$D^{REC}*(B/TA)_{it-2}$	0.0040	
	(0.0038)	
$D^{REC}*\Delta y_{it}$	0.0736	
	(0.0399)	
$D^{REC}*y_{it-1}$	-0.0012	
	(0.0017)	
$D^{Small}*(CF/K^F)_{it-1}$		0.0404
		(0.0316)
$D^{Small}*(B/TA)_{it-2}$		-0.0251
		(0.0853)
$D^{Small}*\Delta y_{it}$		0.0609
		(0.0445)
$D^{Small}*y_{it-1}$		0.0122
		(0.0077)
Sargan/Hansen [df]	209.0 [162]	197.0 [162]
m2	0.237	-0.032

Table 3: Employment equations, further specifications

Dependent variable: n_{it}

* indicates significance at the 5% level.

Notes: As in Table 1.

Independent variables	Plant specific employment growth (a) (i)	Plant specific employment growth (b) (ii)
n_{it-1}	0.6881*	0.6802*
	(0.0341)	(0.0333)
n_{it-2}	0.0123	0.0125
	(0.0087)	(0.0086)
w_{it}	-0.3151*	-0.2773*
	(0.0504)	(0.0485)
w_{it-1}	0.0773*	-0.0655
	(0.0380)	(0.0370)
k_{it-1}	0.0129	0.0117
	(0.0177)	(0.0174)
Δy^d_{jt}	0.0298	0.0378*
	(0.0159)	(0.0155)
y^d_{jt-1}	0.0447*	0.0549*
	(0.0221)	(0.0218
Δy_{it}	0.1369*	0.1279*
	(0.0521)	(0.0518)
y_{it-1}	0.1057*	0.1047*
	(0.0250)	(0.0248)
$(CF/K^F)_{it-1}$	0.0022	0.0080
	(0.0408)	(0.0414)
$(B/TA)_{it-2}$	-0.2106*	-0.1739*
	(0.0886)	(0.0866)
$D^{EXP}*(CF/K^F)_{it-1}$	0.0421	0.0368
	(0.0384)	(0.0380)
$D^{EXP}*(B/TA)_{it-2}$	0.3747*	0.3364*
	(0.0976)	(0.0961)
$D^{CON}*(CF/K^F)_{it-1}$	0.0473	0.0623
	(0.0437)	(0.0438)
$D^{CON}*(B/TA)_{it-2}$	0.0092	-0.0178
	(0.1008)	(0.0981)
$D^{Small}*D^{EXP}*(B/TA)_{it-2}$		-0.0882*
		(0.0322)
$D^{EXP}*\Delta y_{it}$	0.1056	0.1161
	(0.0652)	(0.0649)
$D^{EXP}*y_{it-1}$	-0.0205*	-0.0178*
	(0.0083)	(0.0082)
$D^{CON}*\Delta y_{it}$	0.1264*	0.1334*
	(0.0564)	(0.0559)
$D^{CON}*y_{it-1}$	-0.0098	-0.0091
	(0.0085)	(0.0083)
Sargan/Hansen [df]	227.1 [191]	239.5 [201]
m2	0.065	0.178

Table 4: Employment equations, plant-specific employment growth

Dependent variable: n_{it}

* indicates significance at the 5% level.

Notes: As in Table 1.

Chapter 4

Zeroes and Lumps in Investment: Empirical Evidence on Irreversibilities and Non-Convexities

(Co-author Fabio Schiantarelli)

ZEROES AND LUMPS IN INVESTMENT:

Empirical Evidence on Irreversibilities and Non-Convexities

by

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February 3, 1997*

Abstract

The objective of this paper is to identify and discuss the main stylized facts about the type and degree of non-smoothness of capital adjustment. Using Norwegian micro data, we investigate the frequency of periods of zero investment as well as the lumpiness of investment both at the plant and firm level, and at different level of aggregation across capital goods. We also discuss how the importance of zero investment episodes and lumpiness varies between small and large plants or firms. Finally we estimate a discrete hazard model to determine the probability of having an episode of high investment, conditional on the length of the interval from the last high investment episode. We discuss what the empirical results suggest about the shape of the adjustment cost function and the aggregate implications of our findings.

* We would like to thank G. Bertola, R. Caballero, P. Gottschalk, G. Imbens, T. J. Klette, L. Serven and seminar participants at the University of Bergen, Statistics Norway and the World Bank for useful comments and conversations. Øivind Anti Nilsen gratefully acknowledges the financial support of "Norges Banks Fond for Økonomisk Forskning". The views expressed in this paper are the authors' own and do not necessarily represent those of the organizations they are associated with.

1. Introduction

The standard model of investment is based on the assumption that there are convex costs attached to adjusting capital, in addition to direct investment costs. Following the seminal contribution by Eisner and Strotz (1963), typically adjustment costs are assumed to be zero at zero investment and to be symmetric around zero. In these circumstances, if investment projects are divisible, there are no "technological" reasons why one should observe frequent episodes of zero investment. Moreover, the firm has an incentive to smooth investment over time in order to avoid paying increasing marginal adjustment costs. When investment is irreversible or when there are increasing returns in the adjustment cost technology (for instance, because there are fixed costs), the adjustment path of the capital stock will be non-smooth, in the sense that one may observe zero investment periods and/or lumpy adjustment, with investment activity taking the form of large adjustments concentrated in a few episodes. The non-smoothness may also be enhanced by the inherent indivisibility of investment projects, so that investment can only be changed in discrete increments.

Irreversibility is caused by the fact that capital goods are, at least, partly firm specific. Moreover, lemon problems in second hand markets for capital, could also make investment irreversible, at least to some degree. The basic implications of complete irreversibility (investment must be non negative) were originally analyzed by Arrow (1968) and later by Lucas and Prescott (1971), Nickell (1974) and (1978), and, more recently, by Bertola and Caballero (1994), and Dixit and Pindyck (1994).[1] The main consequence of irreversibility is that one is likely to observe periods of zero investment, alternating with periods of positive investment. However, lumpiness is not implied by irreversibility *per se*. Moreover, intermittent adjustment

[1] For a review of the macro implications of and evidence on irreversibility see Serven (1996).

does not necessarily require the assumption of complete irreversibility, but only that the adjustment cost function is not continuously differentiable at zero.

In addition to indivisibilities in investment, it is the presence of increasing returns (non-convexities) in the adjustment costs technology that explains why investment, when it occurs, is large. The presence of such non convexities was noted by Rotschild (1971) and it characterizes the contribution by Caballero and Engel (1994), Cooper, Haltiwanger and Power (1995), Abel and Eberly (1994), and Caballero and Leahy (1996).

Even though there are a number of theoretical contributions that analyze the consequences of various departures from the standard model of reversible investment with symmetric convex adjustment costs, the empirical evidence on these issues is limited. At the more descriptive level, using the Longitudinal Research Database for the U.S., Doms and Dunne (1994) provide evidence that a large portion of investment at the plant level is concentrated in a few episodes.[2] Cooper, Haltiwanger and Power (1995), on the basis of estimates of the hazard function, provide evidence that bursts of investment lasts for more than one period, but then the probability of a plant experiencing a large investment episode increases in the time elapsed since the last such episode. This last piece of evidence is supportive of non-convexities in the adjustment cost technology. Moreover the probability of observing an investment spike varies procyclically. Barnett and Sakellaris (1995) and Abel and Eberly (1996) show empirically that the relationship between the investment rate and average Q is nonlinear, using firm level data from Compustat. The Abel-Eberly (1994) model predicts that there is a range of values of Q for which investment would not be sensitive to changes in Q, while it would respond outside this range. The non-linearities found in the data are not consistent with this simple model. However, Abel and Eberly (1996) argue that the empirical evidence is

[2] They do not address the issue of the incidence and frequency of zero investment periods. This is also the result of their choice of defining capital growth in terms of expenditure net of depreciation.

consistent with a model with irreversibilities and fixed costs, if one allows for capital goods heterogeneity. Caballero, Engel and Haltiwanger (1995) in the context of (S-s) types of models, relate investment to the gap between "desired" and actual capital stock and show empirically, using the LRD plant level data, that the elasticity of investment to shocks is greater when the gap is large or positive and smaller when it is small or negative. All the previous contributions rely on micro data. Bertola and Caballero (1994) concentrate instead on the implications for aggregate investment of a model with irreversibility.[3] They argue that a combination of non-linear investment policies and idiosyncratic shocks yields a satisfactory fit of the model to aggregate data, although the residuals are non-trivial and serially correlated. Caballero and Engel (1994) allow for increasing returns in the adjustment costs technology and find that their model can explain aggregate sectoral data better than an AR(2) model.

The objective of this paper is to establish a few stylized facts about the pattern of capital adjustment, to discuss the implications of the empirical evidence for the shape of the adjustment cost function, and to draw the aggregate implications of our findings. Throughout we will use a very rich panel of Norwegian plants and firms.

A distinguishing feature of our contribution is the focus both on zero investment episodes and on the lumpiness of capital adjustment. This is important in order to assess the empirical importance of the two forms of departures from the standard model of investment (irreversibilities and non convexities) that have received more attention in the recent literature. Moreover, since the data set specifies the nature of the plant (single plant, main, secondary, or auxiliary unit in multi-plant firms) and it is available both at the plant and the firm level, one can analyze how the relevance of irreversibilities and non-convexities changes as the unit of observation changes. We will indeed show that the nature of the capital adjustment process

[3] See also Bertola and Caballero (1990).

varies substantially depending upon the functional nature of the plant and upon the level of aggregation (firms versus plants).

We also investigate how episodes of zero investment and lumpiness vary when firms (plants) are classified according to size. We do find interesting differences in the pattern of capital adjustment and we discuss how they could be explained on the basis of technological and financial factors. We can analyze the role of financial factors because plant level data can be matched to the information contained in the firm level balance sheets.

In order to address in a somewhat more structured way the issue of the shape of the adjustment cost function, we follow and extend the approach by Cooper, Haltiwanger and Power (1995) and we estimate the hazard function describing the probability of episodes of high investment, conditional on the length of the interval from the last episode of high investment. In addition to controlling for business cycle conditions, we also allow for unobserved (plant) heterogeneity. The main issue we address here is whether the hazard rate is upward sloping. We also discuss whether there are differences in the shape of the hazard between small and large plants (firms) and whether the probability of observing an investment spike is related to the availability of internal sources of finance.

Finally, using the estimates of the hazard model obtained at the micro level, we address the crucial question whether taking into account of non-convexities helps in understanding aggregate investment behavior, and more specifically the fluctuations in the aggregated proportion of plants experiencing an investment spike.

The paper is organized as follows. In Section 2 we describe the data sources, the nature of the panel, and the variables' construction. In Section 3 we present the evidence on episodes of zero investment for equipment and buildings at the plant and firm level. In Section 4 we analyze the degree of concentration (lumpiness) of investment in a few episodes characterized by large expenditures. In Section 5 we estimate the hazard function for investment spikes, discuss what its shape says about the existence of non-convexities and about the importance of financial constraints, and consider the implications for predicting the fluctuations in aggregate investment. Section 6 concludes the paper.

2. The Data

The empirical work in this paper is based on a large set of unbalanced data of private Norwegian plants and firms in the manufacturing sector for the period 1978-1991, collected by Statistics Norway (The Central Bureau of Statistics of Norway). Income statement and balance sheet information is provided in Statistics of Accounts for all firms with more than 50 employees in the period 1978-1990. In 1991 no new small firms (less than 100 employees) were added in the sample due to new sampling routines used by Statistics Norway. For all the firms for which Statistics Norway include in their sample, plant level information about production, production costs, investment and capital stock is available in Manufacturing Statistics. The frequency of all information in Statistics of Accounts and Manufacturing Statistics is annual. After standard data cleaning procedures that are described in detail in the Data Appendix, we are left with an unbalanced panel of 2296 plants (1866 are production plants, while the rest are auxiliary plants such as storage and office units) for which information is available for at least four consecutive years. These plants belong to 1252 firms and account on average for 41 percent of total investment in manufacturing over the period 1978-1991. Their total investment is highly correlated with total investment in manufacturing. The correlation coefficient is 0.86 and it is highly significant.

Throughout the paper, investment is defined as purchases minus sales of fixed capital. Expenditures related to repairs of existing capital goods are not included in the definition of purchases. This distinction is a unique and very useful characteristic of the data set we are using. In most of the paper we distinguish between plant and equipment (equipment from now on), on the one hand, and buildings on the other.[4] Equipment includes machinery, office furniture, fittings and fixtures, and other transport equipment, excluding cars and trucks and represents 64 percent of total investment.[5] Firms are instructed to record investment in equipment at the time of delivery. Buildings include those directly used for production, offices and storage facilities account for 24 percent of total investment. Investment in buildings is meant to be recorded when the contract is signed for existing buildings, while construction work in the year when it occurs. For multi-year projects, some firms may actually report investment purchases in equipment and buildings at the completion of the project, although it is impossible to assess how widespread the practice is.[6] The choice to concentrate on equipment and buildings is imposed by the level of disaggregation at which capital stock data are available. We have obtained the replacement value of the capital stock using the perpetual inventory method, starting from a benchmark calculated using the fire insurance value available from the Manufacturing Statistics.

3. The Distribution of Episodes of Zero Investment Episodes at the Plant and Firm Level: Evidence from the Unbalanced Sample

In order to assess the nature of the non-smoothness of investment patterns, we focus on the salient features of the distribution of investment rates. In Figure 1 we present the distribution of investment rates for equipment and buildings for the entire (unbalanced) sample. Table 1 contains the numerical information on the frequencies for equipment, buildings, and

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[4] See Data Appendix for details on variable definitions and construction.

[5] The definition of equipment investment we use here matches the availability of capital stock data. See the Data Appendix for details.

their sum, together with the share of total real investment accounted for by investment rates within each interval.

Both distributions of investment rates are highly peaked and skewed, with fat and long right-hand tails.[7] Episodes in which the plant refrains from engaging in any investment (or disinvestment) activity occur frequently for investment both in equipment and in buildings. Moreover, the frequency of zero investment is much higher for buildings compared to equipment. Negative investment rates occur quite rarely for both equipment and buildings (2 percent of the observations in both cases involve negative investment expenditure). They represents 2 percent of total investment, net of asset sales, for equipment and a non trivial 10 percent for buildings.

In Table 2 we report more detailed figures on the frequency of zero investment episodes, distinguishing by type of plant (single plant, main production unit, secondary production unit, auxiliary unit in a multi-plant firm) and aggregating up to the firm level. We then see that the high absolute figures for zero investment for all plants (34 percent for equipment and 68 percent for buildings) is partly due to the extremely infrequent investment in auxiliary units. If we concentrate on production units only (which account for approximately 99 percent of investment) they became 21 percent and 61 percent respectively. These figures, although smaller, still confirm that investment has a highly intermittent character that is particularly pronounced for buildings. If we sum the expenditure on equipment and buildings, zero investment episodes represent 20 percent of the total number of observations. This illustrates the general point that aggregating across types of capital goods leads to an underestimate of the intermittent character of investment.

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[6] This would be the figure one actually wants to analyze the non-smoothness of investment orders, instead of expenditure.

[7] Skewness and Kurtosis tests overwhelmingly reject normality.

There are also important differences in the investment patterns, when one classifies the observations according to the functional nature of the production unit. The intermittent character of investment is particularly pronounced for secondary production units (41 percent and 71 percent of zero observations for equipment and building respectively), which are responsible for between a fifth and a quarter of total investment spending. It is less pronounced for single plants and for the main production unit of multi-plant firms (which account for approximately a quarter and a half respectively of total investment expenditure) and their figures are very similar to the ones obtained aggregating the data up to the firm level. At the firm level the frequency of zero investment is 6 percent for equipment and 49 percent for buildings. The figure for buildings remains, therefore quite large, while there is a substantial reduction of the frequency of zero investment for equipment (which accounts for two thirds of total investment). In conclusion, the data provide ample evidence supporting the intermittent nature of building investment. Zero investment periods also characterize equipment investment, although to a lesser extent, and the degree of intermittence depends upon the nature of the plant and upon the level of aggregation (plants versus firms).

Purchases or sales of investment goods is just one of the ways in which firms can change the capital stock. Firms can also rent capital through leasing arrangements. One must be careful that by disregarding leasing, and concentrating exclusively on purchases (or sales) of assets one does not overestimate the importance of zero investment episodes. Using information on leasing contained in the data set, we have estimated that the value of leased equipment is on average 14.2 of owned capital equipment. Leased buildings represent on average 35.3 percent of owned buildings. Moreover, this share rises from 24.1 percent in 1978 to 59.3 in 1991.[8] So leasing is an important activity, particularly for buildings. We have

[8] In order to obtain an estimate of leased capital we have divided leasing expenditure by the sum of the real interest rate and the depreciation rate.

compared the yearly frequency of zero leasing expenditure observations for plants that have zero investment purchases with the frequency for plants that experience positive investment. The evidence suggests that in all the years plants with zero investment expenditure on equipment or buildings are also less likely to resort to leasing in each year.[9] This indicates that it is unlikely that leasing is used as a way to get around irreversibilities and non-convexities at the plant level. It appears instead that leasing and direct purchasing of investment goods are complementary activities.

What do the results we have obtained so far say about the desirability to abandon standard specifications of the adjustment cost function when modeling investment? The descriptive evidence about the frequency of zero investment episodes and the infrequency of negative investment rates suggests that the evidence is quite compelling, particularly at the plant level. However, a fuller answer ultimately lies in estimating models of investment that allow for irreversibility and non-convexities at different level of aggregation both across plants and types of investment goods and in comparing their ability to explain the data with standard models derived from the assumption of convex adjustment costs with no irreversibility or fixed costs.[10]

Table 1 contains additional interesting information concerning the distribution of investment rates. Investment rates in excess of 20 percent occur only 10 percent of the time for equipment, but they account for approximately a third of total real investment expenditure. For buildings, investment rates exceed 20 percent only 5 percent of the times, but these episodes account for more than 50 percent of total investment. The importance of episodes characterized by large investment expenditures, could be suggestive of the relevance of non convexities in the

[9] Detailed results are not reported here for brevity sake, but are available from the authors upon request or can be seen in an earlier working-paper version (Nilsen and Schiantarelli (1996)).
[10] See Abel and Eberly (1996) for results at the firm level.

adjustment cost technology, and will be investigated further below. Here we want to attract attention to another interesting aspect of the distribution, i.e. that "small" investment rates are fairly frequent and quantitatively important. Positive investment rates of less than 10 percent represents 42 percent of the observations for equipment and 23 percent for buildings and they account approximately for around a third of total investment in both cases. Further calculations reveal that 31 percent of the observations for equipment are greater than zero but smaller than 0.06, which is the figure we have used for the depreciation rate, and can therefore be characterized as replacement investment. They account for 21 percent of total equipment investment expenditure. Approximately 13 percent of the investment rates for buildings are greater than zero and smaller than 0.02, the depreciation rate used for buildings.

If one believes that adjustment costs should be defined for gross investment expenditure, independently from investments having a replacement or an expansion purpose, the results for equipment are not supportive of the idea that non-convexities as opposed to irreversibilities are a dominant feature in adjusting equipment. Most of the theoretical papers actually do not make such a distinction. However, it is reasonable to argue that replacement investment is characterized by very small (virtually zero) adjustment costs and that a fixed component becomes important only for expansion investment. This may be the case so that observing small investment rates should not be surprising. Nevertheless, this feature should be formally incorporated in the adjustment cost function. In most empirical papers the distinction between replacement and expansion replacement is implicitly recognized by including a constant, representing the depreciation rate in the quadratic adjustment cost function, written as a function of the investment rate. However, the consequences of kinks are then swept under the carpet by assuming implicitly that the investment rate always exceeds the depreciation rate. Another possible explanation for the frequency and quantitative importance of small investment rates, even in the presence of fixed adjustment costs, could be the fact that time to build and a distribution of delivery dates characterize many investment projects spanning more than one calendar year. If these features are deemed important, they should be made an integral part of the theoretical model as well.

The last issue we want to discuss in this section is whether the intermittent nature of investment differs across small and large firms. There are several reasons why the frequency of zero investment may be inversely related to size. First, larger plants may be considered as agglomerations of plants of smaller size. In this case indivisibilities, irreversibilities and non convexities may be less important because of aggregation within the plant over production lines or production processes. Another possibility is that the fixed component of adjustment cost is relatively more important for small plants (we will return to this issue in the context of the discussion on lumpiness in the next section). Moreover, smaller units may be exposed to demand shocks with a greater variance. If this means that the occurrence of large negative shocks is more likely for small firms, this may give rise to more frequent episodes of investment inactivity. Finally, size is a proxy for access to capital markets. The size of a plant, and even more so the size of a firm, is likely to be correlated, albeit imperfectly, with the existence of asymmetric information problems. In these circumstances internal and external sources of finance are less perfect substitutes for each other and we may observe periods of no investment when internal resources are not available and it is prohibitively expensive to gain access to external funds.

In Table 3 we report the investment rates and the frequency of zero investment for production plants (classified according to their nature) and firms partitioned according to whether the number of employees is less than or greater than a hundred. Independently from the nature of the plant, in all cases smaller units are characterized by more intermittent investment. The same difference exists between small and large firms. Moreover the differences in the frequency of zero investment are substantial. For equipment investment, for instance, the frequency of zero investment for small main units in multi-plant firms is (roughly) three times larger than for large main units (10 percent versus 3 percent). For small firms it is two times larger than for large firms (9 percent versus 5 percent). We have estimated two separate logit models of the probability of observing zero investment for equipment and buildings as a function of dummies that capture the functional nature of the plant and its size. Industry and year dummies are included as well. The difference in the frequency of zero investment episodes according to size is statistically significant and it is robust to controlling for industrial sector. The *t* statistic for the coefficient of the size dummy (defined according to whether a unit has more or less than 100 employees) equals 21.35 for equipment and 25.94 for buildings.[11]

4. Lumpiness: Evidence from the Balanced Plant and Firm Level Sample

In this section we analyze another aspect of the non smoothness of the process of capital adjustment. In particular we investigate to what extent investment activity is concentrated in a few episodes characterized by large expenditures. The presence of lumpiness in investment is important because it can provide information about non convexities in the adjustment cost technology. Lumpiness could also be related to the existence of indivisibilities, particularly when one introduces new technologies embodied in a set of interlocking new capital goods. In order to assess the degree of lumpiness we have concentrated on the sub-sample consisting only of those plants with observations in all of the fourteen years. The balanced plant level panel contains a total of 362 production units with 5068 total observations. We will also provide

[11] The coefficients of the year dummies suggest that the frequency of zero investment has a countercyclical pattern for both buildings and equipment, but weaker and not very significant for the latter. Detailed results are not reported here for reasons of space, but are available from the authors upon request or can be seen in an earlier working-paper version (Nilsen and Schiantarelli (1996)).

results at the balanced firm level sample containing 144 firms and 2016 total observations. Both panel are biased towards larger, healthier, and more successful plants or firms. It is interesting to note that for the balanced plant level panel the frequency of zero observation is smaller than those for the unbalanced panel (18 versus 21 for equipment and 55 versus 61 percent for buildings), but still indicate that episodes of zero investment are an important phenomenon.

In order to assess the degree of lumpiness, following Doms and Dunne (1994), we have ranked the investment rates for each plant (firm) from the lowest (rank 1) to the highest (rank 14). In Table 4 we report the mean investment rate for each rank as well as the shares of total investment it represents. Starting with equipment investment at the plant level the mean investment rate for observations with rank 14 is 0.61. This is six times higher than the average investment rate and two and a half time the second highest investment rate. In terms of shares, 26 percent of total equipment investment is represented by the investment episodes with rank 14, while 53 percent of total investment in equipment occurs in the three highest ranked episodes.

To assess the degree of persistence in investment we have calculated the mean investment rates one and two years before and after observations for each rank. For equipment the mean investment rate at year *t-1* before the observation with the highest rank observation is 0.09. The mean investment rate following at year *t+1* after the highest rank observation is 0.10. Both are much smaller than the mean investment rate for rank 14. This would suggests that there is not much persistence in the occurrence of high investment. However, for the second highest investment episode the observation in the preceding period displays an investment rate which is as high, which suggests a sizable degree of persistence. One plausible explanation for this apparently contradictory result is that large investment projects take several months to complete. If a substantial number of these months belong to two calendar years, this yields both a lower spike and a greater persistence. If they are completed within a year, the spike is higher and there is less persistence.

For buildings the average investment rate for observations with the highest rank is 0.41 which is more than ten times higher relative to the average investment rate and three times the second highest investment rate. Finally, approximately 45 percent of total investment in buildings occurs in the highest ranked episode and 80 percent in the three highest ranked episodes.

How much do investment spikes contribute to explaining aggregate investment? In order to answer this question we have calculated the aggregate investment rate in equipment as the ratio between total equipment investment and the total capital stock for our balanced sample. We have then regressed it against the frequency of firms experiencing the highest investment spike in each year of the sample. The regression results suggest that the spike frequency variable is positively and significantly (t = 3.09) associated with the aggregate investment rate with a correlation coefficient of 0.67. Also for buildings the frequency of firms experiencing the highest investment spike in a given year explains is positively and significantly associated to the share of total building investment that occurs in any given year. The correlation coefficient is 0.86 (t = 5.78). The evidence on the degree of persistence is present both for equipment and buildings. The highest investment episode is neither preceded nor followed by periods of intense investment, but the second highest is preceded by a period of intense investment activity. As we have already explained, time to build or delivery lags considerations spanning more than calendar year can explain this pattern.

Summarizing, there is evidence both for equipment and building that investment spikes are an important component of the investment process at the plant level. Moreover, the occurrence of such spikes contributes significantly to explaining the pattern of aggregate investment. The lumpy nature of investment is suggestive of the importance of what Dixit and

Pindyck (1994) denote as "stock" fixed costs, i.e. lump-sum costs associated with taking an investment action, such as fixed costs of deciding on and placing an order. These should be distinguished from 'flow' fixed costs which occur at a given rate at each instant over the interval during which an action is taken. With "stock" fixed costs a finite instantaneous rate of investment, in the context of a continuous time model, is not optimal and the capital stock can be shown to jump in discrete steps at isolated instants.[12]

Table 4 contains evidence on lumpiness also at the firm level. Starting with equipment, the observation with highest rank is 0.41 and it is about four times bigger than the average investment ratio, as opposed to six times at the plant level. Moreover the top three investment episodes account for 46 percent of total investment, a smaller fraction relative to the plant level panel (53 percent). The investment rate for buildings with highest rank is 0.46 approximately eight times bigger than the average investment ratio (it was approximately ten times bigger than the average at the plant level). The three investment episodes with the highest rank account for 71 percent of total investment in buildings, a smaller figure than at the plant level (80 percent).

In general these results indicate that aggregating plants into firms generates a smoother capital adjustment process. As we have seen in the previous sections, the frequencies of zero-investments are smaller at firm-level relative to plant-level. Moreover the ratio between the highest ranked investment ratios and the average investment ratios for each fixed capital category, as well as the share of total investment accounted for by three highest ranked episodes, are greater at plant-level relative to firm-level.

Just as there is evidence that periods of investment inactivity are more frequent for small plants (and firms), there is also evidence that investment is lumpier for smaller units. In Table 5

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[12] See Dixit and Pindyck (1994), p. 383 and following ones. See also Abel and Eberly (1994) as an example of "flow" fixed costs, and Caballero and Leahy (1996) for the implications of "stock" fixed costs for the break-down of the relationship between investment and marginal q. Note that the distinction between "stock" and "flow" fixed costs loses its importance in investment models formulated in discrete time, as in Abel and Eberly (1996).

we classify plants according to their size. For instance, the average investment rate for the highest ranked investment episode is eight time the mean investment rate in equipment for small plants and four times the mean for large plants. The three highest investment episodes represent 63 percent of total real investment in equipment over the period for small plants and 52 percent for large plants. Similar difference occur when the analysis is conducted for small and large firms, as opposed to plants. However we do not report the results for reasons of space.

The different degree of lumpiness between small and large units provides further information on the nature of the fixed components of adjustment costs. In many contributions the fixed component is assumed to increase with the size of the capital stock, sometimes proportionately as in Abel and Eberly (1996) and Caballero and Leahy (1996). This is meant to reflect forgone profits due to the loss of production that is likely to be associated with installation of capital. If this was the only source of non-convexity, it would be difficult to use the shape of the cost function to rationalize our finding that investment is lumpier for smaller plants. However, this results can be easily explained if there is a fixed component of adjustment costs that does not depend upon size, as in Cooper, Haltiwanger, and Power (1995), or by the presence of indivisibilities.

Another reason for the different degree of lumpiness, completely separate from adjustment costs considerations, is that demand may be more variable for small firms. Finally, there is an explanation based on financial constraints. When firms suffer from asymmetric information problems, aggregate shocks are likely to have a more powerful effect on investment than under the assumption of perfect capital market. For instance, an aggregate demand shock will affect not only the return to investment, but also the cost or access to external finance because it may alter borrower's net worth, which affects the premium to be paid on external finance. In these circumstances the initial impact of the shock will be amplified (the financial accelerator effect) and this may give rise to substantial investment fluctuations that go beyond those predicted by standard models based on convex adjustment costs.[13] We will discuss again the role of financial constraints later in the next section.

5. The Shape of the Hazard, the Structure of Adjustment Costs, and Aggregate Implications

We want now to return to the issue of what we can learn from the lumpiness of the pattern of capital adjustment about the importance of fixed components of adjustment costs in a slightly more structured way. More specifically we will test the empirical implications of the model developed by Cooper, Haltiwanger and Power (1995) concerning the shape of the hazard characterizing the (unconditional) probability of an investment spike. We also attempt to evaluate the implications of the results for our understanding of the fluctuations in aggregate investment and revisit the issue of whether, how, and why the lumpiness in investment differs across small and large plants. In their model of machine replacement they allow for indivisibilities, a fixed component of adjustment costs, independent of size, and a component proportional to output that represents the opportunity cost associated with the diversion of resources away from production. The model is developed under the assumption of perfect capital markets. Under the hypothesis of serially correlated exogenous shocks to firms' profitability and some additional assumptions, they show that, given the state of the economy, the probability of machine replacement increases as the time since last replacement increases.[14] In other words, the hazard is increasing. With serially correlated shocks and convex adjustment

[13] See, for instance, Fazzari, Hubbard and Petersen (1988) and Bernanke, Gertler and Gilchrist (1995).

[14] This result holds under some restrictions on the size of the fixed costs and the curvature of the utility function (utility must not be too concave).

costs, investment should also be serially correlated and, therefore, the hazard decreasing. With serially uncorrelated shocks and no adjustment costs, the hazard should be flat.

In modeling the hazard we assume that time is discrete and we denote with T_{ij} the time at which firm i has an investment spike during the j-th spell of zero investment. The hazard rate can the be written as:

$$p_{ijt} = \Pr\left[T_{ij} = t \mid T_{ij} \geq t,\ t-(T_{ij-1}+1),\ x_{it}\right] \tag{1}$$

where t represents calendar time, $t-(T_{ij-1}+1)$ the interval from the last spike (a zero interval represents the case of two adjacent spikes), and $\boldsymbol{x}_{it}$ a set of additional conditioning variables.[15] We parameterize the hazard as a logistic function and we model the duration dependency in a very flexible way by introducing a set of duration dummies, D_{sit}, equal to one if the interval from the last spike is s=0,1,2, etc.. More precisely:

$$P_{ijt} = \frac{1}{1+\exp\left\{-\sum_{s=0}^{S}\gamma_s D_{sit} - \beta' x_{it}\right\}} \tag{2}$$

where S denotes the longest spell duration. Notice that given the parameterization in (2) we can drop subscript j, since the D_{sit}, and $\boldsymbol{x}_{it}$ variables summarize all the differences in the hazard across spells (i.e. $P_{ijt} = P_{it}$). Define now dichotomous indicator variable, y_{it}, that equals one if firm i has an investment spike in period t and zero otherwise. Notice that P_{it} denotes the

[15] The vector $\boldsymbol{x}_{it}$, may include both time-invariant firm-specific effect and time-varying variables common to all firms.

conditional probability that $y_{it} = 1$. Then it is easy to show that the log-likelihood function can be written as:[16]

$$\log L = \sum_{i=1}^{N} \sum_{t=\underline{t}_i}^{\bar{t}_i} \left[y_{it} \log(P_{it} / (1 - P_{it})) + \log(1 - P_{it}) \right] \tag{3}$$

where $\underline{t}_i$ and $\bar{t}_i$ denote respectively the first and last year firm i appears in our unbalanced sample. The form of the log-likelihood implies that in the absence of firms specific effects, the parameters can be estimated using the standard maximization routines for binary logit models. In a first specification, we have included in the vector $\boldsymbol{x}_{it}$, year dummies, sector dummies, size and multi-plant firm dummies. However, the estimates of the duration dependence parameters, γ_k, may be contaminated by unobserved heterogeneity, resulting in negative duration dependence, when in fact there is positive duration dependence (the conditional probability of an investment spike increases the longer the interval from last spike). For this reason we have also estimated the model allowing for firm specific fixed effects, in addition to the year and duration effects.

In order to estimate the model we must define what is defined as an investment spike. We will follow Cooper, Haltiwanger and Power (1995) in using three definitions: 1) an absolute high spike, when the investment rate exceeds 20 percent; 2) an absolute low spike, when investment exceeds depreciation (set at 6 percent for equipment and 2 percent for buildings); 3) a relative spike when the investment rate exceeds 2.5 the median investment rate for each plant.

[16] See Allison (1982) and Willet and Singer (1996).

The model is estimated separately for equipment and buildings for the unbalanced panel of production plants.[17]

In Table 6a (for equipment) and 6b (for buildings) we first report the OLS estimates of a model in which y_{it} is regressed only on the set of duration dummies. This yields the standard Kaplan-Meier non-parametric estimate of the hazard for the entire panel. The Kaplan-Meier estimator suggests that the hazard is the highest for both equipment and building and for all the spike definitions in the period immediately following a spike and then declines sharply in the following period and remains relatively flat afterwards. However, the Kaplan-Meier estimate of the hazard is consistent if there is no (temporal or firm specific) heterogeneity in the sample.

The second set of results reported in Table 6a and b are the estimates obtained from the logit model that controls for time, sector, and some firm specific characteristics (size and functional nature of the plant). The sector and time dummies are not reported in the tables for brevity sake. Note that an interval of zero duration, meaning that two spikes occur in adjacent periods, is used as the reference case in estimation so that the duration i dummies (i = 1,.., 9 plus) represent deviations from this case. The conclusions derived from the logit model do not suggest a substantially different picture. For all definitions of spikes also in this case the hazard is the highest in the period immediately following a spike and it falls sharply after that. After that it remains relatively flat in most cases. For the relative definition of spikes, for both plant and equipment, there is instead some evidence that the hazard rises mildly after the initial fall. The increase is, however, small and not statistically significant.

The third set of results in Table 6 are obtained from the estimation of the logit models with fixed effects. These have been obtained by estimating the unconditional likelihood

[17] Only plants for which an investment spike is defined are included in the sample used. Therefore the number of observations varies dependent on the definition of the spike.

function allowing for firm specific constants, in addition to the duration and year dummies. [18] As it is well known, the parameter estimates are consistent only when the number of time series observations is large. In our unbalanced panel the number of observations ranges between two and thirteen. 64 percent of the observations belong to firms with eight or more years of observations, and 38 percent to firms with eleven or more years of observations. The availability of relatively long runs of observations for many firms leaves us reasonably confident that the results we will now present are informative.[19]

When we allow for firm specific fixed effects, we still find evidence that the probability of observing another investment spike is high immediately after an episode of large investment expenditure. This is then followed by a decrease in the hazard. However, contrary to the conclusion reached previously, the hazard then increases in all cases, the increase is monotonic in all cases but one, and it very significant. Moreover, generally the conditional probability of an investment spike rises quickly beyond the value attained in the period immediately after a spike.

It is interesting to note that OLS estimation of a linear probability model allowing for fixed effects, in spite of its well known drawbacks, leads as well to similar qualitative conclusions regarding the shape of the hazard. Using this model on data for the US, Cooper, Haltiwanger and Power (1995) also found that the hazard was the highest in the period

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[18] Note for instance that the number of observations falls from 6375 in the case of equipment (high spike definition) for the logit model without fixed effect to 4200 observations for the model with fixed effects. The reduced number of observations is caused by the fact that only those plants with at least two spikes are included in the sub-sample.

[19] The use of the standard conditional logit model (Chamberlain (1980), (1983)) is not appropriate in this case. The standard conditional logit model do not control for state dependence, i.e. an implicit assumption is that the probability of an investment state is assumed to be independent on whether there was any investment spikes in the past. However, if there is any state dependence, the estimated coefficients of a conditional logit model are inconsistent (see Card and Sullivan (1988)). In spite of this knowledge, we have also re-estimated the logit model in its conditional form. It is comforting to know that the estimates of the duration (and year) dummies are very similar to those obtained using the unconditional logit model and lead to the same conclusions.

immediately following a spike. It then decreased in the following period to raise again, but non-monotonically, at longer durations.

In conclusions our results provide a degree of support for the model with non-convexities in adjustment costs, in the sense that, controlling for unobserved heterogeneity, we find evidence of a monotonically increasing hazard, after an initial drop. The high value of the hazard in the period immediately following a spike is consistent with the fact that several investment projects may give rise to expenditures that are spread over many months, belonging to different years. It is also consistent with a model of investment in which there are convex components to adjustment costs. In the absence of fixed components, however, it would be difficult to explain why then the hazard rate increases with the length of the interval from the last investment spike. The increasing hazard is evidence in favor of the importance of fixed costs. Note that the reversal of the results concerning the slope of the hazard (for intervals greater or equal to one period) emphasizes how crucial it is to control for unobserved heterogeneity in estimation.

With regard to the pro- or counter-cyclicality of the hazard rate, in both logit models (with and without fixed effects), the estimate of the year dummies suggest that the probability of an investment spike increases in booms and decreases in recessions. For instance, the correlation coefficient between the rate of growth in manufacturing GDP and the change in the year dummies in the fixed effect hazard model for equipment is 0.66 and significant for both the high and low spike definition (it is positive, but smaller (0.22) and not significant for the relative spike definition). We know, from a theoretical point of view, that there are two contrasting forces at work here. On the one hand, firms would want to replace machines at times when the opportunity cost of lost output is small. On the other hand, they would also want to introduce new machines when returns are high. Empirically it appears that the latter factor dominates.

In order to assess the effect of firm's size on investment patterns, we have allowed the coefficients on the duration and year dummies to vary between small and large plants. The results are contained in the first column of Table 7. The χ^2 test on the joint significance of the duration dummies interacted with a dummy that equals one if the plant is small suggests that the difference is almost significant at the 5 percent level. The time dummies, not reported for reason of space, are significantly different at the 5 percent level, but not at the 1 percent level. Looking at the point estimates of the duration parameters, the hazard increases after an initial drop for both small and large plants, although more quickly for the former.[20]

We have documented in the previous section that investment is lumpier for smaller plants compared to large plants, and we have mentioned that one of the possible explanations is based on the existence of financial constraints. In order to test for the role played by financial factors, we have added as an explanatory variable in the hazard model of the first column firm level cash flow (divided by the capital stock) and cash flow interacted with a dummy that equals one if the firm (not the plant) is small.[21] Note that it is appropriate to examine the role played by the availability of internal resources at the firm, not at the plant level. The cash flow coefficient is positive (see the second column of Table 7), but not very precisely determined. Most importantly the difference between plants belonging to small or large firms is not significant. If we also add the plant level current and lagged sales to capital ratio to the regression, the former has a positive effect on the probability of observing an investment spike. At the same time the role of cash flow becomes even smaller and the result of no difference across firm sizes continues to hold (see the third column of results). This evidence suggest that the different degree of lumpiness for small and large firms is less likely to be related to the

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[20] Note that this is a statement about the behavior of the hazard relative to its level in the period immediately after a spike.

[21] Cash flow is defined as income after interest and taxes, plus depreciation (see Data Appendix for further details). This exercise is in the spirit of Fazzari, Hubbard, and Petersen (1988).

existence of financial constraints, while it is more likely to be related to the presence of fixed component of adjustment costs that do not vary with size and to indivisibilities. It is interesting to note that adding sales and cash flow as determinants of the hazard does not alter the conclusions about its shape that we had reached previously.

How important are non-convexities in understanding aggregate investment fluctuations? More specifically, is there a gain in taking into account of the interaction between macro shocks and the distribution across firms of the length of the interval since the last investment spike? In the context of the Cooper, Haltiwanger and Power (1995) model of discrete investment, the behavior of aggregate investment is represented by the aggregate proportion of plants experiencing an investment spike (that can be thought, at each point in time, as the product of the hazard times the frequency of firms with a given duration, summed over all possible durations). One way to address this question is to conduct a dynamic simulation of the estimated model at the level of each firm, and to construct a simulated measure of the frequency of spikes, allowing for both year and duration effects, year effects only, duration effects only, and to compare them with the actual frequency.

The simulation works as follows. For each firm we have used the estimated year and duration parameters obtained from the unconditional logit model with fixed effects, to calculate the estimated hazard rate for the first year the firm appears in the sample used for estimation. For this first observations we use the information that the spike occurred in the previous period. We then have drawn a random number from a uniform distribution between zero and one. If this number falls short of (exceeds) the estimated hazard rate, then we define the observation as an investment spike (non-spike). We then repeat the process for the following years, using the simulated length of the interval from the last spike to calculate the hazard. We have experimented taking either one set of drawings per firm or up to fifty drawings. In both cases, we then calculate for each year the aggregate frequency of investment spikes. The results suggest that using one or more drawing for each firms makes no difference to the overall conclusions.

As an example we report in Figure 2 the results obtained for the hazard model for equipment of Table 6a, using the high spike definition, and fifty drawings per firm. The results are representative of those obtained for different spike or investment definitions. In the Figure 2, f1 represents the estimated frequency based on the full model, allowing for the consequences of both common macro shocks and the distribution of interval lengths. f2 represents the frequency obtained when the duration parameters are set to zero, and, for this reason, can be seen as being generated by a model that allows for common macro shocks, but assumes a flat hazard. f3 is the frequency obtained when the year dummies are set to zero and all the action comes from changes in the distribution of delivery dates, while no change in macroeconomic conditions is allowed for. We also plot the actual frequency based on the sample of 4200 observation used in estimation of the unconditional logit model (denoted as "small sample"). Note that, given the nature of the estimation procedure, a firm must have had at least two spikes to be included in this sample. We also report the frequency for the full sample of 18043 observations for production units ("large sample").

The first thing to note is that f1 and f2 both provide a fairly close fit for the actual frequency in the small sample. Moreover, the simulated frequency that allows only for duration effects, f3, does a very bad job in reproducing the actual small sample frequency. It is very interesting that the sample frequency is marginally more highly correlated with f2, that allows only for year effects, than with f1, that allows for both year and duration effects. Second, given the sample selection criterion , not surprisingly the frequency in the small sample is higher and more variable than in the large sample, although it is very similar in terms of turning points. As a consequence, also f1 and f2 are higher and more variable that the actual frequency in the total sample. However, they do quite a good job in reproducing its turning points, capturing three out of four. In particular they succeed in capturing the beginning of the downturn in 1981, the end of the recession in 1983, and the beginning of a slow down in 1987. f3 is a failure in this respect as well. These results (in particular the fact that f3 does no better than f2 in the dynamic simulation) suggest that changes over time in the cross sectional distribution of the interval since the last spike seem not to be a crucial factor in explaining fluctuations in the observed aggregate frequency of investment spikes. Its time pattern seem to be dominated by the effects that common macro shocks have even in the presence of a flat hazard. These general conclusions are consistent with those reached, using a different approach, by Cooper, Haltiwanger and Power (1995)

6. Conclusions

The micro evidence we have discussed implies that the occurrence of zero investment episodes at the plant level is a very important phenomenon both for equipment and buildings, and particularly for the latter. Aggregating across different types of capital goods masks the intermittent nature of investment. This can be seen comparing the separate frequencies of zero investment for equipment and buildings and for the total of equipment and buildings.

However, the frequency of periods of zero investment depends upon the unit of observation. For equipment investment by production plants, for instance, it is very high for the secondary production units of multi-plant firms (41 percent) that account for a quarter of total equipment expenditure. It is lower for the main production units of multi-plant firms and for single plants (6 and 7 percent respectively) that account for three quarter of equipment expenditure. Similarly, the intermittent nature of investment is less pronounced when plants are aggregated up to the firm level (6 percent of zero investment observations).

At the plant level there is evidence that investment is lumpy with large expenditures concentrated in a relatively small number of periods. The three episodes with the highest investment rates account for a large percentage of total investment for both equipment and buildings, especially for the latter (53 and 80 percent respectively). The degree of lumpiness is much smaller at the firm level.

The overall evidence at the plant level is consistent with the existence of irreversibilities (partial or total), non-convexities and indivisibilities. There is, however, a piece of evidence that may raise some questions about the importance of non-convexities (such as fixed components of adjustment costs) or severe indivisibilities: more than a third of the observations for equipment consists of positive, but small (less than 0.10) investment rates, which account for a sizable share of total investment. The inconsistency would arise if adjustment costs are specified as a function of gross investment (as it is usually the case) and no distinction is made between the adjustment costs for replacement and expansion investment. If we assume (reasonably) that adjustment costs for replacement investment are very small, and fixed components become relevant only for expansion investment, one should not be surprised to observe small positive investment rates. Moreover, the observation of frequent small investments may be the result of time to build and of the distribution of delivery lags across calendar years. In any case all these features should be incorporated in the theoretical models of investment decisions.

The fact that investment is less intermittent and less lumpy at the firm level raises the question whether the use at the firm level of standard models, based on convex adjustment costs and no irreversibilities or fixed costs, is a reasonable approximation, or whether one throws away important information by disregarding the non smoothness of adjustment at the plant level. The answer ultimately lies in testing whether models that allow for irreversibilites and non-convexities provide a significantly better explanation of investment patterns compared to simpler models.

Another result that we believe is of great interest is that the frequency of zero investment and lumpiness varies substantially across plants and firms of different sizes. In particular, small plants or firms are characterized by a much higher incidence of zero investment expenditure. The investment pattern of small plants is also lumpier than for large plants. This can be explained by the existence of (stock) fixed costs that do not vary with a firm's size, and/or with the existence of indivisibilities. These differences are also consistent, in principle, with the existence of financial constraints, the severity of which is likely to be greater for smaller firms.

We have also investigated the shape of the hazard for the occurrence of investment spikes. The estimates obtained from a discrete time duration model that allows for firm specific fixed effects suggests that the probability of having an investment spike is the highest in the period immediately following another spike. This is consistent with investment expenditures spanning more than one calendar year or with the presence of convex components in adjustment costs. However, in almost all cases the hazard then increases monotonically and significantly after that. This provides powerful evidence for the presence and importance of (stock) fixed components characterizing the adjustment costs technology. The fact that the estimated hazard does not increase when one uses the Kaplan-Meier estimator or the logit model without fixed effects emphasizes that it is very important to allow for unobserved heterogeneity.

When we allow the parameters of the hazard model to differ between small and large plants, we obtain the results that the hazard is increasing for both, after the first period. Moreover, the introduction of cash flow as an additional explanatory variable leads to the conclusion that the differential importance of financial constraints for small and large firms, is not likely to be an explanation of the observed greater degree of lumpiness of investment for smaller units. However, further research will be necessary in order to fully assess the relative role of financial constraints, on the one hand, and of irreversibilities and non-convexities on the other, in explaining the lack of smoothness in the adjustment of capital.

Finally, the simulation results suggest that even in the presence of an upward-sloping hazard, changes over time in the cross-sectional distribution of the interval since the last high investment episode does not seem to help in explaining fluctuations in the aggregate frequency of investment spikes. Its time pattern seem to be dominated by the effects that common macro shocks have even in the presence of a flat hazard. This result is obtained in the context of a framework that does not model the size, as opposed to the occurrence, of an investment spike. Nevertheless, it is a reminder that caution is needed in drawing aggregate conclusions from the importance of irreversibilities and non-convexities at the micro level, which our investigation amply supports.

References

Abel, A. B. and J. C. Eberly, 1994, "A Unified Model of Investment Under Uncertainty", *American Economic Review*, 84, December, 1369-1384.

Abel, A. B. and J. C. Eberly, 1996, "Investment and q With Fixed Costs: An Empirical Analysis", mimeo, The Wharton School, University of Pennsylvania.

Allison, P. D., 1982, "Discrete Time Methods for the Analysis of Event Histories", in *Sociological Methodology*, S. Leinhardt editor, 61-98.

Arrow, K. J., 1968. "Optimal Capital Policy with Irreversible Investment", In *Value, Capital and Growth, Essays in Honor of Sir John Hicks*, edited by James N. Wolfe. Edinburgh University Press, Edinburgh.

Barnett, S. A. and P. Sakellaris, 1995, "Non-Linear Response of Firm Investment to Q: Testing a Model of Convex and Non-Convex Adjustment" University of Maryland, Department of Economics, Working Paper No. 95-11.

Bernanke, B. S., M. Gertler and S. Gilchrist, 1995, "The financial accelerator and the Flight to Quality", *Review of Economics and* Statistics.

Bertola, G. and R. J. Caballero, 1990. "Kinked Adjustment Costs and Aggregate Dynamics", In *National Bureau of Economic Research Macroeconomic Annual 1990*, edited by Olivier J. Blanchard and Stanley Fisher, Cambridge, MIT Press.

Bertola, G. and R. J. Caballero, 1994. "Irreversibility and Aggregate Investment", *Review of Economic Studies* 61, 223-246.

Caballero R. and E. M. R. A. Engel, 1994, "Explaining Investment Dynamics in U.S. Manufacturing: A Generalized (S, s) Approach", NBER Working Paper No. 4887.

Caballero R. J. and J. V. Leahy, 1996, "Fixed Costs: The Demise of Marginal q", NBER Working Paper No. 5508.

Caballero, R. J., E. M. R. A. Engel and J. C. Haltiwanger, 1995, "Plant Level Adjustment and Aggregate Investment Dynamics", University of Maryland, Department of Economics, Working Paper No. 95-09.

Card, D, and D. Sullivan, 1988, "Measuring the Effect of Subsidized Training Programs on Movements In and Out of Employment", *Econometrica*, Vol. 56, No. 3, May, 497-530.

Chamberlain, G, 1980, "Analysis of Covariance with Qualitative Data", *Review of Economic Studies*, 47, 225-238.

Chamberlain, G, 1983, "Panel Data", in *Handbook of Econometrics,* Griliches, Z., and M. Intrilligator, eds., Vol. II, North Holland, Amsterdam.

Cooper, R., J. Haltiwanger and L. Power, 1995, "Machine Replacement and the Business Cycle: Lumps and Bumps", mimeo.

Doms, M. and T. Dunne, 1994. "Capital Adjustment Patterns in Manufacturing Plants", mimeo, US Census Bureau.

Dixit, A. and R. S. Pindyck, 1994, *Investment Under Uncertainty*, Princeton University Press.

Eisner, R., and R. Strotz, 1963. "Determinants of Investment Behavior", In *Impact of Monetary Policy*. Englewood Cliffs, NJ: Prentice-Hall.

Fazzari, F. M., R. G. Hubbard, and B. C. Petersen, 1988, "Financing Constraints and Corporate Investment", *Brookings Papers on Economic* Activity, 1, 141-195.

Halvorsen, R., R. Jenssen and F. Foyn, 1991. "Dokumentasjon av Industristatistikkens Tidsseriedatabase", mimeo, Statistics Norway.

Lucas, Jr. R. E. and E. C. Prescott, 1971, "Investment Under Uncertainty", Econometrica, 39, 5, 659-681.

Nickell, S. J., 1974, "On the Role of Expectations in the Pure Theory of Investment" *Review of Economic Studies*, 41, 1, 1-19.

Nickell, S. J., 1978, *The Investment Decisions of Firms*, Cambridge University Press, NY.

Nilsen, Ø. A. and F. Schiantarelli: "Zeroes and Lumps: Investment Patterns of Norwegian Firms", Working Paper No. 337, Department of Economics, Boston College, July 1996.

Pindyck, R. S., 1982. "Adjustment Costs, Uncertainty, and the Behavior of the Firm", *American Economic Review* 72: 415-427.

Rothschild, M., 1971. "On the costs of adjustment", *The Quarterly Journal of Economics* 85, November: 605-622.

Serven, L., 1996, "Irreversibility, Uncertainty and Private Investment: Analytical Issues and Some Lessons from Africa", mimeo, The World Bank.

Willett, J.B. and J.D. Singer, 1995. "It's Deja-vu All Over Again: Using Multiple-Spell Discrete-Time Survival Analysis", mimeo, Harvard University.

DATA APPENDIX[22]

1. Criteria for Sample Selection

Firms with more than 50 percent of the equity owned by the central or local governments have been excluded from the sample, as well as observations reported as "copied from previous year". This expression means that the information was missing. In an attempt to eliminate plants whose capital stock has a negligible role in production, we deleted observations where the calculated replacement value of equipment and/or buildings was less than 200,000 NOK (1980).[23] We have also deleted plants for which production was zero (or negative) and there were no other plants within the firms with positive production. Finally, we only used plants for which four or more consecutive observations were available.

Looking at the number of plants, there were 5,280 different plants in the initial sample. Our final sample contains 2296 plants, 1866 of which are production units, for which there are no missing years and for which the number of consecutive observations is greater or equal to four. The total number of plant-year observations in the final sample is 22067 plant-year observations (18043 for production units only). The firm level panel contains 1252 firms for a total of 10730 observations. In the balanced plant level panel for production units we have 362 plants with a total of 5068 observations. The balanced firm level sample includes 144 firms with a total of 2016 firm-year observations.

2. Variable Definition and Construction [24]

Investment (I_t^j): Real (fixed price) investment at time t in type j of capital equals purchases minus sales (dismissals) of fixed capital. Our definition of investment in equipment includes machinery, office furniture, fittings and fixtures, and other transport equipment, excluding cars and trucks (using the codes in Manufacturing Statistics, [501]+[521]+[531]-[641]-[661]-[671]).[25] Data for buildings, in addition to those directly used for production, include also offices, and inventory storage buildings([561]-[601]). We will call the aggregate of these three categories buildings used for production. Vehicles include cars and trucks ([511]-[651]). Other fixed assets include housing for employees, building for spare-time activities, sites and property ([541]+[551]+[571]+[581]-[681]-[691]-[711]-[721]).

Replacement value of capital stock ($PI_t^jK_t^j$): The replacement value of capital is calculated separately for equipment and buildings using the perpetual inventory formula

$$PI_t^j K_t^j = PI_{t-1}^j K_{t-1}^j \cdot \left(1-\delta^j\right) \cdot \left(1+\Pi_t^j\right) + PI_t^j I_t^j$$

where superscript j indicates the different types of capital. PI_t^j denotes the price of investment goods (from the Norwegian national accounts) and Π_t^j the corresponding inflation rates between $t-1$ and t. The depreciation rates, δ^j, are also taken from the Norwegian National Accounts (0.06 and 0.02 for equipment and buildings, respectively). In the calculation of the replacement value of capital we use the fire insurance value of the

[22] See also Halvorsen et al (1991) for further details.

[23] Approximately 30,000 US$.

[24] See also Halvorsen et al. (1991).

[25] Other transport equipment includes railroads internal to the plant, funiculars, transport cranes, conveyer belts, etc.

capital stock. This variable is available only for the sum of machinery, fixtures and fittings, and other means of transport, one the one hand, and for buildings used for production, on the other. For each of these types of capital we use the first reported fire insurance value ([871] and [881] for equipment and buildings, respectively) greater than or equal to 200,000 NOK in 1980 prices as a bench-mark. From these initial values we calculate the replacement value backwards and forwards, using the investment figures.[26]

Investment rate (I_t^j/K_{t-1}^j)**:** The investment rate for equipment and buildings is calculated by normalizing real investment in year t by the real replacement value of the capital stock in the beginning of the year.

Cash flow (CF_t) The definition of cash flow is ([ ]$_{\text{Accounts}}$ indicates that the data are collected from Statistics of Accounts):

Profit before year-end adjustments [3100]$_{\text{Accounts}}$
\+ depreciation [2290]$_{\text{Accounts}}$ + [2820]$_{\text{Accounts}}$
\- tax on property and income [3330]$_{\text{Accounts}}$
\- profit on disposals of fixed assets [2710]$_{\text{Accounts}}$
\+ loss on disposals of fixed assets [2810]$_{\text{Accounts}}$
= Cash flow

The cash flow capital rate ($CF_t\ /K^F_{t-1}$): The cash flow capital ratio is calculated by normalizing the cash flow in year t by the aggregate of the capital stock, in the beginning of the year, of all plants within a firm.

[26] If the replacement value of capital became negative, it was set equal to zero. When calculating the capital stock forward it may happen that the replacement value becomes negative because of large sales of capital goods. When calculating it backwards the replacement value becomes negative if the net purchase of fixed capital is larger than the replacement value in year $t+1$.

Table 1. Distribution of investment rates (plant level, unbalanced panel)*

Investment rates	Equipment			Buildings			Equipment+Buildings		
	# obs.	percent	share	# obs.	percent	share	# obs.	percent	share
< 0	419	2 %	-0.019	350	2 %	-0.103	495	2 %	-0.031
= 0	7474	34 %	0.000	14960	68 %	0.000	7292	33 %	0.000
0 < < 0.05	6128	28 %	0.161	4316	19 %	0.181	8958	41 %	0.261
0.05 ≤ < 0.10	3133	14 %	0.215	843	4 %	0.154	2690	12 %	0.248
0.10 ≤ < 0.20	2689	12 %	0.264	672	3 %	0.197	1558	7 %	0.241
0.20 ≤ < 0.30	980	4 %	0.120	297	1 %	0.127	447	2 %	0.103
0.30 ≤	1244	6 %	0.258	629	3 %	0.443	627	3 %	0.179
Total	22067	100 %	1.000	22067	100 %	1.000	22067	100 %	1.000

* Percent refers to the frequency of observations in each interval. Share refers to the ratio of real investment in each interval to total real investment (net of assets sales)

Table 2. Frequency of zero investment episodes by plant type (plant level, unbalanced panel) *

	# obs.	Equipment		Buildings		Equipment+Buildings	
		freq.	share	freq.	share	freq.	share
All plants	22067	34 %		68 %		33 %	
Single plants	4490	7 %	0.199	55 %	0.222	6 %	0.204
Multi Plant	17577	41 %		71 %		40 %	
Main	6106	6 %	0.551	49 %	0.560	6 %	0.555
Secondary	7465	41 %	0.238	75 %	0.201	40 %	0.230
Auxiliary	4006	92 %	0.011	97 %	0.008	91 %	0.010
Production Plants (Single, Main, Secondary)	18061	21 %	0.988	61 %	0.992	20 %	0.989
Firms	10730	6 %		49 %		6 %	

* Share refers to the ratio of real investment for each type of plant to total real investment (net of assets sales)

Table 3. Frequency of zero investment by size (production plants and firms, unbalanced panel)

	Small			Large		
	# obs.	Equipment freq.	Buildings freq.	# obs.	Equipment freq.	Buildings freq.
All plants	11688	29 %	70 %	6355	7 %	45 %
Single plants	2608	9 %	62 %	1881	5 %	47 %
Multi Plant	9080	34 %	73 %	4474	7 %	44 %
Main	2961	10 %	59 %	3144	3 %	39 %
Secondary	6119	46 %	80 %	1330	18 %	54 %
Firms	4768	9 %	60 %	5962	4 %	40 %

Table 4. Lumpiness of investment: mean of ranked investment rates (balanced panel for production plants and balanced panel for firms)

Plant, Equipment	I/K (t)	I/K (t-1)	I/K (t-2)	I/K (t+1)	I/K (t+2)	share
1	-0.010	0.084	0.097	0.113	0.135	0.00
2	0.015	0.132	0.139	0.075	0.122	0.02
3	0.020	0.080	0.110	0.081	0.121	0.02
4	0.025	0.084	0.105	0.072	0.102	0.03
5	0.031	0.105	0.116	0.093	0.092	0.03
6	0.035	0.070	0.169	0.119	0.137	0.04
7	0.045	0.098	0.085	0.079	0.075	0.05
8	0.035	0.052	0.063	0.063	0.061	0.05
9	0.082	0.113	0.117	0.110	0.137	0.06
10	0.099	0.121	0.113	0.107	0.096	0.08
11	0.118	0.118	0.126	0.122	0.089	0.09
12	0.158	0.129	0.098	0.114	0.102	0.11
13	0.229	0.230	0.080	0.139	0.081	0.16
14	0.610	0.090	0.063	0.100	0.076	0.26
Overall	0.102	0.104	0.104	0.097	0.099	1.00

Number of observations: 5,068. Frequency of zero investment: 18 %

Plant, Buildings	I/K (t)	I/K (t-1)	I/K (t-2)	I/K (t+1)	I/K (t+2)	share
1	-0.103	0.080	0.046	0.052	0.065	-0.06
2	-0.013	0.063	0.097	0.027	0.123	-0.00
3	0.000	0.031	0.053	0.051	0.057	0.00
4	0.001	0.058	0.047	0.079	0.060	0.00
5	0.001	0.024	0.061	0.058	0.070	0.01
6	0.001	0.033	0.045	0.059	0.073	0.01
7	0.002	0.011	0.023	0.020	0.017	0.02
8	0.003	0.018	0.029	0.016	0.010	0.03
9	0.021	0.079	0.071	0.048	0.048	0.04
10	0.030	0.078	0.090	0.026	0.033	0.06
11	0.048	0.096	0.060	0.048	0.030	0.09
12	0.076	0.123	0.136	0.055	0.049	0.13
13	0.153	0.149	0.041	0.065	0.020	0.22
14	0.461	0.030	0.008	0.052	0.026	0.05
Overall	0.046	0.048	0.049	0.044	0.041	1.00

Number of observations: 5,068. Frequency of zero investment: 55 %

Firm, Equipment	I/K (t)	I/K (t-1)	I/K (t-2)	I/K (t+1)	I/K (t+2)	share
1	0.002	0.080	0.111	0.091	0.118	0.02
2	0.023	0.104	0.116	0.091	0.083	0.03
3	0.030	0.123	0.125	0.077	0.100	0.03
4	0.041	0.108	0.115	0.074	0.133	0.03
5	0.047	0.101	0.124	0.079	0.097	0.04
6	0.052	0.076	0.099	0.111	0.101	0.05
7	0.066	0.093	0.104	0.092	0.098	0.05
8	0.076	0.076	0.098	0.133	0.124	0.06
9	0.089	0.094	0.118	0.105	0.106	0.07
10	0.105	0.126	0.105	0.108	0.127	0.08
11	0.129	0.126	0.096	0.102	0.078	0.09
12	0.163	0.115	0.096	0.137	0.100	0.11
13	0.213	0.114	0.093	0.117	0.087	0.14
14	0.408	0.096	0.064	0.091	0.076	0.21
Overall	0.103	0.102	0.104	0.100	0.102	1.01

Number of observations: 2,016. Frequency of zero investment: 3 %

Firm, Buildings	I/K (t)	I/K (t-1)	I/K (t-2)	I/K (t+1)	I/K (t+2)	share
1	-0.088	0.071	0.041	0.079	0.080	-0.05
2	-0.016	0.072	0.091	0.030	0.166	-0.00
3	0.001	0.025	0.053	0.045	0.037	0.00
4	0.002	0.087	0.031	0.107	0.053	0.01
5	0.003	0.021	0.085	0.064	0.083	0.01
6	0.005	0.025	0.037	0.023	0.048	0.02
7	0.006	0.014	0.027	0.029	0.034	0.03
8	0.011	0.070	0.104	0.070	0.018	0.04
9	0.026	0.067	0.075	0.036	0.046	0.05
10	0.037	0.091	0.083	0.040	0.032	0.07
11	0.054	0.106	0.043	0.060	0.031	0.10
12	0.089	0.104	0.135	0.056	0.042	0.13
13	0.154	0.100	0.039	0.061	0.046	0.19
14	0.460	0.032	0.022	0.062	0.018	0.39
Overall	0.054	0.057	0.059	0.053	0.048	0.99

Number of observations: 2,016. Frequency of zero investment: 36 %

Table 5. Lumpiness of investment: mean of ranked investment rates by plant size (production plants, balanced panel)

Small, Equipment	I/K (t)	I/K (t-1)	I/K (t-2)	I/K (t+1)	I/K (t+2)	share
1	-0.020	0.117	0.108	0.155	0.150	-0.00
2	0.011	0.223	0.191	0.087	0.199	0.00
3	0.015	0.088	0.116	0.105	0.143	0.01
4	0.018	0.067	0.115	0.076	0.112	0.02
5	0.024	0.122	0.135	0.116	0.086	0.03
6	0.025	0.069	0.210	0.147	0.170	0.03
7	0.040	0.106	0.077	0.076	0.074	0.04
8	0.023	0.032	0.055	0.053	0.047	0.04
9	0.083	0.149	0.123	0.137	0.189	0.05
10	0.101	0.157	0.143	0.118	0.108	0.07
11	0.123	0.140	0.144	0.149	0.106	0.08
12	0.171	0.136	0.124	0.100	0.125	0.11
13	0.264	0.327	0.072	0.166	0.094	0.20
14	0.853	0.090	0.072	0.104	0.075	0.32
Overall	0.113	0.117	0.116	0.107	0.111	1.00

Number of observations: 2,562. Frequency of zero investment: 31 %

Small, Buildings	I/K (t)	I/K (t-1)	I/K (t-2)	I/K (t+1)	I/K (t+2)	share
1	-0.077	0.111	0.080	0.057	0.024	-0.02
2	-0.002	0.082	0.232	0.041	0.083	-0.00
3	0.001	0.034	0.054	0.079	0.070	0.00
4	0.000	0.097	0.058	0.123	0.073	0.00
5	0.000	0.034	0.069	0.074	0.094	0.00
6	0.000	0.037	0.048	0.079	0.099	0.00
7	0.001	0.011	0.027	0.021	0.015	0.01
8	0.001	0.009	0.015	0.005	0.009	0.01
9	0.021	0.139	0.076	0.061	0.073	0.02
10	0.030	0.073	0.103	0.034	0.031	0.04
11	0.047	0.099	0.054	0.045	0.014	0.06
12	0.069	0.162	0.254	0.055	0.045	0.09
13	0.165	0.225	0.038	0.073	0.008	0.21
14	0.605	0.025	0.006	0.049	0.030	0.57
Overall	0.050	0.053	0.053	0.048	0.043	0.99

Number of observations: 2,562. Frequency of zero investment: 67 %

Large, Equipment	I/K (t)	I/K (t-1)	I/K (t-2)	I/K (t+1)	I/K (t+2)	share
1	-0.004	0.065	0.090	0.091	0.128	0.00
2	0.018	0.065	0.102	0.067	0.071	0.02
3	0.025	0.074	0.104	0.060	0.101	0.02
4	0.034	0.102	0.093	0.067	0.091	0.03
5	0.040	0.085	0.093	0.065	0.099	0.04
6	0.047	0.072	0.111	0.082	0.090	0.04
7	0.051	0.089	0.092	0.082	0.076	0.05
8	0.059	0.091	0.079	0.085	0.088	0.06
9	0.081	0.082	0.112	0.088	0.093	0.06
10	0.096	0.090	0.086	0.097	0.085	0.08
11	0.114	0.098	0.108	0.097	0.074	0.09
12	0.146	0.123	0.075	0.127	0.080	0.11
13	0.198	0.142	0.088	0.114	0.068	0.16
14	0.385	0.090	0.054	0.095	0.076	0.25
Overall	0.092	0.091	0.092	0.087	0.087	1.01

Number of observations: 2,506. Frequency of zero investment: 6 %

Large, Buildings	I/K (t)	I/K (t-1)	I/K (t-2)	I/K (t+1)	I/K (t+2)	share
1	-0.115	0.066	0.032	0.050	0.081	-0.07
2	-0.017	0.057	0.048	0.022	0.137	-0.00
3	0.000	0.030	0.053	0.042	0.053	0.00
4	0.001	0.024	0.037	0.042	0.049	0.00
5	0.002	0.013	0.052	0.039	0.044	0.01
6	0.002	0.028	0.041	0.035	0.042	0.01
7	0.003	0.011	0.017	0.019	0.020	0.02
8	0.006	0.036	0.059	0.040	0.013	0.03
9	0.021	0.047	0.069	0.040	0.032	0.05
10	0.031	0.081	0.082	0.022	0.035	0.06
11	0.049	0.094	0.064	0.050	0.041	0.09
12	0.082	0.092	0.035	0.055	0.052	0.14
13	0.143	0.089	0.044	0.058	0.030	0.23
14	0.335	0.034	0.010	0.055	0.022	0.42
Overall	0.041	0.043	0.044	0.040	0.039	0.99

Number of observations: 2,506. Frequency of zero investment: 44 %

Table 6b. Hazard Models results for buildings

	High spikes						Low spikes						Relative spikes					
	Kaplan-Meier		Logit without fixed effects		Logit with fixed effects		Kaplan-Meier		Logit without fixed effects		Logit with fixed effects		Kaplan-Meier		Logit without fixed effects		Logit with fixed effects	
	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio
duration 0	0.189	20.826					0.441	60.410					0.888	280.177				
duration 1	0.051	5.122	-1.409	-7.154	-0.713	-2.894	0.192	19.288	-1.174	-16.465	-0.6862	-8.363	0.272	27.606	-2.831	-38.378	-0.584	-6.468
duration 2	0.045	4.170	-1.495	-6.730	0.077	0.262	0.168	14.214	-1.274	-14.939	-0.3307	-3.306	0.235	18.871	-2.992	-31.728	-0.248	-2.250
duration 3	0.033	2.735	-1.779	-6.431	0.530	1.362	0.161	11.168	-1.304	-12.739	0.0635	0.519	0.235	14.500	-2.949	-24.580	-0.016	-0.118
duration 4	0.065	4.736	-1.111	-4.624	2.105	5.029	0.185	10.606	-1.077	-9.290	0.7239	5.01	0.281	13.167	-2.677	-18.130	0.483	2.851
duration 5	0.056	3.451	-1.247	-4.273	2.854	5.497	0.128	5.794	-1.534	-9.349	0.6239	3.157	0.189	6.567	-3.233	-14.413	0.153	0.613
duration 6	0.075	4.134	-0.942	-3.258	4.191	7.180	0.114	4.289	-1.665	-8.128	0.9126	3.718	0.348	9.703	-2.292	-9.912	1.368	4.991
duration 7	0.058	2.724	-1.147	-3.103	5.156	7.398	0.140	4.241	-1.413	-6.056	1.6556	5.713	0.308	5.588	-2.436	-6.755	1.697	3.981
duration 8	0.043	1.755	-1.317	-2.736	6.104	7.237	0.087	2.084	-1.950	-5.470	1.6519	4.005	0.333	4.749	-2.134	-4.795	2.407	4.551
duration 9, higher	0.028	1.421	-1.305	-2.669	7.735	8.036	0.080	2.219	-1.799	-5.555	2.6683	6.226	0.368	4.671	-1.979	-3.951	3.460	5.126
Small			-0.090	-0.683					-0.318	-5.828					0.721	13.521		
Main plant			0.114	0.767					0.147	2.299					-0.053	-0.841		
Second plant			-0.263	-1.406					-0.364	-4.824					0.721	10.395		
const.			-1.052	-3.346					-0.148	-1.074					1.055	8.503		
Number of observations:	3948		3948		1731		8922		8922		6987		14784		14784		5577	
R^2,Pseudo R^2	0.122		0.099				0.338		0.104				0.844		0.324			
$\chi^2_{duration}(9)$	$F_{10,3938}=54.88$		111.5		121.0		$F_{10,8912}=453.99$		580.1		190.6		$F_{10,14774}=8021.38$		2798.9		123.5	
$\chi^2_{year}(12)$			36.1		116.9				80.3		280.5				30.3		142.4	
$\chi^2_{sector}(12)$			7.7						58.9						204.0			

duration denote years since last spike
small = 1 if employment < 100
Main plant = 1 if Main plant in Multi-plant firm
Second plant = 1 if Secondary Production plant in Multi-plant firms
1979-1991 denote year dummies

Table 6a. Hazard Models results for equipment

	High spikes						Low spikes						Relative spikes					
	Kaplan-Meier		Logit without fixed effects		Logit with fixed effects		Kaplan-Meier		Logit without fixed effects		Logit with fixed effects		Kaplan-Meier		Logit without fixed effects		Logit with fixed effects	
	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio
duration 0	0.292	34.389					0.605	101.692					0.645	109.444				
duration 1	0.139	13.643	-0.899	-9.294	-0.361	-3.156	0.376	37.596	-0.867	-16.637	-0.243	-4.014	0.152	14.784	-2.075	-25.851	-0.418	-4.341
duration 2	0.131	11.086	-0.900	-8.123	0.151	1.113	0.305	22.191	-1.160	-16.513	-0.035	-0.419	0.141	11.786	-2.110	-22.759	-0.010	-0.086
duration 3	0.116	8.146	-1.065	-7.929	0.447	2.649	0.270	14.690	-1.367	-14.580	0.157	1.388	0.124	8.496	-2.302	-19.802	0.052	0.370
duration 4	0.117	6.837	-1.069	-6.829	0.905	4.462	0.270	11.015	-1.361	-11.097	0.529	3.511	0.158	8.922	-1.982	-15.313	0.648	4.083
duration 5	0.115	5.434	-1.195	-6.318	1.135	4.531	0.236	7.101	-1.548	-9.123	0.698	3.362	0.166	7.367	-1.997	-12.376	0.972	4.969
duration 6	0.143	5.629	-0.932	-4.512	2.027	7.012	0.240	5.608	-1.620	-7.513	0.975	3.630	0.170	6.201	-1.914	-10.018	1.448	6.121
duration 7	0.116	3.750	-1.138	-4.220	2.526	6.720	0.203	3.645	-1.793	-6.051	1.189	3.151	0.161	4.672	-1.907	-8.068	1.879	6.221
duration 8	0.137	3.708	-0.766	-2.565	3.493	8.091	0.186	2.550	-1.729	-4.337	1.906	3.689	0.175	4.215	-1.670	-6.100	2.570	7.256
duration 9, higher	0.063	2.006	-1.516	-4.243	3.961	7.491	0.205	2.836	-1.489	-3.918	3.517	5.525	0.202	4.657	-1.313	-4.763	3.950	9.401
Small			-0.021	0.076					-0.183	-4.151					0.376	6.008		
Main plant			0.076	0.087					0.125	2.427					0.151	1.914		
Second plant			-0.319	0.101					-0.489	-8.664					1.368	18.603		
const.			-1.095	0.201					0.533	4.967					-0.957	-7.162		
Number of observations:	6375		6375		4200		11523		11523		9950		10342		10342		5951	
R^2,Pseudo R^2	0.211		0.068				0.524		0.092				0.550		0.280			
$\chi^2_{duration}(9)$	$F_{10,6365}=169.78$		189.1		144.5		$F_{10,11513}=1269.40$		730.4		85.1		$F_{10,10332}=1264.12$		1498.4		178.1	
$\chi^2_{year}(12)$			98.8		201.7				197.9		297.1				92.0		243.62	
$\chi^2_{sector}(12)$			27.2						64.5						124.6			

duration denote years since last spike
small = 1 if employment < 100
Main plant = 1 if Main plant in Multi-plant firm
Second plant = 1 if Secondary Production plant in Multi-plant firms
1979-1991 denote year dummies

Table 7. Hazard Models results for equipment, small and large units, high spikes
Unconditional fixed effects logit model

	coeff.	"t"-ratio	coeff.	"t"-ratio	coeff.	"t"-ratio
duration 1	-0.553	-3.156	-0.565	-2.770	-0.590	-2.844
duration 2	-0.106	1.113	-0.108	-0.452	-0.136	-0.565
duration 3	-0.096	2.649	-0.093	-0.317	-0.142	-0.479
duration 4	0.200	4.462	0.195	0.559	0.100	0.281
duration 5	0.454	4.531	0.457	1.088	0.301	0.706
duration 6	1.811	7.012	1.842	4.116	1.606	3.576
duration 7	1.791	6.720	1.720	2.572	1.386	2.023
duration 8	2.156	8.091	2.128	2.698	1.914	2.429
duration 9, higher	2.281	7.491	2.214	2.663	1.831	2.168
sml*duration 1	0.296	1.199	0.314	1.270	0.354	1.407
sml*duration 2	0.428	1.471	0.441	1.516	0.433	1.471
sml*duration 3	0.861	2.395	0.862	2.391	0.863	2.373
sml*duration 4	1.134	2.624	1.128	2.607	1.150	2.619
sml*duration 5	1.077	2.046	1.062	2.018	1.089	2.045
sml*duration 6	0.337	0.573	0.282	0.478	0.365	0.616
sml*duration 7	1.218	1.501	1.265	1.555	1.448	1.750
sml*duration 8	2.117	2.221	2.123	2.228	2.188	2.296
sml*duration 9, higher	2.943	2.707	2.996	2.753	3.194	2.904
(CF/K^F_t)			0.607	1.458	0.227	0.547
sml*(CF/K^F_t)			0.006	0.011	0.252	0.476
(Y/K_t)					0.249	3.062
(Y/K_{t-1})					-0.020	-0.291
sml*(Y/K_t)					-0.040	-0.384
sml*(Y/K_{t-1})					0.055	0.629
Number of observations:	4200		4200		4200	
$\chi^2_{\text{duration, small}}(9)$	16.8		17.2		17.8	
$\chi^2_{\text{year, small}}(12)$	23.9		24.0		23.6	
$\chi^2_{\text{duration year, small}}(21)$	32.3		32.9		33.1	

duration	denote years since last spike
small = 1	if employment < 100
1979-1991	denote year dummies

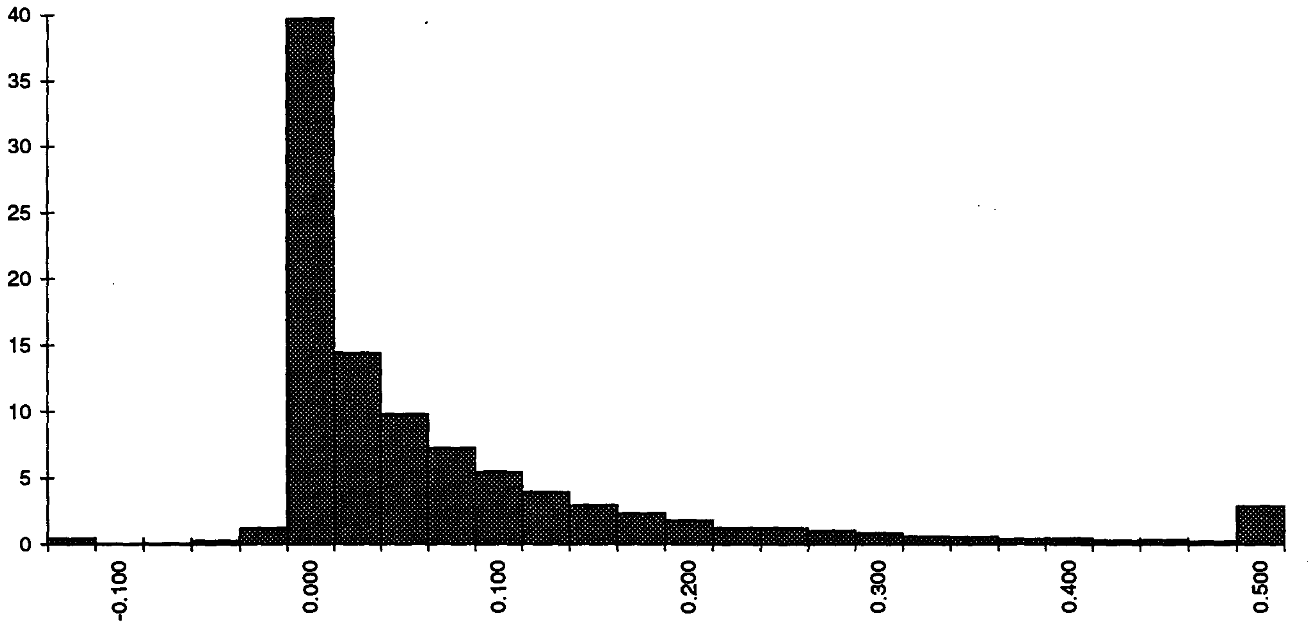

Figure 1a: Distribution of investment rates for Equipment (plant level, unbalanced panel)

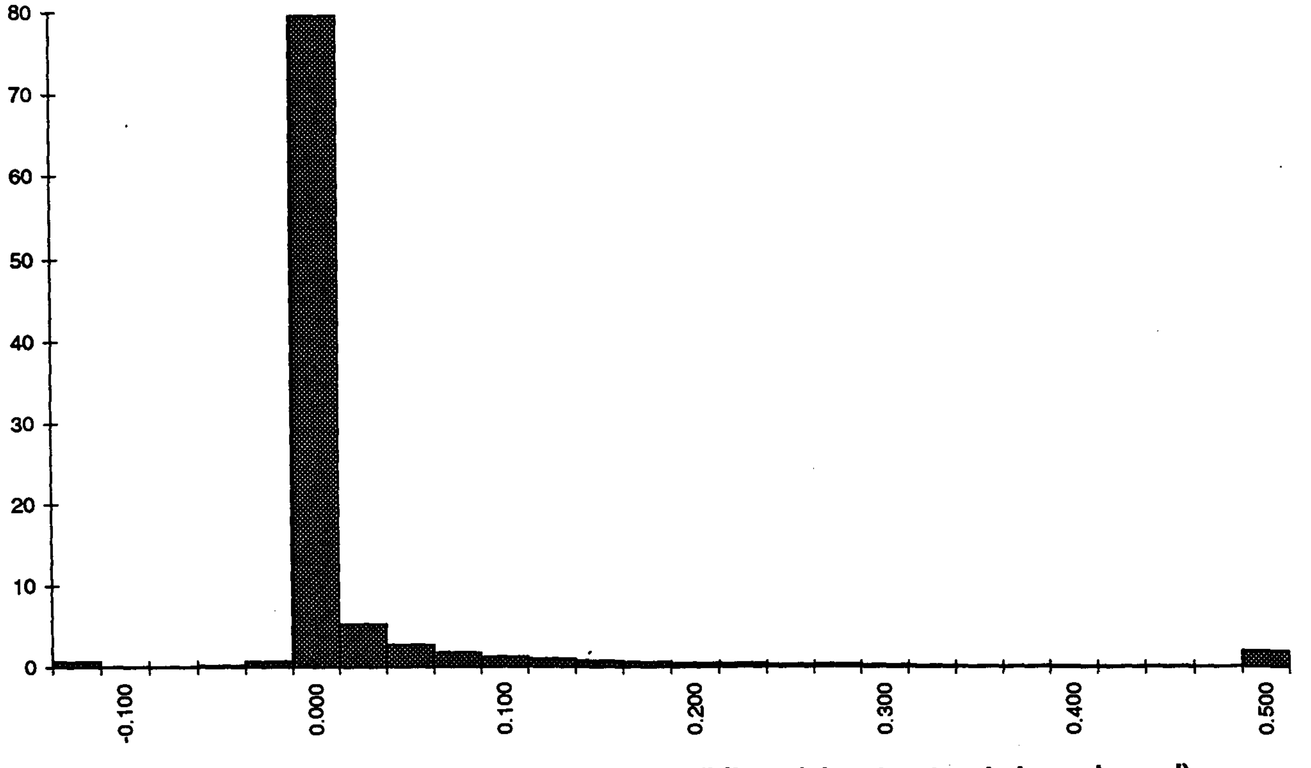

Figure 1b: Distribution of investment rates for Buildings (plant level, unbalanced panel)

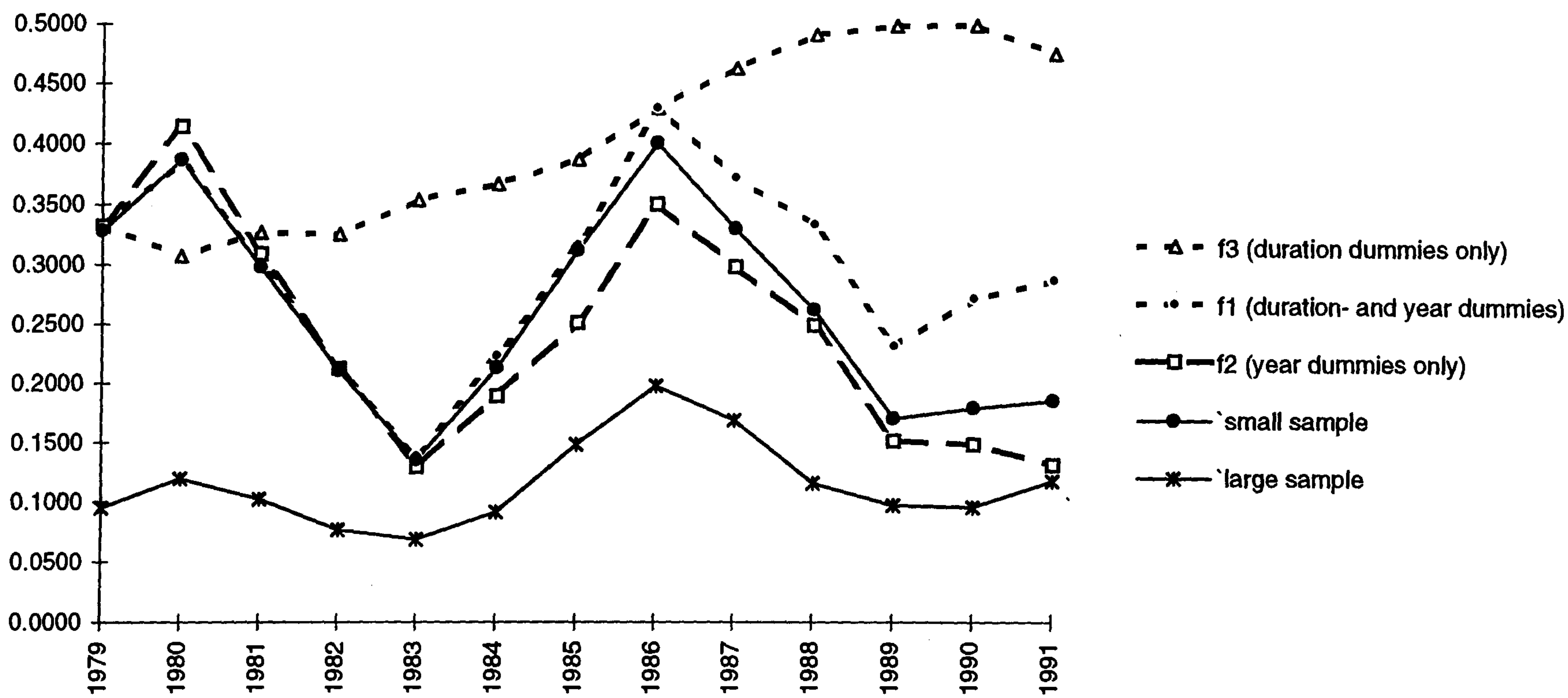

Figure 2: Simulated High Spike Frequencies for Equipment (unconditional fixed effects logit model, 50 drawings)

Chapter 5

Is there any credit rationing at all?
Threshold estimation in an investment model

Is there any credit rationing at all?
Threshold estimation in an investment model

by

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February 7, 1998

Abstract

Most previous studies directed at analyzing effects of credit constraints on firms' investment behavior have been based on the assumption that constrained firms are identifiable. The identification criterion is often a single variable, which is correlated with the probability of being credit constrained. However, the cutoff value is based on the imprecise expression of large or small, high or low values of the sample-split variable. Choosing the correct cutoff value may be critical for the results of an analysis. In this paper, a threshold estimation method is employed to resolve the cutoff value and test its significance in an investment model. The model is tested on a panel data set of Norwegian manufacturing firms. The findings where firms' size is used for discriminating are consistent with the theory in which capital market imperfections lead to financial constraints on firms' investments. However, these results should be interpreted with some care since size may not capture financial fragility only, but also technological and product market differences.

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* This paper has benefited from constructive comments offered by colleagues in the department. Special thanks go to Jan Erik Askildsen and Alf Erling Risa for insightful discussions and suggestions. I would also like to thank Fredrik Carlsen, Eilev S. Jansen, and Erling Steigum Jr. for insightful comments. Christian Wallace has proofread this manuscript. Remaining errors, omissions and conclusions are the author's own.

1. Introduction

In numerous theoretical and empirical studies, focus has been placed on finding determinants of investment decisions of firms, especially the impact of financial constraints.[1] From this research, we have learned that external and internal funds are not perfect substitutes. This has its background in information asymmetries and incentive problems, which make external funding more costly relative to internal resources. When the cost of capital differs for various source funds, a firm's "cash flow" or "net worth" may be an important determinant on the investment decisions and the investment pattern. The availability of internal funds allows firms to undertake desirable investment projects without resorting to high-cost external finance. To test for the existence of credit constraints and capital market imperfections, one approach is to split the data set by criteria assumed to be able to identify firms most likely to face information and incentive problems. The results that internal funds tend to be more important for the firms assumed to be credit constrained is taken as an indicator of imperfect capital markets.

Empirical analyses of the existence and implications of credit constraints on firms' operating behavior is based on the assumption that researchers are able to identify firms in which financial constraints are more important. The *a priori* classification of firms is based on observables correlated with the likelihood that they will suffer from some kind of capital or credit constraints. Several sample split variables have been explored; dividend, size, maturity, debt ratio, ownership, association with banks or industry groups, and bond rating. To discriminate between constrained and unconstrained firms, the researcher has to determine the threshold values for the sample split variables. The threshold values are often chosen more or less *ad hoc*. If size, maturity, or debt is used to classify firms, we may ask 'how big is big', 'how old is old', or 'how much is much'?

In this paper, we use a threshold regression technique to analyze whether the impact of financial constraints on fixed capital investment differ between different classes of firms. The threshold regression technique specifies that individual observations can be categorized based on an observed split-variable. This sample split-variable should be able to identify firms (or

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[1] See Gertler (1988) and Stiglitz (1992) for an overview of the financial asymmetric information literature. Hubbard (1997) and Schiantarelli (1996) discuss the findings and models used in empirical analyses of investment and firms' operating behavior when capital markets are imperfect.

firm-year observations) which are more likely to be financially constrained. An advantage of a threshold technique relative to more *ad hoc* sample-splits and estimation methods is that the technique lets the data sample decide where to set the threshold. Thus, the data itself decides which firms, or firm-year observations are classified as constrained and unconstrained. In addition to finding the relevant thresholds, we also want to investigate whether the threshold values and the share of constrained firms vary over business cycles. As indicated by Gertler and Hubbard (1988), capital market imperfections may have more impact in recessions than booms. In this paper, we use size as a split criterion.

The investment model used is based on the accelerator model with an additional term which is a proxy for the availability of internal funds, and/or firms' net worth. In our model, we allow for the endogeneity of regressors. This is achieved using an instrumental variable estimation method. The analysis is based on an unbalanced data set of Norwegian manufacturing industry firms for the period 1978-1990. During this period, a deregulation of the financial sector took place. This deregulation may influence the threshold and the share of constrained firms, a phenomenon that is also investigated in this paper.

Only a limited number of researchers (of which I am aware) have used the threshold technique to analyze the effect of financial variables on investment in panel data models. Barnett and Sakellaris (1995) tested the investment model by Abel and Eberly (1994). Their results indicate that investment is a non-linearly related to q, and depends on different regimes defined by unknown levels of q. However, Barnett and Sakellaris do not discriminate between assumed financially constrained and unconstrained firms. Hansen (1997) has illustrated the threshold technique on a q investment model where cash flow is included. His sample is split into classes based on their degree of financial constraints measured by firms' debt ratios. Hansen finds that investments of more indebted firms are more sensitive to internal funding relative to more financially healthy firms. This pattern is consistent with the theory of imperfect capital markets. However, Hansen's illustration is based on a balanced panel of firms with series of length 15 years. These firms are all quoted, larger firms. Consequently, his sample is biased towards larger, healthier, and more successful firms. Contrary to Hansen, we use an unbalanced sample of firms with 4 or more consecutive observations. Only a small share of the firms in our sample is quoted. Thus, our sample includes firms that more likely face credit constraints.

The organization of the paper is as follows. Section 2 describes the model we estimate. A brief data description is given in Section 3. Econometric issues and testing methodology are discussed in Section 4. In Section 5 we present our empirical results, while some concluding remarks are made in Section 6.

2. The Investment Model

The accelerator model of investment with an added financial variable is used to find the thresholds. There are several reasons why such a simple *ad hoc* investment model is chosen. The two most relevant alternative model formulations are the Euler equation model and the q model. The q model cannot be applied to our sample since we do not have access to the stock market values of the firms. A disadvantage of studies based on a q model is that the samples only cover relatively large firms. These firms have undergone careful scrutiny regarding their financial health and their future growth opportunities. Thus, a q model is not appropriate when analyzing the investment behavior of smaller firms.[2] An Euler equation model requires that a functional form of the capital adjustment process have to be considered. Both the q model and the Euler equation model, are often based on the assumption that there are convex costs attached to adjusting the capital. With this adjustment costs technology firms will try to smooth investment over time. However, many studies have rejected this model formulation, especially empirical studies based on firm and plant level data. Often it seems to be evident that the investments are irreversible and non-convex.[3] Dums and Dunne (1994) provide evidence that a large proportion of investments at plant level is concentrated in a few episodes. Similar findings have been revealed for Norwegian firms and plants by Nilsen and Schiantarelli (1997). In addition, a large percentage of total investment is concentrated over a relatively small number of periods. To avoid using a restrictive functional form of the adjustment costs function,[4] we use the accelerator model.

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[2] Only 60-65 manufacturing firms each year were quoted on the Oslo Stock Exchange during the period 1980-1990. This is approximately five percent of the firms in the dataset used in this paper.

[3] Bertolla and Cabellero (1990) argued that adjustment costs may well be non-convex. See Dixit and Pindyck (1994), and Hubbard (1994) for discussions and reviews of studies on irreversible investments where future demand and prices are uncertain.

[4] See Hamermesh and Pfann (1996) for a discussion of different adjustment cost structures.

Starting from a constant returns to scale CES production function, with output Y, and two inputs, capital K and variable factors, L, we have:

$$K = \left(mA^{-\phi}\right)^{\sigma} Y u^{-\sigma} \tag{1}$$

Here m denotes the relative weights in the CES function between the two inputs factors, σ denotes the elasticity of substitution, and u denotes the user cost of capital. It can be shown that $\sigma = 1/(1+\phi)$. Setting the elasticity of substitution, σ, equal to zero, gives the accelerator model of investment, where the desired capital stock is simply proportional to revenue. Furthermore, investment is a linear function of increase in output. Another way to obtain an investment model is to log-transform the model in (1), and use the approximations $\Delta \ln(K_{it}) \approx \frac{I_{it}}{K_{it-1}}$, and $\Delta \ln(Y_{it}) \approx \frac{Y_{it} - Y_{it-1}}{Y_{it-1}}$. Furthermore, following the standard approach in the empirical investment research literature, an additional regressor which proxies the availability of internal funds and /or firms' net worth is incorporated in the investment model. Here we use cash flow, CF, as a proxy for the availability of internal financial sources. To eliminate the effects of scale, cash flow is normalized by the capital stock at the end of last period, $K_{i,t-1}$. Then the general form of the reduced-form investment equation is:

$$\frac{I_{i,t}}{K_{i,t-1}} = \beta^{Y} \frac{\Delta Y_{i,t}}{Y_{i,t-1}} + \beta^{CF} \frac{CF_{i,t}}{K_{i,t-1}} + f_i + \gamma_t + e_{i,t} \tag{2}$$

where subscript i denotes firm and subscript t denotes year. We have included a fixed effect for each firm, f_i, which refers to all those firm specific factors (e.g. efficiency) which are constant over time. In addition, a time dummy, γ_t, is included to pick up the effects of macro shocks affecting all firms, such as the real interest rate and tax effects.[5] Under the null hypothesis of efficient capital markets and no cost differential between internal and external funds, the cash flow coefficient, β^{CF}, should be zero.

[5] The inclusion of the fixed firm effects and the time-specific effects may also be seen as a way of controlling for variations in the user costs of capital when the assumption of no substitutability is relaxed. However, an implicit assumption is then that the user costs of capital is the same for all firms each period.

To account for delivery lags and slow adjustment of the actual capital stock to the desired capital stock, we choose to estimate a more flexible dynamic model. In this dynamic specification, both the dependent and the exogenous variables in period *t* and period *t-1* are included.

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha \frac{I_{i,t-1}}{K_{i,t-2}} + \beta_0^Y \frac{\Delta Y_{i,t}}{Y_{i,t-1}} + \beta_1^Y \frac{\Delta Y_{i,t-1}}{Y_{i,t-2}} + \beta_0^{CF} \frac{CF_{i,t}}{K_{i,t-1}} + \beta_1^{CF} \frac{CF_{i,t-1}}{K_{i,t-2}} + f_i + \gamma_t + e_{i,t} \qquad (3)$$

Some notes about this formulation can be given. Financing constraints are likely to bind at the time of the investment expenditure. However, lenders also both receive information and operate with some delay, which may justify the lagged financial variable. Additionally, the lagged effects of the financial variables may also reflect firms' and lenders' expectations about future financial conditions or accounts for lags between investment decisions and expenditure.[6] We focus on the reduced form model for several reasons. First, a structural model that embeds the theories of imperfect capital markets is difficult to construct. Second, even with such a structural model, the resulting inference would probably be fragile with respect to the assumptions made when specifying the model. Finally, we are not interested in the "goodness of fit" of the investment model to the underlying theory. Our primary concern is whether the impact of financial constraints on fixed capital investments differs between different classes of firms using the threshold estimation technique.

3. The Data

The empirical analysis is carried out at firm-level. Some variables are initially given at plant level. These variables are aggregated up to firm level. There are two arguments for making the analysis at the firm level. First, we assume that it is at the firm level financial decisions are made, not at the plant level. In addition, it is at the firm level that the formal accounting information to be used by external sources is reported.[7]

[6] A further argument for including the lagged dependent variable and lagged exogenous variables, is persistence in the error term of a static model, for instance if the error term e_{it} in equation (2) was an AR(1) process. If so, the parameters of the dynamic model would have to satisfy a common factor restriction. For ease of expositions, we assume that the error term in (3) is white noise.

[7] The findings of Lamont (1993) support the assertion that it is the firm level that matters for internal finance.

3.1 Data Sources

We use unbalanced data set of Norwegian firms in the manufacturing sector for the period 1978-1990. The data set is extracted from a larger data set collected by Statistics Norway. Income statement and balance sheet information are provided from Statistics of Accounts for all firms with more than 50 employees.[8] For all firms included in Statistics Norway's Statistics of Accounts, plant level information about production, production costs, investment and capital stock is available from the Manufacturing Statistics.[9] All data are annual.

3.2 Variables[10]

Throughout the paper, investment is defined as purchases minus sales of equipment and buildings. Expenditures related to repairs of existing capital goods are not included in the definition of purchases. The replacement value for capital stock is obtained using the perpetual inventory method, starting from a benchmark calculated from the fire insurance value available from the Manufacturing Statistics. Both investments and the replacement value of capital are measured at the plant level. The investment ratio used in this paper is calculated as the sum of all plant level investments within a firm, normalized with corresponding sum of the replacement value of the capital stock at the beginning of the year.

The output ratio is calculated taking plant level gross production minus taxes plus subsidies and aggregating it up to firm level. This sum is first differenced and normalized with the firm-level replacement values of the capital stock (aggregated from plant-level data). The cash flow is calculated from firm level data, and the cash flow ratio is calculated by normalizing cash flow with the firm-level replacement value of the capital stock. The debt ratio is constructed by taking the book values of short-term and long-term liabilities, and normalizing this value with the book value of total assets.

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[8] There may be some firms with less than 50 employees in the sample. These firms have probably been larger prior to 1978, and information from these firms is still collected.

[9] See Halvorsen et al. (1991) for further details.

[10] See the Data Appendix for details on variable definitions and construction.

3.3 Data Set Construction

Firms in which the central or local governments own more than 50 percent of the equity have been excluded from the sample, as well as observations that are reported as "copied from previous year". This actually means missing data. The remaining data set was trimmed to remove outlayers. Observations with ratios (investment ratio, output ratio, cash flow ratio and debt ratio) outside of five times the interquartile range above or below the sector specific median were excluded. Finally, we included only series with at least four consecutive observations. Since the gross output variable is differenced, we end up with usable series of at least three observations. The models are estimated in first-differences to remove the fixed firm effects. In addition, we use lagged variables as instruments. Therefore, three consecutive observations in each firm series are the minimum number of observations necessary for the estimation.

The final unbalanced panel contains 1231 firms with a total of 8034 observations. The numbers of observations organized according to the length of the period, and by the number of observations per year are given in Table A1 and A2.

4. Econometric Methodology

A threshold model assumes the form

$$y_{it} = \begin{cases} f_i + \beta_1 ' X_{it} + e_{it} & q_{it} \leq \mathrm{T} \\ f_i + \beta_2 ' X_{it} + e_{it} & q_{it} > \mathrm{T} \end{cases} \tag{4}$$

where q_{it} is the threshold variable (a scalar), and the regressor X_{it} is a vector. This structural equation can be written as

$$y_{it} = f_i + \beta_1 ' X_{it} \cdot I(q_{it} \leq \mathrm{T}) + \beta_2 ' X_{it} \cdot I(q_{it} > \mathrm{T}) + e_{it} \tag{5}$$

where *I(.)* is and indicator function taking the value one if its argument is true, and zero otherwise. Thus, the observations are divided into two groups depending on whether the threshold variable q_{it} is smaller or larger than the threshold T. The two groups are distinguished by differing regression coefficients, β_1 and β_2. In our case, these two groups represent financially constrained and unconstrained firms (or firm-year observations). Given that error term e_{it} is orthogonal to the regressors X_{it}, we could use a least-squares method to find a least squared estimator of T, defined as

$$\hat{\mathrm{T}} = \underset{\mathrm{T}}{\operatorname{argmin}} \hat{S}(\mathrm{T}) \tag{6}$$

where $\hat{S}(\mathrm{T}) = \hat{e}(\mathrm{T})' \hat{e}(\mathrm{T})$, i.e. the sum of squared errors, and $\hat{e}(\mathrm{T})$ is the vector of residuals. The advantage of the described threshold technique relative to more standard sample-splits and estimation methods is that the technique lets the data sample decide where to set the threshold, T. Thus, the data itself decides which firms, or firm-year observations are classified as constrained or unconstrained.

There are several points to make about this estimation method. First, the objective of the analysis is to find out whether there is a threshold effect, i.e. whether $\beta_1 = \beta_2$ or not. The null hypothesis is that there are no thresholds. However, under H_0 the threshold is not identified, so standard tests, such as Likelihood Ratio, Wald, and Lagrange Multiplier, cannot be used.[11] The econometric techniques developed by Hansen (1996, 1997) allow us to test for the presence of a threshold and to find the "no-rejection region" for the estimated threshold, $\hat{\mathrm{T}}$.

Under the null hypothesis of no threshold, i.e. $\beta_1 = \beta_2 = \beta_0$, the model described in equation (4) will be reduced to

$$y_{it} = f_i + \beta_0' X_{it} + e_{it} \tag{7}$$

Now the estimated coefficient is $\hat{\beta}_0$, and the sum of squared errors, $\hat{S}_0 = \hat{e}_0' \hat{e}_0$, where $\hat{e}_0$ is the vector of regression residuals. The likelihood test of the null hypothesis is

[11] This is the so-called "Davies' Problem" (see Davies (1987)).

$$LR_0 = \frac{\hat{S}_0 - \hat{S}(\hat{T})}{\hat{\sigma}^2} \tag{8}$$

where $\hat{\sigma}^2 = \frac{\hat{S}(\hat{T})}{df}$, and df is the degrees of freedom found from the estimation the model described in equation (5). This likelihood ratio test has a non-standard distribution. Hansen suggests a bootstrap procedure to simulate the asymptotic distribution of the likelihood ratio test. This procedure is not applied here. However, if the threshold T had not been estimated but known, its distribution would asymptotically have been chi-squared with k (the dimension of the β_0 vector) degrees of freedom.

It is also necessary to test the significance of the estimated threshold. Again, a likelihood test is used. To test the hypothesis H_0 : $\mathrm{T} = \mathrm{T}_0$, the likelihood ratio is

$$LR(\mathrm{T}) = \frac{\hat{S}(\mathrm{T}) - \hat{S}(\hat{\mathrm{T}})}{\hat{\sigma}^2} \tag{9}$$

This likelihood ratio is calculated for all possible threshold values. Hansen shows that the test rejects the asymptotic significance level α if $LR(\mathrm{T})$ exceeds $c(\alpha)$ defined as

$$c(\alpha) = -2\log\left(1 - \sqrt{1-\alpha}\right) \tag{10}$$

The interval where $LR(\mathrm{T}) \leq c(\alpha)$ is narrow indicates that the threshold is relatively exactly defined. To get a better idea of the threshold and its significance, we will plot $LR(\mathrm{T})$ as a function of the threshold.

In sum, the threshold technique basically involves the following steps: 1) For each threshold value, estimate the β-coefficients and calculate the sum of squared errors. 2) Find the threshold value where the sum of squared errors is minimized. 3) Calculate the likelihood ratio, described in equation (8) (and its significance). 4) Find the asymptotic confidence interval for the threshold given by equation (9) and equation (10).

The presence of the lagged dependent variable in the model described in equation (3) violates the assumption that all the regressors are exogenous.[12] Therefore, we estimate the model by an IV method. Ignoring the threshold aspect for a moment, a panel data model with a lagged dependent variable could be written as:

$$y_{it} = \beta^{y} y_{it-1} + \beta^{X}{}' X_{it} + f_i + e_{it} \qquad (i=1, .., N;\ t=1, .. ,T) \qquad (11)$$

We assume that the disturbances satisfy the conditions; $E(e_{it})=0$, $E(e_{it}e_{js})=\sigma^2$ if $i=j$ and $t=s$, and $E(e_{it}e_{js})=0$ otherwise.

To remove the fixed effects we write the model in first differences. As suggested by Anderson and Hsiao (1982), and Holtz-Eakin, Newey, and Rosen (1988), a consistent coefficients vector is

$$\begin{pmatrix} \hat{\beta}^{y} \\ \hat{\beta}^{X} \end{pmatrix} = (Z'\Delta X)^{-1}(Z'\Delta Y) \qquad (12)$$

where

$$\Delta Y = \begin{pmatrix} \Delta y_{13} \\ \vdots \\ \Delta y_{1T} \\ \vdots \\ \Delta y_{N3} \\ \vdots \\ \Delta y_{NT} \end{pmatrix}, \quad \Delta X = \begin{pmatrix} \Delta y_{12} & \Delta X_{13} \\ \vdots & \vdots \\ \Delta y_{1T-1} & \Delta X_{1T} \\ \vdots & \vdots \\ \Delta y_{N2} & \Delta X_{N3} \\ \vdots & \vdots \\ \Delta y_{NT-1} & \Delta X_{NT} \end{pmatrix}, \quad Z = \begin{pmatrix} y_{11} & \Delta X_{13} \\ \vdots & \vdots \\ y_{1T-2} & \Delta X_{1T} \\ \vdots & \vdots \\ y_{N1} & \Delta X_{N3} \\ \vdots & \vdots \\ y_{NT-2} & \Delta X_{NT} \end{pmatrix}$$

Given the assumptions about the e_{it}'s, the asymptotic distribution of the β-vector described in (12), is given by

[12] See Nickell (1981).

$$\sqrt{N}\left(\hat{\beta}-\beta\right)_{\underset{N\to\infty}{\sim}} \mathrm{N}\left(0,\sigma^2\left(\underset{N\to\infty}{\mathrm{plim}}\frac{1}{\mathrm{N}}(Z'\Delta X)^{-1}Z'\Psi Z(\Delta X'Z)^{-1}\right)\right) \tag{13}$$

where $\Psi = I_N \otimes H$, I_N is a NxN identity matrix, and H is a matrix with twos on the leading diagonal, minus ones on the first off-diagonal, and zeros elsewhere.

To fit the dynamic model described in equation (11) into the threshold model framework, we write the model as:

$$y_{it} = f_i + \beta_1^y y_{it-1} I(q_{it} \le \mathrm{T}) + \beta_1^X{}' X_{it} I(q_{it} \le \mathrm{T}) + \beta_2^y y_{it-1} I(q_{it} > \mathrm{T}) + \beta_2^X{}' X_{it} I(q_{it} > \mathrm{T}) + e_{it} \tag{14}$$

In the stacked form, we could find the coefficients of (15) by the following expression

$$\begin{pmatrix} \hat{\beta}_1^y \\ \hat{\beta}_1^X \\ \hat{\beta}_2^y \\ \hat{\beta}_2^X \end{pmatrix} = (Z'\Delta X)^{-1}(Z'\Delta Y) \tag{15}$$

where ΔY is defined as in equation (12), and

$$\Delta X = \begin{pmatrix} \Delta y_{12} I(q_{it} \le \mathrm{T}) & \Delta X_{13} I(q_{it} \le \mathrm{T}) & \Delta y_{12} I(q_{it} > \mathrm{T}) & \Delta X_{13} I(q_{it} > \mathrm{T}) \\ \vdots & \vdots & \vdots & \vdots \\ \Delta y_{1T-1} I(q_{it} \le \mathrm{T}) & \Delta X_{1T} I(q_{it} \le \mathrm{T}) & \Delta y_{1T-1} I(q_{it} > \mathrm{T}) & \Delta X_{1T} I(q_{it} > \mathrm{T}) \\ \vdots & \vdots & \vdots & \vdots \\ \Delta y_{N2} I(q_{it} \le \mathrm{T}) & \Delta X_{N3} I(q_{it} \le \mathrm{T}) & \Delta y_{N2} I(q_{it} > \mathrm{T}) & \Delta X_{N3} I(q_{it} > \mathrm{T}) \\ \vdots & \vdots & \vdots & \vdots \\ \Delta y_{NT-1} I(q_{it} \le \mathrm{T}) & \Delta X_{NT} I(q_{it} \le \mathrm{T}) & \Delta y_{NT-1} I(q_{it} > \mathrm{T}) & \Delta X_{NT} I(q_{it} > \mathrm{T}) \end{pmatrix}$$

$$Z = \begin{pmatrix} y_{11}I(q_{it} \le \mathrm{T}) & \Delta X_{13}I(q_{it} \le \mathrm{T}) & y_{11}I(q_{it} > \mathrm{T}) & \Delta X_{13}I(q_{it} > \mathrm{T}) \\ \vdots & \vdots & \vdots & \vdots \\ y_{1T-2}I(q_{it} \le \mathrm{T}) & \Delta X_{1T}I(q_{it} \le \mathrm{T}) & y_{1T-2}I(q_{it} > \mathrm{T}) & \Delta X_{1T}I(q_{it} > \mathrm{T}) \\ \vdots & \vdots & \vdots & \vdots \\ y_{N1}I(q_{it} \le \mathrm{T}) & \Delta X_{N3}I(q_{it} \le \mathrm{T}) & y_{N1}I(q_{it} > \mathrm{T}) & \Delta X_{N3}I(q_{it} > \mathrm{T}) \\ \vdots & \vdots & \vdots & \vdots \\ y_{NT-2}I(q_{it} \le \mathrm{T}) & \Delta X_{NT}I(q_{it} \le \mathrm{T}) & y_{NT-2}I(q_{it} > \mathrm{T}) & \Delta X_{NT}I(q_{it} > \mathrm{T}) \end{pmatrix}$$

Now the estimated residuals could be calculated as

$$\Delta\hat{e}_{it} = \Delta y_{it} - \hat{\beta}_1^y y_{it-1} I(q_{it} \le \hat{\mathrm{T}}) - \hat{\beta}_1^{X\prime} X_{it} I(q_{it} \le \hat{\mathrm{T}}) - \hat{\beta}_2^y y_{it-1} I(q_{it} > \hat{\mathrm{T}}) - \hat{\beta}_2^{X\prime} X_{it} I(q_{it} > \hat{\mathrm{T}}) \quad (16)$$

and the sum of squared errors is

$$\hat{S} = \sum_{i=1}^{N}\sum_{t=3}^{T} \Delta\hat{e}_{it}^2 \quad (17)$$

Note that in this framework $\hat{\sigma}^2 = \frac{\hat{S}}{df}$ is an estimator for the variance of Δe_{it}, rather than the variance of e_{it}. However, given our assumptions about the error term, $E\left[(e_{it} - e_{it-1})^2\right] = 2E\left[(e_{it})^2\right]$. Thus, the use of the variance of Δe_{it} instead of the variance of e_{it} does not alter the estimated threshold given by equation (6), or the likelihood ratios described in (8) and (9).

Finally, Hansen (1997) shows that even though the coefficient vector in the threshold model depends on the threshold estimate, i.e. $\hat{\beta} = \hat{\beta}(\hat{\mathrm{T}})$, inference on β can proceed as if the threshold estimate $\hat{\mathrm{T}}$ were the true value.

5. Empirical Results

We start out using the size of the firm, measured by the number of employees, as the threshold variable. Several studies use firms' size as proxy for capital market access. Small firms are most likely to face a larger premium for external funds. Information asymmetries will almost make it impossible for small firms to raise capital through new share issue or commercial papers. Larger firms tend to be older with a better-known track-record, more diversified, have more assets that can serve as collateral, and therefore have a lower bankruptcy risk. In addition, larger or more mature firms have also shown their ability to survive, which may be a signal of the ability of staying alive in the future as well. Moreover, transaction costs for issuing debt or equity are likely to vary inversely with size. Finally, monitoring costs are likely to vary inversely with size. Together, these factors will make external finance likely to be more costly for smaller firms, and these firms will probably depend more heavily on internal funds.

To avoid the biases introduced when using an endogenous threshold or split variable, we use firms' size one year prior to the dependent variable. The basic specification of the investment model is given in equation (3), and the results of the IV threshold estimation method on the whole sample are given in column (i), Table 1.[13] The estimated threshold value is 151 employees. Given the threshold value, the share of assumedly constrained firms varies from 60.4% to 67.1% over the estimated period. These proportions are high compared to other international studies. However, we should be aware that most other empirical studies cover larger firms, firms that are less likely to experience financial constraints.[14] Yet, a threshold value of 151 seems also very high in a Norwegian context.[15] In addition, the confidence interval is wide. With a 95% confidence level, the confidence interval is [147, 770]. If we look at the likelihood ratio statistics for the test of no threshold effect (LR_0 defined in (8)), this value is 40.3 with 15 degrees of freedom. If the threshold value had not been estimated, but instead based on *a priori* assumptions or believes, this test would asymptotically be $\chi^2_{df=15}$, and the test statistic value of 40.3 is then very significant. A plot of the likelihood ratio defined in (9) is given in Figure 1. The estimated threshold value of 151 is found where the likelihood ratio hits the zero axis. The confidence interval is found where the likelihood

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[13] All the results presented in the current study have been obtained using a program developed in GAUSS. The standard errors of the coefficients are White-corrected for heteroskedasticity. We have also taken into account that estimating the model in differences to remove the fixed individual effects introduces a MA(1) in the error term.

[14] Fazzari et al. (1988) had 49 assumed constrained firms and 373 unconstrained firms, Hoshi et al. (1991) had 24 independent firms assumed to be financially constrained, and 121 other firms. Hansen (1997) uses debt level as threshold variable and ends up with a percentage of firms with high debt ranging from 4% to 16% over the years.

[15] Numbers from the Manufacturing Statistics reveals that approximately 95 percent of the firms within the manufacturing industry in 1985 have less than 100 employees.

ratio is below the horizontal dotted line. Here we see that there is a second dip in likelihood ratio around $T = 500$, and a third dip around $T = 750$. Hansen (1997) also finds a similar pattern in a single threshold investment model. He states that this finding indicates that there is more than one threshold in the model. We leave this question open in our analysis, and instead focus on the coefficients of the liquidity variable. This is motivated through graph in Figure 1, where the two upper thresholds occur at a much higher level than the estimated threshold.

Given that the revealed threshold is valid, our concerns are about the slope coefficients of the cash flow variables. For both groups of firms, the cash flow variables are significant. However, the relationship between investment and cash flow may be hard to interpret. An important question is whether the cash flow variable should be interpreted as a signal of the profitability of investment not captured in the simple accelerator formulation, or whether the significance of cash flow arises from the effects of credit rationing. By focusing on the differences in the estimated coefficients, we hope to separate the effect of financial funding from the information on investment opportunities.[16] The long-run effects of cash flow are 0.21 for the constrained firms and 0.10 for the unconstrained. The difference is significant with a *t-value* = 3.74.

One explanation for our results is that the size effects are pure industry effects; the size of the firms varies across industry categories. Such differences may be caused by other factors than variations in access to external funding, or the existence of credit constraints. If there are increasing returns to scale, larger firms will probably have higher cash flow rates. With investment rates similar to smaller firms, the regression results will lead to smaller cash flow coefficients for larger firms. Another possible explanation is that larger firms operate in other segments of the output market where they have some market power and therefore generate more cash flow. Thus, if larger firms have the same investment rate as smaller firms, we will find the sensitivity of investment to cash flow to be lower for larger firms compared to smaller ones. Both these effects could generate the pattern described in column (i) in Table 1. However, it could also be that the assets are more specialized in some industries and therefore less suitable as collateral. Then we expect the sensitivity of investment to cash flow to be

[16] Thus, a critical assumption in our analysis is that the biases in the estimated coefficients of the liquidity variable are the same for the two sets of firms (constrained and unconstrained).

larger in these industries. Nevertheless, we are more interested in finding out whether two similar firms, except for their access to external finance, respond in the same way to shifts in cash flow. To control for sectoral variations and heterogeneity not induced by liquidity restrictions, we analyze the sensitivity of investment to cash flow for various industries separately.[17] Columns (ii)-(viii), Table 1 show the results for this part of the analysis.

The estimated threshold varies between 62 employees for Food (31), up to 142 employees for Transport Equipment (384).[18] For all the industries, the confidence interval of the estimated threshold is quite narrow suggesting little uncertainty concerning the nature of the divisions. The likelihood test used to see whether the coefficients are different for the assumed constrained and unconstrained firms, LR_0, varies from 45.9 for Paper and Printing (34), up to 81.3 for Food (31). Thus, based on an (incorrect) chi-square test, it seems to be evident that there are two regimes in each industry. If we look at the share of constrained firms within each industry, we find Food (31) and Paper and Printing (34) with a relative low share of constrained firms, while Metals (37) and Transport Equipment (384) are at the other end of the scale. Food (31) is heavily regulated, and therefore other factors than credit constraints may be more important for their investment behavior. From column (ii), Table 1, we also find that the two accelerator terms, $\frac{Y_{it} - Y_{it-1}}{Y_{it-1}}$, are negative and significant for smaller firms in this latter industry. These signs are hard to interpret. One possible explanation for the findings of relative high share of constrained firms in Metals (37) and Transport Equipment (384) could be that these rely on relatively specialized fixed capital, with a low second hand value. Thus, their investments in general may depend more heavily on internal funding. The shares of constrained firms vary over the sample period. However, these variations seem to be independent of the business cycles. This is evident in Figure 3 where we have plotted these shares over time.

Our main concern is whether the investment of the smaller firms are more sensitive to internal funds compared to larger or assumedly unconstrained firms. Again, we look at the difference in the long-run cash flow coefficients. Here the results are a little more ambiguous.

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[17] Of course, doing the analysis industry-by-industry ignores the fact the industry for which a firm belongs is important information about the firm's borrowing ability. All this between-variation will also be ignored in this part of the analysis.

[18] ISIC numbers in parenthesis.

For four out of seven industries, the difference in the long-run cash flow coefficients is positive, but only one of these is significant. The differences in the long-run cash flow coefficients are negative and significant for two industries, and finally negative and insignificant for one industry. Our findings may indicate some effects of the availability of internal finance on investment. The fact that these effects are generally more significant for smaller firms, is consistent with the theory in which information asymmetries lead to financial constraints and therefore restrict firms' investment spending. However, for some of the industries we found the opposite of our prior beliefs. It is of course difficult to distinguish between the liquidity effect and the investment opportunity interpretations. For instance, an alternative explanation for our findings could be that the cash flow variable to a larger degree proxies unobservable investment opportunities in the sub-sample of smaller firms. It could also be that the revealed size effects have nothing to do with financial constraints, but rather differences in technologies and market power between smaller and larger firms.

In all the regressions made above, we have included separate time dummies for each of the two regimes. However, when we look at the significance of the time-dummies, based on the standard errors corrected for heteroscedasticity, they are insignificant for all industries.[19] To test whether the results are sensitive to inclusion of time-dummies or not in the empirical model, we exclude time-dummies and re-estimate the model. This exercise is done for one sector only, namely Chemicals and Metals (35-36). We have chosen this industry more or less arbitrarily. However, we will not try to conceal the fact that the sign and the significance of the coefficients reported in column (v), Table 1, are promising. Also the figure showing $LR(\mathrm{T})$ is fairly smooth and may suggests the existence of only one threshold in the regression (see 'Figure 2. Chemicals and Minerals (35-36)'). In Table 2, we report the results for the given sector where no time dummies are used, together with copies of the corresponding results from Table 1. The results do not vary much, neither in the size and sign of the coefficients, nor in the estimated threshold and its confidence interval. Furthermore, if we compare the two figures of the likelihood ratio as function of the threshold (Figure 2 and Figure 4), the patterns are very similar.[20] Even though these results should be interpreted with some care, it is apparent that the inclusion of the time-dummies does not alter the results significantly in any way. However, we should emphasize that this is not a general result, and

[19] These particular results are not reported here for sake of brevity.
[20] Note that the scaling of the axes varies.

that we cannot generalize from this single analysis. Still, based on this finding, and keeping in mind that the model still gives consistent and unbiased estimates of the coefficients in the true model and even though irrelevant variables are included, we continue without re-estimating all the regressions without the time-dummies.

One question of interest is whether the threshold and the shares of constrained firms vary before and after the deregulation of the financial sector. This deregulation took mainly place in 1984-1986. To analyze this question, we split the sample into two periods; before the deregulation (1979-83), and after the deregulation (1985-1990).[21] Again, we do this part of the analysis only for 'Chemicals and Minerals (35-36)'. Note that for each estimation, at least three years of observations are necessary. In Table 3, we report the thresholds, their confidence intervals, and the share of constrained firms for this latter part of the analysis. In the pre-deregulation period, the estimated threshold is 84 and the confidence interval [80,84]. The shares of constrained firms vary from 33% to 36%. The corresponding numbers for the post-deregulation period is 100, [99,109], and 34% to 39%. From these numbers, it is hard to see any significant differences between the two periods even though the estimated threshold has increased marginally. These findings are consistent with the results in which we found that the shares of constrained firms varied independently of the business cycles. Yet, it is interesting to notice that the difference in the cash flow coefficients is larger and more significant in the latter period, relative to the first one.

To test the robustness of our results, we may use other split variables that are correlated with the availability of outside financing. Time independent split criteria, such as ownership and quotation, are not appropriate for the threshold technique.[22] Age has also been used in empirical studies to split firms into groups of constrained and unconstrained firms. In our case, approximately 50% of the firms have mis-reported age - the reported day-of-birth is later than the time of first occurrence in the sample. Therefore, we cannot use age as a threshold variable. The tax-regime in Norway in the 80's made retained earnings to the least expensive form of financing.[23] More than half of the firms in our sample paid no dividends

[21] Note that two cross cross-sections of each sub-sample are lost due to differencing and lagged instruments. Therefore, we end up with 'useable' observations for the years 1981-1983 and 1987-1990.
[22] Of course, both quotation and ownership could vary in a firm over time. However, with short panels with as few as 4 observations for the shortest series, the argument above seems reasonable.
[23] The described tax-regime was changed in 1992. The goal of the reform of 1992 was to reduce the distortion in the existing regime.

through the whole sample period. Therefore, we also ignore the dividend behavior as a split criterion for this analysis. A variable that might be used in the threshold model is the debt-to-equity ratio or debt-to-assets ratio. We have constructed the debt-assets ratio variable, defined as the sum of short-and long-term liabilities normalized with total assets. This variable may proxy the financial strength and borrowing ability of a firm and therefore influence firms' investments spending.[24] The debt-assets ratio can convey information about firms' lack of collateral, but may also be a determinant of the agency cost of external funding. Agency costs arise because insiders in a firm may have incentives to act contrary to the interests of outsiders.[25] There also seems to be reason to believe that debt ratio is less sensitive to technological effects, such as size may be, and that the debt ratio is therefore "purer" when it comes to discriminating between financially constrained and unconstrained firms. However, the use of debt ratio to split the sample is not straightforward either. Firstly, in theory, it seems reasonable to assume that the creditors and investors will be reluctant to lend money to, or invest in firms which are heavily indebted and therefore have a relatively high bankruptcy risk. However, outsiders may also look upon significant debt as a signal of creditworthiness, and that firms with high debt have a higher "debt-capacity" relative to less indebted firms. In theory, this effect will have the opposite effect of what we might expect from the theory of asymmetric information. If the "debt-capacity" phenomenon is present, we will find that indebted firms are less financially constrained. Second, we do not have any information about any form of market values, neither for debt nor for equity. This may bias the analysis severely. In booming periods, the market values of the firms will in general increase and therefore make the firms less credit constrained. This effect will not be captured by a book-value based variable. Observations from the booming period will therefore mistakenly be characterized as constrained instead of unconstrained. In recessions, the opposite will happen. Firms or firm-year observations may be assumed to belong to the unconstrained sub-sample even though their market value is low. These measurement errors may be critical for our analysis since the Norwegian economy experienced significant fluctuations through the sample period. Nevertheless, we believe that using different split

[24] Both Whited (1992), and Hu and Schiantarelli (1994) use the debt-assets ratio to determine whether a firm is characterized as credit constrained or not. The authors find that firms that are more indebted are more sensitive to internal funding relative to more financially healthy firms. These findings are consistent with a pattern stemming from imperfect capital markets.

[25] Without going into details, it should be mentioned that Jensen and Meckling (1976) showed that insiders of a firm have an incentive to choose risky projects due to their limited liability. Since the incentive of the insiders is also recognized by potential creditors, this effect generates agency cost for debt financing.

criteria may provide some valuable insight although there are drawbacks with the applied threshold variables.

We should be aware of possible sector differences when the debt-to-assets ratio is applied as a threshold variable. For instance, export oriented industries, and industries with larger fluctuations in demand, and therefore larger fluctuations in profitability, are likely to have higher bankruptcy risk compared to more sheltered industries.[26] Thus, we also adapt this part of the analysis separately for each industry. However, the results from this part of the analysis are very "disappointing".[27] The share of constrained firms varies substantially compared to the size-related shares. However, the most serious problem with the debt-ratio results, is that the difference in the long-run cash flow coefficients between the assumed constrained (high debt) and the unconstrained (low debt) sub-samples, $\beta^{CF}_{Constrained} - \beta^{CF}_{Unconstrained}$, are negative.[28] Thus, these latter findings are not supportive of the prior findings and implications of the theory of information asymmetries. We have already discussed some of the factors that might give such a "paradoxical" pattern. However, these latter findings are in line with the ones of Vale (1996). He analyzes the inventory investments of smaller Norwegian firms and finds that the negative influence of debt to supplier is stronger the larger the firm is. He states that one possible explanation may be that smaller firms are financially less clever. However, it is hard to hold this alternative explanation together with results from where we split the samples based on the firms' size.

Perhaps the most serious problem with empirical analyses of liquidity constraints is measurement errors. We know from the literature that the cash flow variable may proxy market fundamentals or investment opportunities rather than liquidity.[29] If the measurement error problem varies across classes of firms, even the estimates of the differences of the long-run cash flow coefficients will be biased. Schaller (1993) discusses this problem. He shows that if cash flow contains news about expected future returns on investment that is not captured by the variable meant to control for such effects, the estimate of the cash flow coefficient will be biased upward. In our analysis, we control for investment opportunities by

[26] Again, one could argue that we ignore between-variations between the various industries by doing the analysis industry-by-industry.
[27] These results are not reported.
[28] The only exception is for 'Chemicals and Metals (35-36)'.
[29] See Morck, Shleifer, and Vishny (1990), and Blanchard, Rhee and Summers (1993).

the accelerator term, $\frac{Y_{it} - Y_{it-1}}{Y_{it-1}}$. If this term is less able to proxy investment opportunities for smaller firms relative to larger firms, our findings of a higher cash flow coefficient for smaller firms may be misleading. Nevertheless, we believe that part of the problem is solved by including several lags of the accelerator variable in addition to the lagged dependent variable. Another part of the measurement problem is the pitfall of using split-variables that are endogenous to the firms.[30] We have solved this problem by measuring the size of a firm one year before the investment takes place.

6. Concluding remarks

The results presented here suggest some effects of the availability of internal finance on investment when we split the sample according to the firms' size. The fact that these effects in most cases are larger for smaller firms is consistent with the theory in which information asymmetries lead to financial constraints on firms' investment spending. The results seem also to indicate that there are significant differences between various industries, differences that may be of great importance when analyzing the sensitivity of investment to internal liquidity. We have also investigated whether the shares of constrained firms vary over business cycles, and before, as opposed to after the deregulation of the Norwegian capital market. The results indicate that the shares of constrained firms in each industry move independently of the business cycles and of deregulation. However, all these results should be interpreted with some care. Firstly, the size variable may absorb other effects than cost differences between external and internal funding, such as technology and product market behavior. Secondly, when the debt-assets ratio is used as a split variable, we are not able to confirm the size-split findings. However, we point at difficulties in using the debt-assets ratio to discriminate between financially constrained and unconstrained firms. This is related to the fact that an increase in the debt-assets ratio may not only signal increased bankruptcy risk, but also improved debt-capacity. Additionally, since our measure of the debt-assets ratio is based on book values only, we believe the variable is less appropriate for our purpose. Other

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[30] Fazzari, Hubbard, and Petersen (1988) split their sample based on dividend which is definitely endogenous to the firms. The use of an endogenous threshold variable may bias their results.

potential split variables have also been discussed, but we did not find any other relevant split-variables in our sample.

We have pointed at difficulties in interpreting the findings since the impact of the cash flow variable may be related to its role as a proxy for investment opportunities rather than to liquidity effects. In addition, we have also discussed whether measurement problems are more important for assumedly constrained firms relative to the unconstrained, inducing a disproportionally steep cash flow coefficient for the group of constrained firms.

When we find the results to be a little ambiguous about the existence of credit constraints, these findings are in line with several other analyses on Norwegian data. Vale's study of inventory investment (1996) is already mentioned. Johansen (chapter 2, 1995) analyzes the relationship between cash flow and fixed investment in single-plant and multi-plant manufacturing firms. The investments of single-plant firms seem to be more sensitive to cash flow than the investments of multi-plant firms. However, these differences disappear when size is controlled for. The findings in Johansen's analysis indicate that the significance of cash flow is due to other factors than financing constraints, such as investment opportunities.

It may be argued that the data set applied in this paper, with relatively large firms in a Norwegian setting, has marginal relevance for the question whether information asymmetries lead to financial constraints on firms' investment spending. Financing constraints induced by information asymmetries maybe more likely to affect smaller firms that were discarded from our sample. However, when our findings, which are consistent with the effects of financing constraints, appear in the chosen sample, such constraints may be even more evident among the firms left out. Thus, based on our findings we cannot reject the existence of credit constraints and that these constraints are important for firms' investments.

Finally, the threshold regression model with firm-specific effects is relatively new and only a few papers have applied this technique for analyzing financing constraints and firms' investment. We believe this model improves upon more standard regression models. Firstly, whether a firm is financially constrained or not is determined by the data itself. Thus, the researcher does not have to make *a priori* assumptions about the selected cutoff values of the sample-split variables. Secondly, the method may also reveal whether there are one or several relevant thresholds. In addition, we have implemented the use of instrument variables in the model, allowing for endogenous regressors. Future research should consider better ways of modeling investment opportunities, especially for smaller firms where market values do not exist, which eliminates the use of the q model. More emphasis should also be put on finding variables that are able to discriminate between financially constrained and unconstrained firms, variables that mainly capture financial differences. At the methodological side, a threshold model with endogenous variables where the number of instruments exceeds the number of endogenous variables (overidentification) should also be considered implemented.

References

Abel, A. B., and J. C. Eberly, 1994, "A Unified Model of Investment Under Uncertainty", *American Economic Review*, 84, December, 1369-1384.

Anderson T. W. and C. Hsiao, 1982, "Formulation and Estimation of Dynamic Models Using Panel Data", *Journal of Econometrics* 18(1), 47-82.

Barnett, S. A., and P. Sakellaris, 1995, "Non-Linear Response of Firm Investment to Q: Testing a Model of Convex and Non-Convex Adjustment" University of Maryland, Department of Economics, Working Paper No. 95-11.

Bertola, G., and R. J. Caballero, 1990, "Kinked Adjustment Costs and Aggregate Dynamics", In *National Bureau of Economic Research Macroeconomic Annual 1990*, edited by Olivier J. Blanchard and Stanley Fisher, Cambridge, MIT Press.

Blanchard, O., C. Rhee and L. Summers, 1993, "The Stock Market, Profit, and Investment", *Quarterly Journal of Economics*, 108(1), 115-136.

Davies, R. B., 1987, "Hypothesis testing when a nuisance parameter is present only under the alternative", *Biometrika* 74, 33-43.

Dixit, A. and R. S. Pindyck, 1994, *Investment Under Uncertainty*, Princeton University Press.

Doms, M., and T. Dunne, 1994, "Capital Adjustment Patterns in Manufacturing Plants", mimeo, US Census Bureau.

Fazzari, S. M., R. G. Hubbard, and B. C. Petersen, 1988, "Financing Constraints and Corporate Investment", *Brookings Papers on Economic Activity*, 1, 141-195.

Gertler, M., 1988, "Financial Structure and Aggregate Economic Activity: An Overview.". *Journal of Money, Credit, and Banking* 20, 559-588.

Gertler, M. and R. G. Hubbard, 1988, "Financial Factors in Business Fluctuations", in *Financial Market Volatility: Causes, Consequences, and Policy*. Kansas City, MO: Federal Reserve Bank of Kansas City, 33-71.

Halvorsen, R., R. Jenssen and F. Foyn, 1991, "Dokumentasjon av Industristatistikkens Tidsseriedatabase", mimeo, Statistics Norway.

Hamermesh, D. S., G. A. Pfann, 1996, "Adjustment Costs in Factor Demand", *Journal of Economic Literature* 34(3), 1264-1292.

Hansen, B. E., 1996, "Inference When a Nuisance Parameter Is Not Identified under the Null Hypothesis", *Econometrica* 64(2), 413-430.

Hansen B. E., 1997, "Threshold effects in non-dynamic panels: Estimation, testing and inference", Working Paper 365, Department of Economics, Boston College, MA.

Holtz-Eakin, D., W. Newey, and H. S. Rosen, 1988, "Estimating Vector Autoregressions with Panel Data", *Econometrica* 56(6), 1371-1395.

Hu, X., and F. Schiantarelli, 1994, "Investment and Financing Constraints: a Switching Regression Approach Using US Firm Level Data", Working Paper No. 284, Department of Economics, Boston College.

Hubbard, R. G., 1994, "Investment under Uncertainty: Keeping One's Options Open", *Journal of Economic Literature* 32(4), 1816-1831.

Hubbard, R. G., 1997, "Capital-Market Imperfections and Investment", NBER Working Paper 5996, MA.

Jensen, M. and M. Meckling, 1976, "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure", *Journal of Financial Economics* 3(4), 305-360.

Johansen, F., 1995, "Essays on Investment and Financing Constraints", PhD. thesis, Northwestern University, Illinois.

Lamont, O., 1993, "Cash flow and Investment: Evidence from Internal Capital Markets", mimeo, MIT.

Morck, R., A. Shleifer, and R. W. Vishny, 1990, "The Stock Market and Investment: Is the Market a Sideshow?", *Brookings Papers on Economic Activity* 2, 157-202.

Nickell, S., 1981, "Biases in Dynamic Models with Fixed Effects", *Econometrica* 49, 1417-1426.

Nilsen, Ø. A. and F. Schiantarelli, 1997, "Zeroes and Lumps: Investment Patterns of Norwegian Firms", mimeo, Department of Economics, Boston College.

Schaller, H., 1993, "Asymmetric Information, Liquidity Constraints and Canadian Investment", *Canadian Journal of Economics* 26(3), 552-574.

Schiantarelli, F., 1996, "Financial Constraints and Investment: A Critical Review", *Oxford Review of Economic Policy* 12(2), 70-89.

Stiglitz, J.E., 1992, "Capital Markets and Economic Fluctuations in Capitalist Economies". *European Economic Review* 36(2-3), 269-306.

Vale, B., 1996, "Firm's Inventory Investments, Financial Conditions and the Banking Crisis in Norway", *Working Paper 1994/4*, Norges Bank, Oslo.

White, H., 1980, "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity", *Econometrica* 48(4), 817-38.

Whited, T., 1992, "Debt, Liquidity Constraints, and Corporate Investment: Evidence from panel data", *The Journal of Finance* XLVII, 1425-1460.

DATA APPENDIX

Codes in square brackets refer to the variable number in the Manufacturing Statistics.

Investment (I_t^j): Real (fixed price) investment at time t in type j of capital equals purchases minus sales (dismissals) of fixed capital. Our definition of investment in equipment includes machinery, office furniture, fittings and fixtures, and other transport equipment, excluding cars and trucks (using the codes in Manufacturing Statistics, [501]+[521]+[531]-[641]-[661]-[671]).[31] Data for buildings, in addition to those directly used for production, includes also offices, and inventory storage buildings([561]-[601]). We will call the aggregate of these three categories buildings used for production. Vehicles include cars and trucks ([511]-[651]). Other fixed assets include housing for employees, building for spare-time activities, sites and property ([541]+[551]+[571]+[581]-[681]-[691]-[711]-[721]).

Replacement value of capital stock (q_tK_t): The replacement value of capital is calculated separately for equipment and buildings using the perpetual inventory formula:

$$q_t^j K_t^j = q_t^j K_{t-1}^j \cdot \left(1-\delta^j\right) \cdot PI_t^j + I_t^j$$

where superscript j indicates the different types of capital. Depreciation rates, δ^j, are taken from the Norwegian National Accounts (0.06 and 0.02 for equipment and buildings, respectively). Also the price indices for investment, PI_t^j, are taken from the Norwegian National Accounts. When calculating the replacement value of capital, we use as a benchmark the oldest reported fire insurance value ([871] and [881] for equipment and buildings, respectively) larger than or equal to NOK 200,000, measured in 1980 prices. From these initial values we calculate the replacement value backwards and forwards, using the investment figures.[32] Finally we added together the two categories of capital. Real investment at time t in capital of type j equals purchases minus sales of fixed capital. Investments in equipment include machinery, office furniture, fittings and fixtures, and other transport equipment, excluding cars and trucks ([501]+[521]+[531]-[641]-[661]-[671]). The measure of buildings includes buildings used for production, offices and inventory storage ([561]-[601]).

Output (p_tY_t): Gross production [1041], plus subsidies [291], and minus taxes [301]. The current prices are transformed into 1980-fixed prices using price indices for gross output.

Debt-ratio (B/TA): The book value of short-term and long-term liabilities ($[5100]_{\text{Accounts}}$ + $[5200]_{\text{Accounts}}$) normalised with total assets $[5500]_{\text{Accounts}}$.

[31] Other transport equipment includes railroads internal to the plant, funiculars, transport cranes, conveyer belts, etc.

[32] If the replacement value of capital became negative, it was set equal to zero. When calculating the capital stock forward it may happen that the replacement value becomes negative because of large sales of capital goods. When calculating it backwards the replacement value becomes negative if the net purchase of fixed capital is larger than the replacement value in year $t+1$.

Cash flow (CF): Profit before year-end adjustments $[310]_{Accounts}$+ depreciation $[229]_{Accounts}$+ extraordinary (not-tax-conditioned) depreciation $[282]_{Accounts}$ - tax on property and income $[333]_{Accounts}$ - profit on disposals of fixed assets $[271]_{Accounts}$ + loss on disposals of fixed assets $[281]_{Accounts}$. These numbers are normalised with the aggregate replacement value of fixed capital in all plants belonging to a firm.

Price indices (p_t): Price indices for industry sector gross output collected from National Accounts.

Investment goods price indices (q_t): Price indices of investment goods are collected from the Norwegian national accounts and are given separately for equipment and buildings.

Sector specification used in the Tables, ISIC codes in parentheses

Food (31)
Textiles, Wood Products (32-33)
Paper and Printing (34)
Chemicals and Minerals (35-36)
Metals (37)
Metal Products, Machinery, Electrical Equipment (381-383)
Transport Equipment (384)

Number of observations for each firm	Number of firms	All observations	Useable observations
3	226	678	226
4	203	812	406
5	151	755	453
6	134	804	536
7	107	749	535
8	71	568	426
9	79	711	553
10	59	590	472
11	45	495	405
12	156	1872	1560
	1231	8034	5572

Table A1: Number of firms by number of observations
Useable observations refer to observations used after two cross-sections are removed due to first differencing and instrumenting.

	All observations	Useable observations
1979	704	
1980	779	
1981	821	704
1982	799	699
1983	737	637
1984	705	608
1985	662	548
1986	633	516
1987	628	495
1988	608	470
1989	523	460
1990	435	435
	8034	5572

Table A2: Observations by year

		(i) Overall	(ii) 31	(iii) 32-33	(iv) 34	(v) 35-36	(vi) 37	(vii) 381-383	(viii) 384
Unconstrained	$I_{i,t-1}/K_{i,t-2}$	0.201*	0.180*	0.014	0.096	0.236*	0.380	0.163*	0.130
(large)		(0.041)	(0.042)	(0.072)	(0.053)	(0.070)	(0.301)	(0.078)	(0.115)
	$\Delta Y_{i,t}/Y_{i,t-1}$	-0.001	0.028*	0.015*	-0.010	0.017	-0.054*	0.002	-0.023*
		(0.004)	(0.011)	(0.008)	(0.010)	(0.013)	(0.026)	(0.008)	(0.007)
	$\Delta Y_{i,t-1}/Y_{i,t-2}$	0.004	0.028	-0.008	-0.013	0.003	-0.017	0.002	-0.009
		(0.004)	(0.010)	(0.008)	(0.010)	(0.011)	(0.014)	(0.007)	(0.006)
	$CF_{i,t}/K_{i,t-1}$	0.090*	0.087	0.242*	0.185*	0.133*	0.074*	0.147*	0.120*
		(0.013)	(0.021)	(0.029)	(0.037)	(0.047)	(0.027)	(0.035)	(0.034)
	$CF_{i,t-1}/K_{i,t-2}$	-0.011	-0.010	0.154*	-0.093*	-0.055	0.000	0.009	0.018
		(0.015)	(0.023)	(0.031)	(0.045)	(0.045)	(0.059)	(0.037)	(0.035)
Constrained	$I_{i,t-1}/K_{i,t-2}$	0.153*	0.245*	0.127*	0.234	-0.008	0.335	0.209*	0.087*
(small)		(0.025)	(0.107)	(0.063)	(0.170)	(0.094)	(0.324)	(0.066)	(0.042)
	$\Delta Y_{i,t}/Y_{i,t-1}$	0.007*	-0.074*	-0.012*	-0.075	0.021	0.013	0.014*	0.019*
		(0.003)	(0.021)	(0.005)	(0.056)	(0.013)	(0.028)	(0.006)	(0.008)
	$\Delta Y_{i,t-1}/Y_{i,t-2}$	0.008*	-0.067*	-0.010	0.044	0.023	0.011	0.029*	0.005
		(0.003)	(0.025)	(0.007)	(0.047)	(0.013)	(0.019)	(0.006)	(0.007)
	$CF_{i,t}/K_{i,t-1}$	0.132*	0.231*	0.096*	0.518*	0.239*	0.419*	0.028	0.057*
		(0.013)	(0.060)	(0.026)	(0.111)	(0.048)	(0.092)	(0.022)	(0.026)
	$CF_{i,t-1}/K_{i,t-2}$	0.043*	-0.006	0.050*	-0.128	0.315*	0.349*	0.028	0.025
		(0.013)	(0.051)	(0.025)	(0.107)	(0.045)	(0.086)	(0.023)	(0.033)
difference CF/K long run		0.108*	0.202	-0.236*	0.406	0.449*	1.035	-0.115*	-0.069
		(0.029)	(0.113)	(0.066)	(0.234)	(0.107)	(0.785)	(0.046)	(0.093)
Threshold value		151	62	111	75	99	139	141	142
confidence interval		[147,770]	[61,63]	[105,115]	[74,90]	[99,114]	[128,145]	[137,205]	[139,146]
LR_0		40.3	81.3	53.3	45.9	67.6	65.8	48.3	59.7
%cons	1981	63.6	14.5	58.4	20.6	43.7	25.0	58.6	55.8
	1982	64.9	18.3	61.3	20.0	43.7	31.6	58.3	59.7
	1983	64.2	20.3	63.2	20.4	40.6	33.3	60.4	60.6
	1984	67.1	21.5	61.9	23.7	44.9	30.0	59.1	69.5
	1985	65.5	16.7	63.5	23.3	37.1	26.3	59.5	68.0
	1986	65.1	13.4	62.4	18.7	41.4	17.6	56.0	76.6
	1987	62.0	11.2	62.5	14.9	34.4	25.0	53.2	75.0
	1988	61.7	7.5	60.0	15.3	34.9	31.2	59.8	77.3
	1989	60.4	4.6	59.4	14.9	36.8	40.0	66.7	73.8
	1990	63.0	9.4	60.3	15.9	38.7	33.3	65.3	65.9
#firms		1231	233	246	167	143	36	265	141
#obs.(useable)		5572	1081	1015	882	664	186	1206	538

* Indicates significance at the 5 % level.

Notes: (1) The dependent variable is $I_{i,t}/K_{i,t-1}$. For variable definitions, see main text and Data Appendix. (2) All equations are estimated in first differences to eliminate firm-specific fixed effects. Time dummies are included in the regression models. The threshold estimation technique is described in the main text. (3) All standard errors in parentheses are robust to heteroscedasticity. (4) The ISIC codes in column headings are defined in Data Appendix together with corresponding industry names. (5) The *difference CF/K long run* is the difference between the long run cash flow coefficient for assumed constrained and unconstrained firms. (6) The LR_0 test tests the null hypothesis of no threshold. (7) *%cons* describes the proportion of constrained firms each year.

Table 1. Basic results from threshold estimation in an investment model. Firms' size used as split criterion

Time-dummies:		With 35-36	Without 35-36
Unconstrained (large)	$I_{i,t-1}/K_{i,t-2}$	0.236*	0.178
		(0.070)	(0.099)
	$\Delta Y_{i,t}/Y_{i,t-1}$	0.017	0.014
		(0.013)	(0.013)
	$\Delta Y_{i,t-1}/Y_{i,t-2}$	0.003	0.001
		(0.011)	(0.012)
	$CF_{i,t}/K_{i,t-1}$	0.133*	0.142*
		(0.047)	(0.048)
	$CF_{i,t-1}/K_{i,t-2}$	-0.055	-0.016
		(0.045)	(0.076)
Constrained (small)	$I_{i,t-1}/K_{i,t-2}$	-0.008	0.054
		(0.094)	(0.125)
	$\Delta Y_{i,t}/Y_{i,t-1}$	0.021	0.027*
		(0.013)	(0.014)
	$\Delta Y_{i,t-1}/Y_{i,t-2}$	0.023	0.026*
		(0.013)	(0.012)
	$CF_{i,t}/K_{i,t-1}$	0.239*	0.252*
		(0.048)	(0.051)
	$CF_{i,t-1}/K_{i,t-2}$	0.315*	0.201*
		(0.045)	(0.055)
difference CF/K long run		0.449*	0.325*
		(0.107)	(0.104)
Threshold value		99	109
confidence interval		[99,114]	[99,111]
LR_0		67.6	59.3
%cons	1981	43.7	48.8
	1982	43.7	43.7
	1983	40.6	43.5
	1984	44.9	47.8
	1985	37.1	43.5
	1986	41.4	46.6
	1987	34.4	39.1
	1988	34.9	38.1
	1989	36.8	45.6
	1990	38.7	48.4
#firms		143	143
#obs.(useable)		664	664

* Indicates significance at the 5 % level.

Notes: Similar to the ones in Table 1 except for (2). Here in Table 2 we exclude the time-dummies in one of the specifications.

Table 2. Threshold estimation, further specification
With and without time-dummies

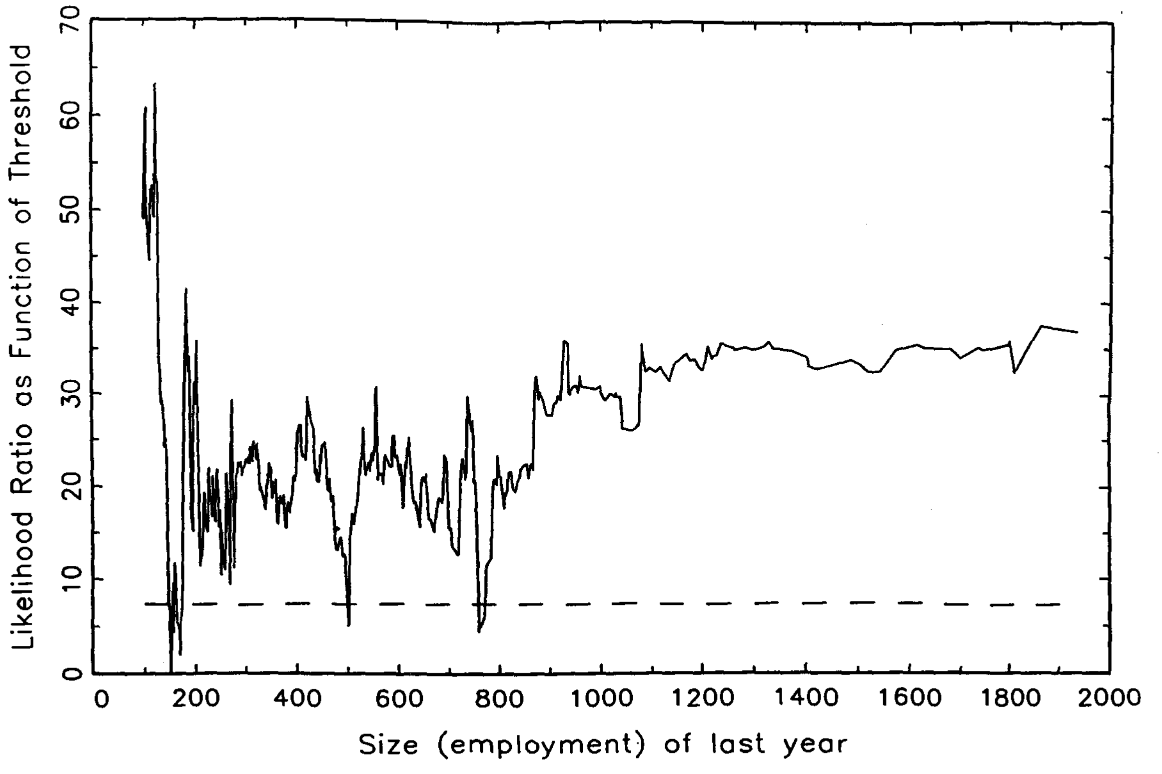
Period:		Before 35-36	After 35-36
Unconstrained (large)	$I_{i,t-1}/K_{i,t-2}$	0.108	0.301*
		(0.073)	(0.111)
	$\Delta Y_{i,t}/Y_{i,t-1}$	0.009	-0.018
		(0.018)	(0.025)
	$\Delta Y_{i,t-1}/Y_{i,t-2}$	0.002	0.001
		(0.013)	(0.018)
	$CF_{i,t}/K_{i,t-1}$	0.051	0.116
		(0.046)	(0.070)
	$CF_{i,t-1}/K_{i,t-2}$	0.031	-0.123
		(0.042)	(0.105)
Constrained (small)	$I_{i,t-1}/K_{i,t-2}$	0.044	0.000
		(0.060)	(0.177)
	$\Delta Y_{i,t}/Y_{i,t-1}$	0.009	0.061
		(0.015)	(0.033)
	$\Delta Y_{i,t-1}/Y_{i,t-2}$	0.033*	0.057
		(0.017)	(0.029)
	$CF_{i,t}/K_{i,t-1}$	-0.013	0.283*
		(0.043)	(0.065)
	$CF_{i,t-1}/K_{i,t-2}$	0.142*	0.232
		(0.062)	(0.119)
difference CF/K long run		0.042	0.525*
		(0.125)	(0.233)
Threshold value		84	100
confidence interval		[80,84]	[99,109]
LR_0		30.3	59.3
%cons	1981	36.3	
	1982	37.5	
	1983	33.2	
	1984		
	1985		
	1986		
	1987		34.4
	1988		36.5
	1989		36.8
	1990		38.7
#firms		95	86
#obs.(useable)		229	246

* Indicates significance at the 5 % level.

Notes: See Table 1.

Table 3. Threshold estimation, different time-periods
Before (1981-1983) and after (1987-1990) deregulation of capital market.

Figure 1. OVERALL



Note: The likelihood ratio is described by equation (9) in the main text. This figure supplements the results reported in column (i) in Table 1.

Figure 2. Food (31)

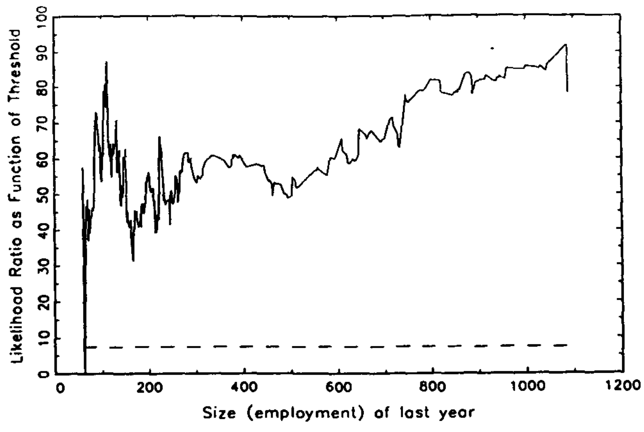


Figure 2. Textiles, Wood Products (32–33)

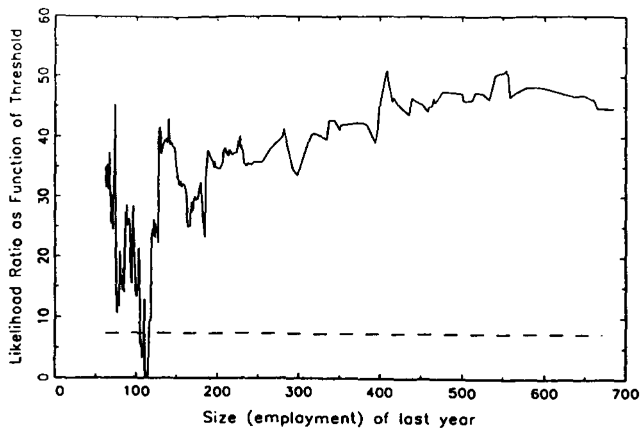


Figure 2. Paper and Printing (34)

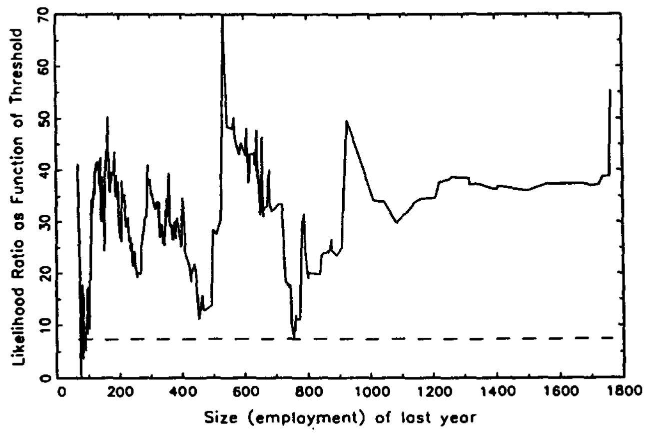


Figure 2. Chemicals and Minerals (35–36)

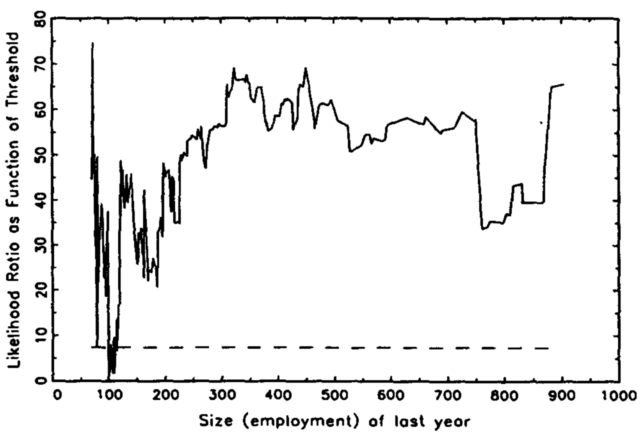


Figure 2. Metals (37)

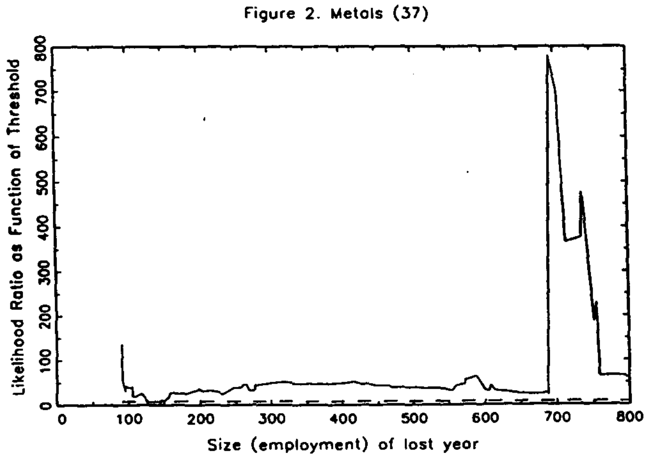


Figure 2. Metal Products, Machinery, Elect. Eq. (381–383)

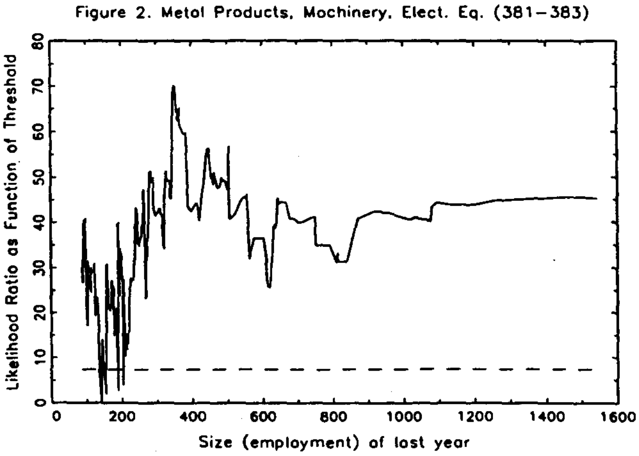
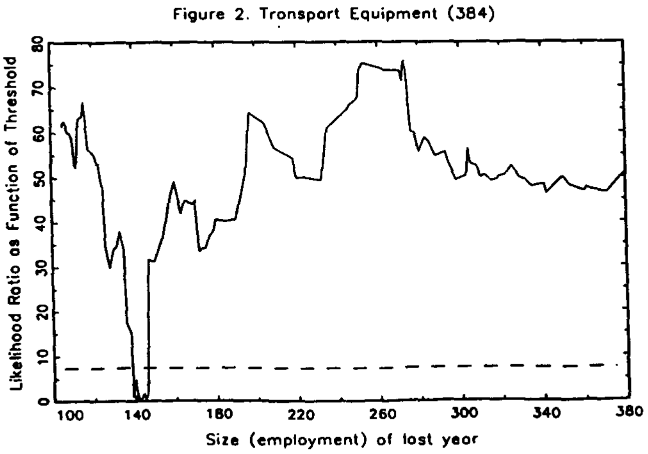


Figure 2. Transport Equipment (384)



Note: The likelihood ratio is described by equation (9) in the main text. These figures supplement the results reported in columns (ii)-(viii) in Table 1.

Figure 3. Percentage constrained

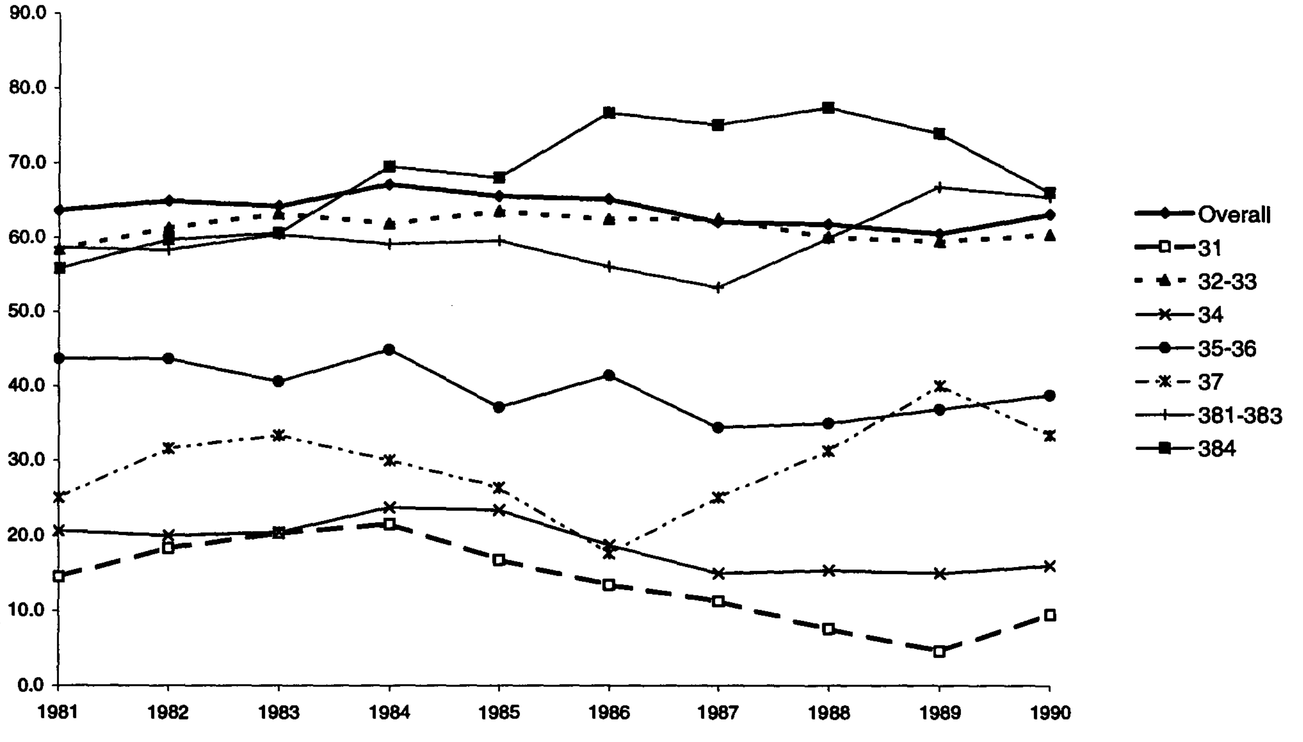
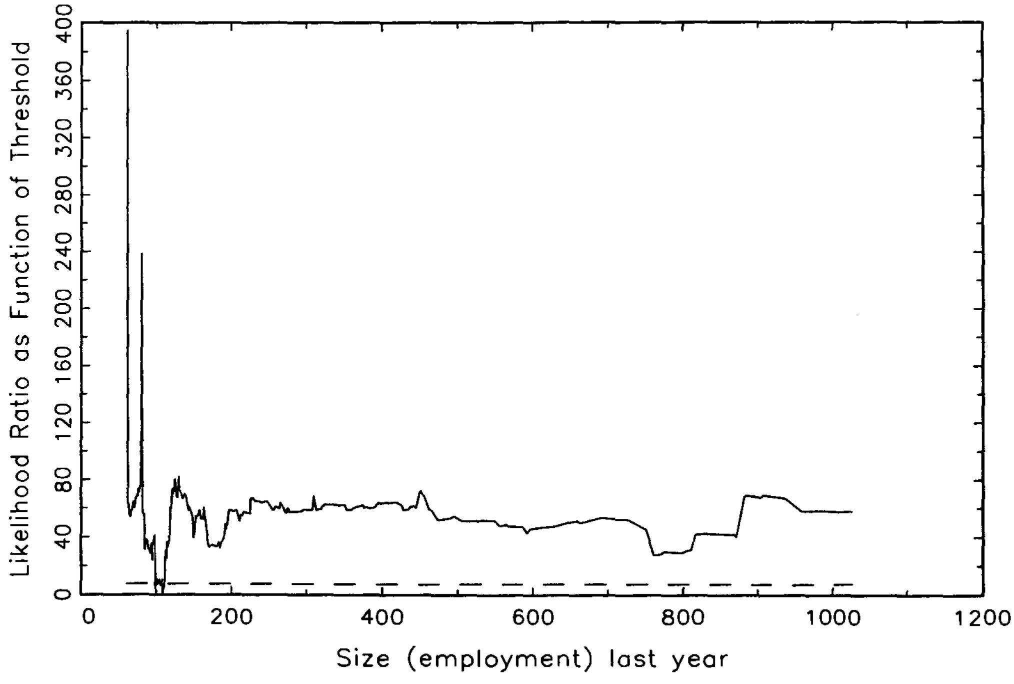


Figure 3 reports the proportion of constrained firms in different industries. The figures correspond to the figures in the lower part of Table 1. See Table 1 for more details.

Figure 4. Chemicals and Minerals (35–36)



Note: The likelihood ratio is described by equation (9) in the main text. This figure supplements the results reported in the second column of Table 2.