Manufacturing Investments in Norway – The Effects of Internal Funds and Credit Spreads[*] [†]

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Abstract

This paper shows how the investment Euler equation may be extended to capture the cost of external funding and the tightness in the credit market. The theoretical model is tested empirically on aggregated time series data for the manufacturing industry in Norway. I find empirical support for the theoretical model, and present a model where real aggregated investments are explained by the cost of external finance, production, profitability, and the credit spreads. Aggregated manufacturing investments are modeled using the bounds testing approach, together with the error correction framework using national accounts figures and financial statistics. I find that an increase in the cost of external funding relative to the cost of internal funding reduces the return on investments. The analysis shows that a one percentage point increase in the credit spread decreases investments with 7 percent. The profit ratio is known to be essential for investments. I find that the effect of a one percent increase in the profit to production ratio raises investments with a rate of 0.13 percent

Keywords:

JEL Classfication: E22, E27

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1 Introduction

In the decades before the Great Recession, there were larger fluctuations in fixed investments than there were in both private and public consumption, see Figure 1 for data from the National Accounts of Norway. The large fluctuations in investments amplify the booms and busts during the business cycle. Hence, being able to predict investment is of utmost importance for central banks and governments.

The discussion in the first paper of this thesis showed that an overweight of the firms in the manufacturing industry, and particularly small firms and middle-sized firms, do not use conventional capital budgeting models when planning their investments. They base their investment decisions partly on gut feeling. This is not the same as saying that the economic conditions are not affecting aggregate investments, but that it is more to it than what can be explained by the behavior of rational agents. Hence, a broader set of models is needed. This raises an important question – is it possible to incorporate the rule of thumb behavior into the investment theories? Motivated by those findings, the second paper in this thesis discusses a panel data study on manufacturing firms that were designed to address the questions raised in the first paper of this thesis. The panel data study of the behavior of the manufacturing industry showed that expected demand and firms' access to credit explains most of the short-term movements in real investments. Factors that enter typically in the net present value calculations, such as funding costs, product prices, and product costs, fail to explain the short-term change in investments. Following the results of the second paper of this thesis, it is evident that capturing firms' access to credit and demand expectations are crucial for forecasting and understanding the short-run movements in real investments. In this paper, I have chosen to study aggregate data from the national accounts, even though there has been a shift in empirical macroeconomic studies towards using firm-level data instead of aggregate data. Increased availability of firm-level data in the last couple of decades explains this shift, together with the fact that it increases the possibility of identifying the effects one is studying. Firm-level studies are essential and may shed light on aspects that are not in reach with an aggregated approach. Forecasting fixed investments are crucial for central banks when it is setting the policy rate, and for that, one needs an aggregate approach. This paper contributes to the literature by showing an alternative way to extend the Tobin's Q-model, Tobin (1969) and the investment Euler equation to capture the effects of credit constraints and the cost of external finance. To test the model, an empirical investment Euler equation is estimated with aggregate data. In contrast to the standard approach, I assume imperfect capital markets and applying the insights from the first paper, which showed the importance of capturing the effect of credit constraints.

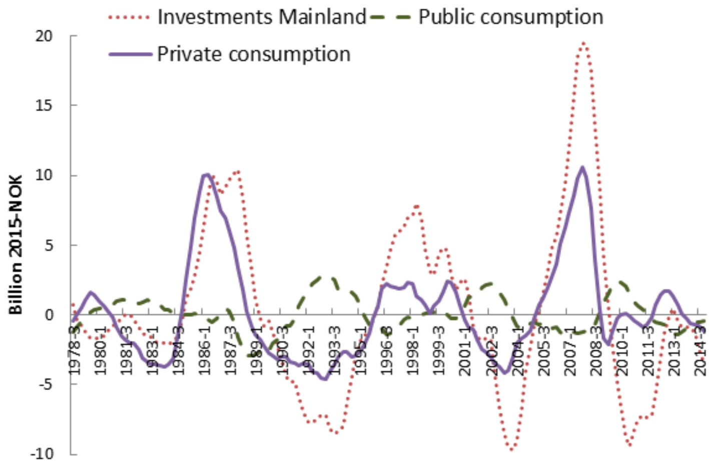


Figure 1: **Key components of Mainland GDP in Norway measured as deviation from its HP-trend in bill. 2012-NOK**. *Source*: Statistics Norway. Due to the high volatility of the national account data, the HP-filter have a smoothing parameter, lambda, of 20.000

The Q-model is known for its usual assumption about the quadratic installation cost function – the cost of installing an extra unit of capital. My approach is to apply a cost function dependent on internal funds and credit market conditions[1]. I use the slightly more general approach from Kaplan and Zingales (1997) as a motivation for the cost function. The extension of the Q-model to capture credit constraints gives a theoretical investment model based on Neoclassical theory, which captures the effect of financial constraints and funding sources on the firms' investment behavior. The theory model shows how aggregated investments depend positively on production and internal funds, and negatively on financial constraints.

To test the theory model, I apply the bounds testing approach for non-stationary time series data. I refer to Pesaran et al. (2001) for a discussion of this empirical approach. The results from the empirical analysis shows that the theory model outlined cannot be rejected when using data for the manufacturing industry in Norway. Investments, production, profits, and credit market conditions form a stable long-run relationship. A highlighted result is that it is necessary to include the credit market conditions in the empirical model for finding a stable long-term relationship. The credit market conditions are particularly crucial for explaining the periods where investments depart from the production and profit ratio trend. The empirical analysis excludes the user cost of capital from the long-run relationship; however, it plays a role in understanding the short-run movements. The reason

[1]An alternative could be to include two cost functions; the installation cost function and the external funding cost function. To simplify the analysis, this paper chooses to include only the latter cost function.

that the empirical analysis excludes the user cost of capital from the long-run relationship may be due to several factors. Two relevant factors are that changes in producer prices are usually small and moving slowly, making it difficult to identify any effect of changes in user costs on investments. Second, because the life of an investment project stretches over several years, it is the expected long-term interest rate, and not the short-term interest rate, that matters when firms make their investment decision. Both arguments make it challenging to identify any effects of the user cost of capital because the firms' expected long term interest rate is not known.

This paper continues with a discussion of relevant literature in Section 2, the theoretical model is presented in Section 3, the data is presented in Section 4, a discussion of the empirical methodology is given in Section 5 and Section 6 covers the empirical testing of the theory model. Section 7 summarizes the paper.

2 Literature review

There has been a large body of research over the last 10-30 years with a focus on explaining the lumpy behavior of real investments. While the early empirical studies focused on aggregated data, see e.g. Bean (1981) or Bernanke (1983), more recent research has been analyzing firm-level data, see e.g. Bloom et al. (2007) or Eklund (2010). Firm-level studies have increased our understanding of the lumpiness at the aggregated level. Contributions by Doms and Dunne (1998), Thomas (2002) together with Gourio and Kashyap (2007) showed that changes in the extensive margin, the fraction of firms investing, explains the lumpiness in aggregate investment. According to Bachmann et al. (2013), it is not the intensive margin, the size of each firm's investment, that fluctuates over the business cycle. Lumpy investment behavior has been studied using different approaches. Kahn and Thomas (2008) apply a generalized (S,s) model, Sveen and Weinke (2007) apply a New-Keynesian model and Bachmann et al. (2013) apply a DSGE model. Although all three approaches contribute with interesting findings, none of them pin-point which factors are driving the lumpiness, and by this explains drivers of the lumpy behavior.

While the early investments models of Jorgenson (1963) and Tobin (1969) explained the capital adjustment process with the development in expected profitability without uncertainty or imperfections in the capital markets, the focus of recent decades has been at studying the effects of uncertainty, as in Abel et al. (1996), Abel and Eberly (1996), Caballero and Pindyck (1996), Bertola (1998), Bond et al. (2004) and Bloom et al. (2007).

A large body of research on capital structure and uncertainty, pioneered by the work of Merton (1973), and followed up by Jensen and Meckling (1976), have shed light on the importance of imperfections in the capital market. The effect of liquidity constraints on investments is studied in the empirical work by many, and particularly by Schiantarelli (1996). Alfaro et al. (2016) study the interaction between uncertainty and liquidity constraints, and show that a shock in uncertainty amplifies the effect of liquidity constraints on investments and vice versa. Empirical studies by Fazzari et al. (1988), Kaplan and Zingales (1997), and Bond and Van Reenen (2007) have shown the importance of cash flow and profits for explaining firm investment. The argument is that because of liquidity constraints; retained earnings are crucial for financing investments.

Estimating models based on the Q-theory failed for many years, Galeotti and Schiantarelli (1991). Cooper and Ejarque (2001) and Galeotti and Schiantarelli (1991) showed how the introduction of market power improved the empirical properties of the Q-model. Another strategy has been to augment Q-models with capital gearing and production as in Cuthbertson and Gasparro (1995) or with retained earnings as in Fazzari et al. (1988) and more recently in Eklund (2010). In a paper by Andrei et al. (2018) show that Tobin's Q explains a large share of the investment behavior without including other factors. Rauh (2006) expands the cost function of the Q-model, such that the model capture credit constraints and exploit the mandatory pension plan payments to identify the effect on reduced cash flow on investments for financially constrained firms.

Bernanke and Gertler (1995) discusses the effect of the credit channel on the optimal investment level. Relevant for the empirical modeling of investments, they highlight that short term interest rates should not affect investments, because most investment projects stretch over a longer horizon. If so, the Jorgenson and Hall (1967) user cost of capital should be insignificant for explaining investment behavior at the aggregate level. Gertler et al. (2007) build a macroeconomic model with a financial accelerator showing how lending affects real variables, such as investments. Particularly interesting for my paper is the effect of the external finance premium. Gertler et al. (2007) show how the leverage ratio plays an essential role in explaining the fluctuations of real investments. Benedictow and Hammersland (2016) study the credit channel using aggregate data on Norwegian businesses. They find a positive link between credit, stock markets, and investment for a part of the industries in Norway.

Two recent articles that study how credit and banking affect real investments are Balduzzi et al. (2017) and Cingano et al. (2016). Balduzzi et al. (2017) find that business investments, particularly for small firms, depend heavily on the banks' funding costs. While Cingano et al. (2016) show using a two-stage procedure to study how real investments are affected by a credit tightening that was caused by a liquidity shock.

In an empirical analysis, Kothari et al. (2014) present evidence for the importance of profits and stock prices on aggregate corporate investments. However, Kothari et al. (2014) focuses on short-run effects and do not address the issue of non-stationarity of the data. The study that is closest to mine is a paper by Love (2003). She shows how an investment Euler equation can be extended to take into account the effect of financial constraints. In her reduced-form model, it is shown that cash flow and production affect investments. I extend the work of Love (2003) by taking explicitly into account credit market conditions into the theoretical and empirical model.

3 The investment model

This section discusses the theoretical investment model. In this model, aggregate production is represented by a standard Cobb-Douglas production function. The production function includes a supply shock parameter, A, real capital, K, and labor, L, and is given by

$$X_t = A_t K_t^{\alpha} L_t^{1-\alpha} \tag{1}$$

where X_t is gross production, α is the capital share in the production function, $1-\alpha$ the labor share. There are constant returns to scale, and labor is fully flexible, such that firms may hire the necessary employment given its capital stock. Production is increasing and concave in capital and labor, ie. $\partial X/\partial K > 0, \partial^2 X/\partial K^2 < 0$, $\partial X/\partial L > 0$, and $\partial^2 X/\partial L^2 < 0$. The choice of using a Cobb-Douglas production function instead of a more general CES-function is not important for the results in this analysis.

I follow the setup of the Q-model with one exception – the cost function. In this model, there is no explicit cost of installing new capital. To leave out the installation cost function is a choice I have done to simplify the analysis. Instead, the cost function is dependent on the change in the credit market conditions and the cost of external funding. The cost function is building on work by Kaplan and Zingales (1997). The cost of external funding is also discussed in Fazzari et al. (1988), but they choose a different strategy and focus on how constraints are affected by firm size. See also Fazzari et al. (2000) for a critique of the approach in Kaplan and Zingales (1997).

The motivation for studying the wedge between the costs of internal and external funding is that the wedge is counter cyclical and consequently is an important factor for explaining the increase in financing costs through the life of a business cycle. Essential for understanding the effect of this wedge, is the fact that cost of internal funds equals the alternative cost of capital, while the cost of external funds is driven up by several factors, such as the information wedge between insiders (equity holders) and outsiders (debt holders), see Jensen and Meckling (1976).

In this paper, the cost of external funds is a function of the investment level, the size of the internal funds available, and the credit spread between average bank loans and the interbank offered rate. The spread typically increases when the competition in the bank loan market is weak or when the banks' funding costs increase, as might happen when the financial supervisor authorities apply stricter bank regulation schemes. An increase in the cost of external funds is assumed to be independent of the firms' investment level and the level of internal funds. Hence, no direct feedback from investments to financial conditions is assumed. This might seem like a strong assumption, but it is worth noting that it is typically financial and not real investments that cause the largest movements in the credit market. External funds is defined as the difference between investments and internal funds: $EX_t = I_t - M_t$. I follow the approach used by Summers (1981) when I design the cost function:

$$(2) \quad C_{EX}(I_t, M_t, S_t) = \frac{1}{2} b S_t \frac{I_t}{M_t}^2,$$

where b is the cost parameter deciding the firms' sensitivity to changes in the spread or the investment to internal funds ratio, S_t is the interest rate spread, I_t is investments and internal funds available at time t are M_t. Internal funds is a function of accumulated profits up to time $t-1$ less dividends payed that period. This give us the reasonable interpretation that, if a firm have been profitable in the past, their funding cost will be lower today. For a positive b, the costs of investing will be positive even in the situation where $I_t = M_t$, and there is no need for external funding. As in Kaplan and Zingales (1997) the cost function is increasing and convex in investments, i.e., $C'_{EX}(I_t) > 0$ and $C''_{EX}(I_t) > 0$, meaning that the higher an investment is, the higher are the cost of external funds. Further, it is assumed that the costs accelerate when the investments increases. The cost function is decreasing and convex in internal funds, ie. $C'_{EX}(M_t) < 0$ and $C''_{EX}(M_t) > 0$. Thus the cost of external funds decreases with the amount of internal funds, but the cost reduction is declining in internal funds. Another way of telling this story, the firms cost of external funds is lower the more profitable a firm has been in the past.

This way of modeling credit constraints may be seen as a reduced form model for the banking sector. The interest rate spread capture changes in the market for bank funding. Gertler and Kiyotaki (2010) present a baseline model for evaluating frictions in the banking sector. Their model implies that the interest rate spread rises when asset prices decline. This is because of the reduction of the net worth of the banking sector that a broad decline in asset prices generates.

The profit at the current time period, t, is given by the revenue less variable costs and investment costs:

$$P_X X_t(A_t, K_t, L_t) - wL_t - C_{EX}(S_t, I_t, M_t) - P_K I_t,$$

where P_X is the product price, P_K is the price of one unit of capital and w_t is the cost of one unit of labor.

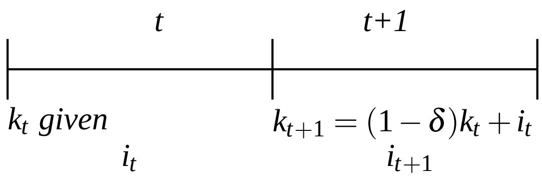


Figure 2: Timing of the events

The capital stock grows according to the capital law of motion, $K_{t+1} = I_t + (1-\delta)K_t$, where δ is the depreciation rate. If we take the profit function as given, including future periods and use the discount factor, β, to find the discounted net profit over an infinite time horizon. I can then set up the Bellmann equation:

$$V(K_t) = \max_{I_t} \left\{ P_X X_t(A_t, K_t, L_t) - P_K I_t - \frac{1}{2} b S_t \frac{I_t^2}{M_t} - wL_t + \beta E_{t+1} V(K_{t+1}) \right\}, \tag{3}$$

subject to

$$K_{t+1} = I_t + (1-\delta)K_t$$

where E_{t+1} is the expectation at time $t+1$, given the information the agent has on time, t. Solving this problem gives us our first order condition (FOC):

$$\frac{\partial V(K_t)}{\partial I_t} = -P_K - bS_t \frac{I_t}{M_t} + \beta E_{t+1} \frac{\partial V(K_{t+1})}{\partial K_{t+1}} \frac{dK_{t+1}}{dI_t} = 0 \tag{4}$$

From the capital law of motion, we have $dK_{t+1}/dI_t = 1$, such that (4) is simplified to

$$\frac{\partial V(K_t)}{\partial I_t} = -P_K - bS_t \frac{I_t}{M_t} + \beta E_{t+1} \frac{\partial V(K_{t+1})}{\partial K_{t+1}} = 0 \tag{5}$$

The last term in the FOC (5), $\frac{\partial V(K_{t+1})}{\partial K_{t+1}}$, is the shadow price of capital, normally labeled λ_{t+1}. If we set $q_{t+1} = E_{t+1}\lambda_{t+1}\beta$ and solve for investment in the FOC, we get the equation for the optimal investment at time t:

$$I_t = \frac{M_t}{S_t b}(q_{t+1} - P_K) \tag{6}$$

This is the well-known result from the Tobins Q-model, Tobin (1969) – one should invest when the shadow price of capital is larger than the price of investing in one extra unit of capital. Contrary to traditional Q-model, the effect of a high q on the investment is positively affected by the amount of internal funds, and moderated by the cost parameter and by the interest rate spread. If the interest rate spread increases, then the optimal investment level goes down. Likewise, if the amount of internal funding decreases the weighted average cost of the funding goes up, and this decreases the net discounted value of the investment project. Hence investments go down. This is typical for economic downturns. Low competition in the banking sector during downturns, due to reduced lending willingness, will lead to an increase in the interest rate spread. If at the same time, firms are struggling to finance new investments with retained earnings due to lower profits, then the decline in the aggregate investment demand is amplified because of the increased funding cost. One will be in the same situation if the investment demand comes from young firms and start-ups without sufficient amounts of equity and hence need to fund itself with external capital.

To solve for the investment Euler equation I apply the envelope theorem

$$(7) \quad \frac{\partial V(K_t)}{\partial K_t} = \alpha P_X A_t L_t^{1-\alpha} K_t^{\alpha-1} + \beta E_{t+1} \frac{V'(K_{t+1})}{\partial K_{t+1}} \frac{dK_{t+1}}{dK_t}$$

I use the product function to replace $\alpha P_X A_t L_t^{1-\alpha} K_t^{\alpha-1}$ with $\alpha P_X \frac{X_t}{K_t}$. After inserting for the derivative of the capital law of motions with respect to K_t, I get the following:

$$(8) \quad \frac{\partial V(K_t)}{\partial K_t} = \alpha P_X \frac{X_t}{K_t} + \beta E_{t+1} \frac{V'(K_{t+1})}{\partial K_{t+1}} (1-\delta)$$

I continue by inserting for $\frac{\partial V(K_{t+1})}{\partial K_{t+1}}$ and $\frac{\partial V(K_t)}{\partial K_t}$ from the first order condition with respect to investments, (5) into equation (8), and replace $\beta = \frac{1}{1+r}$, which after some rearrangement gives us the investment Euler equation:

$$(9) \quad P_K + bS_t \frac{I_t}{M_t} = \frac{1}{1+r} \alpha P_X \frac{X_t}{K_t} + \frac{(1-\delta)}{1+r} \left[P_K + E_{t+1} b S_{t+1} \frac{I_{t+1}}{M_{t+1}} \right]$$

To get an expression for investment level I rearrange the investment Euler equation:

$$(10) \quad I_t = \frac{M_t}{bS_t} \left[\frac{\alpha}{1+r} P_X \frac{X_t}{K_t} - (r+\delta) P_K \right] + E_{t+1} \left[\frac{\tilde{S}_{t+1}}{\tilde{M}_{t+1}} I_{t+1} \frac{1-\delta}{1+r} \right],$$

where I_t is the firms' investment in period t, X_t is production, K_t is the capital level, M_t is internal funds, S_t is the interest rate spread, b the cost parameter, P_K is the price of capital goods, P_X is the product price, r_t is the interest rate, δ is depreciation rate and α is the capital share. Finally, I let $\tilde{S}_{t+1} = \frac{S_{t+1}}{S_t}$ and $\tilde{M}_{t+1} = \frac{M_{t+1}}{M_t}$. The investment model have a long run part, represented by the first elements on the right-hand-side, and a dynamic short run part, represented by the last element of the right-hand-side.

The interpretation of the Euler equation is that any expected increase in the interest rate spread in the first time period, rise current investment costs and hence increases the relative profitability of investing in the second time period. Any decrease in the expected internal funds shifts investments in the same direction.

The long-run element of the investment model is characterized by a higher investment level when the internal funds rise. This happens either if because profits are above its normal level, or because there is less investment spending. A well functioning credit market is essential for investments. A high interest rate spread makes it costly to fund investments. It may also signal to firms that there are substantial frictions in the financial markets and harming investments by making external funding relatively costly. The higher the real capital level is, all else given, the less are the return to capital of a marginal increase in investments. Hence, the incentives to invest further are damped. Increased production rises the aggregate utilization rate and enhances the need for investing in new capital to meet the increased demand. How the price of capital goods affects investments depends on the size of the depreciation rate and the return on capital. A high depreciation rate reduces the value of investments, and a high return on capital increases the alternative cost of the capital, both negatively affect investments.

From our investment function (10) we expect investment to depend positively on production and internal funds and negatively on the interest rate spread and the user cost of capital. Capital is a function of investments and the depreciation rate; hence, it is left out in the reduced form. Compactly the investment function can be written:

$$(11) \quad I = F(\underset{+}{X}, \underset{+}{M}, \underset{-}{S}, \underset{-}{UC}, \underset{+}{P_X}),$$

where UC is the user cost of capital, capturing the price of capital goods, interest rates, taxes, and depreciation rate.[2]

4 Data and the Norwegian manufacturing industry

Large deliveries of goods and services to the Norwegian offshore oil industry characterizes the Norwegian manufacturing industry. Between a third and a half of the industry have been linked to the oil extracting industry. This makes the industry particularly vul-

[2]Taxes are left out of the model for keeping the specification simple, but may easily be included in the model

nerable to oil-price shocks and less dependent on world markets. For an overview of the characteristics of the Norwegian manufacturing industry, see the discussion in Paper 2.

4.1 Data

To study aggregate investments, I use data from the Norwegian national accounts; this includes data for investment (real prices), gross production (real prices), net profit (nominal prices), and net production (nominal prices). The figures are seasonally adjusted, and the sample period stretches from 1984Q1 till 2013Q4. Data for 2014 and 2015 are preliminary and particularly uncertain. Because of this, data for those years are left out when estimating the model. However, the out-of-sample forecasting includes data for 2014 and 2015. Based on the type of end-product the industry produces the manufacturing industries, the National Account aggregates the industry into four different sub-groups.[3] Figure 3 shows the development to real investment and gross production for the four sub-groups during the observation period.

Without access to data for the internal funds at an aggregated level, I need to proxy internal funds in the empirical model. I use the aggregated profit for the different sectors in the manufacturing industry. To get real profits, I deflate the net profit with net production at a nominal price, which give us the profit to production ratio. The use of the profit ratio as a proxy for accumulated internal funds hinges on the assumption that a high-profit share increases retained profits and hence internal funds.

Bank loan rates for businesses are collected from Statistics Norway's financial statistics, the 3-month Norwegian interbank rate (NIBOR) is from Norges Bank, and the sentiment figures are data from the Statistics Norway's business tendency survey.[4] The interest rate margin is calculated as the difference between the bank loan rate for Norwegian businesses and the NIBOR. The user cost of capital is the traditional Jorgenson and Hall (1967) specification. This specification of the user cost is tested against a version where the interest rate is replaced by its moving average to reduce the effect of short term fluctuations in NIBOR when estimating the user cost and by this, capturing the long-run movements in the interest rate.[5] Figure 5 shows the relationship between the usercost of capital and the interest rate spread during the sample period.

[3] The four industries are, with coding in parenthesis: Food and consumption goods (15), Investment goods and intermediate goods (25), Energy intensive goods and raw materials (30), Shipbuilding and machine industry (45).

[4] All data, except the sentiment data, are merged into one database, used by the Statistics Norway's KVARTS macro model, available on request for researchers.

[5] A moving average with four quarters of lags and leads.

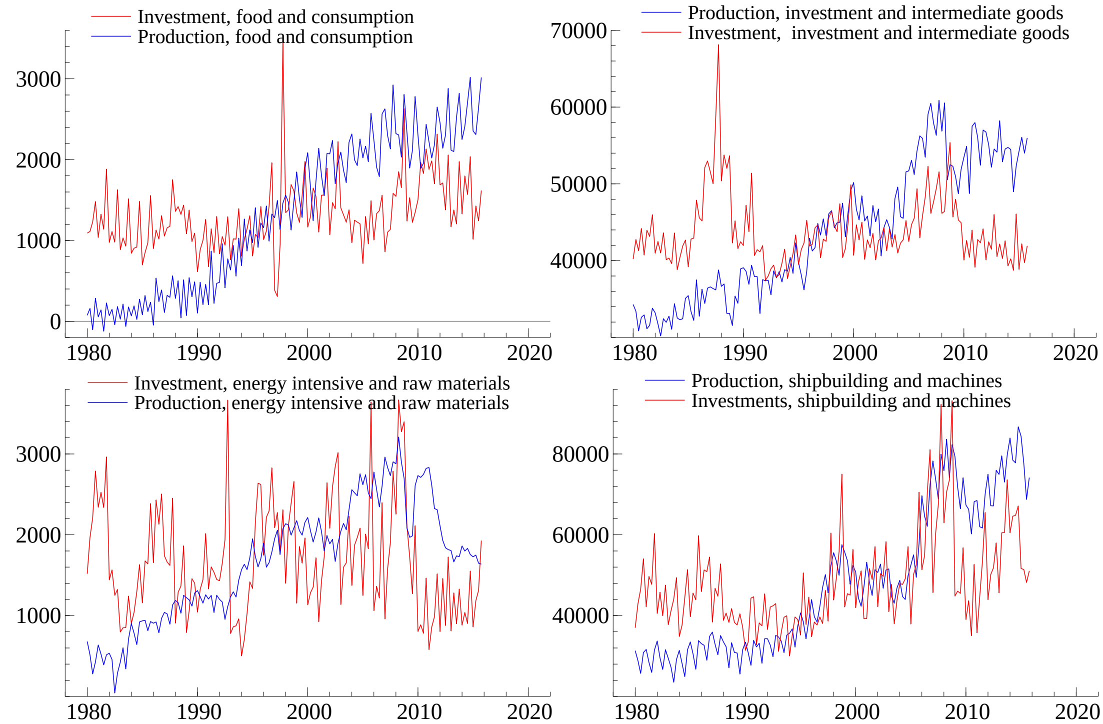


Figure 3: **Real gross investments and real gross production in four different manufacturing industries**. Scaled by means and range, see footnote 4 for labeling details.

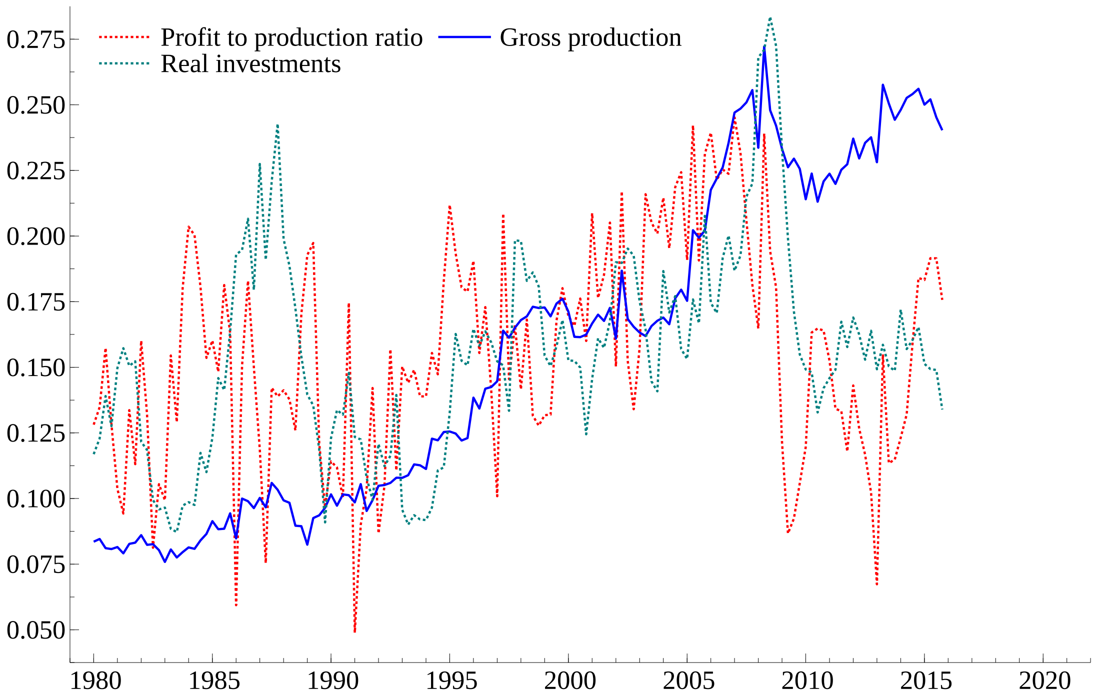


Figure 4: **Real investments, gross production and profit ratio for the manufacturing industry.** Seasonal adjusted, fixed 2013-prices, in logarithmic scale. Real investments and gross production rebased to match profit ratio.

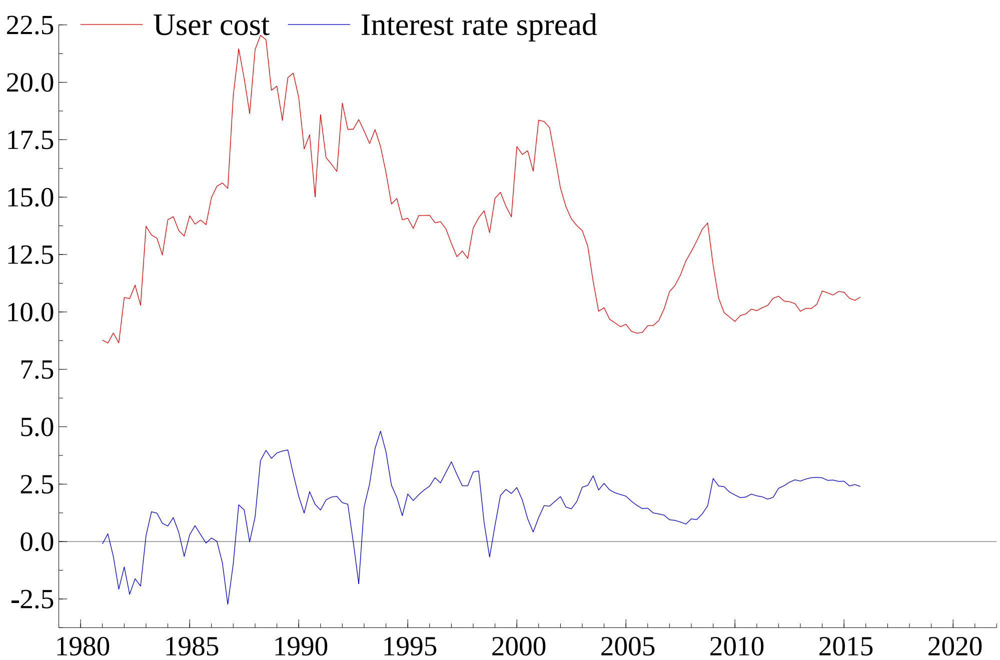


Figure 5: **Interest rate spread and user cost of capital. In percent**
Source: Norges Bank and Statistics Norway

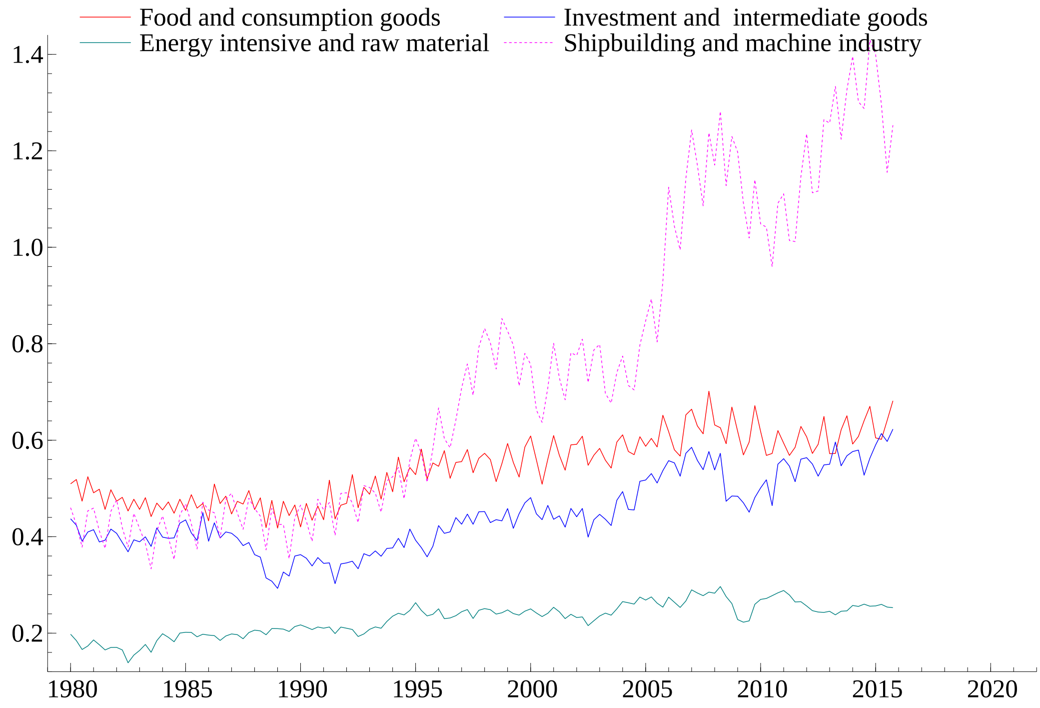


Figure 6: **Gross production to real capital ratio in four different manufacturing industries.** Fixed 2013-prices, in a logarithmic scale

An interesting feature one finds when studying the national account figures for the manufacturing industry is the increased return on capital in the ship, platform, and machine industry during the second half of the 2000s. This industry is mainly producing goods and services to the petroleum industry in Norway and abroad. As shown in Figure 7 the profits in this industry are far above average returns mainly due to the high returns on producing investment goods and intermediate inputs to the petroleum extracting industry during the years of record-high oil and gas prices. A similar picture is drawn in Figure 6, which shows the increase in the production to capital ratio in the same period. For a discussion of the cause of the effects by the deliveries from the manufacturing to the petroleum industry see Cappelen et al. (2013) or Bjørnland and Thorsrud (2016).

5 Empirical testing of the theory model

The last part of this paper will focus on testing empirically the theory model above. The traditional approach when modeling investments is to estimate a model for the investment to capital ratio, or if one abstracts from the depreciation rate – the growth rate of capital. However, the order of integration complicates this way of modeling investments.

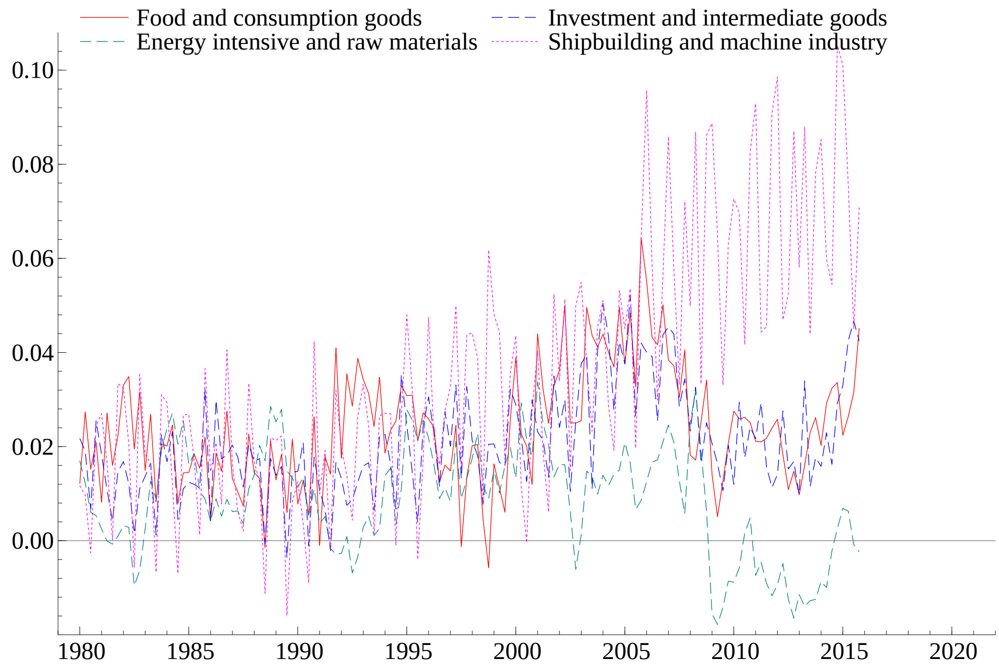


Figure 7: **Real profit to real capital ratio, for the four aggregated manufacturing industries in Norway.**

Aggregate investment is often integrated of order 1, while real capital in many cases is integrated of order 2[6]. Thus, it is not obvious that the growth rate of capital is a stationary time-series. Making the use of traditional estimation methods and specification tests invalid. To come around this, I will first apply the autoregressive distributed lag model (ARDL) with bounds testing as shown by Pesaran et al. (2001). This methodology can deal with the non-stationary we find in most aggregated time series and at the same time study the long-run relationship between the different data series.

The theory model does not impose any a priori parameter values, so it is the role of the researcher to estimate the partial effects of changes in the explanatory variables on the investment growth. I apply an empirical strategy where the long-run structure of the empirical model is linked to the theory model, while the short-run dynamics are freely estimated to enhance its forecasting properties. Eisner and Nadiri (1970) highlight the importance of estimating the coefficients of the Jorgenson investment model freely and letting data decide, instead of using the a priori restrictions given by the theoretical model. Following Eisner and Nadiri (1970), I do not estimate the exact theoretical specification, but a linearized version without any further restrictions. I will then let data and the relevant

[6]Depending on how I structure the ADF-test, I find that capital in the Norwegian manufacturing industry is of order 1 or order 2

tests decide which restrictions that hold.

A conventual method of specifying an empirical Euler equation is to use the hybrid modeling approach, see Fuhrer and Rudebusch (2004). Using a similar approach on the theoretical investment equation (11) where $E[I_{t+1}]$ is approximated with $\alpha_1 i_{t-1} + \alpha_2 i_{t-2} + \mu E_{t-\tau} i_{t+1}$, where $E_{t-\tau}$ is the expectation operator at time $t-\tau$ with $\tau \in [0,1]$ and τ is the timing of the expectation formation. When τ is equal to 1, then the model is estimated on expectations formed on information until the quarter a head of the quarter where the investment is implemented.

We now have the following empirical specification:

$$
\begin{aligned}
(12) \quad i_t =& \alpha_0 + \alpha_1 i_{t-1} + \alpha_2 i_{t-2} + \mu E_{t-\tau} i_{t+1} + \beta_1 E_{t-\tau} (m_{t-n} - \theta_1 S_{t-n}) + \\
& \beta_2 (x_{t-n} - \theta_2 k_{t-n}) + E_{t-\tau} \frac{1}{\kappa} \sum_{j=0}^{\kappa-1} \theta_2 uc_{t+j-n} + \eta_t,
\end{aligned}
$$

where i_{t+s} the log investment level at time $t+s$ with $s \in [-2,1]$. The explanatory variables are; m_t the log profit to production ratio as a proxy for internal funds, S_t the interest rate spread, x_t the log gross production, k_t the log real manufacturing investments, uc_t the user cost of capital. The lag of the explanatory variable is given by the parameter n, with $n \in [1,4]$. Long term interest rates may play an important role in the firms' expectation about the user cost of capital. Where, $j = \kappa > 0$ include lead interest rates. Using forward rate agreements (FRA) as a proxy for the lead interest rates is meaningful from an empirical and theoretical stand point, but as shown in Paper 1, the FRA rate is not commonly used by practitioners.

A challenge when studying investments is the fact that there is potentially a substantial lag from when the firm takes its investment decision and until the actual change in investments happens. Hence, firms' investment decision is taken up to several quarters before the investment is effectuated, meaning that it is lagged variables that explain investments, unless the firms have expectations that are not backward looking. See Haavelmo (1960) for a good discussion on the lag from decision to action. Hence, the hybrid model is particularly suited for studying the empirical validity of an investment model with lagged explanatory variables $(n > 0)$. It is not obvious which lag that affects firms investment decision, so I let the empirical analysis decide on which lag to include in the model. The time lag from decision to investment, make it relevant to let the expectations be formed a quarter before the investment is measured in data $(E_{t-\tau} = E_{t-1})$.

I will start the empirical analyses with the long-run investment model. In addition to the explanatory variables, a constant is added to capture the constant maintenance investments and depreciation of capital, and I also test if a trend is needed to capture any unexplained effects growing over time. If we allow for a longer adjustment process and assume that expectations are formed with adaptive expectations during the months before the data is observed we may rewrite model (12) to become a general error correction model (ECM):

$$\text{(13)} \quad \Delta i_t = \alpha_0 + \sum_{i=0}^{q-1} \alpha_i^* \Delta \mathbf{z}_{t-i} + \sum_{i=1}^{p-1} \beta_i^* \Delta i_{t-1} - \beta(i_{t-1} - \theta' \mathbf{z_{t-n}}) + \kappa \mathbf{c} + u_t,$$

where α_0 is the first element of the constant, Δ is the difference operator, $\mathbf{z_t}$ is a vector of explanatory variables, where the $\alpha's$ are the short-run adjustment parameters, $\mathbf{c}$ is a vector of deterministic variables, such as time dummies and the possibility of a trend. Moreover, u_t is the error with zero mean and constant variance, σ^2. We recognize $\beta(i_{t-1} - \theta' \mathbf{z_{t-n}})$ as the long-run empirical specification. Where β is the adjustment coefficient, and θ is the cointegrating vector. If there is a short time-lag from when the firms' make their decisions to their investment is effectuated, and there is available capacity, then the speed of adjustment will be high – hence the response of changes to the driving factors of investment is fast. Likewise, if the effect on the investments of any changes in the covariates is short-lived, then few lags of the change in z are included in the model, and hence q, is small, and there are few lags of the exogenous variables included in the econometric model.

Unit root and Bounds testing

The ECM builds on a fundamental assumption. That is the stationarity of the left and right-hand side of equation (13). With non-stationary data, this is the case if the variables in the long run solution are cointegrated. Cointegration describes the situation where the variables are typically individually integrated of order one, I(1), while at the same time, there exists a linear combination of the variables that are stationary. It is important to note that if the level variables are I(1), then the Δ-terms are stationary, I(0). Because cointegration as known from Engle and Granger (1987) requires that the variables in the long term relationship all are non-stationary and integrated of order 1, it is crucial for using this methodology that the properties of the variables are as assumed by the researcher.

The standard test for stationarity is the Augmented Dickey-Fuller (ADF) test. Using this test, I find that the Δ-terms are stationary. However, the ADF-tests for investment and the level variables in the $\mathbf{z}$ vector are inconclusive. Some of the variables are stationary, and other variables are non-stationary. Also, the results depend on whether a stochastic trend is included or not. See Appendix Tables 3 to 11 for results from the ADF-tests. Other relevant unit-root tests could have been applied, such as the ADF-GLS (Elliott et al. (1996)), Phillips-Perron test (Phillips and Perron (1988)) or the KPSS-test (Kwiatkowski et al. (1992). However, Pesaran et al. (2001) suggests an alternative approach that is less vulnerable to the assumptions behind those tests. Their approach is known as bounds testing. Instead of estimating an ECM like (13), the approach assumes that the level terms in the ECM are estimated freely. The next step is then to calculate the F-statistics for the null hypothesis that all long-run parameters are zero. The F-statistics is then compared with the critical values estimated by Pesaran et al. (2001). There are upper and lower critical bounds, and a long-run relationship is conclusive only if the F-statistics is greater than the upper bound critical F-statistic.

Testing the theory model

The theoretical model is tested empirically by studying the estimated coefficients in the θ vector. If the elements θ are significantly different from zero and the signs are in line with the theory model. I will conclude that the empirical test do not reject the theory model. If any of the variables in **z** are insignificant, they are excluded from the empirical model.

6 The empirical investment equation

I will start the empirical analysis by estimating an ECM and test the hypothesis that the level variables should be included in the model and a long run relationship exists. This is a test for the presence of cointegration using the Pesaran et al. (2001) approach. The procedure starts with an estimation of the baseline model with an error correction specification, where no restrictions are put on the explanatory variables:

$$\begin{aligned}(14)\quad \Delta i_t =& \alpha_0 + \theta_1 i_{t-1} + \theta_2 x_{t-1} + \theta_3 m_{t-1} + \theta_4 S_{t-1} + \theta_5 UC_{t-1} + \phi t + \\ & \delta_1 \sum_{i=1}^{2} \Delta i_{t-i} + \delta_2 \sum_{i=1}^{2} \Delta x_{t-i} + \delta_3 \sum_{i=1}^{2} \Delta m_{t-i} + \delta_4 \sum_{i=1}^{2} \Delta S_{t-i} + \delta_5 \sum_{i=1}^{2} \Delta UC_{t-i},\end{aligned}$$

where i is real investments, x is real gross production, m is profit to production ratio, S is the interest rate margin, UC is the user cost of capital and t is a time trend. Small caps indicate that the variables are in logarithms. The number of lags of the delta-terms in the baseline model is set based on a F-test of jointly excluding one lag from every variable starting from a model with 4 lags. The test finds that two lags should be included in the model, because the test fails to exclude the second lag.

Estimating equation (14), I find strong support for a cointegrating relationship between investment and variables suggested by theory. The F-test statistics and the critical values for the bounds test are reported in Table 1. The calculated F-statistics are well above the upper threshold (F_U) for all of the estimated cases.

Table 1: Test values of the Bounds test, $H_0: \ \theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = 0$

Case		F_L	F_U	F-statistic
Case 5	Unrestricted trend, unrestricted constant	3.120	4.250	11.10
Case 3	No trend, unrestricted constant	2.620	3.790	9.25
Case 1	No trend, no constant	2.140	3.340	4.35

With evidence of a long-run empirical relationship from the bounds test, I can now proceed to the next step: Modeling investments using an ARDL(p,q) model in levels to find the long-run relationship between investments and the explanatory variables from the theory model (10). The empirical study gives us the long-run relationship shown below in equation (15) and as the standard errors for the coefficients show; the coefficients are all highly significant, except for the coefficient for the user cost of capital which is insignificantly different from zero and excluded from the long-run relationship. The bounds still holds in the case when θ_5 is left out from the empirical model. The ARDL model is estimated with the differenced terms included in the empirical model, but they are excluded when the long-run solution is presented.

$$\begin{aligned} (15) \quad i =& \underset{(0.0491)}{0.3940}x + \underset{(0.0407)}{0.1369}m - \underset{(0.0113)}{0.07297}S + \underset{(0.593)}{4.735} \end{aligned}$$

The results of the ARDL(p,q) give strong empirical support for the generalized theoretical model. Production, profit to production ratio, and the interest rate spread are all important and necessary for explaining aggregate investments in the long run, and the signs are as expected. The long-run effect of a one percent change in gross production is an increase in aggregate investments of about 0.4 percent. Higher production reduces available production capacity and hence pushes the manufacturing industry to increase its capacity by increasing investments and by this being able to meet any further increases in demand. Improved profitability increases the return on capital, and it is likely to possibly affect the firms' profit expectations. The other channel that an increase in profitability has on investment is its effect on reducing funding costs. The way that the firm chose to fund its investment heavily impact the cost of funding. The theory model emphasizes that the higher share of the investment that is funded with retained earning the lower is the funding costs expected to be.

I find that the effect of a one percent change in the profit to production ratio is a 0.14 percent increase in investments. As known from the first paper, a large share of the firms prefer to fund investments with retained earnings, and this holds particularly for smaller firms. As shown in the Appendix to Paper 1, the lack of cash flows reduces investments in small as well as large firms. This may be an argument that funding cost is not only increasing in retained earning but that the firms' funding is bounded when the share of internal funding is sufficiently low.

A necessity for using external funding in an investment project is that banks have sufficient the lending willingness of banks to business' investment projects. I find an estimated effect of 0.07 percentage on aggregate investments of a one basis point decrease in the interest rate spread. Compared to the years ahead of the financial crisis, the interest rate spread, in Norway, was 50 basis points higher than in the years 2012 to 2015. The estimated effect on the investments of a rise in the interest rate spread with 50 basis points is about a 3.5 percent decline in the long-run level. If the increased interest rate spread is motivated by less competition among banks, then it is likely that a part of the investment decline in the years after the Financial Crisis was due to a reduced supply of credit. Paper 2 found that access to credit is together with expected demand by far the most important reasons for changes in firms' investment plans. The competition among banks is essential for understanding the lending willingness, and hence, the changes in the interest rate spread. The many bankruptcies before in 2007 and 2008 made it necessary to tighten the financial regulations. This gave us the Basel III capital requirement. To accumulate a higher equity capital level, many banks increased their interest rates even when the cost of borrowing was unchanged. See Naceur and Omran (2011) for a discussion of the recent developments in the credit markets for bank loans, or Hungnes (2011) for a study of the Norwegian bank loan market.

As in most empirical studies of aggregate investments, also this study finds that there is an insignificant effect of the *level* of the user cost of capital on investments. To see how vital interest rate expectations are for the user cost of capital, I tested for several different specifications of the user cost of capital. The robustness check compared the baseline with a model where the user cost of capital included both lags and leads of the actual interest rate together with the lead of the price of capital goods, but also a version with only leads was tested. None of the specifications gave a significant parameter estimate of the user cost. As discussed in Chirinko et al. (1999), this is a known result from studies on aggregate data. The lack of any effects of the user cost of capital on investments is also backed up by the findings in Paper 2, which showed that there is neither an effect of the price of capital goods nor the funding cost on the probability of a change in the firms' investment plans. Essential to understanding how interest rates affect investment, is to remember the result from the Neoclassical growth model: With a standard Cobb-Douglas production function, the derivative of production with respect to capital equals the interest

Table 2: **Empirical investment model, using a ARDL-model.** The model is specified as an equilibrium correction model and estimated with ordinary least squares using quarterly data that is seasonally adjusted.

Δi_t	Coefficients	Standard errors
Δi_{t-3}	0.269683	0.07485
z_{t-1}	-0.206047	0.04539
Δx_{t-3}	0.608692	0.2141
ΔUC_{t-1}	-0.004541	0.00228
ΔS_{t-1}	-0.018696	0.00856
$\Delta_3\ obx_{t-1}$	0.0707756	0.02946
Constant	-0.003810	0.00719
I:1993(1)	-0.286963	0.07271
I:1997(4)	0.282994	0.07103
I:2006(1)	-0.221740	0.07373
Test summary	**p-values**	
AR 1-5 test:	[0.1826]	
ARCH 1-4 test:	[0.9582]	
Normality test:	[0.0534]	
Hetero test:	[0.0537]	
Hetero-X test:	[0.0851]	
RESET23	[0.6691]	
Forecast, χ^2-test	[0.9592]	
Chow, F-test	[0.9599]	

Note: Estimated using ordinary least squares. Sample period: 1984Q1-2013Q4. The long-run model:
$z_t = i_t - 0.3940x_{t-1} - 0.1369m_{t-3} + 0.07297S_{t-1} - 4.735$

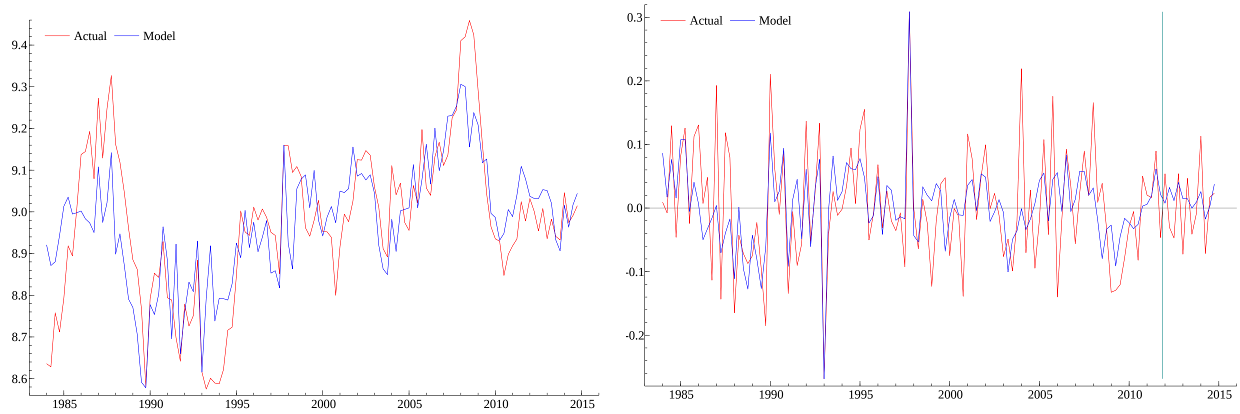
rate. Hence, the interest rate rises when the return to capital rises and vice versa. In other words, it is when the profitability of investments rises, that the interest rate increases. This mechanism makes it near impossible to identify any effect of interest rates on aggregate investments.

Utilizing the long-run model (15) I estimate the short-run investment model, using the error correction specification of equation (14). Table 2 shows the empirical results from the empirical model. The short-run model is estimated freely, but I constrain the model to utilize the long-run relationship from equation (15). To find the exact model specification, I use the automated general-to-specific variable selection procedure in Autometrics, Hendry and Krolzig (2005).

The short-run dynamics continue to support the theoretical model. As expected both an increase in the quarterly change in investments and production increases the investment growth temporarily. Similarly, I find a moderate negative effect of an increase in the change in the interest rate margin. I did not find any long-run effects of changes in the user cost of capital, but as in Chirinko et al. (1999), I find that there are short-run effects of changes in the user cost of capital. The estimated effect is small and as expected; negative. How easy it is to finance the firms' investment, do not only depend on the interest rate margin and the retained earnings. The value of the firm is also a crucial factor. In line with the financial accelerator literature, Bernanke et al. (1996), I test how changes in firm valuation affect the short-run dynamics of the investment level. By using the quarterly change in the Oslo Bors Benchmark Index (OSEBX) as a proxy for change in firm valuation, I find that an increase in the average valuation at the stock exchange increases investment, but the effect is only temporary and last for three quarters.

There are three time-dummies in the model. In November 1992, the Norwegian Central Bank, which at the time were following a fixed exchange rate regime, had to defend the Norwegian krone (NOK) by buying a large amount of NOK. This caused the money market rate to increase much more than bank loan rates, such that the interest rate margin became negative in 1993Q1. The second time-dummy captures the increased uncertainty caused by the Asian crisis in 1997. One of the consequences was an unexpected decline in oil prices, which is an essential predictor for investment goods in the petroleum industry. The third time-dummy captures a policy event. Due to the announcement of a substantial rise in dividend tax in 2006, there was an extraordinary payout of dividends during 2005.

The cointegrating vector, together with the estimated and actual figures from the OLS-regression, is shown in Figure 8. Figure 9 shows the recursive estimates and Chow-tests. As seen in the figure, all parameter coefficients are stable and barely affected by the turmoil of the Financial Crisis. The 1-up Chow-test indicates that there is one outlier, and that is



(a) (b)

Figure 8: (a) The long run model and actual data (b) The full investment model and actual data, quarterly change in investments, Δi_t

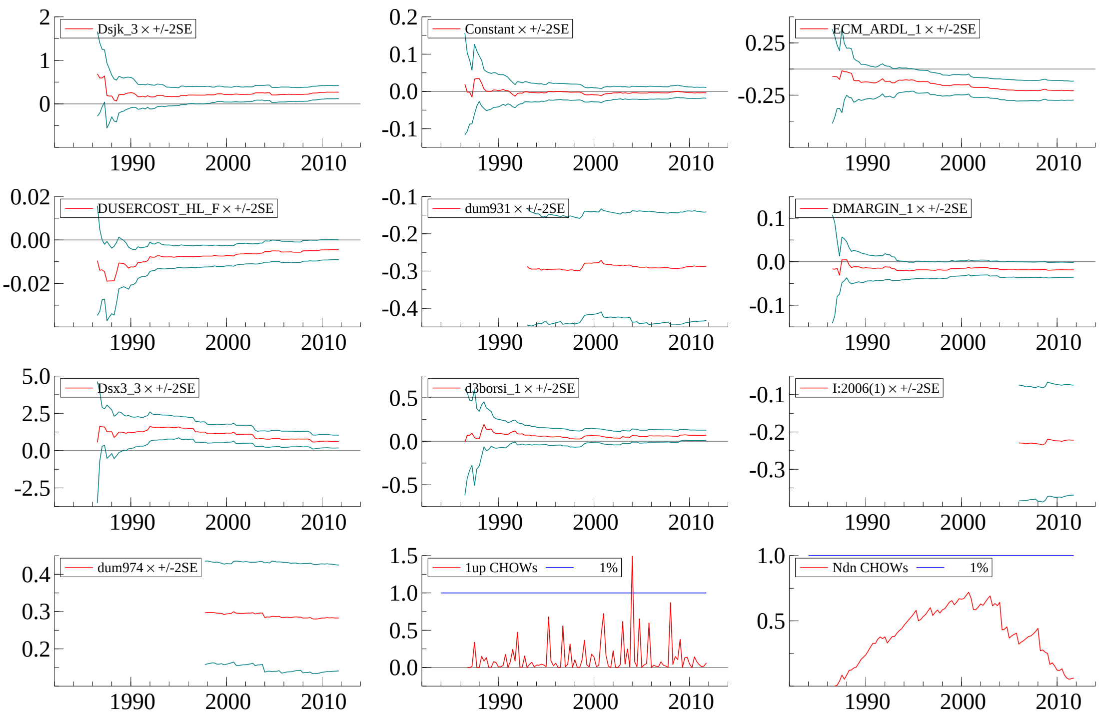


Figure 9: Recursive estimates, Investment model

during the financial crisis. The Break-point chow tests do not find any F-statistic that indicates any structural break in the data generating process.

Forecasting properties

The estimated investment model shows stable forecasting properties. To test whether this model would have forecasted the decline in investments during the Great Recession, I estimate the both the long-run and the short-run model with data until the 4th quarter of 2007. Shortening the sample period reduces the estimated coefficient for the profit to production level in the long run model with a third. The other coefficients are barely affected by the change in estimation period. The results of the dynamic four-step out-of-sample forecasts for the quarterly growth in aggregate investments are shown in Figure 10. The model is forecasted with true realizations of the explanatory variables, which of course helps the model in forecasting the investment behavior. It is interesting to note that the model forecasts the decline in investment in Q1 2008, which is one quarter before the actual decline started, and this with a model where the agents have backward-looking expectations. The forecasts are well within the 95 % error bars. The forecast accuracy measured with the N up-step Chow test and a 1-step Chow F-test is are highly significant with a p-value of 0.95.

The strong forecasting properties strengthen the empirical support of the theoretical model and underline the importance of including the interest rate margin and profit to production ratio when modeling real investments.

7 Summary

Investments are not unpredictable, and this paper suggests a model that forecast real investments and able to predict the decline during the Financial Crisis. I present a neat theoretical framework to model investments in such a way that essential features explaining investment behavior such as profitability, credit market conditions, and the production level is included in the model. The theory model extends the well known Q-theory and does not represent a new way of modeling investment, but is instead an alternative way to capture Neoclassical elements into a theoretical model describing how credit market conditions amplify shocks in the economy. The results are fully backed by earlier work by the author using a different approach. This essay strengthen the results from the two first papers of this thesis, which identified retained earnings, demand expectations and credit conditions as the critical factors explaining short-run investment behavior.

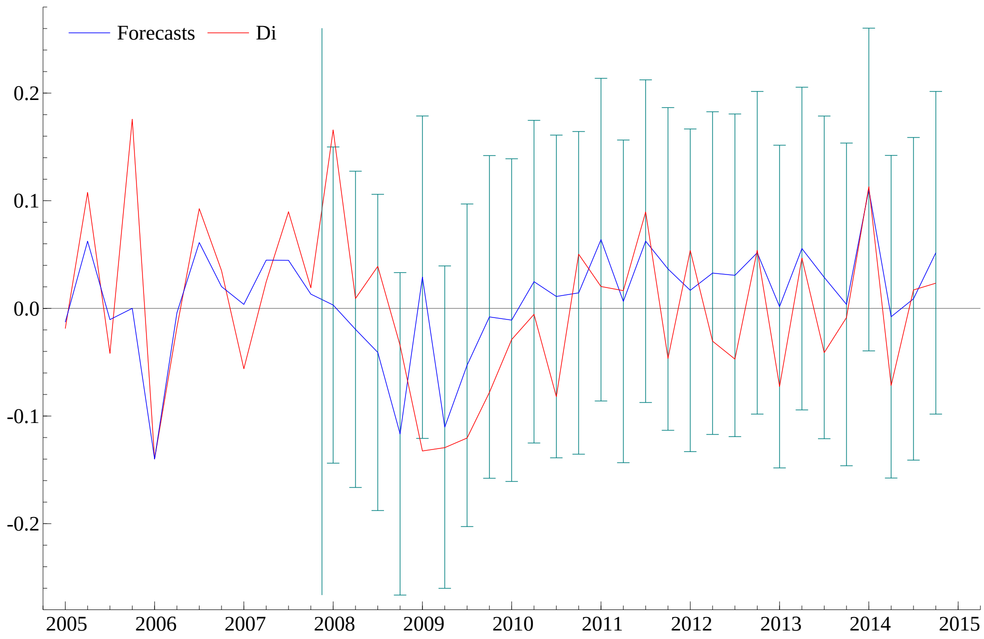


Figure 10: Dynamic four-step ahead out-of-sample forecast

Future work might be to include the investment Euler equation studied in this paper into a macroeconomic model. There is extensive literature studying financial frictions and banking in DSGE models, and extending a DSGE model with the proposed investment Euler equation would give a model where changes in credit markets would amplify aggregate investments.

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A Appendix tables

Table 3: ADF tests **log(I)** (T=120, Constant+Seasonals; 5%=-2.89 1%=-3.49)

D-lag	t-adf	beta Y_{t-1}	sigma	t-DY_lag	t-prob	AIC	F-prob
4	-3.166*	0.83229	0.09523	0.4344	0.6648	-4.631	
3	-3.166*	0.83784	0.09488	2.060	0.0417	-4.646	0.6648
2	-2.765	0.85938	0.09623	0.08618	0.9315	-4.625	0.1156
1	-2.819	0.86028	0.09582	-0.8883	0.3762	-4.642	0.2268
0	-3.151*	0.84910	0.09573			-4.652	0.2738

Date: 1985(1) - 2014(4)

Table 4: ADF tests **Dlog(K)** (T=135, Constant; 5%=-2.88 1%=-3.48)

D-lag	t-adf	beta Y_{t-1}	sigma	t-DY_lag	t-prob	AIC	F-prob
3	-2.569	0.77439	0.004433	-5.425	0.0000	-10.80	
2	-4.068**	0.62562	0.004890	-0.5615	0.5754	-10.61	0.0000
1	-4.543**	0.60799	0.004878	-4.123	0.0001	-10.62	0.0000
0	-7.401**	0.42280	0.005163			-10.52	0.0000

Date: 1982(2) - 2015(4)

Table 5: ADF tests **log(I/K)** (T=120, Constant; 5%=-2.89 1%=-3.49)

D-lag	t-adf	beta Y_{t-1}	sigma	t-DY_lag	t-prob	AIC	F-prob
5	-3.178*	0.80770	0.1233	-0.02365	0.9812	-4.106	
4	-3.340*	0.80729	0.1228	0.8948	0.3728	-4.123	0.9812
3	-3.222*	0.82191	0.1226	2.082	0.0396	-4.133	0.6733
2	-2.762	0.84965	0.1244	0.1820	0.8559	-4.111	0.1726
1	-2.813	0.85205	0.1239	-0.8217	0.4130	-4.128	0.2828
0	-3.173*	0.83997	0.1237			-4.138	0.3339

Date: 1985(1) - 2014(4)

Table 6: ADF tests **Dlog(I)** (T=124, Constant; 5%=-2.88 1%=-3.48)

D-lag	t-adf	beta Y_{t-1}	sigma	t-DY_lag	t-prob	AIC	F-prob
3	-5.283**	-0.075177	0.09812	0.2684	0.7888	-4.581	
2	-5.914**	-0.048705	0.09773	-1.315	0.1912	-4.596	0.7888
1	-8.539**	-0.19299	0.09803	0.3666	0.7146	-4.598	0.4121
0	-12.74**	-0.15410	0.09767			-4.613	0.5907

Date: 1985(1) - 2014(4)

Table 7: ADF tests **Dlog(I/K)** (T=124, Constant; 5%=-2.88 1%=-3.48)

D-lag	t-adf	beta Y_{t-1}	sigma	t-DY_lag	t-prob	AIC	F-prob
3	-5.220**	-0.067474	0.1270	0.03504	0.9721	-4.065	
2	-5.984**	-0.063980	0.1264	-1.224	0.2234	-4.081	0.9721
1	-8.555**	-0.19845	0.1267	0.3256	0.7453	-4.084	0.4778
0	-12.87**	-0.16371	0.1262			-4.100	0.6621

Date: 1985(1) - 2014(4)

Table 8: ADF tests **Dlog(X)** (T=135, Constant; 5%=-2.88 1%=-3.48)

D-lag	t-adf	beta Y_{t-1}	sigma	t-DY_lag	t-prob	AIC	F-prob
3	-6.249**	-0.81424	0.04115	-5.328	0.0000	-6.345	
2	-19.80**	-2.1546	0.04525	10.56	0.0000	-6.162	0.0000
1	-13.29**	-0.88671	0.06133	3.457	0.0007	-5.561	0.0000
0	-19.03**	-0.46835	0.06381			-5.489	0.0000

Date: 1982(2) - 2015(4)

Table 9: ADF tests **GDP GAP** (T=135, Constant; 5%=-2.88 1%=-3.48)

D-lag	t-adf	$\beta GDPGAP_{t-1}$	sigma	t-DY_lag	t-prob	AIC	F-prob
4	-3.416**	0.97190	0.1842	-1.613	0.1092	-3.347	
3	-4.192**	0.96738	0.1854	2.559	0.0116	-3.342	0.1092
2	-3.530**	0.97317	0.1892	-3.088	0.0025	-3.308	0.0116
1	-5.038**	0.96379	0.1952	24.35	0.0000	-3.253	0.0004
0	-1.155	0.98077	0.4544			-1.570	0.0000

Date: 1982(2) - 2015(4)

Table 10: ADF tests **log(M)** (T=135, Constant; 5%=-2.88 1%=-3.48)

D-lag	t-adf	βYE_{t-1}	sigma	t-DY_lag	t-prob	AIC	F-prob
4	-1.642	0.86957	0.1499	-0.6447	0.5204	-3.727	
3	-1.882	0.85613	0.1495	-2.404	0.0178	-3.739	0.5204
2	-2.683	0.80060	0.1525	-0.6783	0.4989	-3.707	0.0496
1	-2.997*	0.78654	0.1522	-4.131	0.0001	-3.719	0.0902
0	-4.867**	0.66439	0.1619			-3.602	0.0002

Date: 1982(3) - 2013(4)

Table 11: ADF tests **Dlog(M)** (T=135, Constant; 5%=-2.88 1%=-3.48)

D-lag	t-adf	beta Y_1	sigma	t-DY_lag	t-prob	AIC	F-prob
4	-6.685**	-1.3945	0.1515	0.3279	0.7436	-3.705	
3	-8.124**	-1.3243	0.1510	1.107	0.2706	-3.720	0.7436
2	-10.02**	-1.1095	0.1511	3.085	0.0025	-3.725	0.5179
1	-10.67**	-0.65328	0.1564	1.448	0.1502	-3.664	0.0157
0	-18.13**	-0.46123	0.1571			-3.663	0.0143

Date: 1982(3) - 2013(4)

Table 12: ADF tests **Residual of the one-equation model** (T=120, Constant; 5%=-2.89 1%=-3.49)

D-lag	t-adf	beta Y_{t-1}	sigma	t-DY_lag	t-prob	AIC	F-prob
3	-6.082**	-0.16838	0.08448	0.8721	0.3850	-4.902	
2	-6.541**	-0.083841	0.08439	0.1951	0.8456	-4.912	0.3850
1	-7.935**	-0.065035	0.08404	0.04199	0.9666	-4.928	0.6717
0	-11.57**	-0.060937	0.08368			-4.945	0.8492

Date: 1985(1) - 2014(4)