Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Economics and Management
Department of Economics

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# Tobin's q and Financial Constraints

## An empirical study of Tobin's q, internal funds and capital market imperfections

Master's thesis in Economics
Supervisor: Joakim Blix Prestmo
June 2022

NTNU
Kunnskap for en bedre verden

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## Preface by Sigve Naustdal Schjølset

First and foremost I would like to thank my co-author and dear friend Lars for showing great patience, understanding, humor and work ethic throughout the production of this thesis. Working with you have been a great pleasure. I could not think of a better person to write my thesis with. I would also like give a special thanks to my friend Ida von Hanno. Being able to go for coffee breaks or to the a bar after work hours with her is perhaps the thing I have appreciated most throughout this semester. I would also like to thank my amazing roommates for the time at NTNU in Trondheim. If not for them the covid-19 pandemic would have been a lot harder. I also want to extend a special thanks to "Byggeprosjektet" in UKA and all the people who have been contributing there. Getting to know you and work with you made my last year in Trondheim extremely memorable. I wish to thank classmates for making the last two years tolerable. I want to thank all my friends for providing support throughout my studies. And lastly i would like to thank my family for providing constant love and support.

We have been forced to make some hard turns and make several changes, or discard results throughout the work on this thesis. I am grateful that both Lars and myself was never afraid to do so. We have tried our best to keep an open mind by not favouring one view over another. We put special emphasis on this when analyzing our empirical results, which in some cases seem ludicrous in comparison to much of the existing theory or older empirical studies. However, we both firmly believe that being open to new ideas and the ability to change ones mind is a great strength. John Maynard Keynes once said *"When the facts change, I change my mind. What do you do, sir?"*. We would very much like to do the same.

## Preface by Lars Djuve Båtsvik

Writing this thesis has been challenging but instructive. In order for two individuals to complete empirical work of such magnitude, it requires patience, trust and good cooperation with your co-writer. Sigve has listened patiently to my comments in times where we have had different views. He has trusted my judgement. And, in addition to always being a team player, he has been a dear friend to me throughout my studies. The social environment on the fifth floor of NTNU Trondheim business school has been truly amazing, and for that I thank my classmates as well as the department of economics (ISØ). After long hours at the university, I have had the pleasure to be a part of NTNUI Samba as both player and coach. To all my teammates, thank you for ups and downs on the pitch. At last, I would like to thank my family for constant support and love.

*"Dæ æ jabbnå så dræge."*

**Abstract**

Using quarterly firm-level panel data from the United States from 2003-2019 we show that there is a strong relation between capital expenditures and Tobin's q. This contrasts to earlier work on the q theory of investment, but is perfectly in line with more recent empirical research. We show that financial constraints have a significant effect on investments. We differ between two types of financial constraints. Firstly, we show that firms that with more internal financing have higher capital expenditure ratios than those with more external financing. Secondly, that tightness in the financial market have a significantly negative effect on capital expenditures. Our results show that the smallest companies in our sample size are more reliant on internal funds compared to larger ones. And that the larger companies are more affected by the credit markets. Our results are robust using both FE and TWFE estimation methods.

**Sammendrag**

Ved å ta i bruk kvartals data fra amerikanske selskaper fra 2003-2009 viser vi at det er sterk korrelasjon mellom realinvesteringer og Tobin's q. Dette er motsigende med mye av tidligere empirisk forskning som er gjort på «the q theory o finvestment», men det er i tråd med mer moderne empirisk forskning. Vi viser at finansielle restriksjoner har en signifikant effekt på realinvesteringer. Vi skiller mellom to type finansielle restriksjoner. Restriksjoner i forbindelse med egenkapital, og restriksjoner i forbindelse med kredittmarkedene. Vi viser at selskaper med mindre intern kapital har lavere investeringsnivåer. Og at investeringsnivået går ned når kredittmarkedene blir strammere. Resultatene våre viser at de minste bedriftene i dataen vår er mer avhengige av egenkapital sammenlignet med de store, og at de store selskapene blir påvirket i større grad av hva som skjer i kredittmarkedene. Resultatene våre er robuste på tvers av både FE og TWFE estimeringsmetoder.

# Table of Contents

# List of Tables



# List of Figures

# 1 Introduction

Analysis of firms investment decisions occupies a prominent space in research fields like macroeconomics, public economics, corporate finance and industrial organization. This research is important for monetary policy, tax policy and for making appropriate business decisions. Most macroeconomic theory is centered around "the total output" of the economy. Total output usually refers to all services and goods that are being rendered, produced, sold or delivered within the economy. To produce a product or provide a service one usually needs a combination of both technology, what is usually referred to as capital, and human labour. Capital enables labour to be more productive. A truck driver is many thousands times more efficient at transporting goods with a truck than without one. Hence the capital like software, machinery, infrastructure, vehicles, machinery or other technologies are very important for the output in a sector or within the economy as a whole. And it is becoming increasingly so, with technological solutions that can even automate entire processes making output entirely dependent on production. It should be clear that the total production in an economy is heavily dependant on the level of capital within the economy. The level of capital is a function of yesterdays capital, depreciation and investment in capital (capital expenditures). And since fluctuations in capital expenditures heavily influence the capital level, which in turn influence and amplify the booms and busts of the business cycle, being able to understand and predict capital expenditures is extremely important for central banks and governments (Prestmo, 2020b, p. 2).

The q theory seeks to explain firms *real investments*,[1] and is one of the most widespread investment theories. Tobin and Brainard (1976) argued that investment decisions of a firm was determined by its q value, that is the market prize of the firm to its replacement cost. q values above 1 should encourage investments while q values below 1 should discourage

[1] Real investments is defined as money invested in assets that actively contributes to productivity. This can be investments into tangibles such as machinery, vehicles, buildings and computers, or intangibles like software, licenses, and R&D. Investments in financial assets like shares, bonds, insurance or securities are not considered real investments.

them. If this is true, simple regressions of investment using Tobin's q should have a strong fit. However, historically, empirical research have found that this regression performs quite poorly. The disparity between theory and empirical findings has sparked the interest of financial and macro economists alike. And thus a large literature concerns itself with potential reasons why Tobin's q fail to explain investments in empirical data. The literature points to inefficient markets, financial constraints, inefficient equity-market valuations, decreasing returns to scale and measurement problems.

Curiously, despite a historically bad record as a predictor of real investment, the relation between investment and Tobins's q has become remarkably tight during the last two decades (Andrei et al., 2019, p. 269). Peters and Taylor (2017) are able to achieve an $R^2$ of 33% with simple OLS regression and Andrei et al. (2019) find a significant link between q and capital investment using both individual FE and TWFE regressions[2]. Our thesis seeks to expand on this research by empirically testing an extension of the classical q theory of investment where we also capture the effect of financial constraints. We include two variables in order to capture two types of financial constraints. The first is the difference between the interest rate offered to firms and the inter-bank interest rate. this specification is used in Prestmo (2020b) and captures tightness in the credit market. The second variable is net liquid assets, which is a proxy for internal funds available to the firm and is adopted by the likes of Hubbard (1997). Our hypotheses can be summarized as follows:

1. Tobin's q has a positive relation with real investment.

2. Tight financial markets have a negative effect on real investments.

3. There is a positive relation between net liquid assets and real investments.

In our thesis, we have defined real investments as the ratio between capital expenditures and fixed assets[3]. This specification is very common in the investment literature and is adopted by Tobin and Brainard (1976) who popularized the q theory of investments. As well as other empirical research like Blundell et al. (1992), Hubbard (1997), Cleary et al. (2007),

[2]They achieve an $R^2$ of 26% in their TWFE model and 17.5% in their individual FE model, both for high-tech firms.

[3]Our proxy for fixed assets is property, plant & equipment (PPE).

and Andrei et al. (2019). Using a fixed effect (FE) regression model we find strong empirical support for all three hypotheses. Our thesis begins by providing a brief introduction to the the q theory of investment in section 2, before providing an overview of the relevant literature in section 3. our data and variables are presented in section 4. We the present our empirical model in section 5, before presenting our empirical results with extensions and robustness checks in section 6. Section 7 is dedicated to discussing our results and possible biases, and in section 8 we provide a brief summary and some concluding remarks.

## 2 Theoretical background

Our empirical model is built upon the q theory of investment. This theory was popularized by James Tobin in the paper "A General Equilibrium Approach To Monetary Theory". In his paper, Tobin states that the rate of investment is a function of q, the value of capital relative to its replacement cost (Tobin, 1969, p. 21). Later, Tobin and Brainard (1976) defined "q" as follows:

> *"the ratio between two valuations of the same physical assets. One, the numerator, is the market valuation: the going price in the market for exchanging existing assets. The other, the denominator, is the replacement or reproduction cost: the price in the market for newly produced commodities." (Tobin & Brainard, 1976, p. 1-2)*

The Q theory of investment is based on a neoclassical economic framework with rational utility maximizing agents. Explicitly, the theory rests upon the assumption that management derives utility from the net worth of the company and hence it seeks to maximize the present net worth of the company. It differs from the neoclassical theory of investment by not assuming instantaneous capital adjustments. Instead, it views capital as an adjustment towards the optimum capital level. The Q theory of investment focuses on the Q value of individual companies, sectors or economies. And as stated in the quote above, the Q ratio is given by:

$$Q = \frac{MarketValuation}{ReplacementCost} \tag{2.1}$$

We differ between average Q, what is also called Tobin's Q and marginal Q. Equation 2 is an expression of average Q. However, it is marginal Q that is of interest. Marginal values above 1 will encourage real investments and values below 1 should discourage them. The marginal q should be interpreted as the marginal return on capital relative to the opportunity. Hence, as long as $q > 1$ it is profitable to invest, when $q = 1$ there are no profitable investment opportunities and capital will be equal to the optimum capital level (Eklund, 2013, p. 9). Tobin and Brainard summarizes the q theory as follows:

> *"The neoclassical theory of corporate investment is based on the assumption that the management seeks to maximize the present net worth of the company, the market value of the outstanding common shares. An investment project should be undertaken if and only if it increased the value of the shares. The securities markets appraise the project, its expected contributions to the future earnings of the company and its risks. If the value of the project as appraised by investors exceeds the cost, then the company's shares will appreciate to the benefit of existing stockholders. That is, the market will value the project more than the cash used to pay for it. If new debt or equity securities are issued to raise the cash, the prospectus leads to an increase of share price. To state the point another way round, suppose the firm sells additional shares at the going market price. Will the proceeds suffice to purchase the earnings that justify that price? If they will do so, with margin to spare, then the joint operation - share issue and investment – benefit the original shareholders." (Tobin & Brainard, 1976, p. 14)*

Tobin and Brainard state that a marginal q value of 1 is consistent with an average q value that differs from 1. There are several reasons why average q differs from marginal q. It can be caused by heterogeneity of capital goods and technological progress, monopoly power, ineffective used goods market, the complexity of implementing new technology, changes in business structure, monetary policies, discrepancies in risk of investment opportunities, heterogeneity in production technology or sluggish capital flow (Tobin & Brainard, 1976, pp. 2–16). [4]

The discrepancies between Q and 1, its "normal value", does not weaken the theory. In fact, if instantaneous arbitrage could move capital goods such that the market valuation and replacement costs were always in line ($Q = 1$), then Q would not be related to investments. Luckily, due to the reasons listed in the last paragraph, discrepancies between Q and its normal value do arise. The velocity at which investments eliminate such discrepancies depends on the cost of adjustment and growth of both the economy as a whole and the individual companies within it, the short run marginal cost of producing new investment goods and the adoption speed of new technologies (Tobin & Brainard, 1976, p. 16).

The logic behind the q theory of investment is remarkably simple; marginal q values greater than 1 leads to higher investment and values below 1 decreases investment with an equilibrium level at $Q = 1$. Nevertheless, we cannot apply the theory as long as the marginal q is not observable. Marginal q is defined as the ratio of the market value of an additional unit of capital to its replacement cost. Capturing the true effect of marginal q is extremely hard, if not impossible. Tobin and Brainard (1976) argue that only average q is directly observable[5]. Consequently, most empirical work on the Q theory of investment has utilized average Q as a proxy for marginal Q. (Hayashi, 1982, p. 214).

When using average q as a proxy for marginal q, we substitute expected average returns to capital with marginal returns for each time period. Hayashi (1982) investigated under which circumstances this is actually true, and showed that two assumptions must hold for average Q to be equal to marginal q. Later, Hubbard (1997) also added the third assumption of no financial constraints.

1. Perfect competition in the factor and product markets.

2. Linear homogeneity of production technologies and adjustment costs. That is, all

[4] We will not discuss these further in this thesis, but interested readers are encouraged to read Tobin and Brainard's paper "Asset markets and the cost of capital" for a more in-depth explanation.

[5] Observing the "true" average q is also arguably extremely difficult as it is virtually impossible to calculate the exact replacement cost

actors have access to the same technologies and are equally effective with adopting them.

3. No financial constraints.

For average q to be a perfect proxy for the theoretically constructed marginal q, all of these assumptions must hold (Hubbard, 1997, p. 17). While some researchers assume these to be true, or at least sufficiently true, other economists like Gilchrist and Himmelberg argue that the assumptions are too strict and have chosen to not use the conventional average Q as a proxy for marginal q (Gilchrist & Himmelberg, 1995). Hubbard (1997) discusses these assumptions at length. He concludes that they are often broken and that further research should investigate them. We wish to answer Hubbard's call. Therefore we allow for financial constraints within our empirical model.

One of the major problems with the q theory of investment is to measure the *real* q value. In order to do this one must be able to measure both the true market value and the true replacement cost. If the company is listed on the stock exchange, measuring the market value is simple since the company is constantly evaluated in the market. However, the problem usually arises when one is trying to capture the true replacement cost. Tobin and Brainard (1976) were heavily influenced by Keynes, and when explaining the rationale behind q they present a quote from Keynes' book *"The General Theory of Employment, Interest and Money"*:

> *"The daily revaluation of the stock exchange, though they are primarily made to facilitate transfers of old investment between one individual and another, inevitably exert a decisive influence on the rate of current investment. For there is no sense in building up a new enterprise at a cost greater than that at which a similar existing enterprise can be purchased; whilst there is an inducement to spend on a new project: what may seem an extravagant sum, if it can be floated off on the Stock Exchange at an immediate profit." (Keynes, 2018, pp. 132–133).*

This is expertly put, and it makes theoretical sense. However, the statement rests upon two assumptions. Firstly, that actors only have financial motivations, and secondly, that it is possible to measure the replacement cost precisely. Let us investigate the first assumption. Even if the neoclassical economic assumption usually holds up well, we would be wrong to assume that humans are only motivated by financial incentives. Prestmo (2020a) find that when asking managers of both small and large firms about their motivation behind investment decisions, nearly no firm prefer to use net present value methods. This is especially true for smaller firms.[6] Secondly, measuring the actual replacement cost precisely can be extremely hard, if not impossible (Hayes, 2021). For instance, consider a company who owns a complicated software that is specialized for its operations. How much is this software worth? If there is no comparable products on the market it is very hard to tell. This is not only restricted to software. It also applies to, but is not restricted to, specific industrial machinery and intangibles such as goodwill and knowledge. And since the late 1990s, with the rise of more complex jobs and technology, intangibles has become an increasingly important feature of the economy (Andrei et al., 2019, pp. 267–268)

After its initial empirical success Tobin's q has preformed quite poorly as an explanatory variable for investment. However, in spite of the challenges listed above, empirical findings show that the relation between Tobin's q and aggregate investment has become remarkably tight the recent years (Andrei et al., 2019, p. 269). Andrei, Mann and Moyen (2019) contribute the sudden relevance of q to the increase of intangible assets in the economy (ibid.). At first this may seem weird, as intangibles should be harder to accurately measure. However, in recent years companies have begun to include the value of intangible assets in their standard accounting, whereas they previously typically only included tangible assets. Thus, making it easier to capture the true replacement cost (Deloitte, 2022). The empirical findings of Andrei et al. (2019) show that q preforms better for research and knowledge intensive industries. In these industries there is a larger volatility in the market capitalization of the company, and hence also in q (ibid.). This makes q a good proxy for capturing investment opportunities in intangibles as it is included in both the market price and replacement cost.

[6] When we ask people at the NTNU school of entrepreneurship why they wish to start a company, almost none of the recipients state economic profits as their main reason. Instead, they talk about passion, freedom and the aspiration or challenge of creating something on their own. This is not very scientific, but it goes to show that humans are not simply economic creatures.

This increased volatility improves the fit of the regression. They conclude that q might be a very efficient proxy for investment opportunities in R&D industries. And since research and knowledge intensive firms are an increasingly growing part of the economy, they predict the q theory of investment to be increasingly more relevant in the years to come (ibid).

# 3 Literature review

## 3.1 A historical backdrop to the q theory of investment

Modern investment theories have emerged from two lines of thought, one emerged from the ideas of Keynes1936, the second from the ideas of Fisher (1930) which was later developed by Hayek (1941). Both schools of thought argued that investments are made as long as the marginal present value of expected returns is greater than the opportunity cost of capital, that is the expected revenue of placing the capital elsewhere. This is equivalent of saying that investments are made as long as the net present value of the investment is greater than zero, when one implements the alternate cost [7] (Eklund, 2013, p. 2). The principle difference between the *"Keynesian view"* and the *"Hayekian view"* lies in the perception of risk, uncertainty, and expectations (ibid. p. 2). Hayek and Fisher believed it was possible to find an optimal capital stock, and hence viewed investment as the optimal adjustment path towards the optimal capital stock. The Keynesian view stands in contrast to this. Within Keynesian theory investments are not determined by an optimal capital stock, on the contrary it is believed that the idea of investments as an adjustment process toward an equilibrium to be misguided (ibid., p. 2). In contrast to many modern economists Keynes believed humans to be *"animal spirited"*, meaning that humans are irrational beings guided by emotions, fear and hope. Accordingly, Keynesian theory focuses on genuine and radical uncertainty, the forming of expectations and subjective probabilities (ibid., pp. 2-3). Jorgenson (1963), developed the neoclassical theory of investment from the work of Fisher and Hayek, while the ideas of Keynes inspired modern probabilistic approaches like the accelerator theory of investment. Keynes also heavily inspired Brainard and Tobin (1968),

[7] This can be expressed in an equation as $NPV = -C_0 + \int_0^\infty C(t)e^{(g-r)t}dt$, where $r$ is the opportunity cost, $i$ denotes rate of return on investments, $g$ denotes growth rate, when $i = r$ then $NPM = 0$

1976, and Tobin (1969) in their construction of the Q theory of investment (Eklund, 2013, pp. 2–3).

During the 1960s there where two prominent theories of investment. The neoclassical, and the accelerator theory. Even though they are thought of as different theories, the accelerator theory is in fact a special case of the neoclassical theory where the opportunity cost of capital and the cost of capital are held constant[8] (Eklund, 2013, p. 7). Both these theories have two fundamental flaws. Firstly, both theories hold the capital stock equal to the optimum capital stock in each time period. Meaning that adjustment of capital is instantaneous and complete in each period, this is obviously a quite strong assumption. Secondly, the theory fails to include expectations which many, including Keynes, argued play an essential role in investment decisions (ibid., p 8.). The first problem was solved by adding an adjustment cost function to the optimization problem, this was first addressed by Gould (1968), Lucas Jr (1967), and Treadway (1969). Since the market evaluation of a company is a function of all expected future profits Brainard and Tobin (1968), and Tobin (1969) were able to fix this problem by asserting that investments are made until the market value of assets is equal to the replacement cost of those same assets. Thus, the q theory can be seen as a modification of the neoclassical theory where one includes expectations and put restrictions on the speed of capital adjustments. In fact, by adding marginal capital adjustment costs to the neoclassical profit function, the two theories become logically equivalent (Eklund, 2013, p. 8). This was first recognised by Lucas Jr and Prescott (1971), in the paper *"Investment under uncertainty"*.

## 3.2 Influential work

The literature following the pioneering work of Brainard and Tobin (1968) and Tobin (1969) is comprehensive, and since the start in the late 1960s there has been a large body of research seeking to re-examine and expand the q theory framework. A majority of the earliest work on investment was done using aggregated data, meaning that data from firms were pooled together as time series (see for instance Ciccolo (1975), Bernanke (1983), and Abel and

[8]This means that the user cost of capital from Jorgensons (1963) can be reduced from $c = s[\delta + r - \frac{(\partial s/\partial t)}{s}]$ into $K^* = \alpha Y$

Blanchard (1986)). Bean (1981) uses aggregated data which is not seasonally adjusted. He therefore includes quarterly dummies to control for seasonality in the data (Bean, 1981, p. 109). We draw inspiration from Bean (1981), and employ a similar approach on our firm-level data where we use quarterly dummies. Less than a decade after the introduction from Brainard and Tobin, Von Furstenberg et al. (1977) finds that q is a weak determinant of aggregate investment compared to other explanatory variables. In the paper, James Tobin himself has been given the opportunity to comment on the results. He states the following:

> *"The notion that q does not matter in the aggregate has some credibility because the downward trend in q since the mid-1960s has not been accompanied by a comparable downward trend in capital investment. I too find this a puzzle" (Von Furstenberg et al., 1977, p. 402).*

A drawback to using aggregated data is that researchers are unable to analyze firm-specific effects. Later work on investment and within the q theory framework has shifted to focusing more on firm-level data, where one can include firm- and time-specific effects. The recent work by Andrei et al. (2019) is an example of a re-examination of Tobin's q using firm-level data. The author points to the fact that Tobin's q for many years was a poor determinant of investment, but recently has made a comeback, portraying a substantially stronger effect for research-intensive firms (Andrei et al., 2019, p. 269). Fixed effects estimation is used in the analysis, where both individual, time and two-way fixed effects are included in specifications (Andrei et al., 2019, p. 263). Results show that the relationship between investment and Tobin's q is tighter for research-intensive firms with a larger share of intangible assets.. Thus, we have that intangible assets fit well into the q theory framework where the original capital stock only consisted of fixed assets such as property and machinery (Andrei et al., 2019, p. 251). We use capital expenditures as a proxy for investment, which contains expenditures in R&D and intangibles as well as fixed assets. Due to changes in international accounting, intangibles are included in both the market evaluation and the replacement cost in our calculation of Tobin's q (Deloitte, 2022). Andrei et al. (2019) and Peters and Taylor (2017) find that Tobin's q helps explain both physical and intangible investment when using firm-level data. In their results, peters2017intangible Tobin's q is actually a much stronger determinant of intangible investment compared to physical investment (Peters & Taylor, 2017, p. 253).

In addition to fixed effects, which is used by Andrei et al. (2019) and others (see for instance Cleary et al. (2007)), estimation methods on firm-level data vary within the literature. Blundell et al. (1992) estimate the relationship between company investment and Tobin's q using Generalized Method of Moments (GMM). Blundell et al. (1992) get a significant effect of Q on company investment, but the effect is small. In roughly the same time period, Devereux and Schiantarelli (1990) find a varying effect of q across different specifications. The small effect of q in Blundell et al. (1992) along with the varying effect of q in Devereux and Schiantarelli (1990) are in line with points made by Andrei et al. (2019) about the poor performance of q in earlier research. In a paper investigating whether the investment curve is U-shaped, Cleary et al. (2007) use the market to book ratio as a proxy for Tobin's q and find it to have a robust effect on investment across all but one specification.

Internal funds have long been stressed as an important factor in explaining investment. The early work of Meyer and Kuh (1957) included net quick liquidity in the estimation model. The authors defined net quick liquidity as total current assets less current liabilities. In their analysis, sales and profits are never included at the same time due to high collinearity. We choose to omit profits from our analysis and include sales, following the intuition of Meyer and Kuh (1957). Results from their regressions show that internal liquidity is an important factor in explaining investments:

> *"The empirical work contained in the preceding chapters suggests a variety of conclusions but all converge in their emphasis upon the importance of internal liquidity"* (Meyer & Kuh, 1957, p. 190)

In addition, the authors find that smaller firms are more sensitive to changes in internal funds.

Fazzari et al. (1988) use cash flow as a proxy for internal funds when they investigate the link between financial constraints and investment-cash flow sensitivities. Their results point to significantly more investment-cash flow sensitivity for firms that are more financially constrained compared to firms that are less financially constrained. The authors use dividend payout as a measure of financial constraint for firms in the sample. Kaplan and Zingales (1997) arrive at the opposite conclusion, meaning that financially constrained firms experience less investment-cash flow sensitivity compared to less financially constrained firms. In other studies of investment, cash flow as a proxy for internal funds has been incorporated within the q theory framework as an important explanatory factor, thus not satisfying the assumption of perfect capital markets (see for instance Gertler and Hubbard (1988), Blundell et al. (1992), Cleary et al. (2007) and Guariglia (2008)). Prestmo (2020b) draws inspiration from Summers et al. (1981) when presenting the cost of external funds. This version of the cost function within the q-model includes credit market conditions through the credit spread, which is the difference between average bank loans and the interbank offered rate (Prestmo, 2020b, p. 7). In addition, the cost of external funding depends on internal funds and investment level. The point of including the credit spread in the q-model is to capture changes in the market for bank funding (Prestmo, 2020b, p. 7). In our thesis, we include a similar credit spread as Prestmo (2020b) for the United States in order to capture changes in credit market conditions.

# 4 Data

## 4.1 Empirical data

In our analysis we use panel data collected from the Eikon database. We have collected and pooled accounting data from 160 US firms in four different industries: Oil and gas, industrial machinery, renewables and construction and engineering. Due to the immense number of firms in these industries we have used filters in the construction of our data set. Firstly, firms have been included only if they are listed on the New York Stock Exchange. By picking listed firms the task of calculating average q becomes straightforward. Since the firms are constantly evaluated in the equity market the market value is simply the share price multiplied by number of shares issued (the market capitalization). If we assume the equity market to be efficient, then according to economic theory the equity market would properly evaluate both tangible and intangible capital, as well as all other factors that can affect future profits. In the data set we have access to market capitalization directly for listed firms. Filtering made the data set more complete and led to a reduction in missing values. Nevertheless, missing values have not been eradicated which means that we are working with an unbalanced panel. Entry and exit of firms can lead to bias, but since we have an unbalanced panel where we allow for entry and exit across the period of our sample, such bias is eliminated.

The time period of our data spans from 2003 to 2019. Since accounting data is reported on a quarterly basis, we can choose whether periods are quarters or years. To catch short-term fluctuations in our variables we have chosen quarterly data. First period is then the first quarter of 2003, while the last period is the fourth quarter of 2019. In periods before 2003 the database in Eikon is limited, the share of missing values for our variables is often larger than the share of complete cases.

## 4.2 Variables

The variables used in our preferred empirical model with their coupled denotation are given in the list below.

$I-$ Capital Expenditures.

$Q_a-$ average q, defined as $Q_{a,t} = \frac{M_t}{R_t}$.

$\Pi-$ Net Liquid Assets (NLA), defined as $\Pi = A - L$.

$X-$ Net sales, (proxy for gross production).

$C-$ US Prime rate and 3-month ICE LIBOR credit spread.

$t-$ subscript to denote time period.

$K-$ Property, Plant and Equipment (PP&E) (proxy for fixed assets).

$S_j-$ Seasonal dummy variables. Where $j = 2, 3, 4$ denotes which financial quarter we are in. $S_i$ is equal to 1 in quarter i and zero if not.

We also have a few other variables that are either used for deriving the variables above or in extensions of our empirical model. These are given by

$M-$ Market Valuation.

$A-$ Total Current Assets.

$L-$ Total Current Liabilities.

$R-$ Total Assets (proxy for replacement cost)

$\delta-$ Total Accumulated Depreciation.

$T-$ Effective Tax rate.

$Q_m-$ Marginal q, defined as $Q_{m,t} = \frac{M_t - M_{t-1} - \delta M_{t-1}}{R_t - R_{t-1}}$.

All monetary variables are measured in 10 000s USD. The other variables $(Q_a, Q_m, C$ and $T)$ are given by their numerical value.

Capital expenditures is the dependent variable in our model. Within the Eikon database **capital expenditures** is defined as *"the sum of: Purchase of fixed assets, purchase/acquisition of intangibles and software development costs."* In other words, capital expenditures cover all investments that are expected to increase production. This is what we call real investments, it encompasses everything from intangibles like research and development expenditures to solid machinery. It differs from financial investments like insurances, gold, currencies or stocks. Since we are interested in capturing real investments this variable is appropriate.

We use average q as our primary explanatory variable. $Q_a$ is given by the market valuation of a firm to its replacement cost ($Q_a = M/R$). In the Eikon database we have access to the market valuation through the variable **total market capitalization**, which is defined as *"the sum of market value for all relevant instrument level share types..."*. Given efficient equity markets, this is the *true* market value. The replacement cost on the other hand, is not directly observable, see chapter 2. We have used total assets as a proxy for the replacement cost. **Total assets** is simply defined as *the total assets of a company.* Total assets encompass financial, fixed and intangible assets. However, it is likely that there are measurement errors related to capturing the value of many intangibles. We also lack other dimensions related to the companies' asset replacement costs that are not captured in the accounting data, like for instance the cost of a good working culture within the company, expert management, a fine CEO etc. We also lack costs related to starting another enterprise to replace the existing like the cost devoting time, energy and the risk of failure. Whereas, if financial markets are efficient, the market valuation should reflect such costs.

Net sales is a proxy for total production. **Net sales** is defined as *"... sales receipts for products and services, less cash discounts, trade discounts, excise tax, and sales returns and allowances. Revenues are recognized according to applicable accounting principles"*. This means that net sales is the actual income the company receive from selling its products. Since we use net sales as a proxy for production, we prefer net sales over gross sales as we avoid double counting products that are being returned and resold. It is also superior in the way that it factors allowances or other discounts since we wish to measure the output in terms of the price the goods and services of the firm actually fetches.

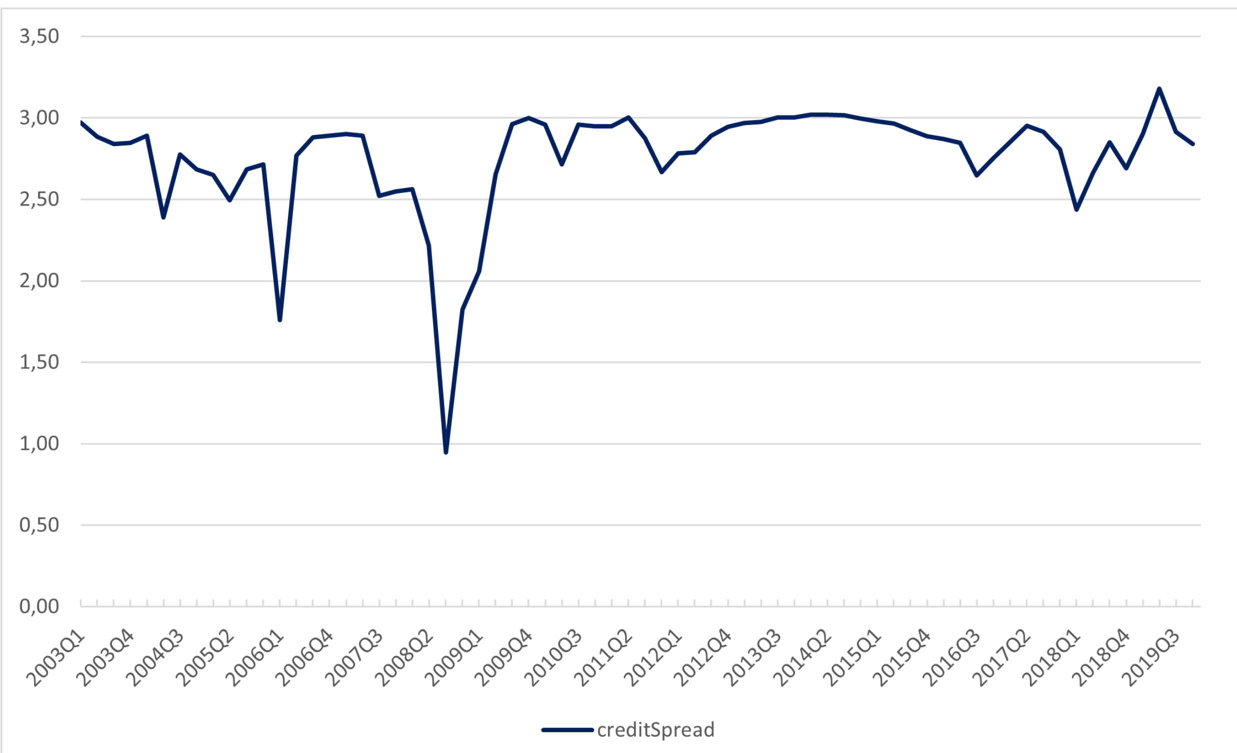
Net Liquid Assets (NLA) is a proxy for internal funds. **NLA** is defined as total current assets less total current liabilities ($\Pi = A - L$). This specification is very common within the literature. It was adopted by Meyer and Kuh (1957) in investment theory even before the q theory was formulated by and was included in later work on the q theory by the likes of Hubbard (1997). Another commonly used proxy for internal funds is cash flow, which is the sum of after-tax profits and depreciation. Due to substantial missing data for depreciation, we prefer NLA as a proxy for internal funds. Within the Eikon database **total current assets** is defined as: *"The sum of: Cash and short term investments; total receivables, net; total inventory; prepaid expenses and other current assets, total"*. **Total current liabilities** is defined as *"current liabilities for industrial and utility companies"*[9]. Hence, total current assets less total current liabilities should give us a reasonable measure for funds available at hand for firms. However, it is not a perfect proxy for internal funds. Some firms within

[9]examples of liabilities are taxes payable, accounts payable, short term debt, outstanding interests and long term debt or other obligations.

our data have negative NLA over several periods, and it is unreasonable to believe that these firms have less than zero liquid funds. Companies must have some liquid funds for daily operations, even if liabilities outweigh assets so that the net liquid assets is negative. Nevertheless, it is likely that companies with higher NLA also have more internal funds.

The credit spread is a proxy for tightness in the credit market, which is included to capture the cost of external financing. We use a specification that was developed by Prestmo (2020b). Prestmo calls this the *interest rate margin*, and it is calculated as the difference between the interest rate offered to businesses and the interest rate offered to banks. We have calculated the credit spread using quarterly data for the US prime rate and the US 3-month LIBOR. The credit spread seeks to capture the effect of tightness and uncertainty in the financial market.

Figure 1: 3-month LIBOR and US prime rate credit spread.




As the figure clearly shows, there is a large decrease in the credit spread from the beginning of 2008 due to the financial crisis. The decrease is as expected and jumps back to pre-crisis levels by the end of 2009. The 2008 financial crisis poses as a shock in our model which we need to control for. We investigate this by creating a dummy variable for the financial crisis and add this in one of the model specifications.

PP&E is a proxy for capital stock. It is not a perfect proxy, and it is likely to be a worse proxy now compared to when Tobin and Brainard developed the q theory of investment. This is due to the fact that intangibles such as software and know-how are becoming an increasingly larger part of the modern economy (Andrei et al., 2019). While intangibles are becoming an increasingly more relevant part of the capital stock, PP&E only covers tangible assets[10]. In the Eikon database, **PP&E** is defined as *"Property/plant/equipment, total & gross reduced by accumulated depreciation, total..."*

## 4.3 Descriptive Statistics

The table below displays descriptive statistics for all the variables in our preferred model. The reason why we do not have the same number of observations in all variables is due to the fact that it differs is because we have some missing values in our data sett. This leads to an unbalanced panel, and can lead to biases if the missing data is systematic. Therefore we have used variables that are available for most companies for all periods. We still have a lot of missing values. However, most of the missing values are missing because many of the companies in our data have not been operating throughout the entire period of analysis. Never the less, We have around 7 thousand observations for all variables and 10 thousand for the credit spread[11]. Because different values are missing for different periods our preferred model has 4745 observations. This is more than enough observations in order to draw inference (Studenmund, 2017, p. 366).

[10]Tangible assets are assets that in their nature can be touched, in contrast intangible assets are assets that cannot be touched.

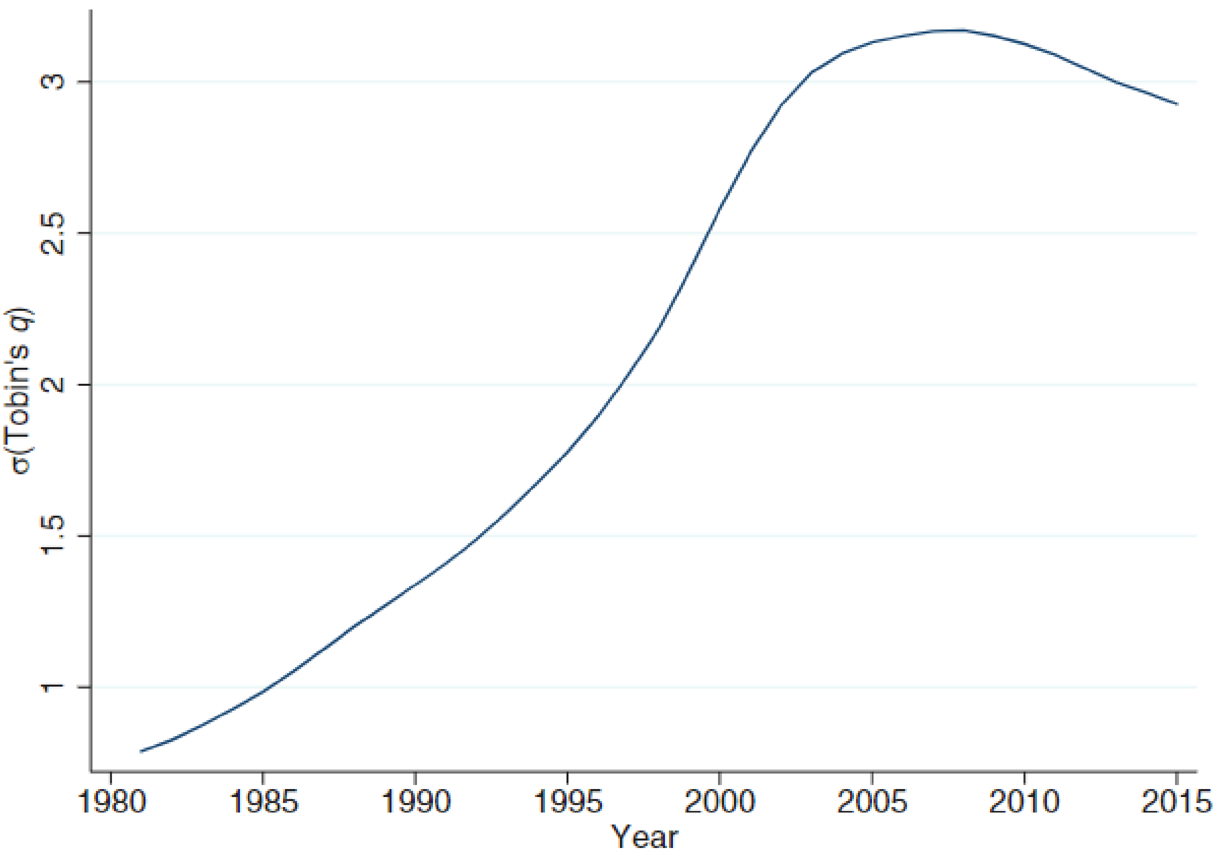
[11]the reason that we have so many variables for the credit spread is that it is a macro variable.

Table 1: Descriptive statistics

| Variable | Obs. | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| CapEx | 7,332 | 41,659 | 127,266 | 0 | 1,909,900 |
| Average Q | 6,673 | 2.97 | 9.72 | 0.05 | 117.32 |
| NLA | 7,332 | 28,258 | 76,056 | -608,600 | 995,300 |
| Sales | 7,432 | 87,668 | 338,698 | -8141100 | 7,154,100 |
| Credit Spread | 10,538 | 2.758 | 0.341 | 0.948 | 3.180 |
| PP&E | 7,239 | 336,618 | 952,004 | 0 | 91,119,900 |

The standard deviations for all variables except the credit spread is more than twice as the mean of the variable. This tells us that the variance in our data is quite large However, this might be a good thing. Andrei et al. (2019) points to increased variance in average q as one of the main reasons for why the regression of investment on q performs better in the recent years. Average q has a theoretical equilibrium value of 1. In our data, it has a mean of 2.97, and a standard deviation of 9.72. This is far from the theoretical value, but is perfectly in line with other empirical research like Andrei et al. (2019, p. 254) who measure a mean value of 2.93 for Tobin's q using Compustat data from 1975-2015. Andrei, Mann and Moyen also point out that Tobin's q has risen substantially in recent years, see figure 2

Figure 2: Calculation of average Q using Compustat data from 1980-2015. Andrei et al., 2019




This might seem strange considering that Tobin's q should have a theoretical equilibrium at 1. However, there are a number of reasons why we see different results in the empirical data. One of them is problems related to measurement of the true replacement cost. Tobin's q is usually calculated using the market to book ratio, which does not necessarily capture the *true* replacement cost. Tobin and Brainard (1976) point out several reasons why we could observe higher values for q that is in line with theory. Firms with high market power are likely to have higher q values. Moreover, since capital adjustments are not instantaneous, innovations will lead to higher q values before adjusting to its equilibrium value Tobin and Brainard (1976, pp. 16–18). Therefore, the q value is usually higher for innovation intensive industries. Since technology and innovation intensive industries are more important in more modern economies it is not surprising that we see a rise in average q. The figures below show the market to book ratio in Tesla, Apple, Nestle and General Motors. This is too small a sample to be representative in any way, but it goes to show that it is very possible to have market to book ratios that are consistently above 1. The figures are collected from YCharts. It is important to note that the book value of these companies is not the same as the total assets used in the calculations of our average Q. The book value does not include the value of intangibles, but our measure for total assets include both tangibles and intangibles.

Figure 3: The market to book ratio for Tesla during the last 5 years (YCharts, 2022d).

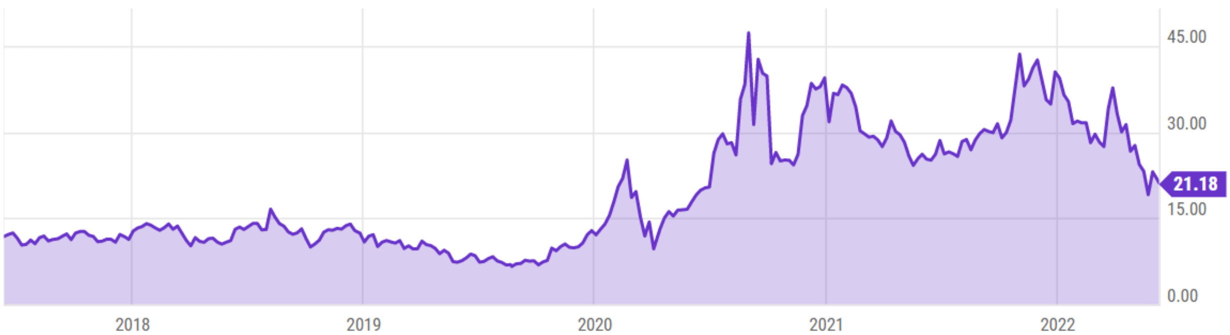



Figure 4: The market to book ratio for Apple during the last 5 years(YCharts, 2022a).

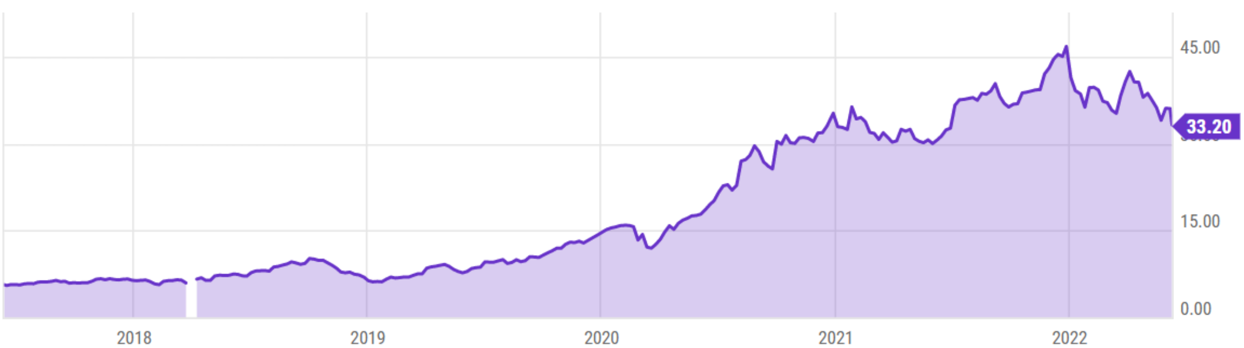


Figure 5: The market to book ratio for General Motors during the last 5 years (YCharts, 2022b)

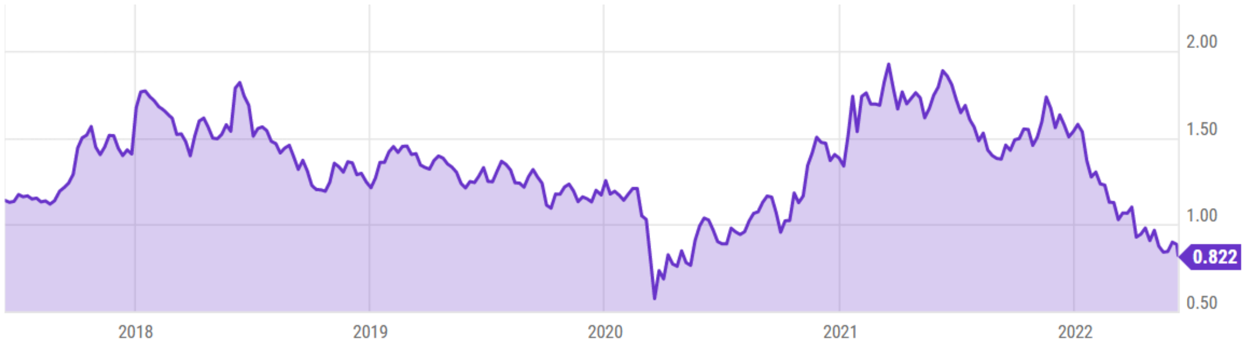



Figure 6: The market to book ratio for Nestle during the last 5 years (YCharts, 2022c).

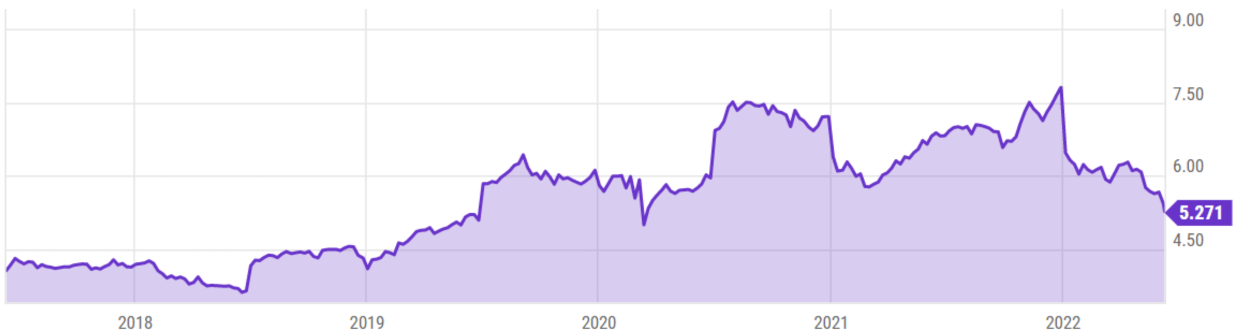



Table 2 below is a correlation matrix for the variables included in our model. We include the correlation matrix to investigate correlation between our explanatory variables. Multicollinearity occurs when two or more of our explanatory variables are highly but not perfectly correlated (Wooldridge, 2015, p. 90). Multicollinearity leads to inflated standard errors for the regressors in the analysis, and may affect the significance of regression coefficients (ibid.). We see from the correlation matrix that there is no substantial correlation between our explanatory variables. Wooldridge (2015) refers to econometrician Arthur Goldberger, who states that multicollinearity is a "problem of small sample size" (ibid., p. 91). Results obtained from the correlation matrix along with a large sample size indicates that multicollinearity is not a problem in our analysis.

Table 2: correlation matrix

| | I | $Q_a$ | Π | X | C |
|---|---|---|---|---|---|
| I | 1.000 | | | | |
| $Q_a$ | -0.057 | 1.000 | | | |
| Π | 0.115 | -0.059 | 1.000 | | |
| X | 0.495 | -0.048 | 0.080 | 1.000 | |
| C | -0.023 | 0.016 | 0.048 | -0.062 | 1.000 |

In order to present a clear graphical presentation of our variables we have converted the firm-level panel data to aggregated time series data by calculating the mean values for each variable in all periods.[12] All the time series are represented in the figure below. Average q and the credit spread is read on the right y axis, while the rest is read on the left.[13] q and credit spread are measured their numerical value, all other variables are measured in 10.000$.

[12]The credit spread is not aggregated since it is already a time series.

[13]In our regressions we trimmed away the first and last percentile in all our firm data variables in order to remove any outliers. In the graphical representations below this not done with any variables except the q values.

Figure 7: Average aggregated time series data

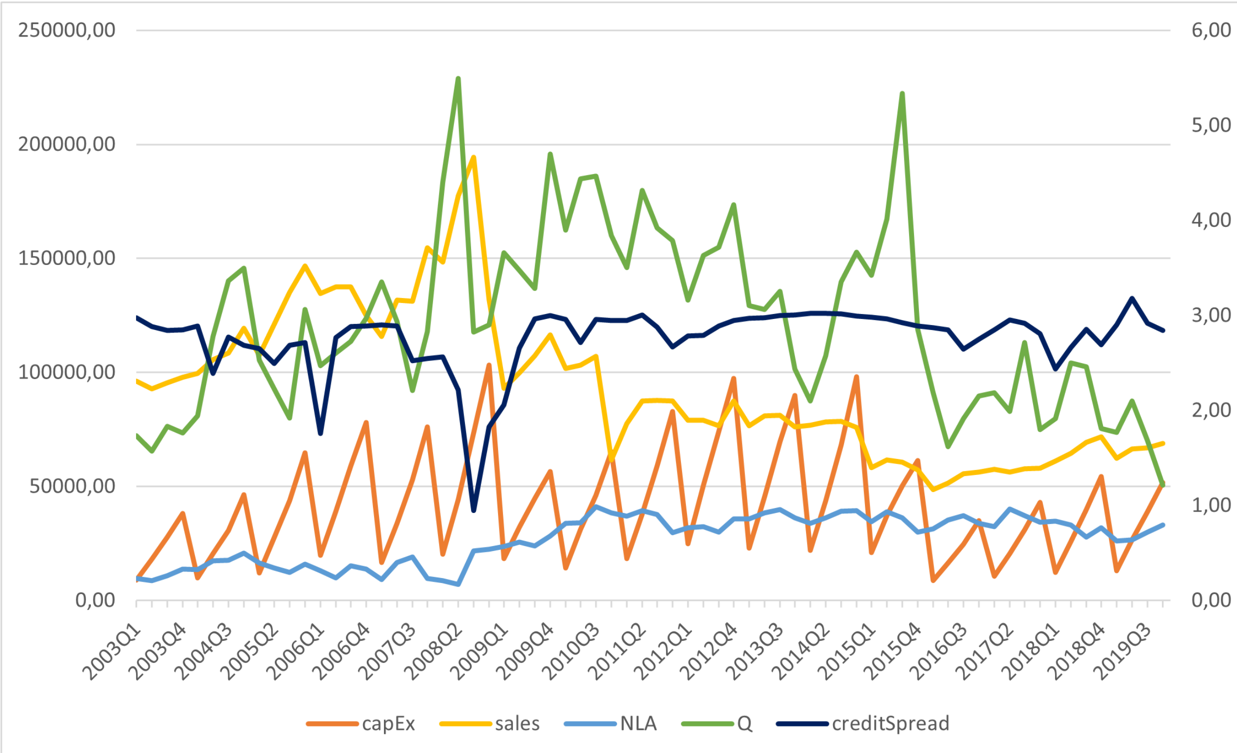
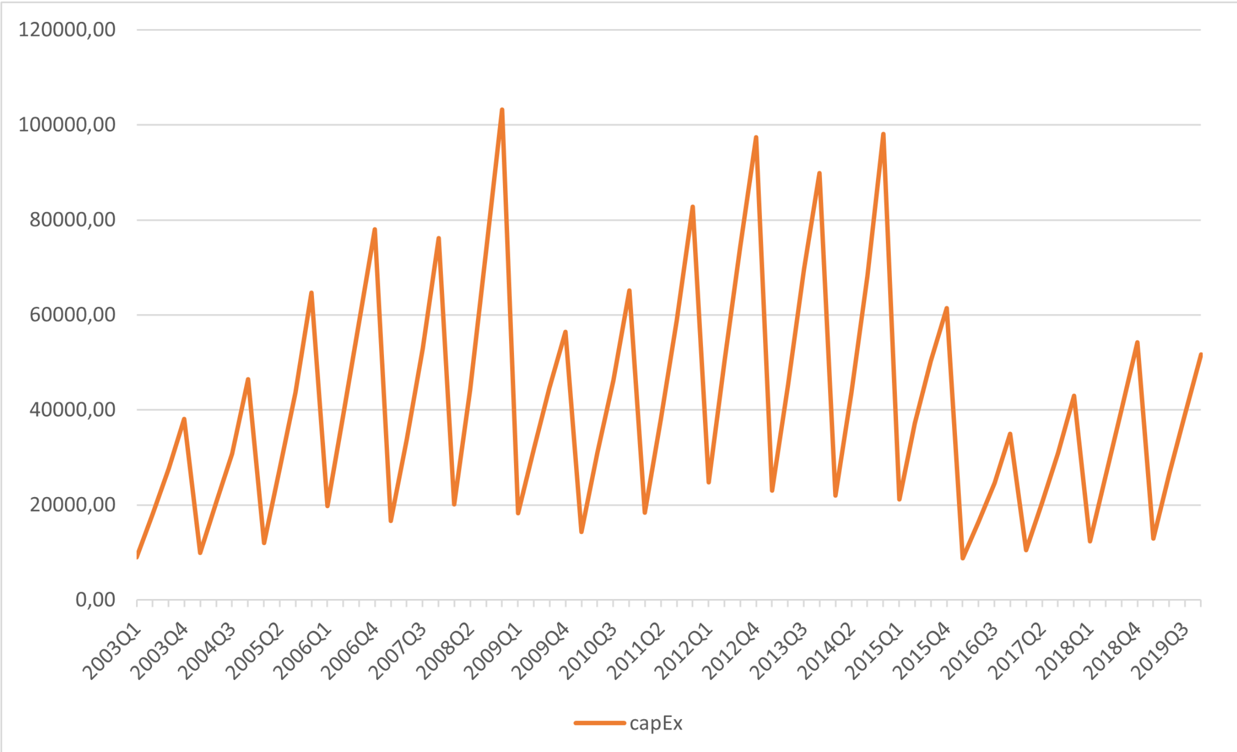



Figure 7 is quite messy. In order to better understand our data we will decompose this figure by displaying all our explanatory variables individually along with our dependent variable capital expenditures. Before we examine the trends between our dependent and our explanatory variables, we begin by taking an inquisitive look at our dependent variable, capital expenditures.

Figure 8: Capital expenditures




*Aggregated average capital expenditures, quarterly time series data*

In figure 8, we see that capital expenditures are extremely seasonally dependent. In fact, within any given year capital expenditures will be the highest in the fourth quarter and lowest in the first. The pattern of capital expenditures can be expressed like: $capEx_{Q1} < capEx_{Q_2} < capEx_{Q3} < capEx_{Q4}$, which is true for every single year within our data set. This is something we must control for in our analysis. We do this by creating seasonal dummy variables or running a TWFE regression. In order to elude the very heavy seasonal variations when analyzing capital expenditures graphically, we will instead view yearly data. In figure 9, we see q measured on the right y-axis and capital expenditures on the left.

Figure 9: Average Q and capital expenditures. Aggregated average, yearly time series data.


In figure 9 we see that average q and capital expenditures have a very close fit. In fact, when only regressing the capital expenditure series on the q series, average q alone predicts 40% of the variation in capital expenditures with a rise of 1% q leading to 0.7% rise in capital investments[14]. However, we would be mistaken to accept this result. Remember that these are aggregated average yearly time series values, and we would be wrong to generalize these results. However, in our analysis we do find that q is a significant predictor, but the effect weakens once we analyze individual firms and quarterly data.

[14] see table 9 in the appendix for the regression.

Figure 10: Capital expenditures and net liquid assets (NLA).

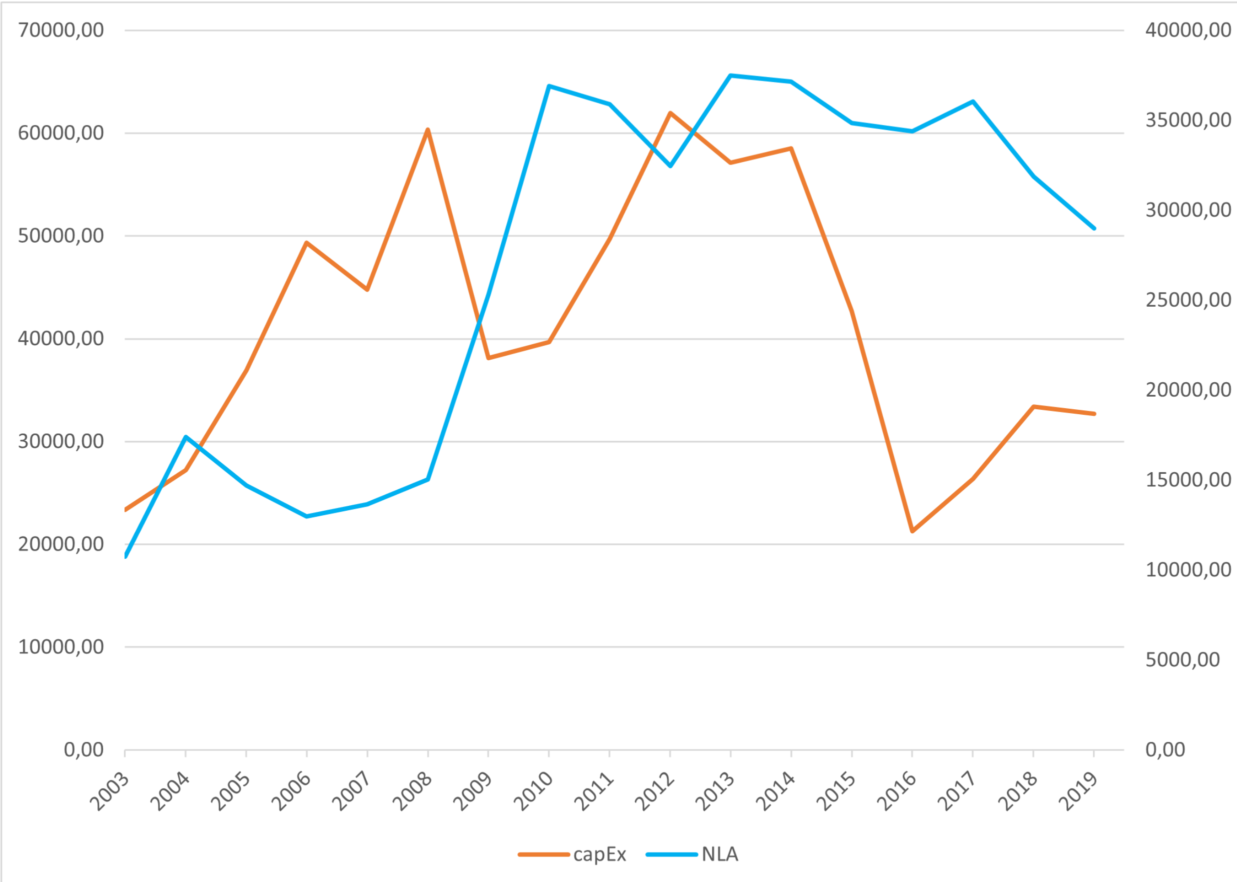
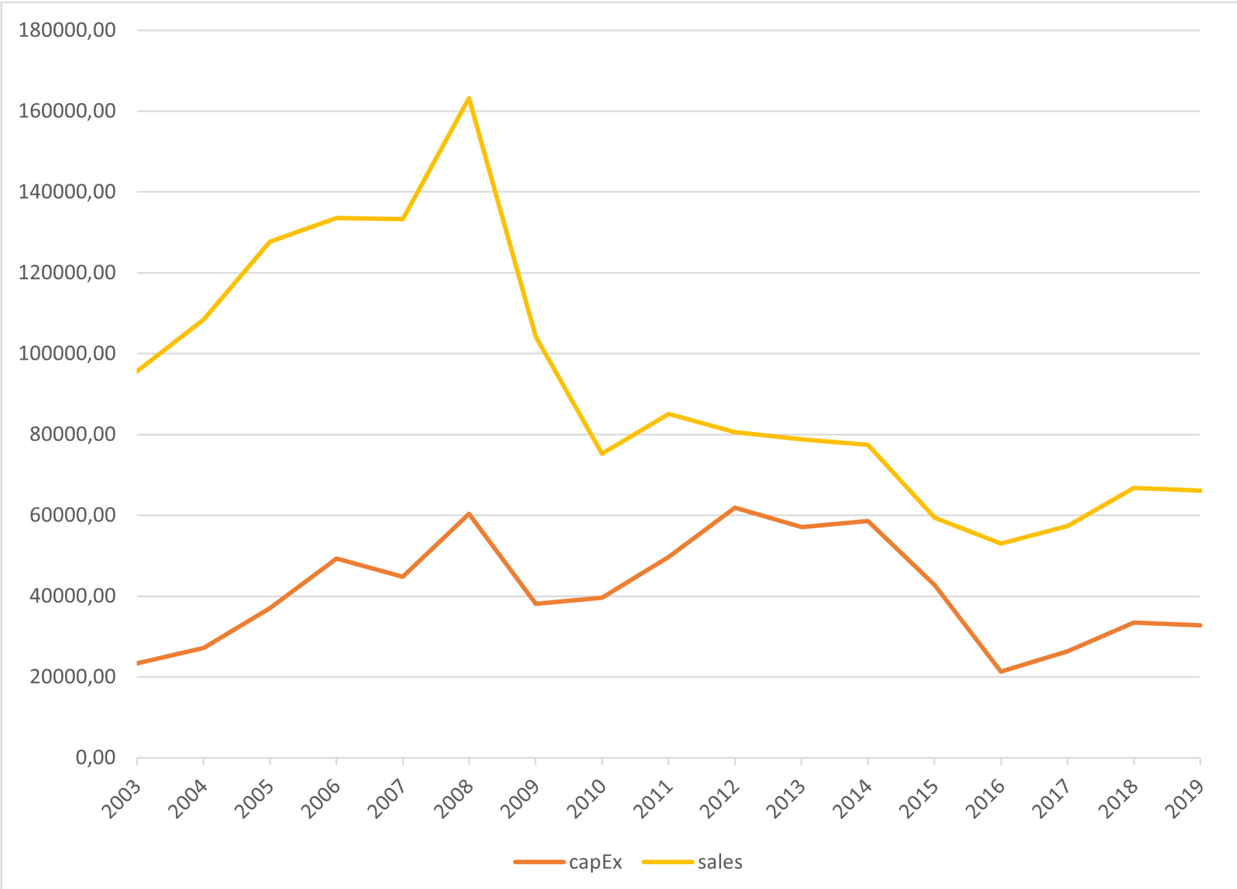


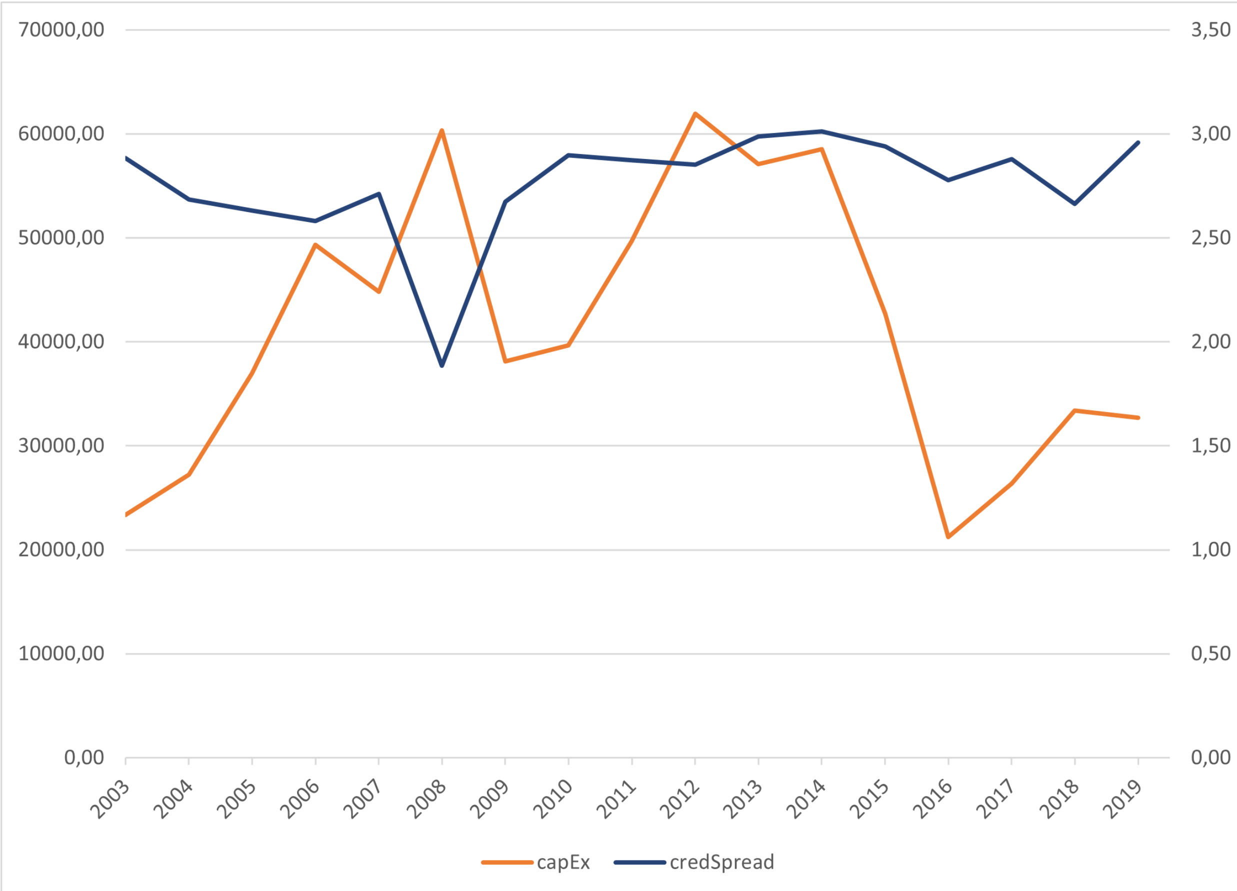

Figure 10 shows the relation between net liquid assets and capital expenditures. NLA is measured on the primary axis (left), and NLA is measured on the secondary axis. The two series seem to follow each other to some extent. We see that average aggregated values for NLA are significantly higher after 2008. This indicates a shift in preferred NLA level for companies. It is reasonable for companies to have more liquid assets if they are afraid of a new crisis. Moreover, if banks fear a new crisis they may be more hesitant to lending capital, making it harder and more expensive for companies to get external financing, thus making internal funds relatively more attractive. The price difference between internal and external financing is what makes NLA an interesting variable. Hence, if our expectations are true, NLA will be a more important predictor of investments after the financial crisis, or other periods with uncertainty.

Figure 11: Capital expenditures and net sales. Aggregated average, yearly time series data.




From figure 11 the time series of sales and capital expenditures are clearly correlated. Both series follow the exact same pattern. What is noticeable here is that sales decline after the last quarter of 2008 before stabilizing at a seemingly permanent level after the first quarter of 2010. In fact, not a single quarter after 2010Q3 has had higher sales than any single quarter dating back to 2003Q1.

Figure 12: Capital expenditures and the 3-month ICE LIBOR and US prime rate credit spread.




In figure 12 capital expenditures is read on the primary y-axis and credit spread is read on the secondary. We expect a decrease in capital expenditures for an increase in the price of external funding.[15] In the periods after 2013 the relationship between capex and the credit spread is somewhat unclear. But from the start of our sample period until 2013 the relationship is clear and negative.

[15]Which is in line with results in Prestmo (2020b)

# 5 Empirical model

Our preferred empirical model is given by the following equation:

$$\begin{aligned} log\left(\frac{I_{f,t}}{K_{f,t}}\right)_{f,t} &= \beta_0 + \beta_1 log(Q_{a,f,t}) + \beta_2 log\left(\frac{\Pi_{f,t}}{K_{f,t}}\right) + \beta_3 log\left(\frac{X_{f,t}}{K_{f,t}}\right) + \beta_4 log(C_{f,t}) \\ &+ \alpha_1 log(C_{f,t-1}) + \phi S_{2,f,t} + \phi S_{3,f,t} + \phi S_{4,f,t} + \varepsilon_{f,t} \end{aligned} \tag{5.1}$$

The subscript $f$ denotes the firm specific fixed effect and $t$ denotes time period. In order to simplify the expression we write logged variables in lower case, so that

$$\frac{i_{f,t}}{k_{f,t}} = \beta_0 + \beta_1 q_{a,f,t} + \beta_2 \frac{\pi_{f,t}}{k_{f,t}} + \beta_3 \frac{x_{f,t}}{k_{f,t}} \beta_4 c_{f,t} + \alpha_1 c_{f,t-1} + \Phi \sum_{j=2}^{4} S_{j,f,t} + \varepsilon_{f,t} \tag{5.2}$$

$\Phi$ denotes the combined effect of all seasonal dummies. Which means that $\left(\Phi \sum_{j=2}^{4} S_{j,f,t}\right)$ is only a more compact way of writing $(\phi S_{2,f,t} + \phi S_{3,f,t} + \phi S_{4,f,t})$.

We divide capital expenditures, NLA and sales by PP&E in order to control for heteroskedasticity due to differences in firm size. This is very common within the literature, and is adopted by the likes of Tobin and Brainard (1976), Hubbard (1997) and Andrei et al. (2019).

## 5.1 Expected results

According to our literature research we expect the following results:

$$\frac{i_{f,t}}{k_{f,t}} = F(\underset{+}{Q_{a,f,t}}, \underset{+}{\Pi_{f,t}}, \underset{+}{X_{f,t}}, \underset{-}{C_{f,t}}) \tag{5.3}$$

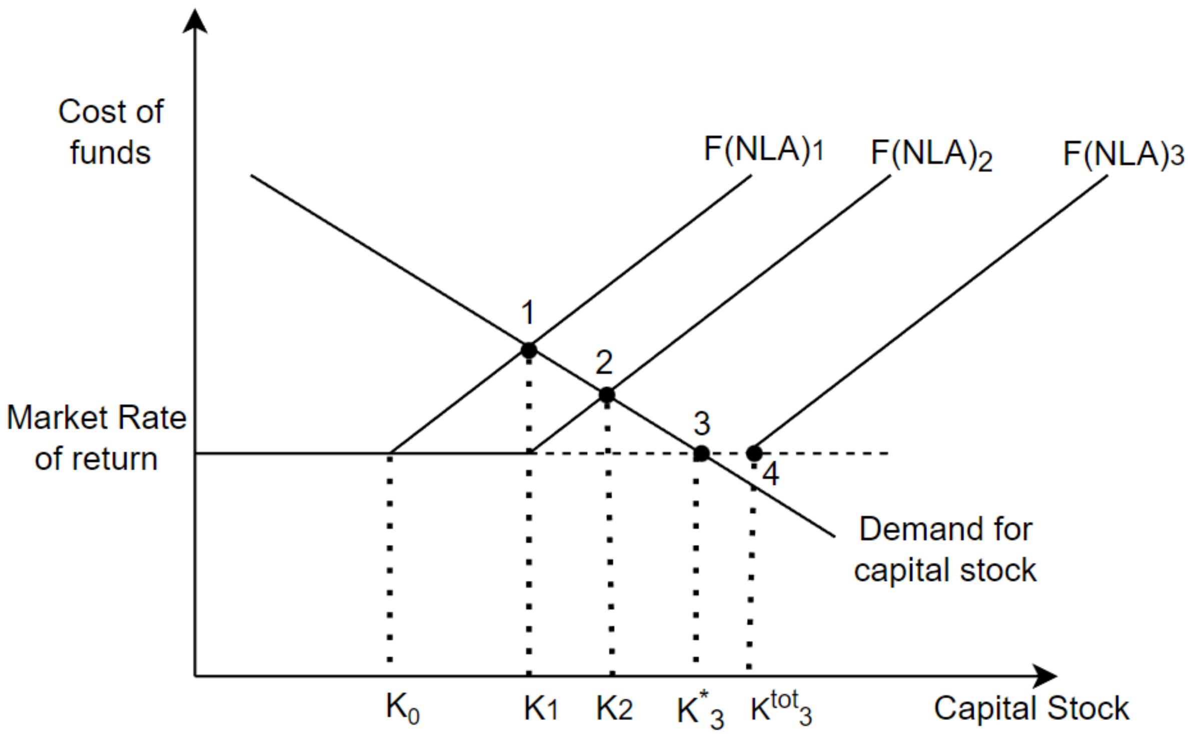
The q theory of investments clearly states that investments will be made when q is greater than 1 and discouraged when they are not. This is something our model is unable to do, and it is impossible with normal panel data regression models. However, the theory implies that higher q values should lead to higher investment levels. This is something we are able to test. Thus, if the theory is correct, we should see a positive significant correlation between $q_{a,s,t}$ and $\frac{i_{f,t}}{k_{f,t}}$.

Production is included in the standard q theory framework. The economic intuition is quite simple; for production to increase, either capital or labour must increase in order for the firm to produce more products. Hence, it stands to reason that production and investments have a strong positive relation. We have used sales growth as a proxy for production. This is a common proxy in the literature and is adopted by the likes of Guariglia (2008). Therefore, $x_{f,t}$ should have a positive relation with $\frac{i_{f,t}}{k_{f,t}}$.

NLA is a variable we have included in order to capture the effect of financial constraints. If we assume no financial constraints it would mean internal and external financing would be equally expensive. Every actor has the option to invest their funds in an internal investment project or lend them to other actors and receive the market rate of return. If they do not have sufficient internal funds to finance the investment projects, they have the possibility to seek external financing at the market interest rate. However, if external financing is relatively more expensive than internal financing, it would mean that firms who are in need of external financing becomes financially constrained since they must now pay a premium for external financing. Using a simple principal-agent model, Hubbard (1997) is able to show that external financing will be relatively more expensive than internal financing in the prescience of uncertainty and incomplete information. In his paper, Hubbard also finds empirical support for his theory. Other empirical research like Cleary et al. (2007) and Guariglia (2008) also finds empirical evidence showing that external financing is more expensive than internal financing. If we have financial constraints and external financing is more expensive than internal financing, we would expect net liquid assets ($\pi_{f,t}$) to be positively correlated with $\frac{i_{f,t}}{k_{f,t}}$.

This relation can be expressed simple graphic model. In the graphical model we assume that we have three firms. Firm 1 ($F(NLA)_1$), firm 2 ($F(NLA)_2$) and firm 3($F(NLA)_3$). Firm 1 has less internal funds than firm 2 and firm 2 has less than 3. All firms have the choice to invest in internally to achieve higher capital stock or externally to achieve the market rate of return. The cost of internal financing is equal to the market rate of return. However, due to financial constraints the cost of external financing is increasing the more external financing a firm seeks. Therefore the supply curve to the firms are equal to the market rate until they no longer have any internal funds left, at this point it starts to slope upwards.

Figure 13: Financial constraints. The cost of external financing, differences in NLA.



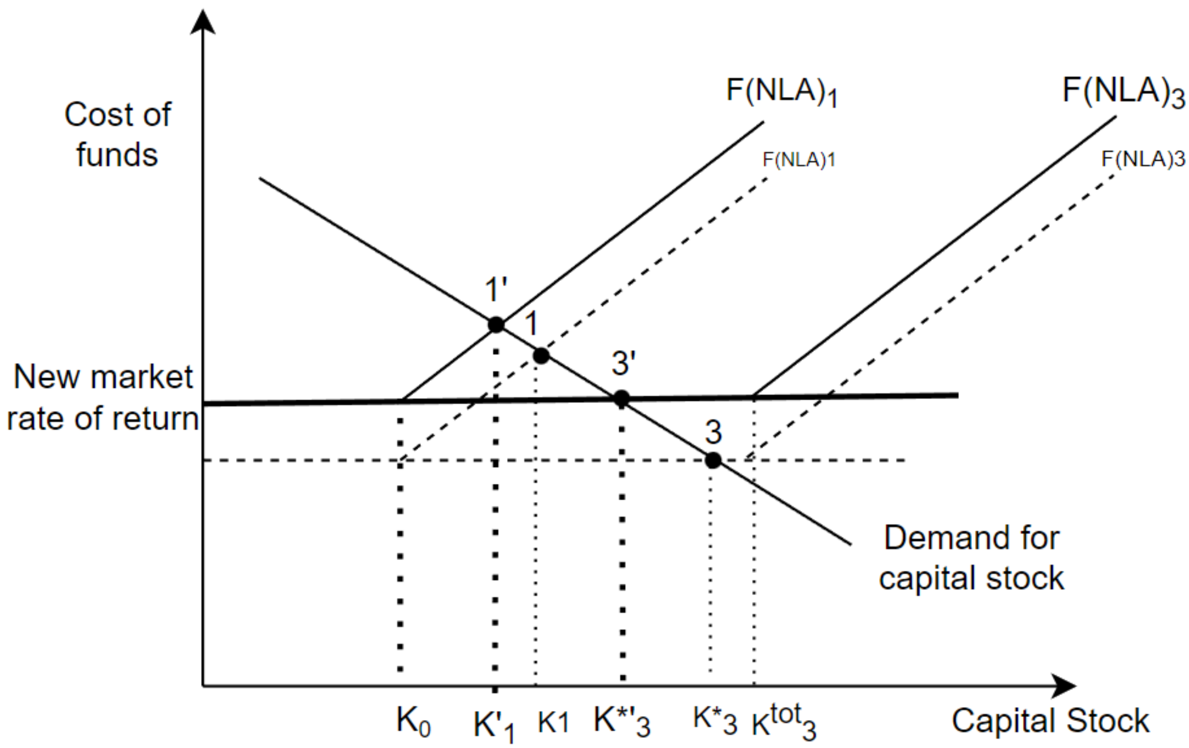

Without external financing firm 1 is able to achieve a capital stock equal to $K_0$. Firm 2 has enough internal funds to achieve $K_1$ and firm 3 $K_3^{tot}$. However because the firms can seek external financing firm 1 has an equilibrium in point 1, firm 2 in point 2, and firm 3 in point 3. If there were no financial constraints, every firm would be able to seek external financing at the same price as internal financing and achieve a capital stock equal to $K_3^*$, which is the unconstrained scenario. If firm 3 invested all of its internal funds in capital stock it could achieve a capital stock equal to $K_3^{tot}$ in point 4. However, this would mean an over-investment given the current demand for capital stock. Instead firm 3 will invest the difference between $K_3^*$ and $K_3^{tot}$ externally. Firm 1 is able to achieve a capital stock equal to $K_1$ and firm 2 is able to achieve a capital stock equal to $K_2$. Since firm 1 and 2 are not able to achieve optimum capital stock. It means that both firm 1 and 2 is financially constrained due to their lack of internal funds.

The credit spread also captures financial constraints. However, it does so by capturing the tightness in the credit market. Therefore, it directly influences the cost of external financing. It is important to include the credit spread in addition to NLA because the credit spread is able to capture some effects of external financing that NLA alone cannot. While NLA only focuses on the price difference between external and internal financing, the credit spread is able to capture the effect of absolute changes to the cost of external funding.

If the credit spread increases (tighter credit markets) due to reduced competition among banks, increased demand or a shortage of capital, then the price of both internal and external financing increases. The price of external financing increases directly. And the cost of internal financing indirectly since the alternate cost of internal investments is now higher as there are higher returns to be made externally. Therefore we would expect investment levels to drop for all companies. However, if the credit spread increases due to uncertainty in the financial market, the shadow cost of external financing is increased. Investors are less willing to invest in projects and lenders are less willing to lend financial capital. Uncertainty raises the information premium one must pay on external financing, and hence the uncertainty disproportionately raises the cost of external financing. The result is that all firms that are at least somewhat financially constrained will lower their investment levels. Since both effects are negative, we should expect a negative correlation between $C_{f,t}$ and $\frac{i_{f,t}}{k_{f,t}}$.

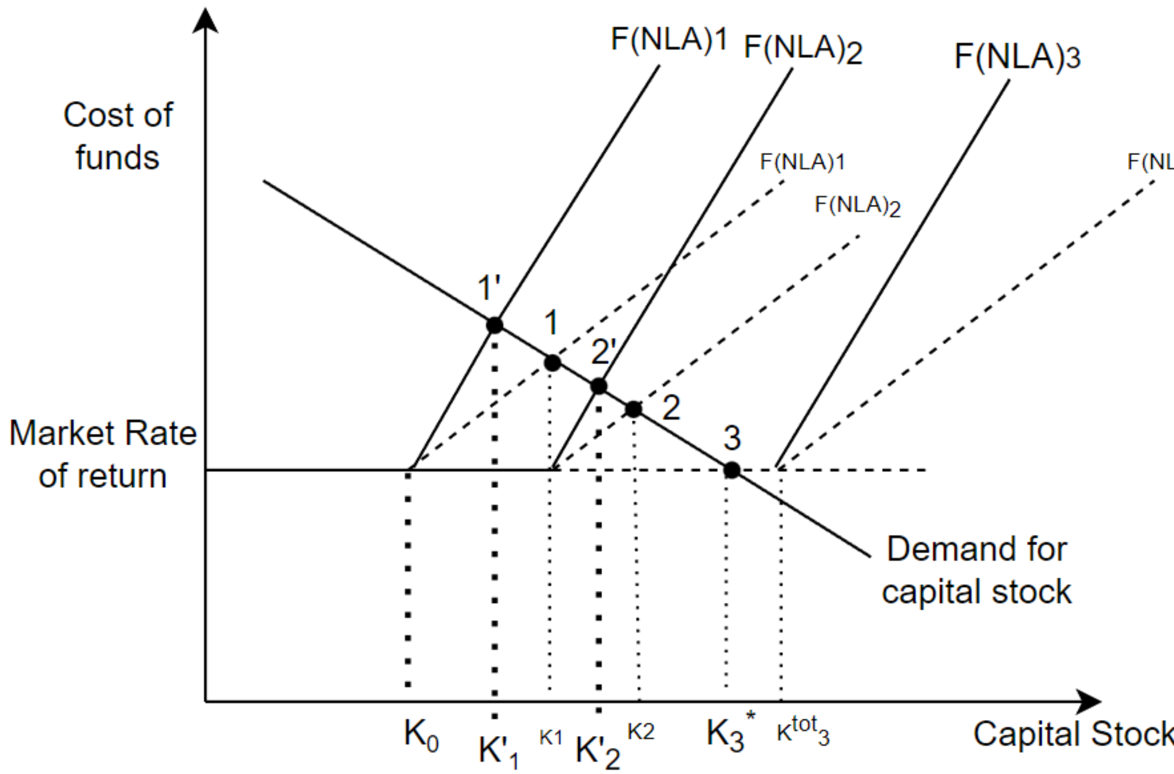
This can be expressed using the same graphical model. In the first scenario, both external and internal costs increase due to increased tightness in the credit markets. This is expressed as a upward shift in the market rate of return. This is interpreted in the same way as an increase in interest rates. Firm 2 is excluded in order to present a tidier diagram. All shifts are indicated with solid lines, and the old lines are now dashed. The new equilibrium points are expressed with the denotation with a dot, firm 1 shifts from 1 to 1'. Firm 1 invest less due to an increase in both external and internal financing. Firm 3 invests less even if it is still unconstrained. This is due to the increased alternate cost of internal financing.

Figure 14: Financial constraints. An increase in internal and external financing due to an increase in the credit spread.




In the second scenario, the shadow cost of external financing is increased due to information costs and uncertainty. This increases the slope of external costs but not the market rate of return. This scenario can also be expressed using the same diagram:

Figure 15: Financial constraints. An increase in credit spread due to uncertainty. Increased risk and information costs leads to an increase in the cost of external financing




We see that firm 1 and 2 will now invest less. However, in this stylized example it does not effect firm 3 as it is not financially restricted due to abundant internal funds.

# 6 Empirical Testing

## 6.1 Log-log specifications, sluggishness and seasonality

It is not clear weather all our variables are linear in relation to capital expenditures. In fact, Cleary et al. (2007) present evidence that NLA and capital expenditures are non-linear in relation and that the investment curve is U shaped.[16] However, using a log-log model we bypass this problem since the log-log transformation generates the desired linearity within

[16] Cleary et al. (2007) use gross investment and cash flow (in addition to NLA), both divided by beginning-of-period net fixed assets

the parameters in our model (Pedace, 2016). In addition, the log-log model makes our results more intuitive when interpreting results. Instead of looking at incremental changes we are now observing elasticities. When NLA is transformed into logarithms, negative values for our proxy for internal funds are omitted[17]. By taking the logarithm of our variables we also change the distribution of the variables, which is not a problem as most of our variables' skewness is reduced and they become more normally distributed.[18]

It is very likely that the effect of tighter credit markets on investments is sluggish. Bernanke and Gertler (1995) conclude how textbook analysis fails to account for such sluggishness and point out that the effect of a change in interest rates on investment is lagged. We do not include interest rates directly, but it is likely to assume that the effect of the credit spread exhibit the same sluggishness as interest rates as they are both measures of tighter credit markets. We therefore include lags of the credit spread in our model. The empirical results from equation 5.1 are shown as model (2) in table 3 below. Model (1) include five lags of the credit spread, however lag 2-5 are highly insignificant. Moreover, the long run effect of all lags does not change significantly when we only use one lag compared to five. To prevent over-fitting we therefore only include one lag in our preferred model, model (2).

When performing a modified Wald test for groupwise heteroskedasticity, we find that there exists some heteroskedasticity in our model.[19] We also run a Woolridge test for autocorrelation that reveals serial correlation in idiosyncratic errors with a clear margin.[20] If we ignore these issues, statistical inference becomes invalid. Although heteroskedasticity and serial correlation, if not controlled for, may have serious consequences for our estimates, the issues are easily controlled for by estimating the log-log model with cluster-robust standard errors. In our data set, we have pooled four industries that we identify as clusters: Indus-

[17]Taking the logarithm of a negative value makes no sense.

[18]For the credit spread, skewness increases when we make the logarithmic transformation. However, when comparing the results with and without the log of the credit spread we see that the results are equally robust. The conclusion is therefore to keep the log of credspread and estimate a full log-log model

[19]We get a chi-squared value of 1.4e+33, which lead us to reject the null hypothesis of homoskedasticity on a significance level $< 0.01$.

[20]F statistic is 295.853, and we reject the null hypothesis of no first order autocorrelation on a significance level $< 0.01$.

trial machinery, construction and engineering, renewables, and oil and gas. If error terms within clusters are correlated it does not matter if they are independent across clusters because we can no longer assume that error terms are independent between all observations. When we estimate cluster-robust standard errors, each individual firm in our data set is identified as a cluster over the sample period (2003Q1-2019Q4). This implies that serial correlation is allowed within these firm clusters. The procedure also makes standard errors heteroskedasticity robust (Woolridge 2015).

Table 3: FE and RE, log-log model.

| | FE | | RE |
|---|---|---|---|
| | (1) | (2) | (3) |
| Variables[21] | $i_{f,t}/k_{f,t}$ | $i_{f,t}/k_{f,t}$ | $i_{f,t}/k_{f,t}$ |
| $q_{a,f,t}$ | 0.323*** | 0.317*** | 0.323*** |
| | (0.019) | (0.018) | (0.018) |
| $\pi_{f,t}/k_{f,t}$ | 0.093*** | 0.092*** | 0.075*** |
| | (0.013) | (0.013) | (0.012) |
| $s_{f,t}/k_{f,t}$ | 0.118*** | 0.119*** | 0.090*** |
| | (0.018) | (0.018) | (0.017) |
| $c_t$ | -0.246*** | -0.259*** | -0.266*** |
| | (0.070) | (0.070) | (0.070) |
| $c_{t-1}$ | -0.236*** | -0.274*** | -0.280*** |
| | (0.079) | (0.070) | (0.070) |
| $c_{t-2}$ | -0.030 | | |
| | (0.080) | | |
| $c_{t-3}$ | -0.090 | | |
| | (0.079) | | |
| $c_{t-4}$ | 0.008 | | |
| | (0.079) | | |
| $c_{t-5}$ | 0.077 | | |
| | (0.028) | | |
| $\sum c_t$ | -0.516*** | -0.533*** | -0.546*** |
| Constant | -2.714*** | -2.703*** | -2.595*** |
| | (0.100) | (0.071) | (0.094) |
| Seasonal Dummies | YES | YES | YES |
| Firm FE | YES | YES | N/A |
| Observations | 4,553 | 4,745 | 4,745 |
| Number of firms | 120 | 120 | 120 |
| R2 within | 0.4750 | 0.4753 | 0.475 |

Cluster robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.
Quarterly data from Eikon ranging from q1 2003 to q4 2019.

[21] The variable denotations are the same as in 5.2. $i-$ capital expenditures, $q-$ Tobin's q, $\pi-$NLA, $s-$net sales, $c-$ credit spread, and $k-$PP&E. $\sum c_t$ captures the long term effect of the credit spread

In table 3 we present three models. Model (1) and (2) are fixed effects (FE) models. We apply the ISIN code of each individual company as an fixed effect, thereby we control for all firm differences that are constant over time. Estimations using pooled OLS (POLS) are dropped due to heterogeneity bias. One crucial assumption we make when employing POLS is that our explanatory variables are strictly exogenous and hence uncorrelated with the residuals. More formally, the error term of our model can be decomposed into two components

$$\varepsilon_{f,t} = a_f + u_f, t \tag{6.1}$$

where $a_f$ is firm-specific unobserved effects. If the firm-specific part of our composite error term is in some way correlated to one of more of the explanatory variables in our model, pooled OLS is biased and inconsistent (Wooldridge, 2015, pp. 439–440). Although one may find it tempting to draw conclusions on the basis of a robust coefficient, POLS estimations need to be treated with caution and will in most cases be invalid when working with panel data.

The only difference between model (1) and (2) is that model (1) includes 5 lags of credit spread while model (2) only includes 1. Model (3) is a random effect (RE) model. With the RE model, we need to assume that the explanatory variables are uncorrelated with the firm-specific part of the composite error term $a_f$ (Wooldridge, 2015, p. 470). In other words, if q is constant over time, we cannot estimate our model using fixed effects and will prefer employing random effects as the estimation method in our analysis (ibid, p. 473). We perform the Hausman test as a way to confirm our beliefs concerning model choice. The test provides evidence sufficient for us to reject the null hypothesis, and we conclude that fixed effects is the appropriate estimation method as opposed to random effects.[22] We employ individual fixed effects to all further specifications unless other estimation methods are pointed out.

[22] The null hypothesis is that our explanatory variables are uncorrelated with the firm-specific error, implying that it does not matter whether we use fixed effects or random effects. If we reject the null hypothesis, we also reject the crucial random effects assumption and will prefer fixed effects estimation (ibid, p. 473). With a chi-squared statistic of 25.98, $H_0$ is rejected with a p-value of 0.0011.

Across all models in table 3, all explanatory variables are significant at a 1% level of significance, except lags 2-5 in model (1). Furthermore, all variables are in line with our expectations expressed in equation 5.3. Average q, NLA and sales have a positive correlation with capital expenditures, while the credit spread has a negative effect on capital expenditures. The results from table 3 gives empirical support for all three hypothesises. We have a positive significant relation between q and $i_{f,t}/k_{f,t}$ which is perfectly in line with the predictions of the q theory of investment. NLA has a positive significant relation with the capital expenditure ratio which supports hypothesis (2). And the credit spread has a negative significant relation which supports hypothesis (3). The significance of both NLA and credit spread implies the prescience of financial constraints and that these constraints has a negative effect on investments.

The beta coefficients in our models are the elasticities between the dependent variable and the independent variables. Thus, from model (2) we see that if average q increases with 1%-point, capital expenditures to PP&E is predicted to increase with 0.317%-points which is quite substantial. Model (2) is our preferred model. We obtain an $R^2$ within of 0.4753, which means that it is able to explain 47.5% of the variations in $i_{f,t}/k_{f,t}$[23].

## 6.2 Extensions and robustness checks

In this section we will test the robustness of the results from model (2). We do this by applying different estimation methods and/or applying different explanatory variables.

### 6.2.1 Split-sample regressions, financial constraints

A natural starting point for this section is to perform split-sample regressions where we distinguish between firms that are more and less financially constrained. We draw inspiration from Cleary et al. (2007) and create sub-samples for positive and negative observations of our internal funds proxy NLA. Guariglia (2008) performs a similar analysis, where firms are split conditional on negative, medium and high levels of cash flow and coverage ratio. The point

[23]It should be noted that most of the variation is due to seasonal differences. In fact, when including seasonal dummies the $R^2$ increases from 7.3% to 47.5%

of the first split-sample specification is to investigate the effects of different levels of internal financial constraint. Further, when estimating our first split-sample regression, we look at internal financial constraints. The way we perform our analysis is by creating dummies for negative and positive values of NLA, and then interacting these dummies with our original NLA variable. Fazzari et al. (1988) argue that the investment-cash flow sensitivity should be higher for firms that are financially constrained and the opposite for unconstrained firms. In their paper, regression results show that firms paying low or no dividends have a higher investment-cash flow sensitivity, while firms paying high dividends are not influenced by cash flow to the same degree (Fazzari et al., 1988). On the contrary, Kaplan and Zingales (1997) point out that it is difficult to identify a firm as completely constrained. In their definition of financing constraints, they write:

> *"The most precise (but also broadest) definition classifies firms as financially constrained if they face a wedge between the internal and external costs of funds. By this definition all firms are likely to be classified as constrained. A small transaction cost of raising external funds would be sufficient to put a firm into this category"* (Kaplan & Zingales, 1997, p. 172)

In their analysis, Kaplan and Zingales (1997) find that effect of internal funds on investments is larger for unconstrained firms compared to constrained firms. which is in contrast with the earlier work of Fazzari et al. (1988). As it turns out, our split-sample regressions point to the conclusion that internally less constrained firms face higher investment-NLA sensitivity through the effect of higher net liquid assets on capex. Results from the regressions are shown in table 4.

Table 4: A split sample regression differentiation between positive and negative values of NLA

| Variables | (2) $i_{f,t}/k_{f,t}$ | (4) $i_{f,t}/k_{f,t}$ | (5) $i_{f,t}/k_{f,t}$ |
|---|---|---|---|
| $q_{a,f,t}$ | 0.317*** | 0.334*** | 0.343*** |
| | (0.018) | (0.016) | (0.036) |
| $\pi_{f,t}/k_{f,t}$ | 0.092*** | - | |
| | (0.013) | | |
| $\Pi_{f,t}$ (all values) | - | 0.009*** | - |
| | | (0.002) | |
| $\pi_{f,t}/k_{f,t}$ (negative values) | - | - | -0.009 |
| | | | (0.022) |
| $s_{f,t}/k_{f,t}$ | 0.119*** | 0.128*** | 0.102*** |
| | (0.018) | (0.015) | (0.035) |
| $c_t$ | -0.259*** | -0.266*** | -0.335 |
| | (0.070) | (0.067) | (0.206) |
| $c_{t-1}$ | -0.274*** | -0.291** | -0.422** |
| | (0.070) | (0.067) | (0.204) |
| Constant | -2.703*** | -2.639*** | -2.180*** |
| | (0.071) | (0.067) | (0.231) |
| Seasonal dummies | YES | YES | YES |
| Firm FE | YES | YES | YES |
| Observations | 4,745 | 5,853 | 1,108 |
| Number of firms | 120 | 127 | 68 |
| R2 whithin | 0.475 | 0.453 | 0.401 |

Cluster robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.
Quarterly data from Eikon ranging from q1 2003 to q4 2019.

From looking at the coefficients positive NLA and negative NLA values we find that the effect of increased NLA on capex is relatively greater for positive observations then for negative. The coefficient for positive NLA is significant on a 1% level, while the coefficient for negative NLA is insignificant. The reason why we get a negative coefficient for negative NLA is that we have taken absolute values for the subset in order to report them in logarithmic terms. Despite getting an insignificant coefficient for negative NLA, our results are in line with the findings of Kaplan and Zingales (1997), who conclude that investment-cash flow sensitivities cannot explain the degree of financial constraint in firms in their sample. In addition, we can compare the coefficients for NLA between our model for the sub-sample of constrained firms with the complete model where both internally constrained and unconstrained firms are included. Studying our main explanatory variable, we find that the coefficient for q increases when allowing for NLA to be both positive and negative in the complete model. But, the increase is not substantial, and q remains robust just as for all other log-log specifications. The investment-sales effect is slightly reduced for constrained firms, and results show that the credit spread is insignificant whereas the lag is still significant.

In addition to internal financial contraints, we will consider the investment-NLA sensitivity when splitting our sample conditional on firm size. The procedure is inspired by Kadapakkam et al. (1998) and Guariglia (2008), and is employed as a way of analyzing the effect of external financing constraints. Due to asymmetric information between lenders and borrowers, the price of raising capital from outside the firm is likely to be more costly for smaller firms. Small firms often have less collateral, higher bankruptcy costs and short track records (ibid, p. 1799). The dummy variables $SMALL_{f,t}$ and $LARGE_{f,t}$ are constructed, and captures firms with the highest and lowest levels of total assets. More precisely, $SMALL_{f,t}$ is true for firm-years within the first quartile of total assets, while $LARGE_{f,t}$ is true for firm-years within the last quartile of total assets. After constructing the dummies, we interact them with the NLA variable in our complete model. We use total assets instead of fixed assets to include intangibles, and the same is done in Kadapakkam et al. (1998). In this paper, the authors split firms by size in the world's six major economies in the sample period (US, Japan, UK, Germany, France, Canada) conditional on total assets, market value of equity and sales volume (ibid., p 318). In their findings, where fixed effects are used as the estimation method like us, large firms have the highest investment-cash flow sensitivity compared to small firms (ibid.). This implies that their results are in line with that of Kaplan and Zingales (1997).

Table 5: Split sample regressions

| Variables | (2) $i_{f,t}/k_{f,t}$ | (6) $i_{f,t}/k_{f,t}$ | (7) $i_{f,t}/k_{f,t}$ |
|---|---|---|---|
| $q_{a,f,t}$ | 0.317*** | 0.641*** | 0.143*** |
| | (0.018) | (0.058) | (0.028) |
| $\pi_{f,t}/k_{f,t}$ | 0.092*** | - | - |
| | (0.013) | | |
| $(\pi_{f,t}/k_{f,t}) * SMALL_{f,t}$ | - | 0.184*** | - |
| | | (0.058) | |
| $(\pi_{f,t}/k_{f,t}) * LARGE_{f,t}$ | - | - | -0.023** |
| | | | (0.010) |
| $s_{f,t}/k_{f,t}$ | 0.119*** | 0.180*** | 0.010*** |
| | (0.018) | (0.047) | (0.017) |
| $c_t$ | -0.259*** | 0.144 | -0.096 |
| | (0.070) | (0.247) | (0.069) |
| $c_{t-1}$ | -0.274*** | -0.263 | -0.170** |
| | (0.070) | (0.245) | (0.068) |
| Constant | -2.703 | -5.002*** | -2.432 |
| | (0.071) | (0.394) | 0.137 |
| Seasonal dummies | YES | YES | YES |
| Firm FE | YES | YES | YES |
| Observations | 4,745 | 740 | 1,207 |
| Number of firms | 120 | 32 | 42 |
| R2 whithin | 0.475 | 0.429 | 0.783 |

Cluster robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.
Quarterly data from Eikon ranging from q1 2003 to q4 2019.

The specification is shown in table 4, and we see that the investment-NLA sensitivity in absolute terms is largest for small firms, in contrast to what Kadapakkam et al. (1998) found. Moreover, the coefficient for the largest firms actually becomes negative, but also quite low. We may have measurement error in Tobin's q influencing the coefficients of NLA, which is discussed in detail in chapter 8. But it seems to be the case that the largest firms are less sensitive to decreases in internal funds. One reason to this may be that the largest and most robust firms have no problems obtaining capital through financial markets, while small firms may find it both more challenging and more costly due to asymmetric information. Our results are in line with what Guariglia (2008) find in her split-sample analysis. For policy makers in the US, results imply that size matters when firms are in demand for external funding. Making sure to break down barriers between smaller firms and financial markets should be the main objective to increase economic welfare.

As in Kadapakkam et al. (1998), we test whether there is support for the pecking order hypothesis. The hypothesis states that when in demand for funding, firms prefer internal to external sources of funding, and when external funding is needed, firms prefer debt to equity (Myers, 1984, p. 9). In Kadapakkam et al. (1998), the pecking order hypothesis is tested by creating an integration variable between Tobin's q and cash flow. If the coefficient is significantly positive, the authors interpret this as support for the hypothesis (ibid., p. 314). If the coefficient is negative, there is support for the free cash flow hypothesis, which states that for firms with poor investment opportunities, cash flow increases the agency costs (Lang et al., 1991, p. 317). The only difference between our approach and the approach of Kadapakkam et al. (1998) is that we use NLA to proxy internal funds instead of cash flow. We create an integration variable between q and NLA, and estimate our complete model. As it turns out, the coefficient of $q * NLA$ is significantly positive, which points to support of the pecking order hypothesis. Indeed, finding support for the pecking order hypothesis strengthens the argument of asymmetric information. It makes intuitively sense to assume that firms prefer internal sources of funding to external ones such as bank loans, but for the largest firms it seems to be less important. In our analysis, we find evidence that size matters for the cost of external funding.

### 6.2.2 Two-way fixed effects and the financial crisis

Going further, we now estimate the complete model using individual and time fixed effects, which is called two-way fixed effects estimation. This is done by adding time period dummies in our regression for every period in our sample, meaning we have a quarterly dummy from 2003 Q1 until 2019 Q4. When we include time dummies in our complete model we replace the seasonal dummies and instead control for all time variation within the sample period between firms, going even further compared to controlling for seasonal effects within years. A consequence of using two-way fixed effects on our model is that the credit spread, which is a time series, gets omitted. This is because it only varies between quarters and not between firms, resulting in perfect collinearity. Omitting the credit spread from the analysis is a major drawback, as we would then be unable to measure the effect of tighter credit markets on capital expenditure. When comparing the results from our two-way fixed effects with individual fixed effects, we see that the effect of our explanatory variables are reduced, but to little extent. Since the specification yields no radical changes to our results we conclude that our complete model with individual fixed effects and seasonal dummies is appropriate. This strengthens our model since it implies that our model is robust to time differences as these are likely to be picked up in our explanatory variables.

Another interesting extension to our analysis is to control for the 2008 financial crisis. Much of the literature we have reviewed is before 2008, and hence the authors were not able to include data from the financial crisis in their data sets. Fortunately, our sample period stretches from 2003 Q1 to 2019 Q4 and enables us to include a control variable we denote FC. The variable is constructed as a time dummy that is true for the years 2008 and 2009. By adding this dummy to our complete model, we control for the extraordinary events that occurred in these years. In the data chapter, the aggregated figures of our variables of interest portrayed clear trends in the years of the financial crisis. Capital expenditure experienced a sharp decrease before recovering, the same trend applies to sales and net liquid assets. In this extension we are interested in particularly two things: Firstly, whether the inclusion of the financial crisis dummy in our complete model leads to any radical changes in the coefficients for our other regressors. Secondly, whether the coefficient of the financial crisis dummy itself has a significant effect on capital expenditure. As it turns out, we find no proof of the financial crisis influencing our complete model[24]. This indicates that the credit spread and NLA variables are able sufficiently control for financial shocks like the financial crisis.

[24] We also find that adding interaction variables that control for permanent changes before and after the financial crisis make no to little differences in our model.

Table 6: FE, TWFE, and the financial crisis

| | FE | | TWFE |
|---|---|---|---|
| | (2) | (8) | (9) |
| Variables | $i_{f,t}/k_{f,t}$ | $i_{f,t}/k_{f,t}$ | $i_{f,t}/k_{f,t}$ |
| $q_{a,f,t}$ | 0.317*** | 0.318*** | 0.294*** |
| | (0.018) | (0.018) | (0.065) |
| $\pi_{f,t}/k_{f,t}$ | 0.092*** | 0.092*** | 0.089*** |
| | (0.013) | (0.013) | (0.038) |
| $s_{f,t}/k_{f,t}$ | 0.119*** | 0.119*** | 0.106*** |
| | (0.018) | (0.018) | (0.061) |
| $c_t$ | -0.259*** | -0.228*** | omitted |
| | (0.070) | (0.076) | |
| $c_{t-1}$ | -0.274*** | -0.236*** | omitted |
| | (0.070) | (0.0762) | |
| Constant | -2.703 | -2.780*** | -3.374*** |
| | (0.071) | (0.091) | (0.123) |
| Seasonal Dummies | YES | YES | N/A |
| Financial Crisis | NO | YES | N/A |
| Firm FE | YES | YES | YES |
| Time FE | NO | NO | YES |
| Observations | 4,745 | 4,745 | 4,793 |
| Number of firms | 120 | 120 | 120 |
| R within | 0.475 | 0.476 | 0.499 |

Cluster robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.
Quarterly data from Eikon ranging from q1 2003 to q4 2019.

### 6.2.3 Industry specific sub-samples

In his conclusions, Hubbard (1997) points to studying firms within a given industry as a potential extension to the literature. In their empirical analysis, Devereux and Schiantarelli (1990) extend their model by splitting their full sample and controlling for industry. The full sample in Devereux and Schiantarelli (1990) is split into growing and declining sectors.

In his re-examination of the results by Meyer and Kuh (1957), Vilasuso (1997) suggests the study of industry effects in addition to aggregate data. As mentioned earlier in the data chapter, our sample consists of firms from four different industries: Industrial machinery, construction and engineering, renewables, and oil and gas. An addition to our complete model, where firms from these different industries are pooled together, would be to estimate the complete model on these industries separately. This is done by creating sub-samples for each industry and re-running the regression for the complete model.

The effect of q, NLA, and sales on capex is significant across all specifications. Concerning the credit spread and its lag, we only get significant coefficients for construction and engineering. As for q, the coefficient is positive for all industries but the effect differs in magnitude. Similarly, NLA also has a positive coefficient which differs in size depending on the industry. The investment-NLA sensitivity is highest for the renewables sector with a coefficient of 0.156, while it is lowest for the oil and gas industry. One noticeable result concerning sales is that we get a negative effect when running the model for the renewables industry. This result may be explained by the fact that noted firms in this industry have smaller values of sales compared to other industries.[25] Such renewable equities are often referred to as growth stocks, where the pricing in the stock market is based on expectations of profitability in the future. Other than that, all coefficients for sales are positive. When it comes to the effect of tighter credit-market conditions through an increase in the credit spread, a majority of the coefficients are insignificant on a 5% level. But, except for a positive value for industrial machinery, all coefficients are negative.

[25] By comparing mean sales for the industries in our sample, we find that the renewables industry have by far the smallest values. Mean values (measured in 10 000$) are 10 718 (renewables), 71 340 (construction & engineering), 179 058 (oil & gas), and 54 242 (industrial machinery)

Table 7: Industry specific differences

| Industry | Industrial Machinery | Construction & Engineering | Renewables | Oil & Gas |
|---|---|---|---|---|
| | (10) | (11) | (12) | (13) |
| Variables | $i_{f,t}/k_{f,t}$ | $i_{f,t}/k_{f,t}$ | $i_{f,t}/k_{f,t}$ | $i_{f,t}/k_{f,t}$ |
| $q_{a,f,t}$ | 0.132*** | 0.501*** | 0.372*** | 0.248*** |
| | (0.023) | (0.037) | (0.051) | (0.039) |
| $\pi_{f,t}/k_{f,t}$ | 0.072*** | 0.071** | 0.156*** | 0.060*** |
| | (0.021) | (0.035) | (0.044) | (0.018) |
| $s_{f,t}/k_{f,t}$ | 0.470*** | 0.221*** | -0.064 | 0.124*** |
| | (0.038) | (0.040) | (0.052) | (0.027) |
| $c_{t-1}$ | 0.042 | -0.295** | -0.610* | -0.172 |
| | (0.077) | (0.123) | (0.317) | (0.136) |
| $c_{t-2}$ | -0.086 | -0.291** | -0.504 | -0.260* |
| | (0.077) | (0.124) | (0.312) | (0.138) |
| Constant | -3.49*** | -2.757*** | -2.461*** | -2.252*** |
| | (0.081) | (0.140) | (0.322) | (0.209) |
| Seasonal dummies | YES | YES | YES | YES |
| Company FE | YES | YES | YES | YES |
| Observations | 1,745 | 1,188 | 793 | 1,019 |
| Number of firms | 34 | 27 | 23 | 36 |
| R2 within | 0.675 | 0.535 | 0.313 | 0.480 |

Cluster robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.
Quarterly data from Eikon ranging from q1 2003 to q4 2019.

# 7 Critique

## 7.1 Measurement error

Erickson and Whited (2000) point out that measurement error in the capital stock may lead to measurement error in other variables. The reason is that capital stock is used as a divisor in their investment model on both investment and cash flow (ibid., p. 1035). This implies that when we have measurement error in the capital stock variable, we consequently have measurement error in both investment and cash flow. Concerning our analysis, relevant variables are capex, NLA and sales, which is divided by fixed assets. A further investigation into the valuation of fixed assets leads to the conclusion that measurement error in the proxy for capital stock is not necessarily a problem in our data. As made clear in Nichols and Buerger (2002), there exist a range of different valuation methods for fixed assets. For instance, historical cost is a method that is quite conservative, and values the asset at the price when it was originally purchased (ibid., p. 156). Other methods include inflation adjustments in the accounting of fixed assets, periodic revaluations and revaluations at the current replacement cost (ibid.). Further, different valuation methods lead to different valuations of fixed assets. Such different valuations can lead to bias in the relationship between capex, which is divided by fixed assets[26], and Tobin's q if different valuation methods are employed within the sample we are analyzing. In addition, both NLA and sales are divided by fixed assets, meaning that the possible measurement error will have repercussions and bias three additional variables in our model. Fortunately, in the US, all firms value fixed assets using the historical cost method (Nichols & Buerger, 2002, p. 156). Since our sample consists of US firms only, fixed assets are reported using the same valuation method. This argument lead us to conclude that measurement error due to differing valuation methods of fixed capital is not a problem in our model.

Fixed capital is not the only variable that may be subject to mismeasuring in the investment literature. The investment variable itself is traditionally defined as the firm's investment in tangible/physical capital. Since the early research on the q theory (see for instance Ciccolo and Fromm (1979)), the mix of assets a firm invests in has changed from the likes of property, plant and equipment. As mentioned in the theoretical background, Tobin's q was for many years not particularly successful in explaining investment, but has made a comeback in recent years (Andrei et al., 2019). A reason to why this comeback has occured may be explained by the introduction of intangible assets in the investment and q variable, as intangible capital has become more and more dominant in the US economy. Peters and Taylor (2017) state that by omitting intangibles in the investment-q equation, it leads to measurement error in both the investment and q proxies. They find that the

[26] Which is proxied by PP&E.

neoclassical theory is better at explaining investment for firms with more intangible capital (Peters & Taylor, 2017, p. 270). Andrei et al. (2019) also find that the q theory applies to intangible capital expenditures. As it turns out, accounting for such intangibles improves the empirical performance of the investment-q relation (Andrei et al., 2019, p. 269). In the construction of our investment-q model we have used capital expenditure, which includes fixed assets, intangibles and software development costs. Tobin's q, which is the market to book ratio, has total assets as divisor on market capitalization. Since total assets also include intangible capital, we argument that our model is able to correct for a substantial share of measurement error due to omitted intangibles.

A problem which may potentially generate substantial bias in our model is classical measurement error in the market to book ratio as a proxy for Tobin's q. The financial market's valuation of a firm's capital stock may be a good approximation to the real value of the capital stock, but this measure is still only an approximation (Erickson & Whited, 2000, p. 1034). To calculate the true value of the replacement cost of capital one needs to include everything that relates to some sort of value within the firm. This implies that non-physical assets such as R&D and goodwill also need to be included in calculations. Although accounting data for R&D and goodwill is collected for most firms, it is tough to measure all non-physical assets. In Erickson and Whited (2001), an investigation into the correlation between the market to book ratio and average q gives a somewhat weak relationship. The authors find that only 40% of the variation in average q is explained by the market to book ratio (ibid., p. 22). The bias in proxies for q is due to classical measurement error, which biases the estimates towards zero (ibid., p. 23). They also point out that if the variable is used as a proxy for Tobin's q, measurement error only *may* be a serious problem (ibid., p. 22-23). Still, in spite of trying to improve the measure of Tobin's q, there is still a lot of unexplained variation:

> *"Interestingly, although using sophisticated algorithms to compute the components of Tobin's q from accounting data can add to measurement quality, all such efforts still leave a substantial part of the variation in any proxy for average q unexplained. The difference between true average q and true Tobin's q may be sufficiently large that it substantially outweighs the improved estimates of Tobin's*

*q arising from different computational algorithms. The measurement error problem must therefore stem more from issues such as aggregation and unobservable assets."* (Erickson & Whited, 2001, p. 22)

For instance, some of this unexplained variance may be caused by the exclusion of intangible assets. Since we have included such assets in our proxy for Tobin's q, recent findings suggest that it strengthens the investment-q relationship (see Peters and Taylor (2017) and Andrei et al. (2019)). Further, the increase in explained investment variation provided by the inclusion of intangibles offers some reconciliation concerning the efficiency of our proxy for Tobin's q. Despite being among the most used relationship in corporate finance, one should tread carefully when assessing the causality of investment-q relationships in general. Since there in many cases is a gap between the true theoretical variables (for instance the replacement cost of capital) and empirical proxies, these proxies will, in most cases, contain measurement error (Erickson et al., 2014, p. 219).

## 7.2 Simultaneity

Simultaneous determination of corporate finance variables can lead to biased and inconsistent estimates, and by reflecting on the relation between capex and our regressors it becomes clear how simultaneity may affect our estimates. When investing in capital, the pecking order hypothesis points to the fact that firms prefer internal sources of funding rather than external ones (Myers, 1984, p. 9). Since we find support for this hypothesis in our analysis, we assume that firms prefer internal funding when investing in new capital. Simply put, the short run effect of an increase in capital expenditure on NLA is negative. If we assume that firms only take on investment projects that are profitable, the long run effect of increased capital expenditure on internal funds is positive. There may also be exogenous factors influencing the effect of capex on NLA. But, if we assume that the profit of the investment is greater than the cost, we have a positive effect of capex on NLA which may generate biased coefficients for NLA. Increased capital expenditure will also lead to increased sales in almost all cases, again assuming profit maximizing firms. The effect of increased capex on q in the long run is unclear. On the one hand, the effect is negative because it increases the replacement cost of capital proxied by total assets, which is the denominator in the calculation of q. On the other hand, the effect may be partially or completely offset by an increase in market value proxied by market capitalization, which is the numerator in the calculation of q. The only variable we can argument is exogenous in our model, and thus immune to the simultaneity problem, is the credit spread, which is given by macro data outside our data set.

Devereux and Schiantarelli (1990) point to the fact that endogeneity arises due to the simultaneous determination of cash flow, debt, current assets, q, and investments. In their analysis, generalized method of moments (GMM) is used to estimate different specifications where endogeneity between regressors is allowed for. GMM estimation is also preferred by Blundell et al. (1992) and Peters and Taylor (2017). On the other hand, recent work by Cleary et al. (2007) and Andrei et al. (2019) uses fixed effects as the preferred estimation method. Although simultaneity may affect our estimates, the strong investment-q relationship is in line with recent empirical work including the role of intangible assets.

Despite drawbacks associated with endogeneity, evidence from our analysis as well as from a large body of research points to the conclusion that the relationship between investment and Tobin's q has strengthened remarkably in the recent decades. In addition to our graphical representation of aggregated capex and q, Andrei et al. (2019) present a similar figure. When plotting aggregate quarterly fixed investment and lagged Tobin's q from 1975-2015, they also estimate R-squared before and after 1995 (Andrei et al., 2019, p. 254). Pre-1995, R-squared is 6.49%, but post-1995 R-squared increases to a staggering 71.23% (ibid., p. 254). In addition, our other regressors' effects on capex are backed by earlier research.

# 8 Concluding remarks

We contribute to the literature by creating an empirical model that captures financial constraints with a specification of Tobins's q that captures investment in both tangible and intangible assets. Our empirical results find strong support for all three hypothesis. That is:

(I) We find a strong and significantly positive relation between Tobin's q and real investment. (II) The credit spread with one lag has a significantly negative effect on real investment. This indicates that firms are financially constrained due to tightness in the credit markets. And (III) NLA has a strong and significantly positive relation with real investments. This suggests that external financing is relatively more expensive than internal financing and the existence of financial constraints. Our results are robust across all specifications of the FE model and the TWFE model.

When analyzing the difference in how large and small firms in our data set are affected by financial constraints[27]. We see that smaller firms are more reliant on internal funding and are not significantly affected by tightness in the credit markets, while larger firms are less reliant on internal funds and more reliant on the tightness in the credit market. This indicates that it is easier for larger firms to obtain external financing, while smaller companies are more heavily financially constrained and must be more reliant on internal financing. These results are perfectly in line with the empirical results of Guariglia (2008).

We find that Tobin's q works as a strong predictor of real investments. Using a FE model with Tobin's q as the key explanatory variable, we are able to explain 47.5% of the variation in $i_{f,t}/k_{f,t}$. Our results stand in stark contrast with the results of Von Furstenberg et al. (1977), Devereux and Schiantarelli (1990), Blundell et al. (1992), and a long history of empirical research on the q theory of investment who finds average q to be weak determinant of investments. However, our findings are perfectly in line with more recent research from the likes of Peters and Taylor (2017), and Andrei et al. (2019). During the last 20 years the relation between aggregate investments and Tobin's q has become remarkably tight. Peters and Taylor (2017) and Andrei et al. (2019) point to two potential reasons. Firstly, that it seems like Tobin's q is a particularly good proxy for predicting investment opportunities in intangibles and R&D intensive industries. And since research intensive firms are becoming an increasingly larger part of the economy, the q theory should preform increasingly better. Secondly, that both innovation jumps and increased updating on investment decisions

[27] Note that all firms are publicly traded equity firms, so we do not have any small firms, nevertheless we have substantial differences in size within our data set.

introduces volatility in valuations. This endogenously produce more variation in Tobin's q. This increased variation improves the fit of the regression (Andrei et al., 2019, p. 269), and our results support this claim. In table 7 we see that q has a stronger relation with capital expenditures in the industries with higher variations in Tobin's q.

For further research we think it could be interesting to investigate how the q theory performs in different countries, especially between countries with different wealth and technology levels. If the relation between average q and real investments have become closer due to economies becoming more technology and research intensive, one might expect Tobin's q to preform worse in less developed countries. It would also be interesting to further investigate how financial constraints affect different firms and industries. Our results indicate that it is harder for small companies in growth to find external financing compared to large firms. If this is true, it means that the credit markets are inefficient since they fail to allocate capital effectively. The result is a welfare loss for society as a whole because innovation and growth are halted for smaller firms in growth. If this is the case, future empirical research should investigate the relation between financial restraints and firm size further in order to get a better understanding of the phenomena, and to create better policies and institutions to allocate capital more effectively in the economy.

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# 9 Appendix

## 9.1 Further tables

Table 8: Correlation matrix of coefficients of our complete model

| | Tobin's q | NLA | Sales | $CredSpread_t$ | $CredSpread_{t-1}$ |
|---|---|---|---|---|---|
| Tobin's q | 1.000 | | | | |
| NLA | -0.124 | 1.000 | | | |
| Sales | -0.044 | -0.264 | 1.000 | | |
| $CredSpread_t$ | 0.046 | -0.040 | 0.053 | 1.000 | |
| $CredSpread_{t-1}$ | -0.065 | -0.013 | 0.017 | -0.531 | 1.000 |

Table 9: Time series regression on aggregated yearly data

| Variables | capEx |
|---|---|
| Tobin's q | 0.720*** |
| | (0.226) |
| Constant | 9.835*** |
| | (0.243) |
| Observations | 17 |
| $R^2$ | 0.403 |

*** $p < 0.01$;  ** $p < 0.05$;  * $p < 0.10$.

Sample period: 2003-2018

Table 10: Descriptive statistics of average q differentiated by industry

| Variable | Obs | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| q all sectors | 6,673 | 2.974 | 9.719 | 0.054 | 117.324 |
| q industrial machinery | 1,824 | 1.093 | 1.254 | 0.055 | 18.138 |
| q construction & engineering | 1,39 | 2.055 | 7.400 | 0.054 | 101.284 |
| q renewables | 1,274 | 7.954 | 18.792 | 0.054 | 117.324 |
| q oil & gas | 2,185 | 2.225 | 5.299 | 0.057 | 46.901 |

Table 11: User cost of capital (depreciation and tax rate)

| VARIABLES | $i_{s,t}/k_{s,t}$ | $i_{s,t}/k_{s,t}$ |
|---|---|---|
| Tobin's q | 0.317*** | 0.154*** |
| | (0.018) | (0.023) |
| NLA | 0.092*** | 0.062*** |
| | (0.013) | (0.015) |
| Sales | 0.119*** | 0.119*** |
| | (0.018) | (0.027) |
| Tax Rate | | 0.007 |
| | | (0.017) |
| Depreciation | | -0.104*** |
| | | (0.021) |
| $CreditSpread_t$ | -0.259*** | -0.235*** |
| | (0.070) | (0.068) |
| $CreditSpread_{t-1}$ | -0.274*** | -0.162** |
| | (0.070) | (0.072) |
| Constant | -2.703*** | -1.731*** |
| | (0.071) | (0.230) |
| Seasonal dummies | YES | YES |
| Firm FE | YES | YES |
| Observations | 4,745 | 2,308 |
| Number of firms | 120 | 95 |
| R2 within | 0.475 | 0.609 |

Cluster robust standard errors in parenthesis

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

## 9.2 Panel data unit root tests

Table 12: Fisher-type unit-root test for $i_{f,t}/k_{f,t}$ based on augmented Dickey-Fuller tests

| | | | |
|---|---|---|---|
| H0: All panels contain unit roots | | Number of panels: | 137 |
| Ha: At least one panel is stationary | | Avg. number of periods: | 49.10 |
| AR parameter: | Panel-specific | Asymptotics: | T ->Infinity |
| Panel means: | Included | | |
| Time trend: | Not included | | |
| Drift term: | Not included | ADF regressions: | 1 lag |
| | | Statistic | p-value |
| Inverse chi-squared(266) | P | 3,098.865 | 0.0000 |
| Inverse normal | Z | -43.528 | 0.0000 |
| Inverse logit t(644) | L* | -74.792 | 0.0000 |
| Modified inv. chi-squared | Pm | 122.820 | 0.0000 |

Table 13: Fisher-type unit-root test for $s_{f,t}/k_{f,t}$ based on augmented Dickey-Fuller tests

| | | | |
|---|---|---|---|
| H0: All panels contain unit roots | | Number of panels: | 130 |
| Ha: At least one panel is stationary | | Avg. number of periods: | 50.28 |
| AR parameter: | Panel-specific | Asymptotics: | T ->Infinity |
| Panel means: | Included | | |
| Time trend: | Not included | | |
| Drift term: | Not included | ADF regressions: | 1 lag |
| | | Statistic | p-value |
| Inverse chi-squared(252) | P | 664.939 | 0.0000 |
| Inverse normal | Z | -9.595 | 0.0000 |
| Inverse logit t(619) | L* | -12.602 | 0.0000 |
| Modified inv. chi-squared | Pm | 18.393 | 0.0000 |

Table 14: Fisher-type unit-root test for $\pi_{f,t}/k_{f,t}$ based on Phillips-Perron tests

| | | | |
|---|---|---|---|
| H0: All panels contain unit roots | | Number of panels: | 128 |
| Ha: At least one panel is stationary | | Avg. number of periods: | 41.13 |
| AR parameter: | Panel-specific | Asymptotics: | T ->Infinity |
| Panel means: | Included | | |
| Time trend: | Not included | | |
| Newey-West lags: | 1 lag | | |
| | | Statistic | p-value |
| Inverse chi-squared(244) | P | 893.491 | 0.0000 |
| Inverse normal | Z | -13.592 | 0.0000 |
| Inverse logit t(589) | L* | -19.034 | 0.0000 |
| Modified inv. chi-squared | Pm | 29.401 | 0.0000 |

Table 15: Fisher-type unit-root test for $c_t$ based on Phillips-Perron tests

| | | | |
|---|---|---|---|
| H0: All panels contain unit roots | | Number of panels: | 155 |
| Ha: At least one panel is stationary | | Avg. number of periods: | 67.99 |
| AR parameter: | Panel-specific | Asymptotics: | T ->Infinity |
| Panel means: | Included | | |
| Time trend: | Not included | | |
| Newey-West lags: | 1 lag | | |
| | | Statistic | p-value |
| Inverse chi-squared(310) | P | 2717.634 | 0.0000 |
| Inverse normal | Z | -44.886 | 0.0000 |
| Inverse logit t(779) | L* | -60.211 | 0.0000 |
| Modified inv. chi-squared | Pm | 96.693 | 0.0000 |

Table 16: Fisher-type unit-root test for $q_{ft}$ (industrial machinery) based on Phillips-Perron tests

| | | | |
|---|---|---|---|
| H0: All panels contain unit roots | | Number of panels: | 34 |
| Ha: At least one panel is stationary | | Avg. number of periods: | 53.65 |
| AR parameter: | Panel-specific | Asymptotics: | T ->Infinity |
| Panel means: | Included | | |
| Time trend: | Not included | | |
| Newey-West lags: | 1 lag | | |
| | | Statistic | p-value |
| Inverse chi-squared(68) | P | 151.778 | 0.0000 |
| Inverse normal | Z | -5.539 | 0.0000 |
| Inverse logit t(174) | L* | -5.7552 | 0.0000 |
| Modified inv. chi-squared | Pm | 7.1839 | 0.0000 |

Table 17: Fisher-type unit-root test for $q_{ft}$ (construction and engineering) based on Phillips-Perron tests

| | | | |
|---|---|---|---|
| H0: All panels contain unit roots | | Number of panels: | 31 |
| Ha: At least one panel is stationary | | Avg. number of periods: | 44.84 |
| AR parameter: | Panel-specific | Asymptotics: | T ->Infinity |
| Panel means: | Included | | |
| Time trend: | Not included | | |
| Newey-West lags: | 1 lag | | |
| | | Statistic | p-value |
| Inverse chi-squared(62) | P | 109.4350 | 0.0002 |
| Inverse normal | Z | -2.494 | 0.0063 |
| Inverse logit t(154) | L* | -2.402 | 0.0088 |
| Modified inv. chi-squared | Pm | 4.260 | 0.0000 |

Table 18: Fisher-type unit-root test for $q_{ft}$ (oil and gas) based on Phillips-Perron tests

| | | | |
|---|---|---|---|
| H0: All panels contain unit roots | | Number of panels: | 40 |
| Ha: At least one panel is stationary | | Avg. number of periods: | 54.63 |
| AR parameter: | Panel-specific | Asymptotics: | T ->Infinity |
| Panel means: | Included | | |
| Time trend: | Not included | | |
| Newey-West lags: | 1 lag | | |
| | | Statistic | p-value |
| Inverse chi-squared(80) | P | 117.5380 | 0.0040 |
| Inverse normal | Z | -2.332 | 0.0098 |
| Inverse logit t(204) | L* | -2.437 | 0.0078 |
| Modified inv. chi-squared | Pm | 2.968 | 0.0015 |

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