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The Effect of Uncertainty on Investment

Empirical evidence from listed Norwegian firms 2005-2018

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This thesis is written as part of our master's degree in Economics and Business Administration at the Norwegian School of Economics (NHH).

Writing this thesis has been an exciting challenge and an experience which has led to greater insight into the necessary requirement of conducting academic research. We have developed a greater understanding of the challenges of handling large data sets and the effort required to present empirical research in a structured manner.

We express our gratitude towards our supervisor Øivind Anti Nilsen, who has provided valuable insight, shared his knowledge, and challenged our perspective. He has expressed a genuine interest in our topic throughout the process, providing us with a good source of motivation. We also express our gratitude towards SNF and Børsprosjektet at NHH for providing detailed data on Norwegian firms, without which we could not have pursued this topic.

Abstract

The relationship between uncertainty and investment is an extensively explored topic in economic and financial literature. Regardless, the dramatic events of recent years have reinvigorated the need to garner a greater understanding of this relationship. Diverse and often competing theoretical literature on the effects of uncertainty on investment has not managed to provide a conclusive answer on the direction of this relationship, underscoring the need for additional empirical research.

This thesis aims to investigate the relationship between uncertainty and investment on a panel of listed Norwegian firms from 2005 to 2018. In addition, we analyse potential differences in the direction and magnitude of this relationship between business sectors.

Controlling for both firm-specific and macro-specific characteristics, we find evidence of a negative relationship between both firm-specific and an aggregate uncertainty on firm-level investment. Furthermore, when conducting a comparative analysis, we observe indications that there are differences in the magnitude of the effect between business sectors. Lastly, our results suggest that manufacturing firms are less responsive to demand shocks during times of higher uncertainty.

Our findings shed light on the effect of uncertainty on firm investment behaviour in a Norwegian context. As with earlier empirical literature, our findings could have important implications for fiscal and monetary policy.

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1. Introduction

1.1 Motivation and purpose

Since the turn of the century, there have been several significant global events causing widespread uncertainty and instability. 9/11, the outbreak of SARS, the 2008 financial crisis, Brexit, the Covid-19 pandemic, and the war in Ukraine serve as just a few examples. These disruptive events manifest themselves as exogenous shocks, increasing levels of global uncertainty, destabilizing financial markets, disrupting global trade, and decreasing worldwide economic output. The consequences are fluctuations in economic activity, higher unemployment, lower inflation, and political instability (Federal Reserve Bank of St. Louis, 2019). Interestingly, Ahir et al., (2020) found few episodes in the past 60 years where uncertainty has been at levels close to what we have observed in the past decade. This gives credence to the notion that uncertainty is the theme of the decade.

Understanding the impact of uncertainty on decision-making processes has fascinated economists for years. It is widely believed that the lack of knowledge about the future state of events, caused by uncertainty, constrains the decision-making capabilities of policymakers, business executives, and consumers. A clear understanding of uncertainty and its relation to the real environment is essential to avoid risky and unjustified decisions. This mechanism is especially relevant from an investment perspective. The decision to undertake an investment is often irreversible (Pindyck, 1988), which makes the timing of the decision a crucial factor for the success of the investment project.

It is estimated that investment account for 20 to 25 % of GDP for a given country each year (World Bank, n.d.). This means that investment fluctuations are enormously important in explaining economic performance (Carruth et al., 2000). This has important implications for fiscal and monetary policy. In times of economic crisis, it is important for policymakers to deploy the “correct” fiscal policy and monetary policy tools to stabilize economic output. Uncertainty, which accompanies times of crisis, makes it difficult to form expectations about the future, thus constraining the effectiveness of a policy response. A thorough understanding of the relationship between uncertainty and investment is therefore essential.

Despite the large body of theoretical literature on investment behaviour and its relationship with uncertainty, there is no clear consensus on its sign (Fuss & Vermeulen, 2008; Bontempi et al., 2010; Tran, 2014). A considerable amount of studies at the aggregate, industry and firm-level have attempted to conduct empirical research on the relationship between uncertainty and investment and how irreversibility affects investment timing. Most of these studies focus on the manufacturing sector and are geographically confined to Anglian or continental European firms (e.g., Leahy & Whited, 1996; Bloom et al., 2007). This casts doubts on the transferability of previous findings to other geographical areas or industrial sectors, necessitating exploring the relationship between uncertainty and investment in a Norwegian context.

Norway is a small open economy, and the country's business environment is sensitive to foreign economic and political influence. The largest, and in many regards the most important, sectors of the Norwegian economy, shipping, offshore services, energy, and aquaculture (Hemmings, 2018), are intricately linked to international markets. Thus, uncertainty in these markets originating from exogenous shocks like wars, sanctions and supply chain disruptions will affect Norwegian firms. Furthermore, operating in these sectors usually requires considerable amounts of tangible fixed assets, and investing in such assets requires substantial long-term commitments. The inflexibility of such commitments makes Norwegian firms vulnerable to changing market conditions.

Most studies on the relationship between uncertainty and investment in a Norwegian context have focused on the oil and gas industry (e.g., Hurn & Wright, 1994; Mohn & Osmundsen, 2011; Mohn & Misund, 2009). However, this thesis will collect a broad sample of firms across several business sectors, in order to conduct a comparative analysis. It would not be controversial to speculate that firms with large amounts of tangible fixed assets (e.g., offshore, shipping or manufacturing firms) will be impacted differently by changes in uncertainty than firms with lower amounts of tangible fixed assets (e.g. technology or consulting firms).

1.2 Research question

Based on the previous subsection, this thesis aims to investigate the following research question:

"What effect does change in uncertainty have on investment for listed Norwegian firms, and does the said effect differ between business sectors?"

We attempt to answer this question by conducting a panel data analysis on a sample of 113 Norwegian firms listed on OSE from 2005 to 2018. We will split our analysis into two parts. First, we will conduct an estimation on a broad sample of firms to uncover the sign and general magnitude of the effect uncertainty has on investment. Secondly, we will split the broad sample into smaller sector-specific subsamples to conduct a comparative analysis. This part aims to uncover fundamental differences in the sign and magnitude of the effect across a broad representation of capital intensive (e.g., offshore and shipping) and labour intensive (e.g., technology and services) sectors.

We will analyse subsamples intended to mirror business sectors that represent substantial value-creation, thus influencing Norwegian GDP. In the context of Norwegian firms, this would be, as mentioned, sectors like offshore and shipping, energy, technology, and manufacturing (SSB, 2021). We are interested in these sectors because how they adjust their investment behaviour to changes in uncertainty could have considerable implications for the Norwegian economy. The sectors included in our analysis reflect the composition of firms on the OSE. However, they are somewhat adjusted in order to obtain sufficient data points for our analysis.

One of the primary challenges of researching uncertainty is the absence of a reliable and standardized measure that can be utilized for empirical analysis. There are conflicting opinions on what level uncertainty (aggregate, industry, or firm-specific) should be measured. There is also no consensus on what proxies should be used within the various levels (Carruth et al., 2000). As this thesis is interested in uncovering the general effects of uncertainty, we will include uncertainty measures for both the firm level and the aggregate level.

To construct our firm-level uncertainty (henceforth firm-specific uncertainty) measure, we follow the methodology of Bloom et al. (2007), which builds upon the seminal paper of Leahy and Whited (1996). This method constructs a proxy for firm-specific uncertainty through firm-specific share price volatility. We use an economic policy uncertainty index, constructed following the methodology of Baker et al., (2016), as a proxy for aggregate uncertainty. Including an economic policy uncertainty index as a control variable in our analysis allows us to isolate and compare aggregate uncertainty to firm-specific uncertainty (Al-Thaqeb & Algharabali, 2019).

The key dependent variable in our analysis is the firm investment rate. We construct a proxy for this rate by following the methodology of Leahy and Whited (1996). We base our investment rate on investments into tangible fixed assets. The reason is that tangible fixed assets are more transparent, easier to measure, and less subject to market imperfections than financial assets and intangible assets (Chang et al., 2007).

The remainder of this thesis is organized as follows: Section 2 provides an overview of the relevant theoretical and empirical literature. Section 3 presents the methodology used to conduct our empirical analysis. Section 4 describes our data and the sample adjustment process. Section 5 reports and discusses our empirical results. Section 6 highlights some of the limitations of our study, and Section 7 offers some concluding remarks and suggestions for further research.

2. Literature Review

2.1 Ambigious theoretical and empirical contributions

During the last decades, several important theoretical and empirical papers have been published on the relationship between uncertainty and investment. The sentiment is that uncertainty influences investment, but the direction and magnitude of this influence is inconclusive. Luckily, recent innovations in econometric methodology and access to more comprehensive datasets have allowed researchers to test many of the proposed theories. This has fostered a growing empirical literature, which presents, with few exceptions, evidence of a negative relationship between uncertainty and investment (Caruth et al., 2000). Still, the general perception is that the way in which uncertainty affects investment is complex, diverse and in many cases ambiguous.

2.2 Uncertainty, investment, and adjustment cost

Most theoretical contributions on the relationship between uncertainty and investment agree that the relationship is dependent on the interaction between a series of variables and assumptions. These include, but are not limited to, the risk preference of the given firm, the cost function, the shape of the marginal productivity of capital, and the degree of competition in the market (Pindyck, 1982; Abel, 1983).

Early theoretical papers highlight the implications of convexity pertaining to the firm's profit function (e.g., Oi, 1961; Hartman, 1972; Abel, 1983, 1984, 1985). Exploring the role of price uncertainty, they found a potential positive relationship between uncertainty and investment. The theory is that if expectations about the future are clouded in uncertainty and firms operate in competitive markets with symmetric and convex adjustment costs, the firm can optimise price volatility. Furthermore, any increase in uncertainty increases the marginal profitability of capital, giving uncertainty a positive effect on capital accumulation and thus growth. This mechanism is later referred to as the Oi-Hartman-Abel effect (Oi, 1961; Hartman, 1972; Abel, 1983). Furthermore, this theory implies that the effect will be negative if the expected profits are a concave function of adjustment costs.

Caballero (1991) argues that asymmetric adjustment costs are not sufficient to render a negative relationship between uncertainty and investment. The structure of the market is essential. In fact, the Oi-Hartman-Abel effect carries over to the case of asymmetric adjustment costs. Furthermore, suppose the firm operates in a perfectly competitive market with constant return to scale (CRS) technology. In that case, the asymmetry of the adjustment costs has little to no impact on the sign of the relationship between uncertainty and investment. The marginal profitability of capital has little to do with the level of capital. Thus, the dominating factor is the convexity of the marginal profitability of capital with respect to price. This implies that current investment does not affect the firm's future profitability, thus giving the firm no reason to disinvest, leading to a non-negative relationship between uncertainty and fixed capital investment.

However, Caballero (1991) also argues that when the firm operates in an imperfectly competitive market with CRS technology, the marginal profitability of capital is in fact affected by the firm's current level of capital. This implies that investing in the current period increases the probability that the firm's capital stock in the next period will be too large relative to the firm's desired level of capital. When adjustment costs are asymmetric, having too much capital is worse than having too little, as increasing the capital stock is cheaper than decreasing it. If this effect is strong enough, uncertainty will negatively affect investment.

2.3 Investment, irreversibility, and real options

The works of Cukierman (1980), Bernanke (1983), McDonald and Siegel (1986), Bertola (1988), and Pindyck (1988) study the implications of irreversible capital goods and introduce the concept of the “perpetual call option” value of an uncommitted investment plan. The essential assumption of these contributions is that if investments are irreversible, the firm is provided with a real option to defer investment. Accordingly, increased uncertainty around the future profitability of the investment will increase the value of the option, thus depressing investment. Consequently, Pindyck (1993) argues that the positive relationship Caballero (1991) proposed is contingent on ignoring industry-wide uncertainty and only focusing on firm-specific uncertainty. He illustrates that even under perfect competition and constant CRS technology, industry-wide uncertainty has a negative effect on irreversible investment.

The influential work of Dixit and Pindyck (1994) expands upon the real options framework. Their book argues that an increase in uncertainty reduces investment via the irreversibility effect in a monopolistic and stochastic setting. The firm delays the investment decision in anticipation of new information, which can partly dissolve uncertainty. This happens because there is an implied asymmetry in the adjustment cost structure. Furthermore, their model introduces threshold values of expected project profitability. These trigger values determine the firm's investment behaviour and dictate the firm's choice between investment, inaction, or disinvestment. The hurdle these trigger values represent increases with irreversibility and the level of uncertainty. The concept of real options is a central piece in understanding the relationship between uncertainty and investment. Therefore, we have included an in-depth mathematical review that explains the dynamics of real options in relation to uncertainty. The review can be found in Appendix A.

Abel et al. (1996) and Abel and Eberly (1999) investigate the case in which the costs of postponing the investment are not irreversible. In their model, the firm has an option to wait, which may be costly when future investment prices are higher than current investment prices. However, if the capital stock can be resold, the firm has a reversibility option. They argue that increased uncertainty increases the value of both the wait and the reversibility option, making the total effect of increased uncertainty on a firm's fixed capital investment inconclusive.

2.4 Risk aversion and financial friction

The theories of irreversible investments and the traditional neoclassical approach assume risk-neutral investors. Nevertheless, this view is challenged by the contributions of Sandmo (1971), Zeira (1990), and Nakamura (1999), who find that risk-aversion reinforces the negative influence uncertainty has on investment. These findings are supported by Cadsby and Maynes (1998). Through the review of several experimental studies where risk preferences are misaligned between managers and shareholders, they observed investment behaviour that could be characterized by inertia and myopic loss aversion. They argue that this behaviour will amplify the negative influence of uncertainty on investment. Contradictory contributions like that of Malmendier and Tate (2005) find that overconfident managers might overestimate the profitability of future projects, dampening the negative influence of uncertainty on investment.

Osmundsen et al. (2007) found that pressure from the financial market resulted in a redirection of investment spending in the oil and gas industry in the late 1990s. Firms shifted from sustainable long-term projects to less sustainable short-term projects to improve short-term earnings. Accordingly, Matsumoto (2002) found that managers tend to take action to avoid negative earnings surprises, thus amplifying the negative influence of uncertainty on investment. Minton and Schrand (1999) explore how financial friction affect the relationship between uncertainty and investment and found evidence that financial constraints reinforce the negative effects of uncertainty on firm investment decisions.

As we can observe, numerous different factors affect the relationship between uncertainty and investment from a theoretical point of view. This limited the early empirical studies as it has traditionally been challenging to find relevant data with information on irreversibility, market power and risk aversion. This has improved as more comprehensive datasets have become available during the last decade.

2.5 Empirical literature

There is comprehensive empirical literature on the aggregate effects of uncertainty, which Caballero and Pindyck (1996) suggest is the most important type of uncertainty. Price (1996) found that increased uncertainty relating to domestic GDP reduced macroeconomic investment by 5% in the UK. He also presented evidence of delayed effects of uncertainty, arguing that the full effects would not be apparent until after three years. Caselli et al., (2003) found that increased uncertainty, quantified through the standard deviation of monthly sector industrial production indexes, depressed investment on an aggregate level in 1990s Europe.

At an industry-level, Ghosal and Lougani (2000) found that profit uncertainty measured by the standard deviation of the residual of a profit forecasting equation negatively affected investment. Henley et al., (2003) found that output price uncertainty also negatively impacted industry-level investment. They also argue that the magnitude of this effect is contingent on the degree of competition in the market. Lastly, the paper found that the effect is more significant in concentrated industries. Fedderke (2004) found that sector uncertainty, quantified through the standard deviation of value-added[1], negatively affects manufacturing investment.

Kang et al. (2014) investigate the relationship between economic policy uncertainty and firm investment in manufacturing firms. They found that economic policy uncertainty depresses the firms' investment rate through interaction with firm-specific uncertainty. The thought is that firms who are uncertain about the cost of doing business because of potential future changes in the regulatory environment will be more hesitant to embark on new investment projects. This is in line with Al-Thaqeb and Algharabali (2019) findings, who document that higher economic policy uncertainty leads the firm to act more conservatively, thereby depressing investment in production and employment.

Fuss and Vermeulen (2008) argue that firm-specific uncertainty is the type of uncertainty closest to the theoretical literature. This notion is supported by Leahey and Whited (1996), who argue that for a panel of US manufacturing firms, idiosyncratic and not aggregate uncertainty is what is essential. They both find a negative relationship between firm-specific uncertainty and firm investment.

Bloom et al. (2007) argues, using a panel of UK firms, that when investments are irreversible, this introduces a link between uncertainty and the speed of policy transmission. When uncertainty increases, the firm becomes more cautious in the short run and, therefore less responsive to demand shocks. This implies that uncertainty leads to slower policy response in the private sector. In the long run, the effect of uncertainty on the level of capital stock was ambiguous. These results were similar to the earlier findings of Bo (2002), who investigated a panel of Dutch firms.

Most studies that examine the relationship between uncertainty and investment at the firm level focus on US and UK data (e.g., Leahy & Whited, 1996; Bloom et al., 2007; Baum et al., 2008), whereas only a handful of studies investigate non-Anglo-Saxon countries[2].

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[1] Fedderke (2004) uses the standard deviation of real value added for sectors computed over a three-year moving window as a measure for sectoral uncertainty.

[2] Pattillo (1998) looks at a panel of firms from Ghana, von Kalckreuth (2000) studies West German firms, Fuss and Vermeulen (2008) look at a panel of Belgian firms, Guisio and Parigi (1999) and Bontempi et al. (2010) uses data on Italy firms, while Tran (2014) study a panel of Australian firms.

In contrast to the research on US and UK manufacturing firms, the research investigating the determinants between uncertainty and investment in Norwegian firms is limited and often focused on the oil and gas industry. Hurn and Wright (1994) found that price uncertainty had an insignificant effect on petroleum field investment in the North Sea. Interestingly, Mohn and Misund (2009) found that financial market uncertainty had a negative effect, while oil price uncertainty had a positive effect, painting an inconclusive picture. Later, Mohn and Osmundsen (2011) found that uncertainty, measured through oil price volatility and underground risk, negatively affected investment in the Norwegian oil and gas sector.

In summary, econometric innovations of modern panel data techniques have spurred a series of contributions that, for the majority, provide evidence of a negative relationship between uncertainty and investment (Bond et al., 2005). Interestingly, studies which are based on microdata tend to be somewhat clearer than studies using an aggregate data sample (Carruth et al., 2000; Greasley & Madsen, 2006). However, relatively few studies have been conducted in the Norwegian geographical space, and even fewer have ventured beyond the oil and gas sector.

3. Methodology

3.1 Estimation method

This thesis will use a panel data estimation technique to investigate the relationship between uncertainty and investment. By organizing the data using a panel data structure, we can observe the individual firms *i*, across time *t*. The estimation technique also allows us to account for unobserved firm-specific effects that are constant over time using fixed or random effect models (Wooldridge, 2019).

We assume that unobserved firm-specific effects correlate with the explanatory variables in the fixed-effect model, while for the random effect model, we assume that unobserved firms-specific effects are uncorrelated with the explanatory variables. Fixed-effect models are also less efficient than random effect models, and both models view their respective assumptions for correlation to be true for all periods. Similar to Bloom et al. (2007) and Tran (2014), we will use the fixed-effect model, as we believe it is unlikely that unobserved firm-specific effects (firm culture, management style and risk preference) are uncorrelated to our explanatory variables. As a result of using fixed-effect transformation, we remove the a_i factor[3] from our regression model, consequently reducing omitted variable bias and ridding our model of inconsistent results. The adjusted regression model (3.1) is presented in the following subsection.

We test for potential heteroskedasticity and serial correlation in the error term by conducting a modified Wald test[4] and a Wooldridge test[5]. The results reveal that standard errors are both non-constant and serial correlated. Thus, we account for the issues that heteroskedasticity and serial correlation cause by applying clustered-robust standard errors as proposed by Woolridge (2019). The presence of heteroscedasticity does not invalidate our analysis, but it weakens the efficiency of our results by impacting the standard errors. The full test results are presented in table C.1 and C.2 in Appendix C.

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[3] The time-invariant unobserved firm-specific effects.
[4] Modified Wald test for heteroskedasticity (Laskar & King, 1997).
[5] Woolridge serial correlation test for panel data (Wooldridge, 2010).

3.2 Regression model

To investigate the relationship between uncertainty and investment of Norwegian listed firms, we need a variable which can proxy for firm-specific uncertainty. We follow the method used by Caballero and Pindyck (1996), Leahy and Whited (1996), Bloom et al. (2007) and Baum et al. (2008) and construct the firm-specific uncertainty variable with the realized within year standard deviation of the daily stock returns[6]. Within year stock volatility has been widely used in literature on the relationship between uncertainty and investment as it provides several advantages. The method provides a forward-looking indicator, which is weighted implicitly in accordance with the impact of different sources of uncertainty on the firm (Bloom et al., 2007). In addition, as uncertainty is an elusive concept, using firm-specific stock returns reflects the aspects of a firm's environment that the investor deems important (Leahey & Whited, 1996). Lastly, stock prices are a frequently reported and accessible data source, allowing for extensive and detailed data samples.

With the method for calculating a proxy for uncertainty established, we can start constructing our regression model. Our base regression model uses firm investment rate as the dependent variable and uncertainty as the key explanatory variable. Our base model can be written as

$$\frac{I_{it}}{K_{i,t-1}} = \beta_0 + \beta_1 \sigma_{it}^{s} + u_{it} \tag{3.1}$$

where $(I_{it} / K_{i,t-1})$ is the investment rate for firm i at time t, β_0 represents the intercept of the regression model and β_1 is the coefficient indicating the effect of firm-specific uncertainty (σ_{it}^{s}). As a result of the fixed-effects transformation, time invariant unobserved effects represented by a_i have been removed. u_{it} is the remaining composite error term. The input components of the investment rate variable is investment (I_{it}) and capital stock $(K_{i,t-1})$, where (I_{it}) is annual net difference in tangible fixed assets and (K_{it}) is calculated using the perpetual inventory method (PIM)[7].

[6] The method for calculating the firm-specific uncertainty is described in subsection 4.3.
[7] Calculation of firm investment, capital stock and the investment rate can be found in Appendix B.

But as markets suffer from frictions, there are additional factors (Mills et al., 1995; Romer, 2006) that may influence a firm's investment decision. In the spirit of Bo (2002), Bloom et al. (2007) and Tran (2014), we account for additional influencing factors by expanding our base model with a series of control variables. These variables include cash flow ($C_{it} / K_{i,t-1}$), sales ($y_{it} / K_{i,t-1}$) and financial leverage ($L_{i,t-1}$)[8]. Cash flow is included as a proxy for financial constraints and firm expectations of future profitability (Bond et al., 2004) while the sales variable is a proxy for changes in demand. Financial leverage is included to control for financial gearing, which could affect the firm's risk preferability (Tamari, 1981).

In addition to the firm-specific uncertainty variable, we introduce a control variable for economic policy uncertainty (σ_t^p). The additional measure of uncertainty is constructed by following the methodology of Baker et al. (2016), to account for economic policy changes that could affect the economic environment of the firm[9]. The variable is included since uncertainty about future government policies and the effect of said policies is likely to influence the firm's investment decision (Kang et al., 2014).

A time dummy is included to account for potential business cycle fluctuations in the sample period and any macroeconomic factors influencing the firms from year to year. In addition, Guiso and Parigi (1999) proposed that under the irreversibility condition, uncertainty weakens the response of investment to demand shocks. To account for this feature, we will include an interaction term between our proxy variable for demand (sales), and both of our measures of uncertainty.; ($\sigma_{it}^s * y_{it} / K_{i,t-1}$) and ($\sigma_t^p * y_{it} / K_{i,t-1}$).

With the control variables, dummy variable and interaction terms included, the regression model can be written as

$$\frac{I_{it}}{K_{i,t-1}} = \beta_0 + \beta_1 \sigma_{it}^s + \beta_2 \frac{C_{it}}{K_{i,t-1}} + \beta_3 \frac{y_{it}}{K_{i,t-1}} + \beta_4 L_{i,t-1} + \beta_5 \sigma_t^p$$
$$+ \tau_t Year_{\gamma,t} + \beta_6 \sigma_{it}^s x \frac{y_{it}}{K_{i,t-1}} + \beta_7 \sigma_i^p x \frac{y_{it}}{K_{i,t-1}} + u_{it} \tag{3.2}$$

[8] Details on the input factors and control variable calculations are in Appendix B.
[9] The method for constructing the economic policy uncertainty index is detailed in subsection 4.4.

where β_1 is the coefficient of firm-specific uncertainty. β_2, β_3, β_4 and β_5 are the coefficients of the respective control variables cash flow, sales, financial leverage, and economic policy uncertainty. The vector $Year_{y,t}$ is the business cycle dummy for each year $\gamma \in$ (2005, 2006,....,2018) where the base year 2005 is omitted. τ_t is the coefficient representing the business cycle effect. If γ = t the dummy is 1, otherwise 0. β_6 and β_7 are the coefficients of the two interaction terms.

4. Data

4.1 Sources and time horizon

In order to conduct an empirical analysis of the relationship between uncertainty and investment on a panel of Norwegian firms, we need access to three data streams: firm accounting data, firm stock data and aggregate economic policy uncertainty data.

The accounting data was provided by the Centre for Applied Research at NHH[10] (henceforth SNF). The database contained comprehensive accounting data for all Norwegian firms listed on OSE from 1992 to 2018, with additional information on firm characteristics. [11] The database allows us to construct our dependent variable investment rate. In addition, it provides us with the accounting details required for the inputs in our control variables. The construction of the variables based on accounting data used in regression equation (3.2) is described in appendix B. In addition, table B.1 in Appendix B presents the input factor codes used to retrieve data from SNF.

To construct a variable that proxies for firm-specific uncertainty, we need to obtain daily closing stock prices. The S&P Compustat Global database[12] provides a comprehensive source for daily closing stock prices for listed Norwegian firms. In addition, we will also use the Børsprosjektet at NHH[13] database as a supplementary data source. We need two different databases in the construction of our firm-specific uncertainty proxy. The reason is that the Børsprosjektet at NHH database has significant gaps in the closing price data for many firms due to corruption errors when retrieving the data, thus in many cases breaching our requirement of at least 200 observations for each trading year for each firm.

The problem with solely relying on the Compustat Global database is that it does not contain information on the firm's Norwegian organizational number. The organization number is the primary identifier used in the SNF database and is the identifier we will use to match stock data and the accounting data for each firm *i* at time *t*. Therefore, we cross-reference each

[10] Norwegian: "Samfunns- og næringslivsforskning AS".
[11] SNF collects data from Bisnode D&B Norway AS delivered Menon Business Economics AS, Brønnøysundregisteret, SSB, NHH Børsprosjektet and Norges Bank (Berner et al., 2016).
[12] S&P Compustat Global was accessed through the Wharton Research Data Service (WRDS) interface, provided by the NHH library resources portal.
[13] Børsprosjektet is a NHH created database on listed Norwegian firms from 1980 to present day. Accessed through the NHH library resources portal.

firm's ISIN[14], which the Compustat Global database does contain, with each firm's organizational numbers provided in the SNF database. The cross-referencing process is done through the Børsprosjektet at NHH database, which contains each firm's ISIN and organizational numbers. This allows us to correctly match the firm stock data from Compustat Global and the firm accounting data from SNF.

To construct our control variable for economic policy uncertainty, we will use the media archive database ATEKST[15]. The database allows us to employ conditions when searching for news articles, and it includes a vast selection of both online-and print-based sources. ATEKST ensures that there are no duplicates, neither for print articles nor for online articles. The construction of the control variable is described in subsection 4.4.

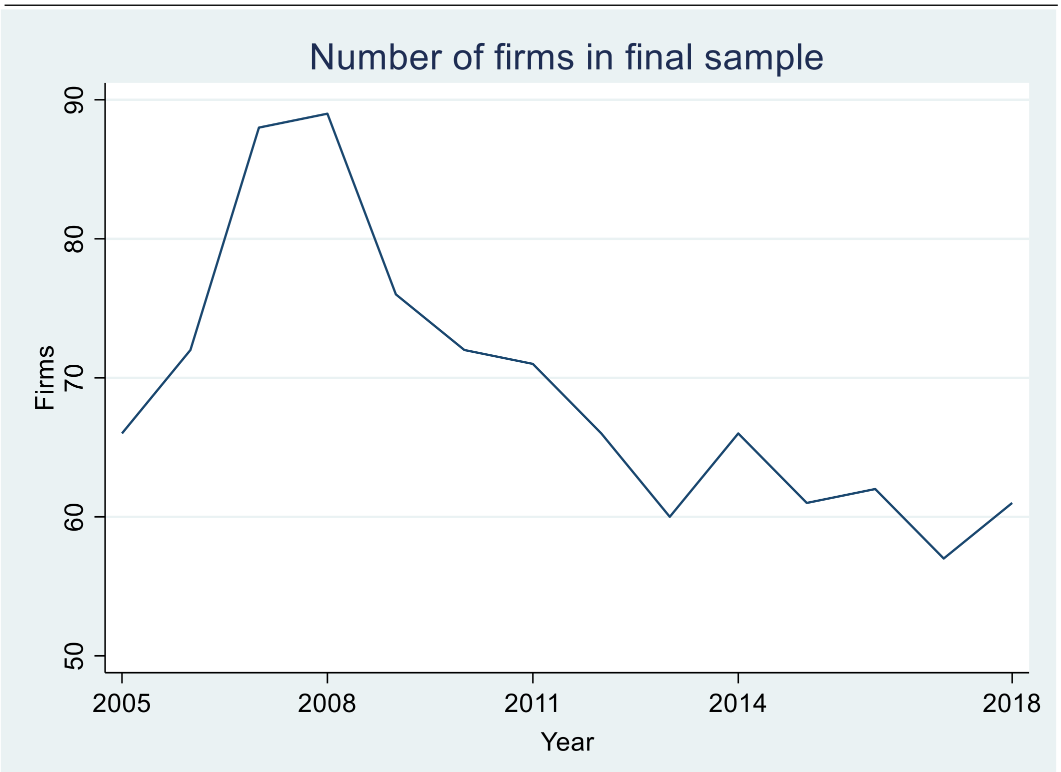
Our analysis will use data from listed Norwegian firms from 2005 to 2018. Although SNF, Compustat Global and ATEKST have data available before 2005 (1992, 1986 and 1980, respectively), we disregard data prior to 2005. This is due to the changes in the accounting rules implemented in 2005 by the European Union with resolution No 1606/2002 (European Union, 2002). The resolution effectively implemented IFRS rules on all listed companies and shifted accounting standards from the transaction-based model to a balance-sheet-oriented model. This means that different accounting solutions arise from the different models. Fardal (2007) and Bernhoft (2008) identified investment properties and other operating assets as key areas where standards differ. To ensure our analysis's robustness and not base our data samples on accounting data with two different models, we limit our data sample to 2005 and onwards. 2018 is set as the upper time limit for the data sample, as the SNF database currently does not contain any accounting data past this point[16].

[14] International securities identification number.
[15] Accessed through the NHH library resources portal.
[16] As of 15.01.22 the SNF database only contains accounting data up to 2018. The database is updated annually (Berner et al., 2016).

4.2 Stock data

Compustat Global provides both closing stock prices daily for the Norwegian firms currently listed on OSE and for the firms that have been delisted in our selected period. Our stock data sample includes firms listed on three OSE marketplaces, the primary listing Oslo Børs, Euronext Growth and Euronext Expand. Firms trading on Euronext Growth and Euronext Expand are included in the sample of firms to increase the total number of observations in our sample. Figure 4.1 illustrates the total number of firms in our sample per year after completing our data cleaning and merging. It should be noted that the low number of firms listed on OSE is a potential limiting factor to our analysis.

Figure 4.1 - Number of firms in final sample



We choose to include both the currently listed and delisted firms from OSE in our data sample. There are two main reasons for this approach. First, we wish to account for survivor bias. Including only currently listed firms on OSE would not consider the firms delisted due to factors like mergers, privatization, and bankruptcy, thus removing essential data points for our sample. Secondly, we would end up with a very small data sample. Since Norway has a relatively small economy, few firms are listed on the national stock exchange, and even fewer of the firms were continuously listed from 2005 to 2018. Furthermore, we follow the method of Tran (2014) and include all sector types of Norwegian listed firms, except for firms in the financial sector such as banks, insurance companies and holding companies. The exclusion of firms in the financial sector is due to the firm's operations, as they have a relatively small amount of tangible fixed assets and are expected to have a low degree of investment in physical assets.

We follow Boom et al. (2007) and require the firms to have at least three years of consecutive daily stock price observations to be included in the dataset. We use a requirement of three and not higher to have a sufficient number of firms represented in our dataset, as there are several firms only listed on OSE for a brief period. In addition, three consecutive observations allow us to include lagged control variables in our regression model.

A few of the firms we retrieved from Compustat Global were dual listings. A firm is dual listed when it is listed on a foreign stock exchange in addition to the listing on the OSE. We only want to analyse the effects of uncertainty on listed Norwegian firms, as stocks listed on foreign exchanges may be influenced by other factors specific to the listing country. Therefore, we limit the sample to firms listed only on the OSE and remove all duplicates.

To account for the effects of mergers and acquisitions for firms on the OSE in the data sample period, we remove the last year of daily stock observations of the delisted firm. The removal of the last observations accounts for uncertainties regarding the firm in the period leading up to the change of ownership. The possibility of a merger or acquisition may cause volatility in the firm's stock price and produce unrelated noise we want to omit.

Following practice in asset pricing literature, we also consider the effects of penny stocks and firms with a low market capitalization in our data sample. Ødegaard (2020) suggests defining penny stocks by two criteria: i) stocks with a trading value of under 10 NOK and ii) stocks with a total market capitalization under 1 million NOK. Including penny stocks in our sample may lead to a misrepresentation in our analysis. The low monetary value means that slight fluctuations in price may lead to a considerable change in return. Ødegaard (2020) suggests removing the observation if either of the two criteria is met. As the two criteria would substantially reduce our number of observations, we choose to adopt modified versions. We instead remove observations with a market cap of less than 1 million NOK and stocks trading under 1 NOK. The criteria of stocks trading under 1 NOK is applied to the whole year, so that any stock trading under 1 NOK at any given time of the year is omitted.

In our case, the requirements mainly affect the Euronext Growth and Euronext Expand observations due to distinctions between the markets[17] (Euronext, 2022). We believe omitting all the firm's observations is reasonable. Any structural issues resulting in the stock's low trading value are likely to be present in the previous and following period. Removing the penny stocks that meet the criteria will also address the issue of financial friction in smaller firms. Biases in our model from smaller stocks may arise as they have lower capital and cause calculated variables to become abnormal. The criteria remove the extreme observations and do not notably reduce the total sample.

4.3 Calculation of annual firm-level volatility

Since the accounting data retrieved from the SNF database is reported annually, we need to aggregate our daily stock data to merge the two data streams. Our required number of annual daily stock observations required for firm *i* in year *t* was set to 200. Since the requirement is set below the average maximum number of trading days within a year, annual firm volatility for some firms is calculated over a slightly different level of precision[18]. The requirement is set below the average number of trading days to have a sufficient number of observations. However, we do not consider the effects of the slight difference in observations over a trading year to be a significant limiting factor to the robustness of the results.

After cleaning and adjusting the daily stock data as described in the previous subsection, we calculate the daily stock returns. An additional factor to consider before calculating returns is stock splits and dividends. Compustat Global provides a built-in tool to account for stock splits and dividends when retrieving the data. The method for calculating daily returns can be written as

$$r_{it} = \frac{p_{it} - p_{i,t-1}}{p_{it}} \tag{4.1}$$

[17] Euronext Expand: small firms seeking financial growth and reputational advantages, not meeting Euronext Growth requirements. Euronext Growth: for small to mid-size (SME) firms that wish to raise funds and a steppingstone for listing on the main index (Euronext, 2022).
[18] Average number of trading days on the OSE is set equal to 250.

where (r_{it}) is the daily stock return of firm i at time t. (p_{it}) is the closing price of the stock at time t, while ($p_{i,t-1}$) is the closing price of the stock price for the previous time period t-1.

We now estimate the annual within year volatility in the series using the daily stock return rates. The annual within year volatility is defined as the average standard deviation of daily stock returns within the respective financial year. The method for calculating annual stock volatility can be written as

$$V = \sqrt{\frac{\sum (x-\bar{x})^2}{n}} \times \sqrt{250} \tag{4.2}$$

where the volatility is the product of the roots of the variance $\Sigma(x\text{-}\bar{x})^2/\,n$ multiplied by the root of the average number of trading days within a year 250. x is the daily stock return of the closing prices, while n is the number of return observations in the given return series. Since we use daily returns, each calculation of volatility is based on a large pool of observations. The high number of observations for each year should contribute to yield a low sample variance. Hence, by using daily stock returns we should obtain a variance that reflects the movement in the underlying process.

As Leahy and Whited (1996) discuss, one concern when using stock returns to measure uncertainty is noise unrelated to fundamentals. Volatility in stock return may arise from stock bubbles unrelated to the underlying firm's fundamentals, thus reducing the robustness of the model. To account for unrelated noise, we follow Bloom et al. (2007) and set all observations of annual firm standard deviation greater than five equal to five[19]. Boxplot 4.2 illustrates the volatility of firms on a year-by-year basis in our data sample period. As observed, several outlier observations have been set equal to five when accounting for noise. The boxplot illustrates how uncertainty measured by stock volatility for Norwegian firms had a peak around the year 2008, corresponding with the financial crisis. Similarly, we observe a slight increase around 2011 and 2015, corresponding with the European debt crisis around 2011 and the decline in oil prices at the end of 2014[20].

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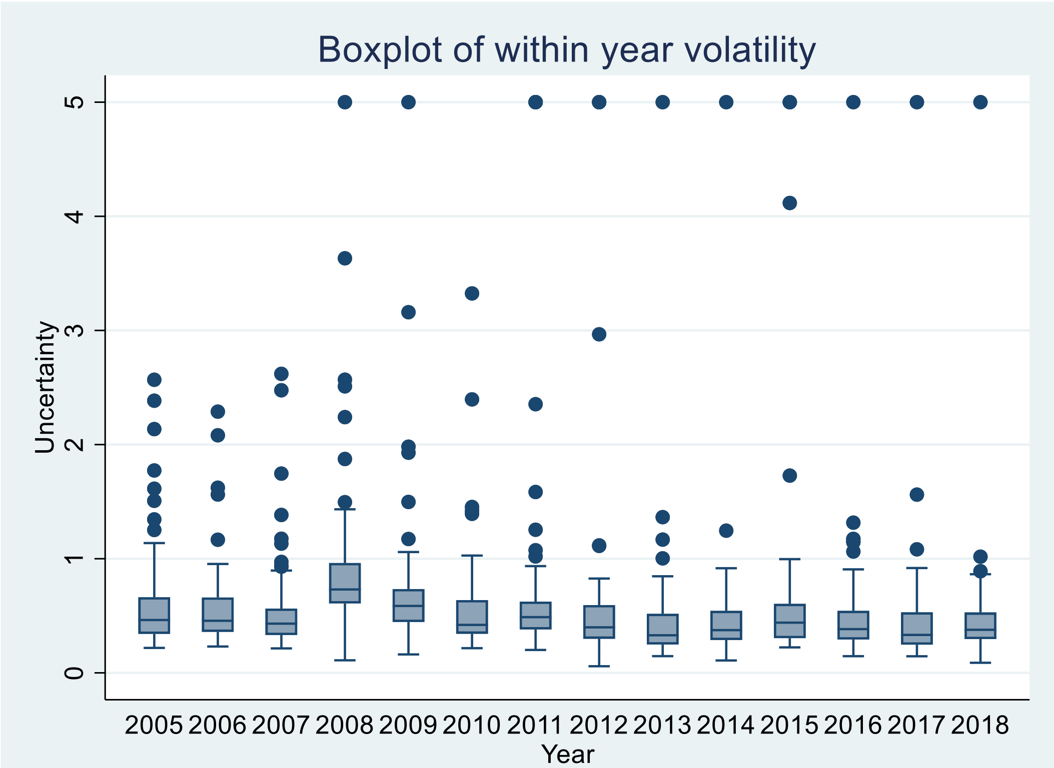
[19] Bloom et al. (2007) also proposes to normalize the firm's daily share return to the return on the FTSE All share Index, in our case Oslo Børs All-share Index, to remove any effects of stock bubbles. An alternative is to apply a Hodrick- Prescott (HP) filter on the daily returns to remove the effects of extreme observations.

[20] Between June 16th 2014 to January 18th 2015 Brent spot dropped from 114.22 USD/Bbl to 28.57 USD/BbL.

Figure 4.2 - Boxplot of within year volatility



4.4 Economic policy uncertainty index

In order to control for the effects of aggregate uncertainty in our analysis, we follow Baker et al. (2016) and construct an economic policy uncertainty index. The index is constructed by mapping the frequency of a selection of identification words from both online and paper news articles. To collect data from news sources, we will use the media database ATEKST. The identifier words are divided into three broad categories, “Economic”, “Policy”, and “Uncertainty”. Each category will again contain a list of words closely related to the category title. Each article must contain at least one word of each category to be counted in the index. Requiring the articles to contain at least one of the identification words from each category ensures that the article has the wanted focus of economic policy uncertainty. Each category is weighted equally in the construction of the index. Table 4.1 below shows the identifier word in each of the three categories.

Table 4.1: Economic policy uncertainty index dictionary

Dictionary EPU index		
Economic	Policy	Uncertainty
økonomi*	regjering*	usikker*
Norges Bank	department*	usikre
Sentralbank*	regulering*	usikkerhet*
Oslo Børs	minister*	uro*
olje	direktiv*	
	storting*	

*Note: * indicates that all suffixes of the word are included*
*** Translation of terms to English in Appendix C*

For the constructed index to be a reliable and trustworthy proxy for the level of aggregate uncertainty, two key assumptions need to be fulfilled. First, we must assume that the published news articles capture the perceived aggregate uncertainty and reflect the public's current opinion. An issue when using news articles is that the publication of articles on uncertainty can have a leading effect on public perception, thereby manipulating the level of uncertainty. However, Hopkins et al. (2017) found that the media in the US reflects to a large degree the public opinion and does not have a leading effect on the public's perception. If we assume the findings of Hopkins et al. (2017) apply to the effect of news articles on public perception in Norway, the first assumption for the index to be a trustworthy proxy for economic policy uncertainty is met.

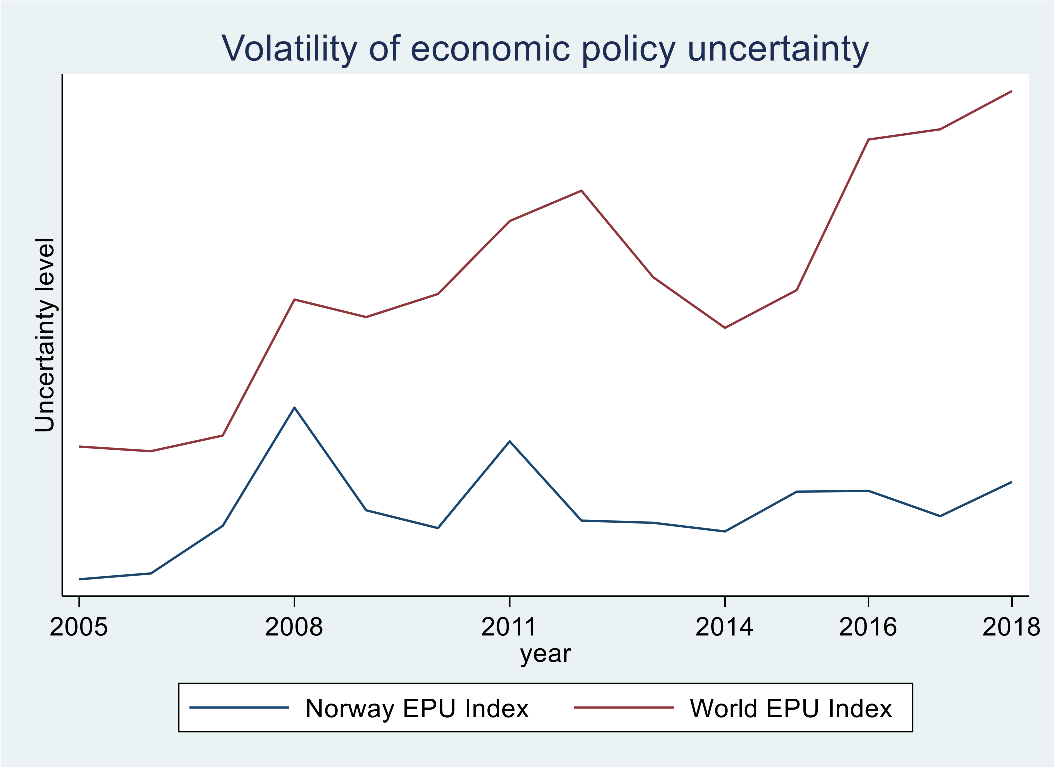
Secondly, we must assume that the selection of news sources does not have a distinct agenda. The index could be biased if the publishers used as a source have a political agenda or a specific goal with the published articles. A news source with a distinct political agenda may publish news articles with a greater focus on uncertainty, instability, and economic conditions, especially in election years. Therefore, the economic policy uncertainty index would not reflect the actual level of uncertainty but rather a political agenda of the publishers.

Boxell (2021) studied the media coverage of the 2016 US presidential election and found evidence that political affiliation influence how media covers news stories in election years. Although studies like Kundsen (2020) point out that the political environment is more polarized in the US than in Norway, we wish to adjust our sample of Norwegian media sources to avoid agenda bias. We, therefore, only include large nationally distributed and reputable news sources known not to have particularly strong ties to any political party. With the second assumption accounted for, we consider the economic policy uncertainty index as a reliable proxy for economic policy uncertainty.

Our article-based measure starts in January 2005 and ends in December 2018, matching our accounting and stock data time horizons. There is some variation in newspapers included in the index due to data availability from ATEKST, where the online version of Aftenposten and the print version of Dagens Næringsliv are not available. To ensure that we have the most comprehensive index possible, we base our search on the following newspapers and online-based news sites, which are the most read newspapers in Norway; VG, Aftenposten, Dagbladet, Dagens Næringsliv, NRK, TV2, Nettavisen and E24 (Medienorge, n.d).

Figure 4.3 illustrates the economic uncertainty policy index created, with annual levels of uncertainty from 2005 to 2018. The constructed index indicates peaks of uncertainty in 2008, 2011, and 2015, similar to the volatility in figure 4.2 for stock volatility. As mentioned, the peaks of the Norwegian economic policy uncertainty index (blue) correspond with the global financial crisis, the EU debt crisis in the wake of the financial crisis, and the drop in oil prices. The figure also includes a world economic policy uncertainty index (red) for comparison (Federal Reserve Bank of St. Louis, 2022). The two indexes have a somewhat similar trajectory, with a correlation equal to 0.4889.

Figure 4.3 –Volatility of economic policy uncertainty



4.5 Winsorizing and trimming

In order to account for outlier observations in our data sample, we adjust the accounting variables. First, we follow the method of Tran (2014) and calculate the growth rate of each firm's total assets and remove the growth observations in the 5th and 95th percentiles. These observations are trimmed away to account for firms experiencing an abnormal change in size. Secondly, all accounting variables, including investment rate, sales, cash flow, and financial leverage, are winsorized at the 5th and 95th percentile. By following the approach of Barnett and Lewis (1994) and winsorizing the accounting data, we reduce the impact of the extreme observations in our sample. Winsorizing involves assigning cut off values to the sample, where all of the observations above the upper and below the lower percentiles are removed. Following Fuss and Vermeulen (2008), the adjustment of the accounting data was made on a year-by-year basis. This is to account for trimming and winsorizing biases due to business cycle fluctuations.

Furthermore, when calculating the value of capital for the firms using the perpetual inventory method, we observed, in some instances, a negative value. The negative value of the capital stock may incur due to large sales of the capital stock. Following the procedure of Nilsen and Schiantarelli (2003), we set the observations with negative capital equal to zero. Similar to their observations, when calculating backwards, the value of capital becomes negative if the purchase of fixed capital is greater than the value in the following year.

Table 4.2 presents an overview of the data adjustments and calculations done in subsection 4.2, 4.3 and 4.5. The first section of the table describes the retrieval and adjustments steps described for the daily stock prices. The second section presents the merger of the two datasets, trimming and the winsorizing of the accounting data.

Table 4.2: Data adjustment

Description of the adjustment steps and impact on sample size		
Stock data		
	Observations	Difference
Retrieved Compustat/Børsprosjektet	475,524	
Omit financial firms	390,961	-84,563
Omit less than 3 consecutive	333,580	-57,381
Omit dual listings and duplicates	273,873	-59,707
Omit mergers and acquisitions	260,505	-13,368
Omit penny stocks	258,525	-1,980
Calculate annual volatility	1,120	-257,405
Accounting data		
	Observations	Difference
Merging accounting and volatility data	1,120	
Omit no tangible fixed assets	1,074	-46
Trim growth rate	1,074	-107
Winsorize variables	967	
Final sample size	967	

4.6 Business sectors

The sample retrieved from the SNF database includes an industry identification variable, dividing the firms listed on the OSE into ten different sectors. The variable will be used as an identifier to run our regression model on the sector-specific data samples.

As a result of the limited size of the OSE and the data cleaning and adjustment described in the previous subsections, a number of the SNF defined sectors only contain a small number of firms in the final data sample. In order to conduct a robust analysis of the sector-specific relationship between uncertainty and investment, it is critical with a sufficient number of firms and observations in the different subsamples[21]. We therefore restructure and reduce the ten categories listed in SNF into four new adjusted categories. The new categories are manufacturing, offshore/shipping, tech/IT/telecom, and other services.

For the sector-specific regression results to have validity, we attempt to maintain the integrity of some of the larger sectors when adjusting the categories. The manufacturing, offshore/shipping and tech/IT/telecom sectors remain largely the same, as these categories are well represented on the OSE and have a large number of observations. The new other services category is introduced to account for the sectors with too few observations[22].

The distribution between our new sectors in our sample period is presented in figure 4.4. As observed, figure 4.4 indicate a relatively constant ratio between the sectors manufacturing (blue), offshore/shipping (red), telecom/IT/tech (green) and other services (yellow). In addition, the figure follows a similar trajectory as figure 4.1 in subsection 4.2, suggesting that the observations in our sample are, in general, evenly distributed across firms. Figure 4.5 presents and compares the distribution of observations between the sectors. The four categories are similar in size and reside in the range of between 200 and 270 observations, with the offshores/shipping (red) being the most numerous and other services (yellow) the smallest.

[21] The cut-off limit for the required number of observations for each category was set to a minimum of 150.
[22] The new other services category consists of wholesale/retail, agriculture, construction, transport, trade, electricity, and the old other services.

Figure 4.4 – Annual distribution of observations across sectors

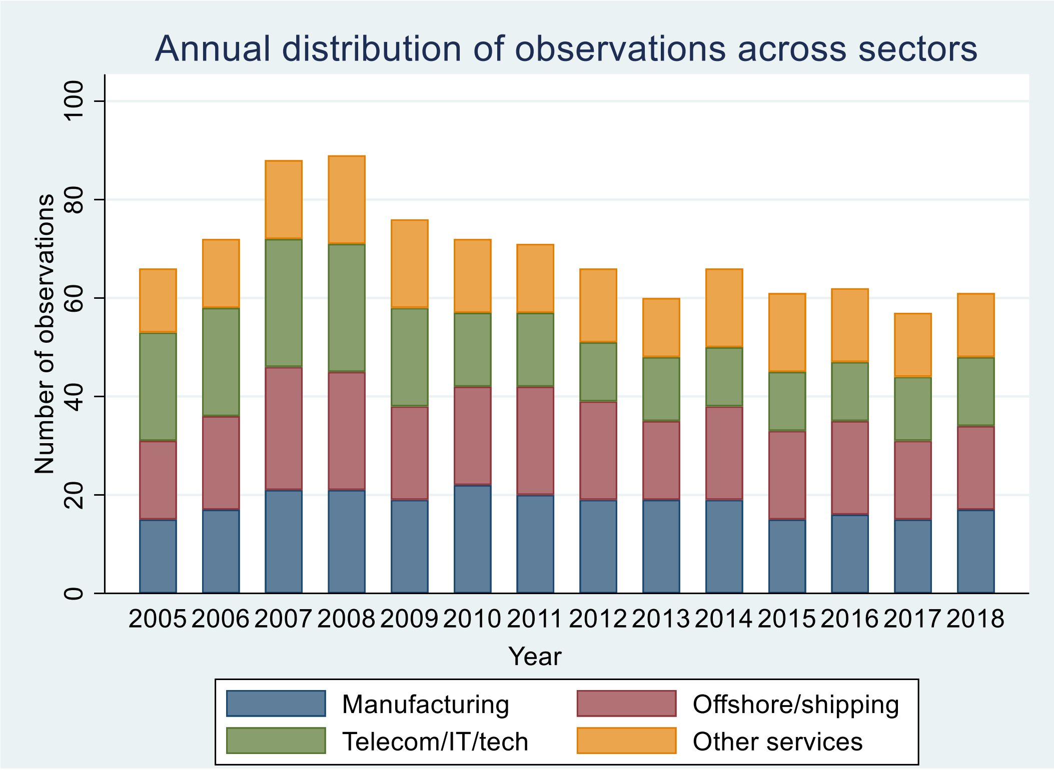
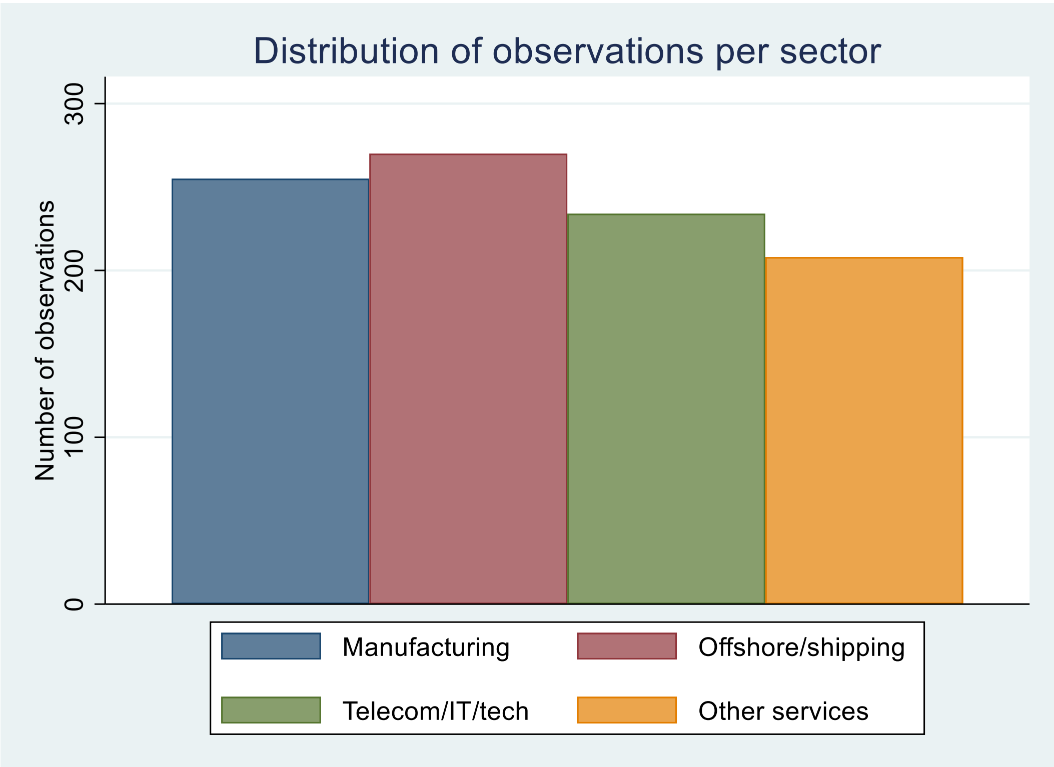


Figure 4.5 – Distribution of observations per sector



4.7 Descriptive statistics

Table 4.3 presents the descriptive statistics of the variables after the data adjustments, for the broad sample of firms. It should be noted that the cash flow variable has an unexpectedly large value, at negative 12.99. In addition, we observe a large maximum value of 208.5 in sales. The long tail values are due to the nature of the telecom/IT/tech sector firms, as we observe that firms in this sector tend to have few tangible fixed assets reported in the accounting data. Instead, these firms have a higher ratio of reported intangible assets, compared to our other sectors. As a result, if the firms have a negative cash flow, our variables will become abnormally large. Similarly, if the firm's profit from sales is large, our variable of sales can become abnormal, thus producing the long tail values observed[23].

Table 4.3 - Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
Investment Rate	0.129	0.300	-0.508	1.2
Firm-Specific Uncertainty	0.622	0.682	0.058	5
Cash Flow	0.051	1.087	-12.99	3.302
Sales	18.00	29.71	0	208.5
Financial Leverage	1.342	1.488	0.002	7.356
Economic Policy Uncertainty	4.428	1.656	1.83	8

Table 4.4 presents a correlation matrix for the regression model variables. The correlation matrix is used to check for multicollinearity and give insight into the relationship between variables. Multicollinearity arises when there is a high correlation between two or more predictor variables (Wooldridge, 2019). We observe that investment positively correlates with cash flow, consistent with the intuition that firm investment depends positively on internal cash flow. We also observe that the two uncertainty variables, firm-specific uncertainty, and economic policy uncertainty, are significantly positively correlated at 0.127. However, the correlation is not large enough for multicollinearity issues and creating a bias[24].

[23] Details on the calculation of our cash flow and sales variables is located in Appendix B.
[24] Woodridge (2019) defines a correlation of 0.475 as a moderate level of multicollinearity.

Table 4.4 - Correlation matrix

Variable	Investment Rate	Firm-Specific Uncertainty	Cash Flow	Sales	Financial Leverage	Economic Policy Uncertainty
Investment Rate	1.000					
Firm-Specific Uncertainty	-0.096***	1.000				
Cash Flow	0.124***	-0.241***	1.000			
Sales	0.003	-0.029	0.075**	1.000		
Financial Leverage	-0.020	-0.080**	0.159***	0.075**	1.000	
Economic Policy Uncertainty	-0.129***	0.127***	-0.114***	0.046	0.014	1.000

**** p<.01, ** p<.05, * p<.1*

The investment rate is the dependent variable constructed in the regression model[25]. Figure 4.6 illustrates the distribution of the investment rates for the broad sample across the entire period. As presented in the descriptive statistics for the variables in table 4.3 above, the mean of the investment rate is 12.9 %. Although the variable has been winsorized at the 5th and the 95th percentiles, we still observe a long tail. Attempting to adjust the winsorizing percentiles is discussed in the robustness subsection 5.4.

The boxplot in figure 4.7 presents the year-by-year differences in the investment rate. The figure illustrates how the investment rates have varied for firms on OSE in the period 2005 to 2018. We observe a reduction in the average investment rate from 2007 to 2010 due to the financial crisis. In addition, we also observe a slight reduction in the period of 2014 to 2016. Many of the firms in our sample and on the OSE are connected to the oil sector, such as our largest subsample sector offshore and shipping. Thus, the decline in investment rate might be explained by the drop in the oil price in late 2014.

[25] The method and inputs for constructing the investments rate can be found in Appendix B.

Figure 4.6 – Distribution of investment rate

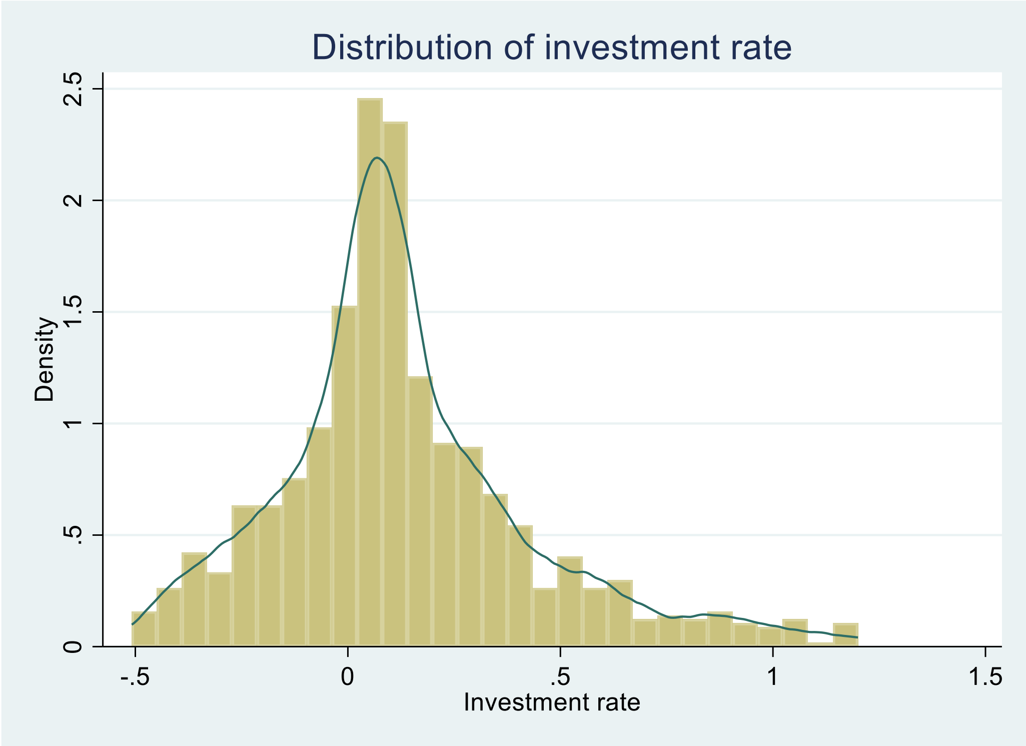
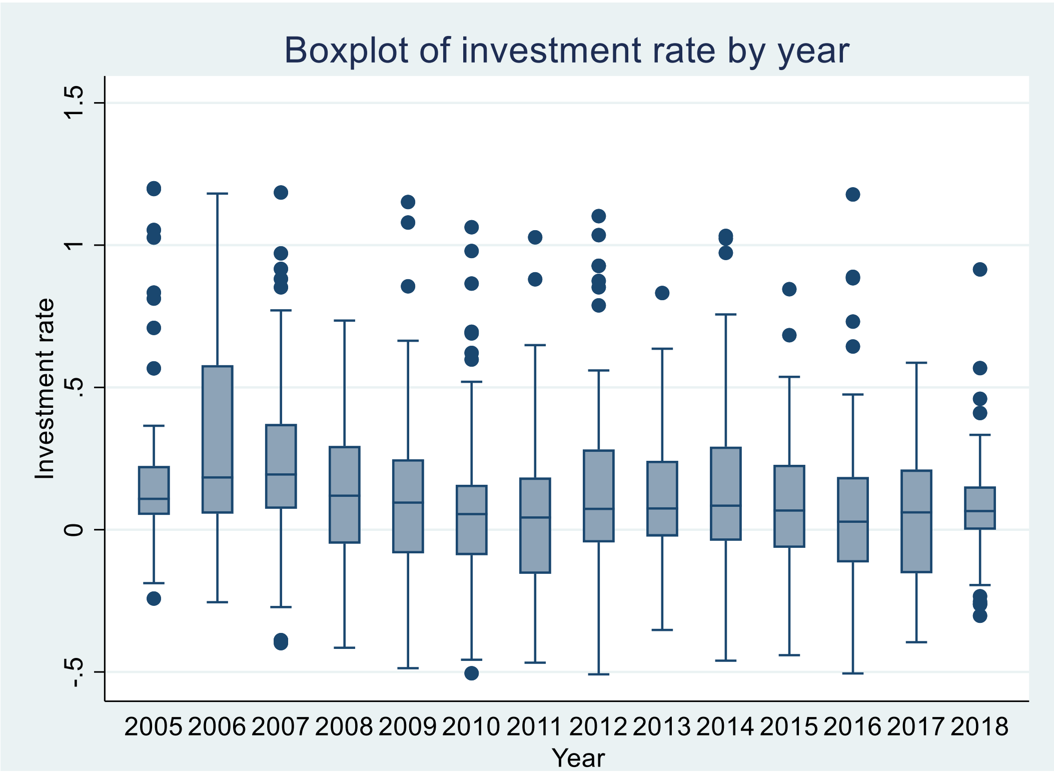


Figure 4.7 – Boxplot of investment rate by year



5. Results and Discussion

5.1 Analysis of the broad sample

Table 5.1 presents the regression results of the relationship between uncertainty and investment using the regression equation presented in section 3 on a broad sample of listed Norwegian firms. We use a fixed-effect model to control for unobserved time-invariant firm-specific effects and year dummies for macro-specific characteristics like business cycle fluctuations. All estimates have standard errors clustered at the firm level.

The key explanatory variable of our regression equation is firm-specific uncertainty (σ_{it}), and the key dependent variable is firm investment rate ($I_{it} / K_{i,t-1}$). In column (1) we present a baseline estimation, and control for the firm-specific characteristics; cash flow ($C_{it} / K_{i,t-1}$), sales ($y_{it} / K_{i,t-1}$) and financial leverage ($L_{i,t-1}$). In column (2), we control for economic policy uncertainty (σ_t^p) , which allows us to compare the effects of aggregate uncertainty to firm-specific uncertainty. Lastly, in column (3) we control for interactions between uncertainty and sales ($\sigma_{it} * y_{it} / K_{i,t-1}$ & $\sigma_t^p * y_{it} / K_{i,t-1}$), to account for the dynamics between increased uncertainty and demand.

The regression results in columns (1) to (2) of Table 5.1 imply that changes in firm-specific uncertainty and the economic policy uncertainty negatively affect firm investment rates. This aligns with the findings of influential papers like Leahey and Whited (1996) and Bloom et al. (2007). These results also support the theory of real options in capital budgeting decisions proposed by McDonald and Siegel (1986) and Dixit and Pindyck (1994). They explain that the observed reduction in investment rate is a consequence of the firm choosing to delay the investment decision in anticipation of new information that can dissolve uncertainty about the investment project's future profitability. This means that investment projects are only initiated when the project's expected return exceeds a trigger value. This value represents the strike price of the firm's "perpetual call option". Lastly, our result contradicts the theories expecting a positive relationship between uncertainty and investment (e.g., Oi, 1961; Hartman, 1972; Abel, 1983, 1984, 1985; Caballero, 1991).

To obtain some insight into the economic significance of the effects of uncertainty on firm investment rates and to be able to compare the estimations across sectors, we will compute the standardized regression coefficient[26] of our uncertainty variables. In column (1) of table 5.1, we observe a statistically significant coefficient of firm-specific uncertainty with a negative sign and a value of 0.0300. This estimate translates to a negative standardized regression coefficient of 0.0680. All other things being equal, a one standard deviation increase in firm-specific uncertainty, equal to an uncertainty shock, leads to a 6.8% drop in the firm's investment rate. This is in line with the findings of Tran (2014), who investigated a broad sample of listed Australian firms.

Furthermore, economic policy uncertainty displays a statistically significant negative coefficient of 0.0610. This means that a one standard deviation increase in economic policy uncertainty reduces the firm's investment rate by 33%. There are few applied studies on the relationship between economic policy uncertainty and firm investment. However, our results are qualitatively similar to Chen et al. (2019), who investigated a sample of US firms.

Controlling for the interaction between uncertainty and sales in column (3) reduces the effect of firm-specific uncertainty on firm investment rates by 2.3%, which results in a total effect of 4.5%. In the case of economic policy uncertainty, the magnitude of the effect increases by 3%, leading to a total effect of 36%. Intuitively, aggregate uncertainty shocks could have greater effects on firm investment rates than firm-specific uncertainty shocks, as these types of shocks represent major destabilizing events.

The interaction term between firm-specific uncertainty and sales displays a negative coefficient. This might indicate that an increase in firm-specific uncertainty would weaken the link between sales and investment. Which, according to Bloom et al. (2007), suggests that the short run-response of firm investment to demand shocks is lower at higher levels of uncertainty. If this is true, the implication would be that the increase in uncertainty around shocks like 9/11 or the financial crisis could reduce the short-term responsiveness of firm investment to monetary or fiscal policy. However, as the interaction term is not statistically significant, we cannot draw any conclusion on this topic.

Some speculate that uncertainty has a negative effect on firm investment rates because uncertainty actually proxies for credit constraint (Scaramozzino, 1997). Suppose access to credit is related to the firm's risk appetite (firms with higher risk appetite have already

[26] We calculated the standardized regression coefficient by following the methodology of Siegel and Wagner (2022): $\beta_i (S_{X_i} / S_Y)$.

exhausted their access to credit). In that case, risk-seeking firms have a higher chance of being credit-constrained, thus leading them to invest less. To address this notion, we control for the firm's cash flow in our estimated regression equation, using it as a proxy for both financial constraints (Fazzari et al., 1988) and expectations of future profitability (Bond et al., 2004). We observe that the cash flow coefficient exhibits a positive, statistically significant effect on firm investment rates across all columns of table 5.1. This mirror the findings of Bloom et al. (2007) and suggests that uncertainty affects investment independently of credit constraints.

We also observe that our proxy for demand (sales) displays a positive relationship with firm investment rates, which we observe in similar studies (e.g., Bo, 2002; Bloom et al., 2007; Kang et al., 2014). It is plausible that firms experiencing higher levels of demand will engage in new investment projects to service that demand. However, the coefficient is not statistically significant across all three models.

Lastly, we control for financial leverage. This is to control for the potential effect that gearing[27] has on a firm's sensitivity to uncertainty. The coefficient of financial leverage shows a negative sign which is in line with our expectations and the findings of Tran (2014). This could mean that high debt to capital ratios lowers the firm's probability of carrying out new investment projects, as taking on additional debt increases the firm's riskiness. However, as the coefficient of financial leverage is not statistically significant across all three models, we cannot say this for sure.

Overall, the results in columns (1) and (2) in table 5.1 indicate that the firm’s investment decision is influenced by the sales (demand), cash flow, financial leverage, and uncertainty. Both columns (1) and (2) indicate a statistically significant relationship between firm-specific uncertainty and firm investment. In addition, when introducing the control for economic policy uncertainty in (2), we observe a statistically significant result. These regression results support the theory of real options in capital budgeting decisions, which predicts that uncertainty causes firms to delay production and investment (Dixit & Pindyck, 1994). The results in column (3), where we introduce the interaction terms, are inconclusive.

[27] Gearing refers to the relationship, or ratio, of a company's debt-to-equity (D/E).

Table 5.1 – Results of the estimation on the broad sample

Dependent Variable: Investment Rate	(1) Firm-Specific Uncertainty	(2) Economic Policy Uncertainty	(3) Interaction Term
Firm-Specific Uncertainty	-.0300*	-.0300*	-.0197
	(.0177)	(.0177)	(.0201)
Cash Flow	.0323***	.0323***	.0292**
	(.0119)	(.0119)	(.0123)
Sales	.0011	.0011	.0005
	(.0007)	(.0007)	(.0015)
Financial Leverage	-.0088	-.0088	-.0089
	(.0099)	(.0099)	(.0098)
Economic Policy Uncertainty		-.0610***	-.0658***
		(.0158)	(.0162)
Firm-Specific Uncertainty x Sales			-.0007
			(.0009)
Economic Policy Uncertainty x Sales			.0002
			(.0002)
Observations	967	967	967
Number of Firms	113	113	133
R-squared	.1271	.1271	.1292
Year Dummy	YES	YES	YES
Fixed Effect	YES	YES	YES

Clustered Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

5.2 Analysis of the sector specific subsamples

Previous research on the relationship between uncertainty and investment has primarily been concentrated on specific sectors (Caruth et al., 2000). Therefore, by splitting our broad sample into sector-specific subsamples, we can conduct a comparative analysis and explore differences (if any) in the relationship between uncertainty and investment across sectors. For this analysis, we utilize the complete model presented in equation 3.2 of section 3 (the same model used in column (3) of table 5.1.).

To this end, we create a subsample consisting of all the manufacturing firms in our original sample. This allows us to compare our results with seminal studies from the US, UK, and continental Europe, which predominantly focus on the manufacturing industry. As we can see from column (1) in table 5.2, firm-specific uncertainty has a negative coefficient of 0.0130, which indicates that a one standard deviation increases in firm-specific uncertainty lead to a 3.3% drop-in firm investment rates. This is close to the findings of Guiso and Parigi (1999) and Butzen and Vermeulen (2003), who looked at Italian and Belgian manufacturing firms. They found that a one standard deviation increase in demand uncertainty led to a 4.7% and 2.9% reduction in investment rates. Our results are also similar to Ghosal and Loungani (1996). They observed that a one standard deviation increase in price uncertainty would decrease firm investment between 4.2- 6.9% in US manufacturing firms. Lastly, they are close to the results of von Kalckreuth (2000) and Henley et al. (2003), who explored the relationship between sales and price uncertainty in West German and UK manufacturing firms. They found a negative effect of 3.7% and 3.6%, respectively.

Furthermore, our economic policy uncertainty index displays a statistically significant negative coefficient of 0.0524, meaning that a one standard deviation increase in uncertainty reduces firm investment rates by 31%. This is similar to the findings of Kang et al. (2014). The result also indicates that the magnitude of the effect of aggregate uncertainty shocks is higher than the effect of firm-specific uncertainty shocks. It should be noted that our coefficient for firm-specific uncertainty is not significant. This might partly be explained by the fact that the manufacturing sector subsample only contains 255 observations, as illustrated by figure 4.5 in section 4, making inference difficult. Nevertheless, this means that the impact of firm-specific uncertainty on investment in manufacturing firms is inconclusive.

We observe that cash flow displays a negative non-significant coefficient. According to Tran (2014), who had a similar result for cash flow in a study of Australian firms, the negative sign could be a consequence of the selection criteria we have employed in our sample. Although we have removed the firms showing the most apparent signs of financial distress, there are still firms that could exhibit a negative cash flow for several years without being delisted from the OSE. Nevertheless, as our financial leverage proxy also displays a counterintuitive sign (positive) of its coefficient coupled with the fact that this was not an issue with our previous broader sample in table 5.2, we suspect the low number of observations is responsible.

Interestingly, the interaction term between firm-specific uncertainty and sales displays negative statistically significant coefficients. This tells us that the short run-response of investment to demand shocks is lower at higher levels of firm-specific uncertainty in Norwegian manufacturing firms (Bloom et al., 2007).

Column (2) of table 5.2 presents the results of the offshore and shipping sector sub sample. The firms represented in this sector are some of the most influential on the OSE and annually contribute to a sizable portion of Norwegian GDP (Hemmings, 2018). The results are therefore of particular interest, as the dynamics of the relationship in the sector can impact GDP. In column (2), we observe that firm-specific uncertainty has a coefficient of negative 0.0505, which indicates that a one standard deviation increase in firm-specific uncertainty will lead to an average reduction of 12.1% in firm investment rates. This is qualitatively in line with Mohn and Osmundsen (2011) findings, who explored the relationship between price uncertainty and investment in the oil and gas sector. However, as the coefficient is not statistically significant, we cannot draw any conclusions from the regression output.

Our economic policy uncertainty index in column (2) is statistically significant and displays a negative coefficient of 0.0908. This implies that a one standard deviation increase in economic policy uncertainty reduces the investment rates of offshore and shipping firms by 45.5%. This number might seem large. However, keep in mind that firms in this sector operate in a very cyclical market, often with large projects requiring substantial fixed capital. The study by Kang et al. (2014) observed that firms experiencing greater firm-specific uncertainty also experience increased economic policy uncertainty. Therefore it could be reasonable to assume that an economic policy uncertainty shock would greatly affect fixed capital investment at the firm level.

The subsample consisting of telecom, IT and tech firms is presented in column (3) of table 5.2. Firm-specific uncertainty displays a negative coefficient of 0.0948, which translates to a decrease of 10.25% in firm investment rate for each standard deviation increase in firm-specific uncertainty. This is a sizable impact, but it could be attributed to the fact that several firms represented in this sample are typically growth firms that operate with a small number of fixed assets and often a different capital structure than that of manufacturing or offshore and shipping firms. If these firms have to adjust their investment behaviour in the face of an uncertainty shock, it will greatly affect the few projects they have.

Furthermore, the economic policy uncertainty index indicates that a one standard deviation increases in the economic policy uncertainty leads to a reduction in firm investment rates of 40.8%. However, as the coefficients of both firm-specific uncertainty and economic policy uncertainty are not statistically significant, we cannot draw any substantial conclusions based on the results. We believe that similar to our previous two sectors, this is attributed to the small size of the sample.

Surprisingly, the other services sector displayed in column (4) table 5.2 presents a firm-specific uncertainty coefficient with a positive value of 0.0477. Although the coefficient is non-significant, the result suggests that a firm-specific uncertainty shock is associated with a 12.68% increase in firm investment rates. However, as this sample consists of some firms operating in the business services industry, our results might be explained by the fact that those firms typically rely on human capital as their primary mode of production (e.g., consulting). Thus, they are prone to utilize little fixed capital, and what they do use is typically leased (Merrill, 2020). Nevertheless, as our coefficients are not statistically significant and move in the opposite direction of what the real option framework (McDonald & Siegel, 1986; Dixit & Pindyck, 1994) predict, we must take these results with a grain of salt.

Furthermore, the economic policy uncertainty index is not statistically significant but exhibits the correct sign. It has a negative coefficient of 0.0435, suggesting that a one standard deviation increase in uncertainty would reduce firm investment rates by 23%. Surprisingly, this sample also exhibits a negative statistically significant coefficient of our interaction term between firm-specific uncertainty and sales, which again indicates that the short run-response of investment to demand shocks is lower at higher levels of firm-specific uncertainty in this subsample of firms.

Table 5.2 – Results of the estimation on the subsamples

Dependent Variable: Investment Rate	(1) Manufacturing Sector	(2) Offshore/Shipping Sector	(3) Telecom/IT/Tech Sector	(4) Other Services Sector
Firm-Specific Uncertainty	-.0130	-.0505	-.0948	.0477
	(.0153)	(.0417)	(.1502)	(.0331)
Cash Flow	-.0036	.0098	.1048**	.0680**
	(.0167)	(.0204)	(.0457)	(.0319)
Sales	-.0015	.0067*	-.0006	.0040
	(.0019)	(.0034)	(.0036)	(.0028)
Financial Leverage	.009	-.0102	-.0210	-.0208
	(.0091)	(.0160)	(.0359)	(.0520)
Economic Policy Uncertainty	-.0524**	-.0908**	-.0663	-.0435
	(.0246)	(.0358)	(.0391)	(.0290)
Firm-Specific Uncertainty x Sales	-.0024**	.0003	.0009	-.0038***
	(.0009)	(.0011)	(.0046)	(.0011)
Economic Policy Uncertainty x Sales	.0005*	-.0009	.0005	-.0002
	(.0002)	(.0006)	(.0005)	(.0004)
Observations	255	270	234	208
Number of firms	28	31	29	25
R-squared	.1284	.2467	.2373	.2292
Year Dummy	YES	YES	YES	YES
Fixed Effect	YES	YES	YES	YES

Clustered Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

5.3 Summary of results

Overall, the effect of firm-specific uncertainty and economic policy uncertainty on investment varies in magnitude but is consistent in direction across all sectors, except for other services displayed in table 5.2. Unfortunately, our results are not statistically significant.

The coefficient for economic policy uncertainty exhibits a statistically significant negative relationship between aggregate uncertainty and investment across the broad sample displayed in column (3) of table 5.1, the manufacturing sector subsample displayed in column (1) of table 5.2. and the offshore and shipping subsample in column (2) of table 5.2. This is in line with the findings of Al-Thaqeb and Algharabali (2019) and provides supporting evidence for the theory of real options in capital budgeting decisions, which predicts that uncertainty causes firms to delay product and investment.

We also observe a statistically significant negative coefficient on the interaction term between firm-specific uncertainty and sales in our manufacturing sector subsample and the other services sector subsample. According to Bloom et al. (2007), firms adjust their investment decisions in response to demand shocks at higher levels of uncertainty. These dynamics could have implications for monetary and fiscal policy effects, especially in times of crisis.

The summarized results in table 5.3 indicate that the manufacturing sector (except for other services) is the least affected of our sectors by both types of uncertainty shocks. Interestingly, the offshore and shipping sector looks to be more affected by firm-specific uncertainty shocks than the telecom, IT, and tech sector. This might be explained by the fact that the offshore and shipping business is heavily dependent on fixed capital investments instead of the telecom, IT and tech sectors which are usually dominated by growth companies, possessing few fixed tangible assets. We also notice that the samples (except for other services) that experience a higher impact from firm-specific uncertainty also experience a higher impact from economic policy uncertainty. This is in line with Kang et al. (2014), who observed that the effect of economic policy uncertainty was greater for firms experiencing higher levels of firm-specific uncertainty.

If the differences between sectors are accurate, it will support the argument that government aid to businesses should be sector-specific in times of crisis. However, as most of our results are non-significant, we can only speculate. Lastly, the other services sector results are highly counterintuitive and inconclusive, thus providing little insight into the uncertainty and investment relationship for the remaining firms on OSE.

Table 5.3 – Summary results

Data Sample	Firm-Specific Uncertainty(%)	Economic Policy Uncertainty(%)
Full Sample	-6.82	-33.00
Full Sample/interaction terms	-4.49	-36.00
Manufacturing	-3.30	-31.00
Offshore/Shipping	-12.15	-45.40
Telekom/IT/Tech	-10.25	-40.80
Other Services	12.68	-23.20

5.4 Robustness

We conduct several robustness tests on our estimations. First, we test omitting the cash flow variable and omitting the control variable, financial leverage. Neither of the tests has any noteworthy effect on the direction or the significance of the coefficients of interest. We also experiment with additional nonlinear terms and interaction terms, e.g., sales growth and the interaction between uncertainty and cash flow. However, similar to the previous test, none of these new variables are found to be of any significance to our result.

We also test our measure of firm-specific uncertainty by replacing daily stock returns with monthly stock returns when calculating within year standard deviation. The use of more aggregate level stock data yields no qualitative difference in our results. We also attempt to adjust the fixed capital depreciation rates used to construct our capital stock. We try using a 6% and 10% depreciation rate without any qualitative differences in our regression output.

When winsorizing the annual within year standard deviations in the analysis, we set all observations above five equal to five. Instead of using the limit of five when winsorizing, we test adjusting the requirement to three. We adjust downward to further reduce any effect on our results due to unrelated noise in the stock market. The adjustments did not meaningfully affect the regression results of the broad sample or the sector-specific samples. We choose to keep the winsorizing limit of five to follow the existing literature and not miss out on important data points on the relationship between uncertainty and investment.

In addition, we test adjusting the percentiles for the trimming of the accounting variables. First, we trim at the 10th and 90th percentiles, which did not significantly affect the results. Secondly, we test the 1st and 99th levels. Reducing the number of trimmed observations resulted in regression (1) and (2) in the broad sample no longer yielding significant results for firm-specific uncertainty. To reduce the effects of extreme variables and have sufficient observations, we view the existing 5th and 95th percentiles to yield the most robust results.

Lastly, we test including our dependent variable investment rate as a lagged explanatory variable. The theory is that a firm's investment in a project in period t could affect its willingness to invest in a new project in period $t+1$. Unfortunately, including this variable caused our current estimation technique to encounter endogeneity issues.

6. Limitations

Data collection was a time-consuming and challenging process, as no single database included accounting and stock exchange data. Compatibility challenges forced us to rely on three databases, as our two primary databases, Compustat Global and SNF, lacked a common identifier for our firms. This forces us to use the Børsprosjektet at NHH database as a bridge between the two.

When constructing a panel with three different data sources and identifiers, the risk of losing significant data points increases. In addition, several observations were missing for key variables in SNF, such as sales of fixed assets. The gap in the available data prevented us from adjusting our investment variable for sales of fixed assets. Manually filling in the gaps through reviewing firm financial reports proved challenging because of the different reporting practices and the overall lack of availability of financial reports for the delisted firms. We therefore calculated investment only based on differences in tangible fixed assets.

An additional limiting factor is stock data, as relatively few firms are listed on the OSE. This means that after adjusting the dataset, as described in section 4, our final sample is relatively small compared to similar studies. The limited size of our sample will affect the robustness of our study, both for the broad analysis and the comparative sector analysis. Extending the time horizon of the analysis also proved difficult, as there are disparities in standards of financial reporting prior to 2005, and there are currently no accounting data in SNF past 2018. In addition, extending our sample to non-listed firms would require a different method of measuring uncertainty.

Because of the limited size of OSE and sample time restriction, we also risk the results being affected by omitted variable bias. Our broad sample does not contain enough observations for us to test lagging all the control variables preferred. This naturally restricted the size of our subsamples, which made inference and comparison to similar studies difficult. In addition, we were not able to try out other estimation techniques like dynamic panel data models that would have allowed us, among other things, to circumvent problems like autocorrelation and thus tested models with the lagged dependent variable as a regressor.

Based on the mentioned limitations, the reader should be cautious about extending the results from our study to companies operating outside of the period 2005-2018, companies outside of a Norwegian context and non-listed Norwegian companies.

7. Concluding Remarks

7.1 Conclusion

This thesis aims to explore the relationship between uncertainty and investment for Norwegian firms listed on the Oslo Stock Exchange from 2005 to 2018. We include both firm-specific uncertainty and aggregate uncertainty in our empirical model to quantify the overall effect of uncertainty on firm investment and uncover any differences in this effect between sectors.

We construct a proxy for firm-specific uncertainty using firm-level daily stock returns and a proxy for aggregate uncertainty by constructing an economic policy uncertainty index to capture the elusive concept of uncertainty. A proxy for firm investment is obtained by calculating firm investment rates into tangible fixed assets. We employ various control variables for firm-specific and macroeconomic characteristics. In addition, we used a fixed-effects estimator to control for time-constant unobserved firm-specific effects.

Our empirical analysis reveals some interesting results and provides some key takeaways. We find evidence indicating that firm-specific and aggregate uncertainty depresses firm investment in a broad sample of listed Norwegian firms. However, when we control for interaction between uncertainty and demand, the negative relationship between firm-specific uncertainty and firm investment is no longer statistically significant. We also find evidence suggesting that the effect of aggregate uncertainty on firm investment differs between sectors, while the observed effect of firm-specific uncertainty is inconclusive. Lastly, in the manufacturing sector, we observe indications that a one standard deviation increases in firm-specific uncertainty, typically observed around significant uncertainty shocks like the outbreak of the financial crisis or the drop in oil prices in 2015, potentially reducing the firm's sensitivity to demand shocks.

Our findings present some potentially important policy implications. If Norwegian manufacturing firms become less sensitive to demand shocks in periods of higher uncertainty, it could imply that fiscal and monetary stimuli become less effective. We also contribute to the existing literature by exploring this topic in the Norwegian context and examining how different business sectors react to change in uncertainty.

7.2 Further research

We suggest expanding the data sample of Norwegian firms used for analysing the relationship between uncertainty and investment for future research. We believe it could be beneficial to focus on specific sectors in combination with other types of uncertainty, as dependence on Norwegian stock data limits the scope of the sample. Focusing on specific sectors would benefit from access to sector-specific data and allow for the use of sector-specific control variables. Using more sophisticated estimation methods, e.g., dynamic panel models, would also be interesting, as it would help minimise endogeneity issues by allowing more flexibility in choosing control variables. Lastly, we suggest expanding the analysis period to capture the effects of the gulf war, the dot-com bubble and 9/11 as they could provide interesting data points. It will also be interesting to analyse the effects of the Covid-19 pandemic and the war in Ukraine as data surrounding those events become available.

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Appendix A – Mathematical Review

The following example draws heavily on chapter 4 and 5 from Dixit and Pindyck (1994) and the work of McDonald and Siegel (1986).

To illustrate the effect of uncertainty on a firm considering an irreversible investment, we will consider a monopolist who contemplates initiating an investment project with the present value of *X*. To proceeded with this project the firm must incur a sunk cost with the present value *I*. If we had looked at this project through the lens of a conventional NPV calculation, the firm would initiate the investment project if $X - I \geq 0$. But will assume that there is uncertainty surrounding the future value of *X*, and that this uncertainty evolves according to a Brownian motion with drift:

$$dX = \alpha X dt + \sigma X dz \tag{A.1}$$

where α is the mean of dX and σ is the standard deviation of dX. dz is the random increment of a Wiener process such that:

$$dz = \varepsilon_t \sqrt{dt} \tag{A.2}$$

$$\varepsilon_t \sim N(0, 1)\ ,\ E(\varepsilon_t \varepsilon_j) = 0\ \forall\ i, j\ i \neq j$$

i.e., ε_t is a serially uncorrelated standard normal random variate. Equation (1) is a special case of an Ito continuous-time stochastic process. A detailed explanation of this process can be found in Dixit et al. (1993). Equations (1) and (2) imply that the future values of the investment project are log-normally distributed with expected value $E(X_t) = X_0 \exp \alpha t$ (where X_0 is the value of *X* today) and a variance that grows exponentially with *t*. The firm will aim to time its investment decision in a manner that allows it to maximize the expected present value of the option to invest, F(*X*), given by:

$$F(X) = max\ E\Big[\big(X_T - I\big)\, exp(-\rho T)\Big] \tag{A.3}$$

where X_t is the value of the investment at the unknown future point in time, T, at which the investment decision is made and ρ is the discount rate (it should be noted that ρ must be greater than α or else the firm will hold on to the option to wait indefinitely). Delaying the decision to invest in the project (holding on to the option of waiting) is the equivalent of holding an asset which pays no dividends but may appreciate as time passes. The fundamental condition for optimality, also called the Bellman equation, if the firm delays the investment is given by:

$$\rho F = \frac{E(dF)}{dt} \tag{A.4}$$

The left-hand side of equation (4) is the discounted normal rate of return an investor would require from holding the option to wait, while the right-hand side is the expected return per unit of time from the option If the condition holds, the firm equates the expected return from delaying the investment with the opportunity cost of delay. In effect equation (4) derives a non-arbitrage condition.

Using Ito`s Lemma to obtain the total differential of a continues time stochastic process, we can express dF as:

$$dF = F'(X)\,dX + ½\,F''(X)\,(dX)^2 \tag{A.5}$$

using the expression in equation (1) for dx and taking expectations gives:

$$E(dF) = aXF''(X)\,dt + ½\,\sigma^2X^2F''(X)\,dt \tag{A.6}$$

terms in dz dissapear since its expectation is zero. Substituing (6) into (4) we obtain the Bellman equation in the case where dX is a continuous stochastic process:

$$\rho F = aXF'(X) + ½\,\sigma^2X^2F''(X) \tag{A.7}$$

If the firm is following the optimal investment rule, the option’s value to wait must satisfy the second-order differential equation given in equation (7). In addition, it must satisfy three boundary conditions:

$$\begin{aligned} F(0) &= 0 \\ F(X^*) &= X^* - I \\ F'(X^*) &= 1 \end{aligned} \tag{A.8}$$

The first condition states that if the value of the investment project falls to zero, then the value of the option to invest is also zero. The second describes the net payoff at the value of X at which it is optimal to invest. The third is the "smooth-pasting" condition (Dixit et al., 1993) which requires the function $F(.)$ to be continuous and smooth around the optimal investment timing point. The solution to (7) subject to the conditions given in (8) is:

$$F(X) = aX^b \tag{A.9}$$

where $\alpha = (X^* - I)/X^{*b}$ is a constant and

$$b = ½ - \frac{a}{\sigma^2} + \sqrt{\left(\frac{a}{\sigma^2} - ½\right)^2 + \frac{2\rho}{\sigma^2}} \tag{A.10}$$

By substituting (9) into the second and third of the boundary conditions given in (8) we obtain the result that the optimal investment timing payoff is given by:

$$X^* = \frac{b}{b-1} I \tag{A.11}$$

Equation (11) defines the "wedge", $b/(b-1)$ between the payoff necessary to induce the investor to exercise the option to invest, X^* and the present value of the cost of the investment, I. Since b>1, then $b/(b-1) > 1$ land hence $X^* > I$. Thus, in the presence of irreversibility and uncertainty, the simple NPV principle which equates X^* with I is no longer applicable. Simple calculus reveals that the size of the wedge between X^* and I increase as uncertainty about future returns, σ rises. It is also increasing in the discount rate, ρ, and in the drift term in the evolution of the expected rate of return, α. Thus, this framework gives a theoretical explanation of why changes in uncertainty can make it attractive for firms delay their investment decision in anticipation of new information about the future profitability of their project.

Appendix B - Variables

Overview of the underlying calculations and construction of the variables:

Investment (I_{it}): The investment variable is the firm's annual investment in tangible fixed assets and is calculated by the difference in tangibles from period *t* to *t-1*. This paper defines tangibles as all assets that the firm intends to use over several periods and that are not of a financial or intangible nature. Investment can be written as

$$Investment = Tangible\ Fixed\ Assets_t - Tangible\ Fixed\ Assets_{t-1}$$

As the SNF database lacks complete data for annual firm investment activity in tangible fixed assets, we calculate an adequate proxy for investment ourselves. We start by smoothing the reported book values of tangible fixed assets to mitigate outliers' impact. The smoothing process constructs an annual value of tangible fixed assets for time *t*, based on the average of time *t-1*, *t,* and *t+1*. The first and last observed values used the two succeeding and preceding periods.

Deprecation rate (δ): In this thesis, we will use a common deprecation rate for all the firms in the sample. The depreciation rate is set to 8 %. This is based on the rates provided by the Norwegian tax authority for fixed assets in 2014 and an average of the deprecation rate for sectors represented at OSE (Skatteetaten, 2022). We use the rates for 2014 as the tax authorities do not provide any data on rates prior to 2014.

Capital Stock (K_{it}): The variable is the value of the capital stock in period t for firm i. The value of K_{it} is calculated using the Perpetual inventory method (PIM). The model can be written as

$$Capital\ Stock = (1 - deprecation\ rate) \times Capital\ Stock_{t-1} + Investment$$

Where the value of the firm's capital stock at time t is a function of the deprecated value of the previous period *t-1* capital stock and the investments made in tangible fixed assets.

Investment rate (I_{it}/K_{t-1}): The investment rate is our dependent variable and serves as a proxy for the firm's investment decision. The variable is defined as the firm's investment in tangible fixed assets in year *t*, in relation to the firm's overall value of the capital stock at the beginning of the period. The formula for calculating the investment rate can be written as

$$Investment\ Rate = \frac{Investment}{Capital\ Stock_{t-1}}$$

Cash Flow (C_{it}/Kt_{-1}): Cash flow is used as a control variable in the regression model and proxies for the firm's cash flow in the year. The calculation of the cash flow variable has two steps. First, we calculate the *Non-Scaled Cash Flow* (C_{it}) using the firm's reported annual ordinary profit or loss before extraordinary items and after-tax, then adding on the firm's reported annual ordinary depreciation incurred from tangible fixed assets. Non-scaled cash flow can be written as

$$Non - Scaled\ Cash\ Flow\ = Ordinary\ Prof\,it\ \vee Loss\ af\,ter\ tax\ +\ deprecation$$

Using the results of the non- scaled cash flow calculations, we estimate our final cash flow variable used in the regression model

$$Cash\ Flow\ = \frac{Non - Scaled\ Cash\ Flow}{Capital\ Stock_{t-1}}$$

Sales ($y_{it}/K_{t\text{-}1}$): Sales is a control variable in the regression model and proxies for firm-specific demand. We calculate sales by following the method of Tran (2014) and retrieve annual reported sales profit *i* at time *t* and divide by firm's capital stock at time *t-1*. However, the accounting data on sales retrieved from SNF does not consider the increase in prices of goods and services from year to year. Therefore, the sales numbers retrieved can be misleading regarding the actual demand increase for the firm's goods and services. In the model, we wish to isolate the increase in sales from the growth in prices to measure firm sales accurately. Therefore, we adjust the annual firm sales by the corresponding GDP deflator for the given year. The GDP price deflator measures changes in prices for goods and services in the economy (Joulfaian & Mookerjee, 1991). The GDP deflators for 2005-2018 were retrieved from Statistics Norway (SSB, 2022). The method for calculating the Adjusted sales (*y*) is given by

$$Adjusted\ Sales = \frac{Sales\ revenue}{(1 + GDP\ Deflator)}$$

and the formula for *Sales* is given by

$$Sales = \frac{Adjsuted\ Sales}{Capital\ Stock_{t-1}}$$

Financial Leverage (L_{it}): Financial leverage is a control variable in the regression model and proxies for the debt level and the financial constraints the firm experiences at time *t*. We calculate the level of firm financial leverage by following Tran (2014). We retrieve the firm reported annual total debt and divide it by the firm's total book value of equity. The calculations of the variable can be written as

$$Finacial\ Leverage = \frac{Total\ Debt}{Total\ Book\ Value\ of\ Equity}$$

Table B.1 provides an overview of the SNF database codes retrieved and used to construct the variables. Uncertainty, capital stock, investment rate and economic policy uncertainty are not included, either being constructs of the variables in the table or not using any data from the SNF database.

Table B.1- SNF codes

Element in formula	SNF code(s)
Tangible Fixed Asset	vardrmdl
Ordinary Profit/ Loss After Tax, Deprecation	orders,avskr
Sales	salginn
Total Debt, Total Book Value of Equity	gjeld, ek

**Note: Retrieved from SNF* (Berner et al., 2016).

Appendix C – Test Results and Dictionary

Table C.1 – Modified Wald test

Chi squared	DF	P-Value	Conclusion
3400000	113	0.000	Heteroskedasticity

Table C.2 – Wooldridge test

F-Statistic	DF	P-Value	Conclusion
161.073	142	0.000	Serial Correlated Errors

Table C.3 - Dictionary

Translation of terms used to construct the economic policy uncertainty index

Norwegian Terms	**English Terms**
Økonomi	Economy
Norges bank	Bank of Norway
Sentralbank	Central bank
Oslo børs	Oslo Stock Exchange
Olje	Oil
Regjering	Government
Departement	Ministry
Regulering	Regulation
Minister	Minister
Direktiv	Directive
Storting	Parliament
Usikker	Unsure
Usikre	Uncertain
Usikkerhet	Uncertainty
Uro	Unrest