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Economic Uncertainty and Norwegian Producer Prices

An empirical study of the relationship between uncertainty and producer prices in Norway with evidence from Norwegian PPI data in the period of 2005 - 2016

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Abstract

In this study, we investigate the relationship between uncertainty and the price-setting of production companies. To investigate this, we use micro-data underlying the Norwegian Producer Price Index ranging from 2005-2016. We construct a new uncertainty index based on textual analysis. We utilise this measure and recently developed methodologies to indirectly quantify the effect of uncertainty. The measures are Economic Policy Uncertainty (EPU) in Norway, Global Economic Policy Uncertainty (GEPU), the Norwegian Volatility index (Novix), Macroeconomic uncertainty in the USA, and three uncertainty indices for measuring uncertainty in Norway. By utilising a multinomial logistic model, we compare the uncertainty measures to the price fluctuations and analyse if uncertainty affects price-setting in Norway.

We find a statistically significant effect of uncertainty on the probability of price changes. Our findings indicate that uncertainty and prices are counter-cyclical. An increase in uncertainty will increase the probability of a negative price change and decrease the probability of a positive price change. The results are important as they show a clear connection between uncertainty and price adjustments for production companies.

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1 Introduction

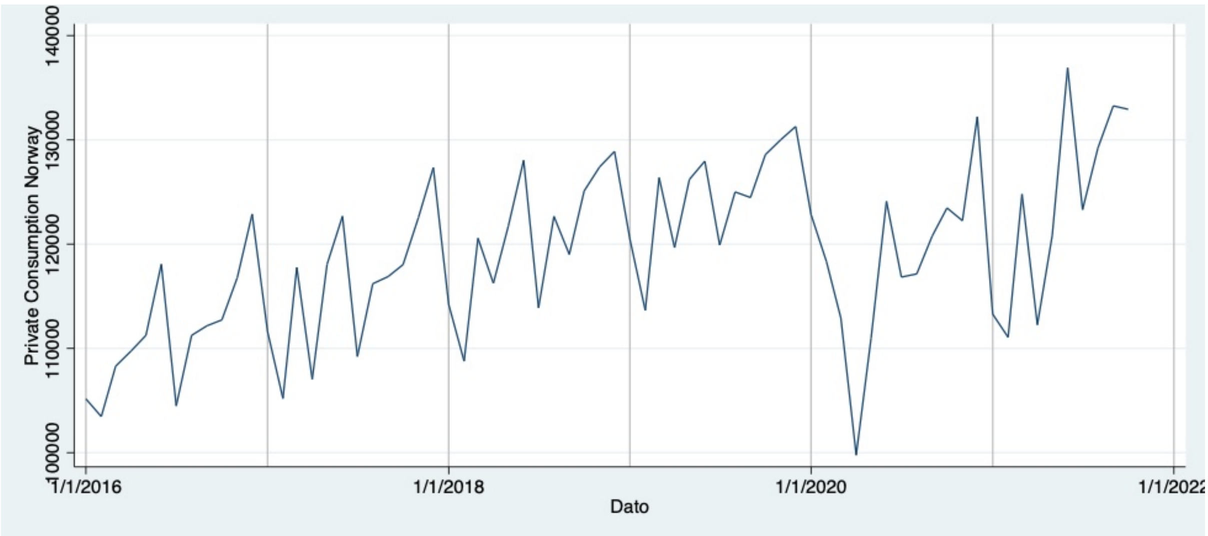
1.1 Motivation and purpose

The world is in constant movement, and despite technological inventions, there is still no telling what the future might hold. This fact has become apparent when looking at the current events.

In March 2020, the economy was hit by a severe shock. The Covid-19 pandemic took lives, broke hospital capacities, and caused a global economic slowdown. With the Covid-19 pandemic and the following economic slowdown, came a rise in uncertainty. As said by the Federal Reserve System Chairman Jerome Powell, "We are now experiencing a whole new level of uncertainty" (FED, 2020). This is evident when looking at the VIX-Index: The uncertainty on the S&P 500-Index had never been higher (CNBC, 2020).

The Covid-19 pandemic had a considerable impact on Norway: The GDP fell ten percentage points from February to April 2020, and private consumption in Norway took a severe hit (SSB, 2021).

Figure 1.1: Private Consumption Norway, 2021

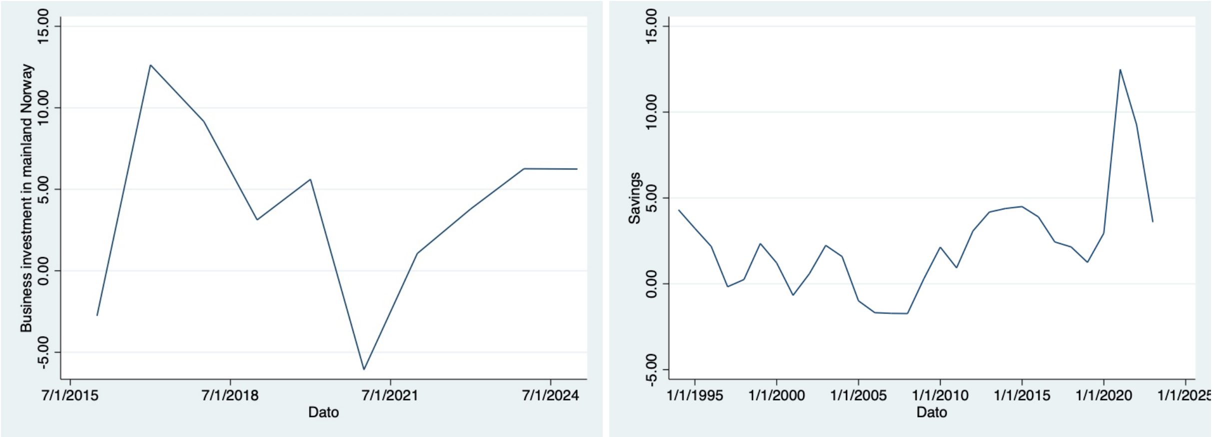


Source: SSB (2021)

We also see that the uncertain nature of the Covid-19 pandemic caused the business investment in Norway to plummet and the private savings in Norway spiked.

Figure 1.2: Business investment and savings in Norway

(a) Business investment in mainland Norway **(b)** Savings in Norway



Source: (Norges Bank, 2021a)

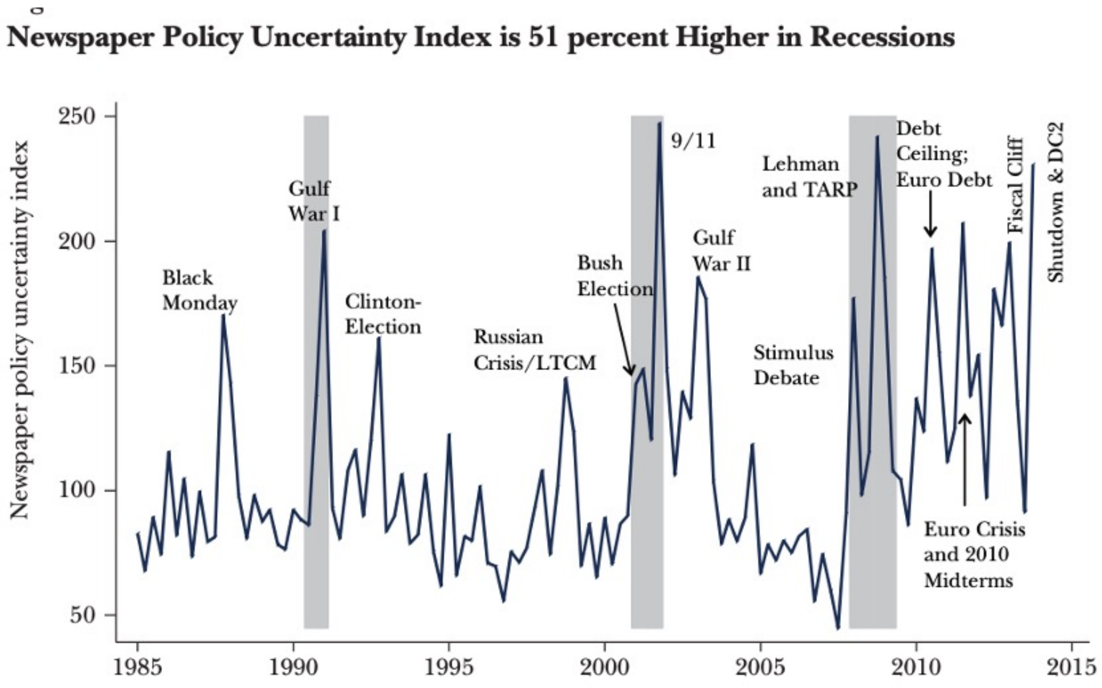
The global economy was also greatly affected. The US GDP had the largest drop since the Great Depression, and the unemployment rate rose from 3,5 per cent in February to 14,7 per cent in April. (Altig et al., 2020).

We find a similar picture when looking at the 2008 global financial crisis. After the collapse of the US housing market, a financial crisis spread into the global financial system (RBA, 2021). Unemployment in the US soared, and the global financial crisis led to a decrease of nearly 4 per cent to the global economic growth (Merle, 2018). In Norway, the Oslo Stock Exchange dropped by 64 per cent from May to November 2008, and Real house prices declined by 18 per cent from August 2007 to December 2008. However, due to government crisis packages and high petroleum revenues, the impact on the Norwegian economy was less severe than comparable economies (Grytten and Hunnes, 2010; Grytten, 2020).

Again, uncertainty was rising. This is clear both from uncertainty indices and from listening to leading economists at the time. Christina Romer, the Chair of the Council of Economic Advisers, said, "Volatility, according to some measures, has been over five times as high over the past six months as it was in the first half of 2007. The resulting uncertainty has almost surely contributed to a decline in spending, especially in the last few months" (Romer, 2009). Olivier Blanchard, the chief economist of the International Monetary Fund, said, "Uncertainty is largely behind the dramatic collapse in demand"

(Blanchard, 2009). There is a clear connection between recessions and uncertainty. This is even more evident in Figure 1.3, where we see that uncertainty and recessions are closely related.

Figure 1.3: Uncertainty Index and recessions



Source: Bloom (2014)

The Covid-19 pandemic and the global financial crisis showed us that established truth could be challenged, the things we take for granted might disappear in seconds. We can still be caught off guard, thereby sending the world into a well of uncertainty. The complex and unpredictable nature of uncertainty is fascinating , and we want to explore how uncertainty affects price-setting of producer prices.

Even though volatility, uncertainty and risk are concepts that have fascinated researchers for the last forty years (Bernanke, 1983; Pindyck, 1990), the macroeconomic research regarding uncertainty has blossomed after the global financial crisis in 2008. Following, Bloom (2009), a growing literature has investigated the relationship between uncertainty and different variables. For instance, the relationship between uncertainty and investment decisions of firms (Bachmann and Bayer, 2013; Bachmann et al., 2019; Bloom, 2009), fiscal and monetary policy (Baker et al., 2016; Born and Pfeifer, 2014; Aastveit et al., 2017) and even on family dynamics (Kreyenfeld et al., 2005, 2012) have all been greatly explored.

The price-setting literature focuses mainly on are how much prices are generally changed, how often they are changed, and whether there is synchronisation within firms or industries (Dhyne et al., 2005; Lach and Tsiddon, 1994; Nilsen et al., 2018). However, the relationship between price-setting and uncertainty remains largely unexplored, and therefore contains a lot of potential discoveries for those willing to investigate it.

1.2 Research question

The purpose of this paper is to investigate the role of economic uncertainty on pricing behaviour in production companies. We use a rich and relatively unexplored dataset on Norwegian PPI data. The dataset provides information on firm[1] prices for the period 2005 to 2016, including the global financial crisis, the oil price plunge in 2014 and Brexit. We construct a new uncertainty index based on textual analysis. We use this and different measures of uncertainty together with the pricing data to analyse the effect of uncertainty on price changes. A more specified formulation of the research question is as follows:

Are there evidence of uncertainty influencing producer prices in Norway?

We find this is interesting because the analysis can provide important information on both the micro and the macro level. On the micro level, understanding the drivers of price-setting is valuable knowledge for both consumers and firms. On the macro level, Vermeulen et al. (2012), claims that the prices modelled in macroeconomic models are producer prices. Therefore, it is of great importance to understand the transmission effect of uncertainty when making macroeconomic models.

We contribute to the literature in the two following ways. Firstly, we try to capture and measure Norwegian Economic Policy Uncertainty by textual analysis of Norwegian Newspapers. By doing this, we hope to create a robust measurement of uncertainty in Norway. Secondly, we investigate the relationship between several uncertainty measures and price adjustments. Which, to the best of our knowledge, we are the first to do.

[1] In the remainder of the paper, we use the terms firm, company, and producer interchangeably.

1.3 Outline

The thesis is organised in the following way:

Section 2 reviews related literature and look into the most relevant methodologies. This section will provide further knowledge about the literature in this field and merge price-setting theory with uncertainty theory. The focus will be to provide a basis for the analysis and familiarise the reader with the most important theories.

Section 3 presents the main two data sources used in the empirical analysis. We will present the main content of the data, how we structure the data , how we process the data, and why we believe this to be relevant. In the section we will also inform about the adjustments of the price dataset and the construction of the uncertainty indices.

Section 4 presents the empirical model for the analysis, the multinomial logistic model. We will present the theory behind model, how we will use the model , and why we believe this model to be relevant.

Section 5 presents and interpret the results of the model. We will analyse the marginal effect of uncertainty on prices by employing a multinomial logistic regression model. Firstly, we will analyse the marginal effect of uncertainty measures on price-setting, given either positive, negative or no price adjustments. In other words, we will investigate if an increase in uncertainty increases or decreases the probability of a positive/negative price change. We will analyse the effect of uncertainty on price-setting for all prices, for prices that have frequent price changes and for prices with infrequent price changes. We do this because we find it reasonable to assume that products with frequent price changes are more exposed to uncertainty shocks. Secondly, we will analyse the lagged effects of uncertainty on price-setting. We will analyse this with lags on 1, 3 and 12 months, because it might take some time before we see the effect of uncertainty on prices, and try to adjust for this by adding lags.

Section 6 will summarise and conclude the thesis.

2 Literature Review

2.1 Uncertainty Literature

The modern definition of uncertainty stem from Frank Knight (1921), where he distinguishes the difference between uncertainty and risk. He argues that risky events are events where the probability that a certain set of outcomes may occur is estimable, whereas uncertain events are events where such probabilities are impossible to calculate. In the paper *Fluctuations in Uncertainty*, Nick Bloom (2014) reviews facts and patterns concerning economic uncertainty. The paper discusses how uncertainty affects our societies, both at the macro and the micro-levels. Bloom find that exogenous shock can cause a recession, increasing general uncertainty, and that uncertainty increases when economic development stagnates. From existing literature, we know that more significant uncertainty seems to reduce firms' willingness to invest and employ, and it also affects consumers' willingness to spend money (Bloom, 2014). Bloom finds that uncertainty has both positive and negative channels of influencing growth. He focuses on four channels where uncertainty influences growth: real options, risk aversion, growth options, and Oi-Hartman-Abel effects.

The real options channel of uncertainty influencing growth stems from the real option theory (Bernanke (1983); Pindyck (1990); Dixit and Pindyck (2012). The theory consider on investments as options, where you can either exercise the option or wait. When uncertainty is high, the value of delaying the investment is high. The influence of uncertainty on investment, according to this theory, is that with more uncertainty, firms become more cautious. The real option effect can also be translated to consumers, where the value for delaying durable investments rises during periods of high uncertainty. Therefore, uncertainty from the real option argument reduces consumption both at the consumer and firm levels, and reduces growth.

The risk aversion channel of uncertainty influencing growth originates from the concept of investors wanting compensation for risk (Fama and MacBeth, 1973; Kahneman and Tversky, 2013). If uncertainty increases risk, then uncertainty raises the cost of finance. According to the theory, a rise in uncertainty will raise borrowing costs and reduce growth (Arellano et al., 2010; Christiano et al., 2014). Higher uncertainty can also increase precautionary savings for consumers, which again would reduce consumption, leading to reduced growth (Bansal and Yaron, 2004). However, a rise in precautionary savings could be used for investments in the future, making the long-run effects unpredictable.

The growth options channel is based on the argument that if uncertainty rises the size of the potential outcome, then uncertainty can encourage investments (Bar-Ilan and Strange, 1996). Suppose the potential outcome has a limited downside, then a rise in uncertainty can expand the size of the potential outcome. This can increase investments, which leads to higher growth. This argument is especially relevant for research and development-intensive firms (Bloom, 2014). The growth options channel is evident in the Covid-19 pandemic. In the early stages of the pandemic, the increase in uncertainty was perceived by business executives as an increase in downside risk, leading to lower growth. In the fall of 2021, the downside is limited, and almost all the perceived uncertainty is to the upside, possibly leading to higher growth (Bunn et al., 2021).

The Oi-Hartman-Abel Effects channel of uncertainty influencing growth originates from the articles of Oi (1961), Hartman (1972) and Abel (1983). The argument is that "if profits are convex in demand or costs, then demand or cost uncertainty increases expected profits". This means that if firms can control for negative outcomes, then they can exploit positive outcome. This can increase investments and growth.

The macro uncertainty rises in recessions and after uncertainty shocks (Bloom, 2014). Different market volatility indices and money market volatility rise steeply during economic recessions, and the overall pattern of the uncertainty measures seems to be counter-cyclical. The literature find strong evidence of this trend by observing the VIX index of the Standard & Poor's 500 stock market index. On average, the VIX index rises by 58 % in recessions. The same rise in volatility is present in the exchange rate, options and bond-market (Bloom, 2014).

The literature presents other uncertainty measures that exhibit the same patterns. The newspaper scraping technique, introduced by Baker et al. (2016), show similar results in recessions. We apply this technique in our study, and it will be thoroughly explained in the dataset section. The words "uncertain or uncertainty" together with "economy or economics" appeared on average over 52% more often in U.S newspaper during the same recessions (Bloom, 2014). These findings are solid indicators of how uncertainty builds up in markets and societies.

The link between macro and micro effects is highly relevant to our research question. Due to recent development in technology, the ability to study micro-data has become widespread (Bloom, 2014). Bloom confirms that micro uncertainty also rises in recessions, based on a survey of 200 U.S manufacturing firms. The study shows a clear decreasing revenue and growth pattern, and increased stock-return variation. Uncertainty affects manufacturers differently. Bloom looks at the difference in sales growth before and after the financial crises in 2008 and finds that the variance of the plants' sales growth rate rose by 152 % (Bloom, 2014). Even more relevant for our research, Vavra (2014) finds that price changes at the product level are about 50 % more volatile during recessions. With these findings in mind, we are looking deeper into the literature regarding the measuring of uncertainty.

2.1.1 Measuring uncertainty

Uncertainty has long been an important and well-known factor for the world's financial markets. However, measuring the level of uncertainty quantitatively is a recent phenomenon in the literature. This could be due to the unobservability and abstractness of uncertainty. In the later years, we have seen academics and researcher developing proxies for quantifying uncertainty in an attempt to capture its actual effects. No universal definition of uncertainty is agreed upon and applied in the literature. The result is that the term is used differently depending on the topic at hand. This paper will focus on uncertainty as a more general term. "Uncertainty" will work as a superordinate term in this paper, and we will also discuss different variations and their specific properties. Although uncertainty is hard to quantify because of its latent nature, there are several ways to measure it indirectly.

Al-Thaqeb and Algharabali (2019) define economic policy uncertainty as "the economic risk associated with undefined future government and regulatory frameworks". The paper by Baker, Bloom and Davies titled *Measuring Economic Policy Uncertainty* (2016), illustrates what has now become the standard method for measuring and quantifying Economic Policy Uncertainty (EPU). The method developed by Baker et al. (2016), uses a scraping technique to measure Economic Policy Uncertainty, going through newspaper articles and looking for a predetermined set of keywords. In their study, Baker et al. (2016) discover a connection between reduced investment rates and decreasing employment when the level of EPU increases. Since then, it has become more common to quantify and measure uncertainty against key financial figures.

Another way to measure uncertainty is to observe stock market and option based volatility. The most common measures are the monthly standard deviation of daily stock returns and the VIX-Index (Laws and Monitor, 2012). The VIX index is constructed from the implied volatility on Standard & Poor's 500 index options, represent the market's expectation of volatility over the next 30 days (Chicago Board Options Exchange, 2009).

The last relevant way to measure uncertainty is statistical forecast uncertainty. This method measures uncertainty by separating the unforecastable factors from forecastable factors in large-scale time-series models (Baker et al., 2020). An example of this is the macroeconomic and financial uncertainty indices created by Jurado et al. (2015).

We want to utilise these methods for measuring uncertainty, to investigate if some of the fluctuations in producers prices can be explained by uncertainty. As we discuss in the last subsection, the theory on pricing behaviour is inconclusive, and the topic we are investigating is, to our knowledge, not something that has been done in Norway before.

2.2 Studies on Market volatility and the price setting of firms

Although few, some studies have been conducted for investigating uncertainty's effect on producer prices. In their study, Bachmann et al. (2019) investigate if "time-varying business uncertainty/volatility affect the price setting of firms and in what way?". Their estimates are based on micro-data from the German Ifo Business climate survey. They find that the frequency of price adjustments increases with idiosyncratic business volatility. They also find that higher volatility leads to a rise in the intensive margin of price adjustments. Their baseline probit model reveals that the cost of essential production materials is the most important determinant of firms pricing decisions.

The work by Canales et al. (2021), describes the relationship between different uncertainty measures and the price-setting within firms in Chile. The paper analyses the role of uncertainty and risk for price-setting behaviour and inflation. Similarly to our study, they exploit micro-level data, and where we are looking and the PPI, they are looking at the CPI in Chile for 2010-2018. Their study concludes that uncertainty and risk are positively associated with product-level inflation. More importantly, positive price changes at the variety-establishment level and negative association with the frequency of adverse price changes.

Linking to the upcoming theoretical part, Vavra (2014) surveyed the menu cost price-setting models and how heightened business volatility can affect them. He wanted to investigate whether the increased business volatility empowers the "wait and see"-effect, or if it results in increased price adjustments frequency and price dispersion. The study concludes that the volatility effects dominate but show no direct empirical evidence that higher volatility leads to increased price adjustment frequency and dispersion.

2.3 Price Adjustment Literature

2.3.1 Pricing theory

To understand uncertainty's effect on producer prices, we need knowledge on how price-setting works "normally". For that reason, we have studied several research papers and articles to get the latest reviews regarding price-setting behaviour. The theoretical models currently present in the literature come with several assumptions and do not necessarily fully explain the dynamics we see in the real world (Bloom, 2014). In the following parts, the terms price-setting, price change, and price adjustments will be used interchangeably, all meaning the act of changing prices.

The relationship between uncertainty and price-setting behaviour is still relatively untouched, and it remains to be seen whether there is one at all.

2.3.2 Price Stickiness

Cecchetti (1986) was one of the pioneers of empirical research on pricing behaviour. He found strong evidence for the presence of price stickiness in US magazine prices, in addition to solid empirical support for sticky-price models based on monopolistic competition. Nominal rigidities is a central aspect of New- Keynesian economics. The rigidities stem from the fact that nominal prices and wages are reluctant to adjust, even if the market conditions suggest a different price to be the optimal one (Cecchetti, 1986) . Carlton (1986) found significant rigidities and a great deal of heterogeneity regarding price durations. The work of both Cecchetti and Carlton was an essential contribution to the genesis of empirical research on pricing behaviour. Academics have expanded on these theories using the far more detailed data available now, leading to more precise results.

In their paper, Fabiani et al. (2005) finds that mark-up pricing is the most common price-setting policy among companies in the Euro-zone. Mark-up pricing refers to how price adjustments only occur when the companies expect the cost to change. Cost-based pricing theory uses production cost as a baseline and then adds multipliers depending on the market. Companies also tend to decide upon a pricing strategy based on market competition (Zbaracki et al., 2004). As we know from economic theory, prices are set to a market-clearing equal to the marginal cost when there is perfect competition (Goolsbee et al., 2016). However, in the New-Keynesian framework, companies are set to be monopolistic competitors, thereby setting prices above the marginal cost (Alvarez et al., 2006). Even in markets with a high level of competition, surveys show that companies tend to hold some degree of price setting autonomy and postpone their price-setting decision until they know the competitor's price (Alvarez et al., 2006). This coordination failure leads to price stickiness.

Together with mark-up pricing and market competition, implicit contracts are listed as the main reason for price stickiness (Alvarez et al., 2006). Often companies hold long term contracts with both suppliers and customers and base their price setting on these agreements. Typically, contracts can be written, oral (explicit) or silent (implicit). The latter is often more challenging for the researcher to detect, as it is often used as a tool to build customer loyalty and keep the cost of price changes to a minimum. In addition, building loyalty among its customers reduces competition from other market players by creating a more personal relationship with existing customers and reducing their search costs (Liu and Yang, 2009).

In the book *Asking About Prices*, Blinder et al. (1998) survey a random sample of U.S industry firms. The information is collected through a standardised questionnaire. They wanted to know if prices were sticky/rigid and gain more profound knowledge on the reason and frequency of price adjustments. This study's main results on price stickiness confirm that prices are rigid and that the mean price response time to changes in demand/supply is about three months, but that there are substantial differences between firms. Among several findings, one of them was that time-depending rules were twice as common as the state-dependent rules (Blinder et al., 1998).

2.3.3 State-dependent and Time-dependent pricing models.

The existing literature on price behaviour typically gets divided into two main categories, State-dependent and Time-dependent models (Alvarez et al., 2017). The division is generally made to account for the sticky prices and the rational expectations we saw in the last part.

The state-dependent models assume that the observed rigidity in prices stem from economic conditions. In their paper, Sheshinski and Weiss (1977) develop a model based on the assumption that there are actual costs associated with the price changing process, where firms typically fix the nominal price over constant intervals. Sheshinki and Weiss describe how pricing decisions are related to inflation rates and the general state of the economy. These findings have led to the development of several state-dependent model classes. Some of the models that are getting most international acknowledgement are Menu Cost models (Golosov and Lucas Jr, 2007; Alvarez and Lippi, 2014), Convex cost models (Rotemberg, 1982), and consumer anger models (Zbaracki et al., 2004; Rotemberg, 1982). The convex cost models are assumed to have a convex relationship between adjustment cost and price change. To explain this further, significant price changes generate higher marginal adjustment costs, increasing price-rigidity (Rotemberg, 1982). The characteristics of a convex cost model make us expect a pricing pattern with small and frequent price changes rather than significant and rare.

Through our research, we stumble upon the menu cost model quite often, as it has been a popular model for explaining the pricing behaviour of production companies. This model assumes that companies face both direct and indirect costs when adjusting prices. Direct costs include material, advertising, and labour, while indirect costs are associated with customer relationships and competition. The indirect costs have a non-convex behaviour and might cause incentives for postponing adjustments to the price (Asphjell, 2014). A weakness with the menu cost model is its inability to pick up small price changes (Klenow and Kryvtsov, 2008). Facing this problem, Dotsey et al. (1999) introduce a stochastic menu cost model. In this model, the adjustment costs are spread independently across time and firms. The stochastic menu cost model thereby targets firms with low adjustment costs and allows for small price changes.

Calvo (1983) presented a time dependency model that showed how firms change prices after receiving a random signal (Shock). In this model, Calvo assumes that the shocks are stochastic and independent both geographically and across industries distributed over the period (Calvo, 1983). The model also assumes a constant probability of price change, which he called hazard rates. Nakamura and Steinsson (2008) conducted a study investigating this assumption and found that these hazard rates tended to slope downwards for the first couple of months post price change, then flattening out.

The time-dependent models assume further that exogenous factors mainly give the rigidity found in price decisions. Also, the research presents results that indicate price adjustments made at fixed points in time or by receiving a "signal" that has a constant probability independent of time (Calvo, 1983) . Time-dependent pricing models are viewed as overly simplistic by some, but some studies fit the assumptions set by these models. For our research, this approach is attractive due to its notion of reacting to shocks, and it would be interesting to know what is the driver behind the different "signals".

3 Data

The data used in this thesis is obtained from several data sources, falling into two main categories. The first category is pricing data, where the data source is a dataset supplied by Statistics Norway (SSB) and contains monthly data on product-level prices in Norway. The second category is uncertainty data, where the data sources are uncertainty indices either created by us or obtained from highly reliable sources.

3.1 Pricing data

The pricing dataset is supplied by SSB and covers the period 2005 – 2016. The dataset is used to develop the Norwegian producer price index (PPI), which measures the price development of producers' products, both sold to the Norwegian market and exported abroad. The PPI is an integral part of a system for short-term statistics prepared for monitoring the Norwegian economy. A selection of approximately 1300 companies is used to collect the monthly prices on more than 5000 products. The selection is supplemented continuously, consequently the duration of the products price history will be varying (SSB, 2021).

In the analysis, we will not consider exported or imported products. The reason for this is that we are interested in analysing how uncertainty impacts domestic products' pricing. Furthermore, these products' price-setting and development are expected to differ from domestic products, exposing our analysis to unwanted noise.

Before conducting the analysis, we need to process the data. We remove data that are either incomplete, undefined, and non-reported. Further, there are instances where some products have abnormal price changes. Following the method denoted in Bratlie (2013), we assume that if the prices are reduced by more than 49% or increased more than 99%, the changes were probably due to either a quality change or representing a new product. We therefore, exclude prices with abnormal changes. Finally, we decide to exclude the water supply and sewage and wholesale and retail sectors, "as they hold little relevance when analysing producer pricing behaviour" (Skuterud and Webster, 2020). We also exclude the mining and quarrying sectors as these have unnatural adjustment frequencies (Nilsen and Vange, 2019). With all changes made, the dataset we are using in the upcoming analysis contains 208 391 price observations on 2880 products distributed across 516 firms. The dataset has individual identifiers for products, firms and enterprises. In addition, previous studies on Norwegian PPI data find strong evidence of price stickiness and price rigidity (Nilsen et al., 2021).

The dataset is organised with a hierarchical structure after the Harmonized System (HS) classifications. HS is an international customs and statistical product nomenclature (WCO, 2021). In HS a commodity code consists of 8 digits (Tolletaten, 2021). The first two digits are the product category, the next four digits are for the product category within the section, and the final two are specific for the specific good. To explain the structure of the Harmonized System we will use an example. The product "Seed" has HS8 code 10.01.1101 where the HS6 code is 10.01.10 for Durum wheat, the HS4 is 10.01 for Wheat and meslin, and the HS2 code is 10 for Cereals (Shippingsolutions, 2021). This is illustrated in table 3.1

Table 3.1: HS Codes

HS Code	Names
Section 2	Vegetable Products
10	Cereals
10.01	Wheat and meslin
10.01.10	Durum wheat
10.01.1101	Seed

Note: This table presents the HS-structure.

Source: SSB (2021).

3.1.1 Price adjustments

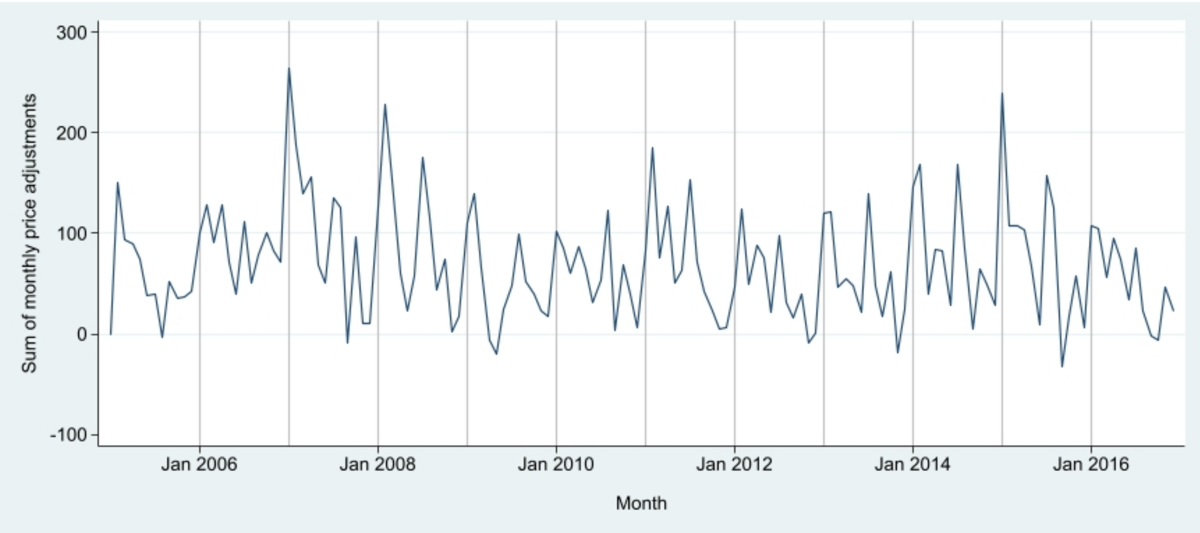
To understand how prices change, we chose to analyse the price adjustment at the extensive margin. We make this choice because there is more action on the extensive margin compared to the intensive margin, and because it is a standard in the prominent literature (Born and Pfeifer, 2014; Bachmann et al., 2019; Nilsen et al., 2021).

The first step we take to understand how prices change is to look at how the sum of price adjustments develop over time. We accomplish this by creating a price adjustment indicator variable, $UD_{ijk,t}$, that indicates if there has been a negative or positive price adjustment from one period to the next.

$$UD_{ijk,t} = \begin{cases} 1 & \text{if } P_{ijk,t} > P_{ijk,t-1} \\ -1 & \text{if } P_{ijk,t} < P_{ijk,t-1} \\ 0 & \text{otherwise} \end{cases} \tag{3.1}$$

Then we calculate the sum of the positive and negative price adjustments for each month. This is shown in figure 3.1, where the total price changes are on the y-axis and the dates are on the x-axis.

Figure 3.1: Sum of monthly price adjustments



Note: We utilise the $UD_{ijk,t}$ to plot the development of the sum of monthly price adjustments.
Source: Estimations of authors based on PPI data.

To further understand the price adjustments of Norwegian producer prices we calculate the frequency of price adjustment. To calculate the frequency of price adjustment, we create a price change frequency variable. The price change frequency variable F_{ijk} is calculated by the quotient of the sum of two indicator variables.

The first indicator variable $I_{ijk,t}$, indicates if there has been a price adjustment from one period to the next. $I_{ijk,t}$ gives us a method for calculating the total number of price adjustments.

$$I_{ijk,t} = \begin{cases} 1 & \text{if } P_{ijk,t} \neq P_{ijk,t-1}\text{, and } P_{ijk,t} \text{ and } P_{ijk,t-1} \text{ are both observed} \\ 0 & \text{otherwise} \end{cases} \tag{3.2}$$

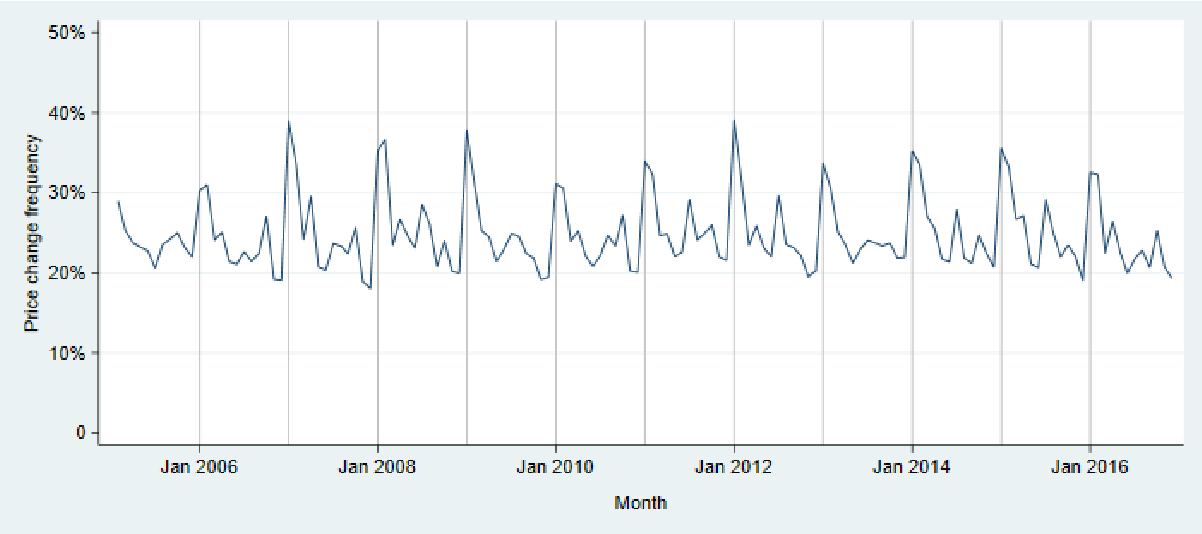
The second indicator variable $J_{ijk,t}$ indicates whether the price of product $I_{ijk,t}$ has been observed for two successive months.

$$J_{ijk,t} = \begin{cases} 1 & \text{if } P_{ijk,t} \text{ and } P_{ijk,t-1} \text{ are both observed} \\ 0 & \text{if } P_{ijk,t} \text{ is observed, but not } P_{ijk,t-1} \end{cases} \tag{3.3}$$

Using the two indicator variables, we can calculate the price change frequency variable F_{ijk}. The price change frequency is the number of price changes as a share of the number of price quotes. As shown in Figure 3.2.

$$F_{ijk,t} = \frac{\sum_{t=1}^{T} I_{ijk,t}}{\sum_{t=1}^{T} J_{ijk,t}} \tag{3.4}$$

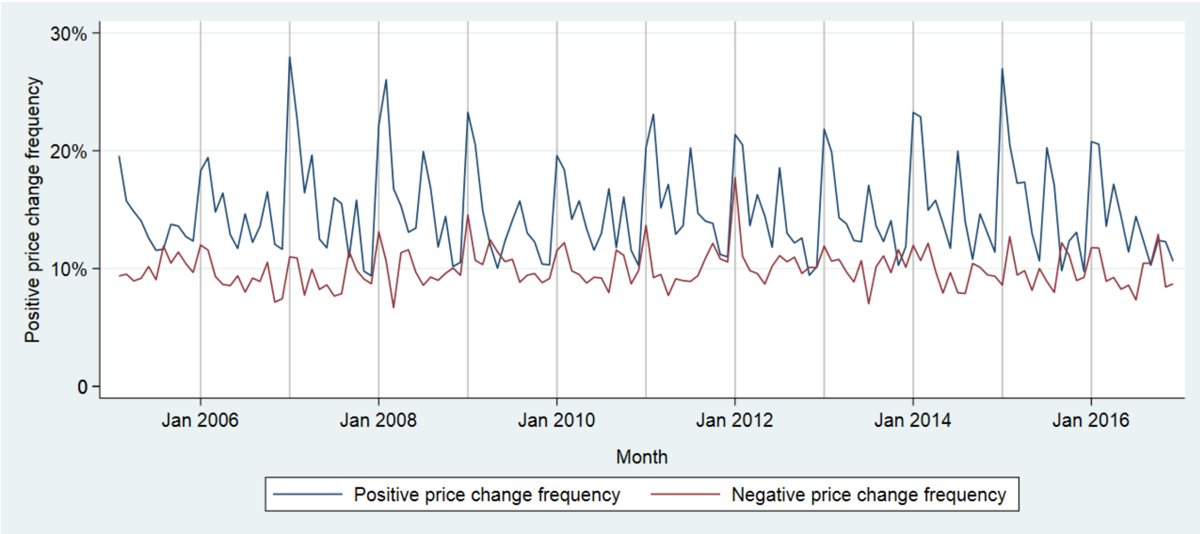
Figure 3.2: Price change frequency, a



Note: We utilise the frequency variable F_{ijk} to plot the development of the average monthly price change frequency
Source: Estimations of authors based on PPI data

We are interested in analysing if there is a difference between positive and negative price adjustment. Therefore, we utilise the $UD_{ijk,t}$ variable and the $F_{ijk,t}$ variable to find the average monthly price change frequency for products with positive changes and the average monthly price change frequency for products with negative changes. This is illustrated in 3.3. We see that there are clear seasonal patterns for the positive price changes, but the negative price changes appear to be less influenced by seasonality. We also see that the two lines move differently, suggesting that there might be different factors affecting them.

Figure 3.3: Price change frequency, b

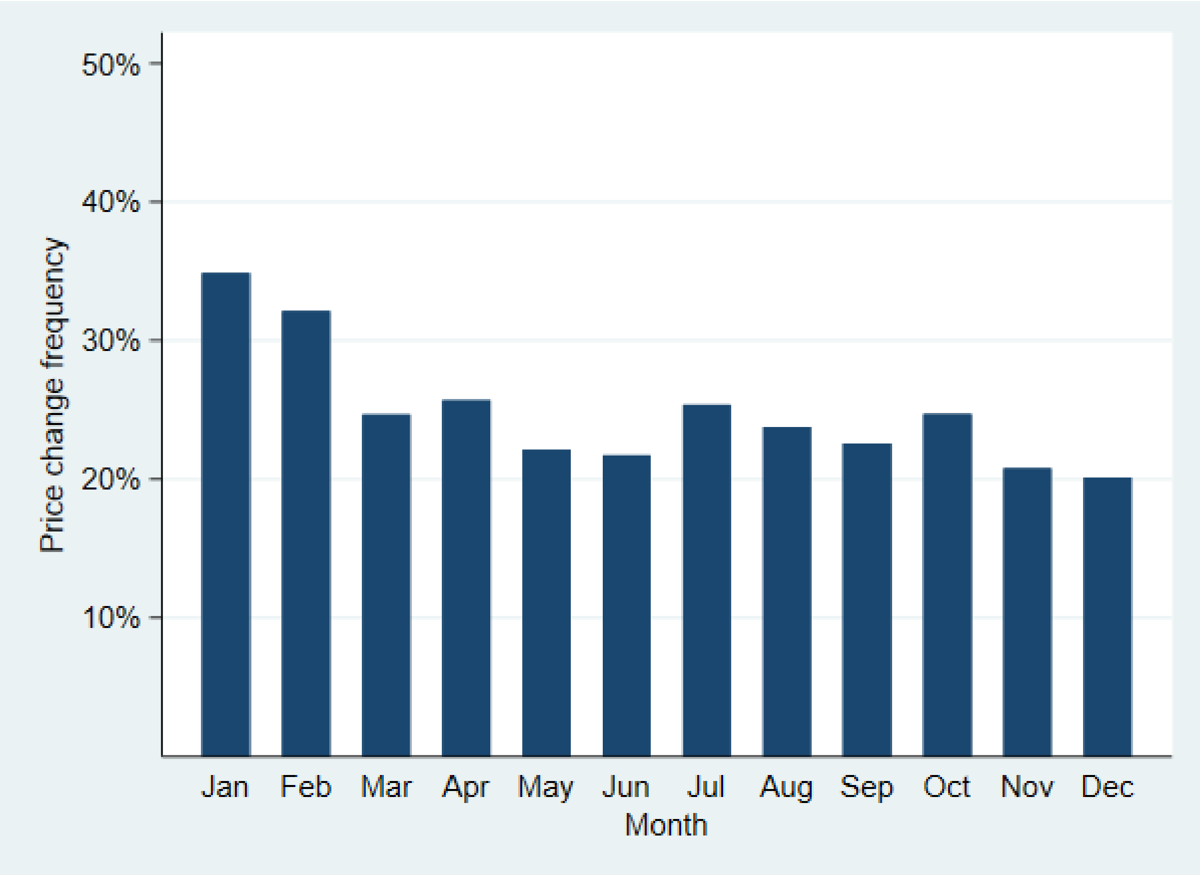


Note: We utilise the price change variable $UD_{ijk,t}$ and the frequency $F_{ijk,t}$ variable to plot the development of the average monthly price change frequency for products with positive changes and the average monthly price change frequency for products with negative changes.
Source: Estimations of authors based on PPI data.

We notice seasonal patterns from the figures above, with spikes at the start of each year and quarterly price increase intervals. This result is in line with what we expected, and Nilsen et al. (2018) find "that Norwegian producers' price adjustment behaviour is more or less in line with the rest of Europe", and that could be due to negotiation and signing of price contracts which is normally set in January.

To further investigate the seasonal patterns, we create a figure showcasing the average price change frequency per month. In Figure 3.4, we can again observe that the price change frequency peaks at the start of the year. After that, the price change frequency remains relatively stable, with small quarterly peaks. These results are similar to the ones found in the literature, and Vermeulen et al. (2012) find identical patterns throughout Europe.

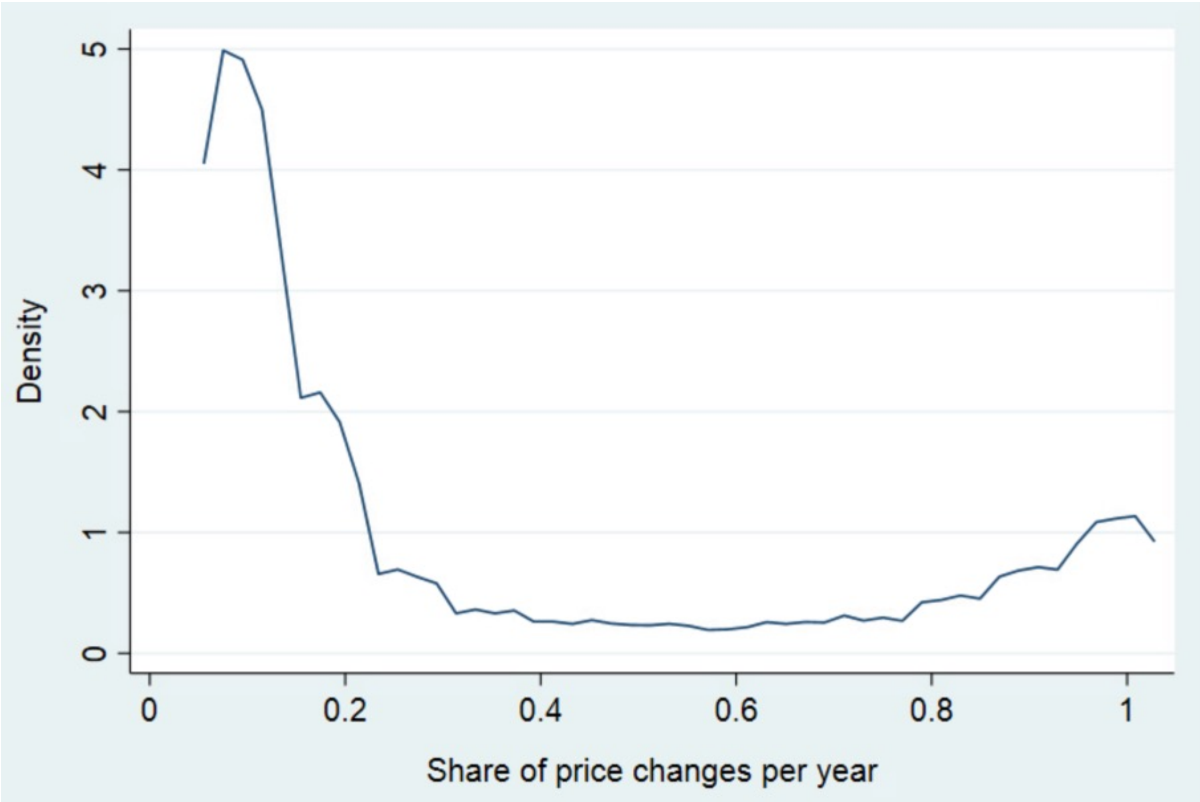
Figure 3.4: Monthly price change frequency



Note: We utilise the price change variable $UD_{ijk,t}$ and the frequency $F_{ijk,t}$ variable to plot the price change frequency each month.
Source: Estimations of authors based on PPI data.

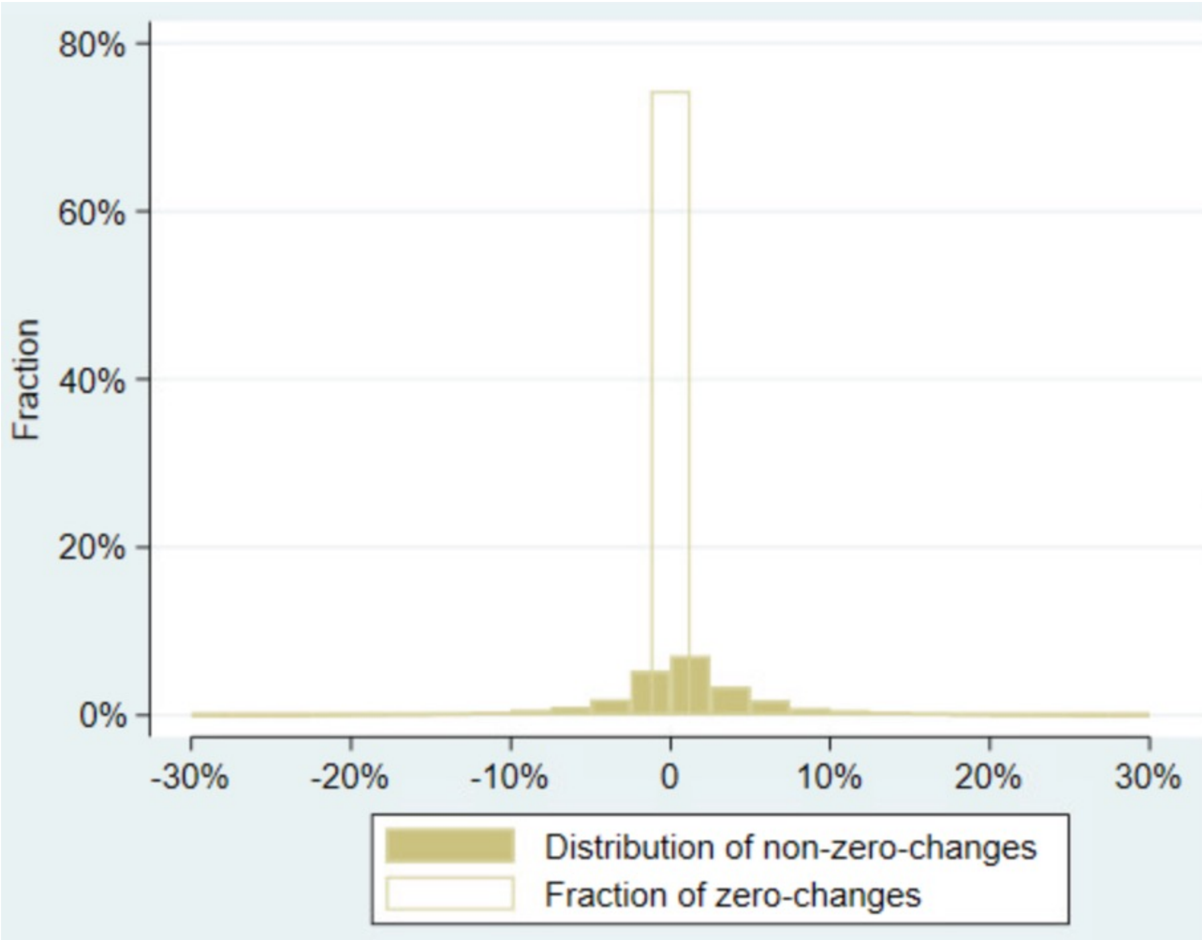
We are also interested in products with frequent and infrequent price changes, because it reasonable to assume that products with frequent price changes are more exposed to uncertainty shocks. In figures 3.5 and A2.3, we illustrate the kernel distribution of price changes and the fraction of price changes. We see evidence of products either making few or many price changes, and that the most common is zero or almost zero price changes. With these results in mind, we divide products groups at the HS4-level into infrequent if they have a mean price change share below 0.09 per year(e.g. approximately one price adjustment per year) (Nilsen et al., 2021).

Figure 3.5: Kernel density



Note: The share of price changes per year.
Source: Estimations of authors based on PPI data.

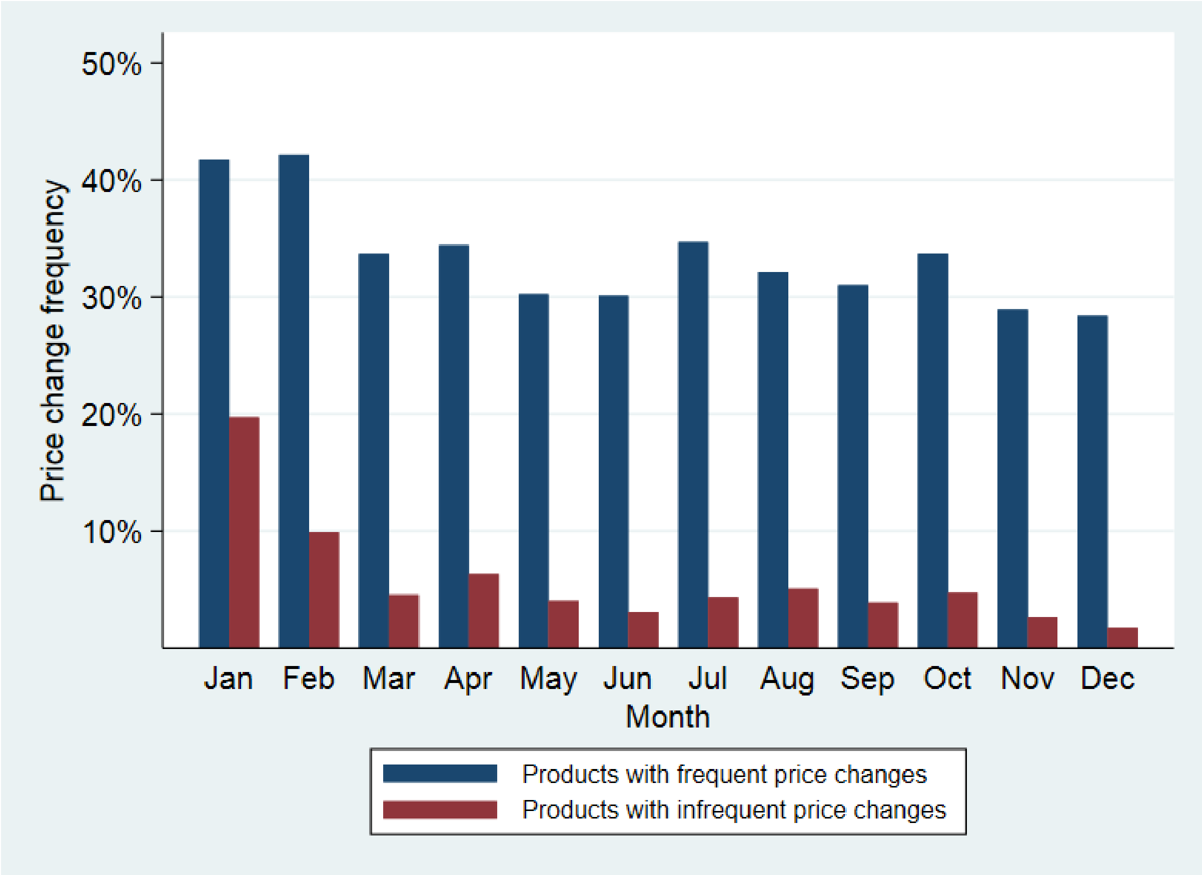
Figure 3.6: Fraction of price changes



Note: The fraction of of price changes per year.
Source: Estimations of authors based on PPI data.

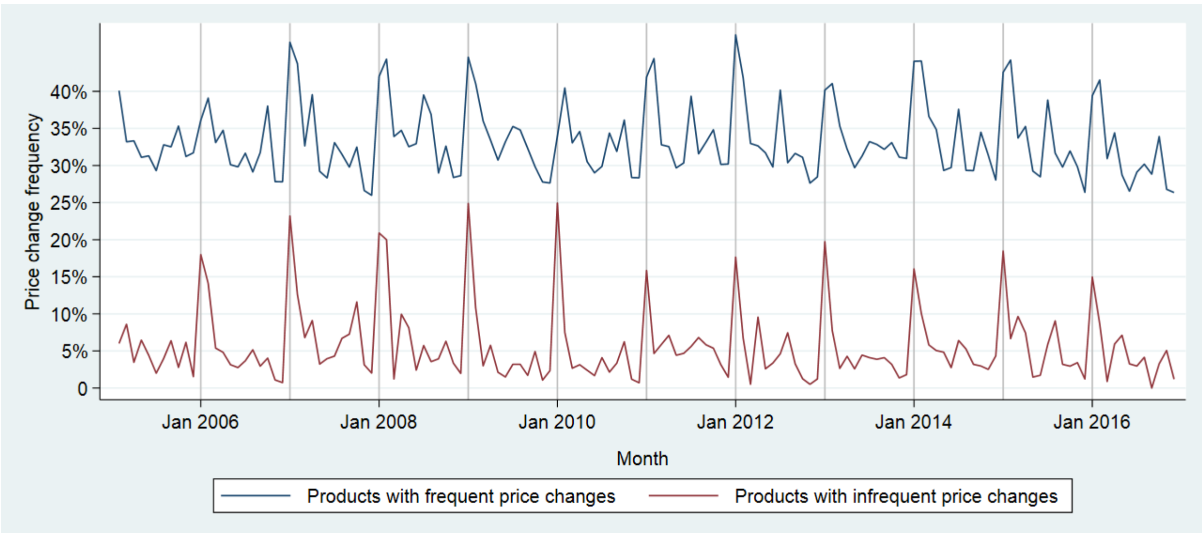
From figures 3.7 and 3.8, we see that there are differences between products with frequent and infrequent price changes. We want to analyse these differences and investigate whether uncertainty might be the driving force behind them. We note that the price change frequency in January and February for products with infrequent price changes is more prominent than for products with frequent changes. A reason for this could originate from explicit contracts with a one-year duration as discussed by Alvarez et al. (2006).

Figure 3.7: Monthly price change for frequent and infrequent products



Note: We utilise the the price change variable $UD_{ijk,t}$ and the frequency $F_{ijk,t}$ variable to plot the price change frequency each month for products with frequent and infrequent price changes.
Source: Estimations of authors based on PPI data.

Figure 3.8: Price change frequency for frequent and infrequent products



Note: We utilise the price change variable $UD_{ijk,t}$ and the frequency $F_{ijk,t}$ variable to plot the development of the monthly price change frequency for products with frequent and infrequent price changes.
Source: Estimations of authors based on PPI data.

3.2 Uncertainty index based on textual analysis

As mentioned in the literature review, Economic Policy Uncertainty(EPU) indices are common proxies indicating uncertainty. To our knowledge, there is no Economic Policy Uncertainty Index available for Norway, we therefore decided to construct one. The purpose with this index is to capture how Economic Policy Uncertainty affects the pricing in Norway, using a news-based approach. We consequently create an EPU-index based on the methodology of Baker et al. (2016).

We use Retriever's Atekst database to create a newspaper-based Economic Policy Uncertainty Index for Norway. The database holds 353 digitised newspapers, as well as 1709 online newspapers (Ifwarsson et al., 2021). We want to analyse Economic Policy Uncertainty on the most extended horizon possible, and therefore we use the first data available, which is 1983.

In creating our EPU-Index, we have chosen three national papers: VG, Finansavisen, and Aftenposten. We would preferably include Dagens Næringsliv (DN) in the analysis, but there is no longer any DN data in Atekst Retriever (Kolsrud, 2020). We chose these newspapers because we consider these papers to be high-quality newspapers that are not affected by the political view of the newspapers. Furthermore, DellaVigna and Hermle (2017) finds that media reputation is an essential factor for biased coverage, and thus, we will only include newspapers that we consider to uphold this standard. The newspaper data for the EPU-Index is included in Table 3.2.

Table 3.2: Newspaper data for the Norwegian Economic Policy Uncertainty index

Newspaper	First article	EPU articles	Total articles	Average monthly EPU articles
Aftenposten	01.05.1983	8338	2 326 449	36
VG	01.05.1983	2524	1 264 475	11
Finansavisen	01.01.2011	1200	188 096	5

Note: Descriptive statistics of newspaper data for the Norwegian Economic Policy Uncertainty index.

Source: Estimations of authors.

The index is created by counting the frequency of EPU articles relative to the total number of articles in the relevant dates and papers. An EPU article is an article that contains at least one word associated with one of the categories Economic, Policy, and Uncertainty.

To decide which words to include in the different topics, we adopt words from Baker et al. (2016) and translate them using academic dictionaries. To construct the EPU Index, we follow the methods of Baker et al. (2016), Eriksen and Tobiassen (2020), and Ifwarsson et al. (2021).

The first step in creating a Norwegian EPU-Index is to extract the relevant EPU-articles from Atekst Retriever. We accomplish this with an extensive search through the database where we extract all articles containing at least one word related to "Economic", "Policy", or "Uncertainty" over the relevant time period. For a complete list of the words, look at Table 3.3.

Table 3.3: Norwegian policy uncertainty keywords

Word type	Root of keyword	Full list of keywords
Economic	Økonomi	økonomien økonomier økonomiene
	Økonomisk	økonomisk økonomiske
Policy	Norges Bank	Norges Bank
	Sentralbank	sentralbanken sentralbanker sentralbankene
	Regjering	regjeringen regjeringer regjeringene
	Departement	departementet departementene
	Regulering	reguleringen reguleringer reguleringene
	Minister	ministeren ministere ministerene
	Direktiv	direktivet direktivene
	Storting	stortinget stortingene
Uncertainty	Usikker	usikkert usikre usikkerhet
	Usikkerheten	usikkerheter usikkerhetene
	Uro	uroen uro

Note: Words used in the construction of the Norwegian Economic Policy Uncertainty index.

Source: Words from Baker et al. (2016) translated using Det Norske Akademis ordbok.

Then we find the monthly total number of newspaper articles by searching in the database for the 50 most commonly used Norwegian words. The words used gathered from Korrekturavdelingen (2021), and list of these words can be found in Table 3.4.

Table 3.4: The 50 most commonly used Norwegian words

Word type	Full list of keywords
The most common Norwegian words	og i det på som er en til å han av for med at var de ikke den har jeg om et men så seg hun hadde fra vi du kan da ble ut skal vil ham etter over ved også bare eller sa nå dette noe være meg mot

Source: (Korrekturavdelingen, 2021).

Then the next step is to create a time series X_{it} for the news sources $i \in I$ using the count of relevant articles (EPU articles) at month $t \in T$, divided by the total number of articles in the newspapers.

3.3 Uncertainty data

According to Saltzman and Yung (2018) and Larsen (2017) different uncertainty types have different implications of uncertainty. Therefore, we will utilise seven different types of uncertainty measures to analyse the different effects of uncertainty. In Table 3.5 we provide an overview of the different uncertainty measures, their start-and-end dates, and the uncertainty-type they capture.

Table 3.5: Uncertainty measures

Name	Dates	Uncertainty type
Norwegian EPU-Index	01.08.1983 - 01.10.2021	Norwegian Economic Policy uncertainty
Global EPU-Index	01.01.1997 - 01.05.2021	Global Economic Policy uncertainty
Novix	01.01.2000 - 01.05.2017	Norwegian financial market volatility
American macroeconomic uncertainty	01.07.1960 - 01.06.2021	American macroeconomic uncertainty
Norwegian macroeconomic uncertainty	02.05.1988 - 31.12.2020	Norwegian macroeconomic uncertainty
Norwegian monetary policy uncertainty	02.05.1988 - 31.12.2020	Norwegian monetary policy uncertainty
Norwegian fear uncertainty	02.05.1988 - 31.12.2020	Norwegian fear uncertainty

Source: Estimations of authors.

We want to conduct our analysis on the most extended period possible. The frequency of the pricing dataset provided by SSB is at the monthly level from 2005 until and including 2016. Therefore, we must extract the relevant dates for the analysis and process the data at the right frequency. We smooth the indices by applying a 3 month backward looking rolling mean. The reason for averaging the uncertainty measures is to reduce variance and pick up the accumulated effects of uncertainty on prices.

3.3.1 Norwegian Economic Policy Uncertainty

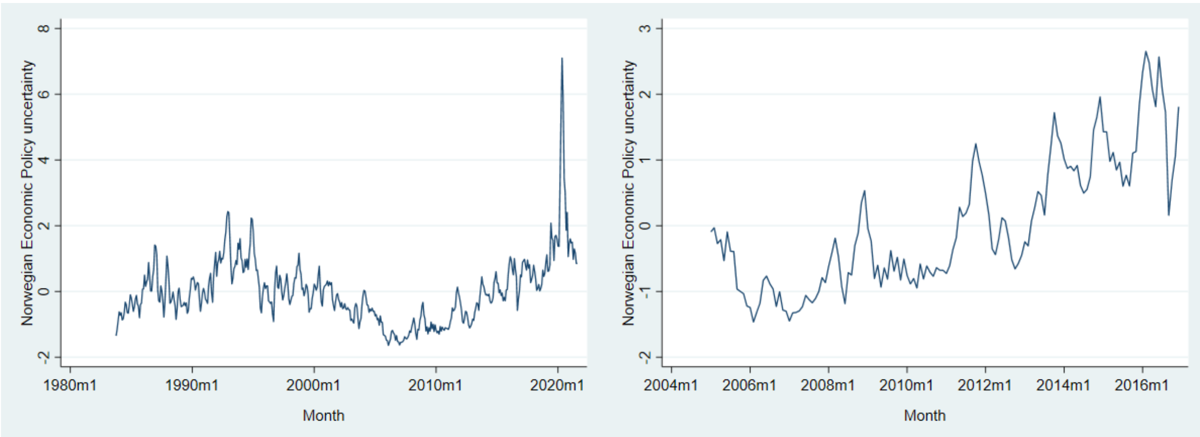
Newspaper-based uncertainty indices are essential for understanding how households experience uncertainty (Alexopoulos et al., 2009). We use the constructed EPU-index from Section 3.2, to capture Economic Policy uncertainty in Norway. The Norwegian

EPU index is shown for the entire time series in Figure 3.9. On the y-axis is the number of monthly EPU-articles in relation to the total number of monthly articles, with the dates on the x-axis.

In Figure 3.9a, we analyse the development of economic policy uncertainty in Norway over the last 40 years. It is possible to notice specific events that spike the Norwegian EPU. For instance, we see a massive spike in the index at the end of the 1980s, which corresponds with the Norwegian banking crisis. Furthermore, we note that the EU referendum in the middle of the 1990s, the oil glut and Brexit in the middle of the 2010s, and the Covid-19 crisis left significant marks on the index.

In Figure 3.9b, we analyse the development of economic policy uncertainty in Norway for the period of our pricing data. It is possible to see the effects of the global financial crisis, 22. July, the oil price plunge and Brexit which all caused uncertainty shocks.

Figure 3.9: Norwegian Economic Policy Uncertainty



(a) Norwegian Economic Uncertainty Index, 1983-2021

(b) Norwegian Economic Uncertainty Index, 2005-2016

Source: Estimations of authors

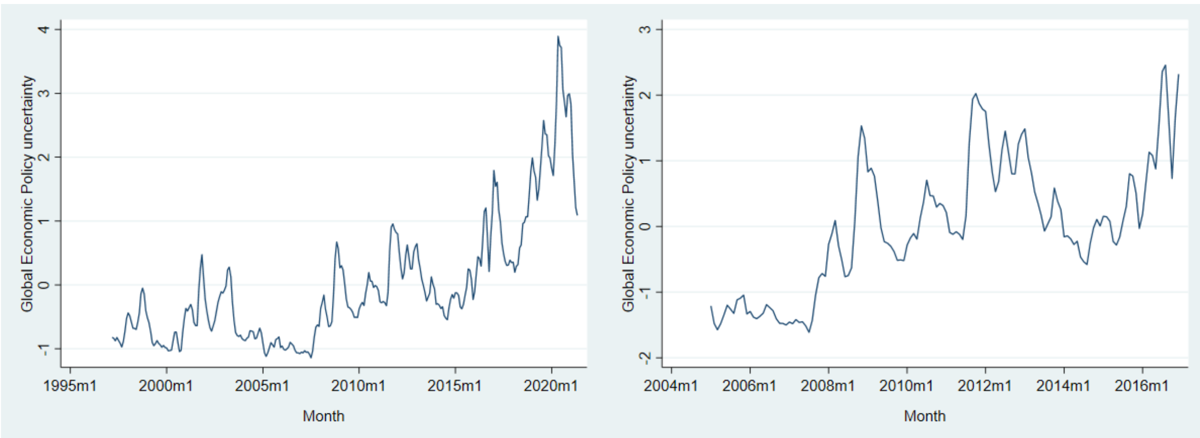
3.3.2 Global Economic Policy Uncertainty

We are interested in finding measures for global uncertainty, as the global uncertainty might have a different effect on producer prices than Norwegian based uncertainty. Global economic policy uncertainty is one of the global measures we are interested in. To measure global economic policy uncertainty, we utilise the dataset *Global EPU Data* from

An Index of Global Economic Policy Uncertainty [2] (2016). The dataset is a monthly Global Economic Policy Uncertainty (GEPU) index ranging from January 1997 to 2021. The GEPU-Index is a GDP-weighted average of national EPU-indices for 21 countries: Australia, Brazil, Canada, Chile, China, Colombia, France, Germany, Greece, India, Ireland, Italy, Japan, Mexico, the Netherlands, Russia, South Korea, Spain, Sweden, the United Kingdom, and the United States (Policyuncertainty.com, 2021).

The GEPU-index is constructed in the same manner as our Norwegian EPU-index, both following the method of Baker et al. (2016). We can from Figure 3.10, see that several international events increase the global economic uncertainty. For instance, we see that both 9/11 and the invasion of Iraq makes significant spikes in the early 2000s. Furthermore, we can identify the uncertainty effect of the global financial crisis in 2008, and Eurozone crisis, U.S.fiscal battles and China leadership transition in the early 2010s. Finally, we can see that Brexit and Covid-19 cause the highest amount of uncertainty in the period.

Figure 3.10: Global Economic Policy Uncertainty



(a) Global Economic Uncertainty Index, 1997-2021

(b) Global Economic Uncertainty Index, 2005-2016

Source: (Policyuncertainty.com, 2021)

3.3.3 NOVIX

We are interested in a measure that express financial uncertainty in Norway. This is because we believe that financial uncertainty might directly influence price-setting firms and it might therefor be a good driver of price changes. To measure financial uncertainty in Norway we chose the Implied Volatility Index for the Norwegian Equity Market.

[2] The uncertainty data is frequently updated and accessible at http://www.policyuncertainty.com/index.html (Policyuncertainty.com, 2021)

The Implied Volatility Index for the Norwegian Equity Market, or NOVIX, is constructed to capture financial market volatility on the OBX following the methodology of the standard VIX and was created by Bugge, Guttormsen, Molnár & Ringdal (2016)[3]. The NOVIX is a volatility index based on the VIX methodology, and we employ this index to measure stock market uncertainty in Norway.

The index is computed from OBX options traded on Oslo Børs and consists of daily close data on all available call and put options from 2000 – 2016 and 5-minute close data on all available call and put options from from 2017-2020. (Bugge et al., 2016). For the NOVIX data to fit our pricing data, we first calculate daily averages from the 5-minute data and then calculate a monthly index for the daily data.

The index is generated from OBX options using the model-free VIX metrology, following this formula (Bugge et al., 2016; Chicago Board Options Exchange, 2009):

$$\sigma^2 = \frac{2}{T}\sum \frac{\Delta K_i}{K_i^2} e^{RT} Q(K_i) - \frac{1}{T}(\frac{F}{K_0} - 1)^2 \tag{3.5}$$

where:

σ	NOVIX/100
T	Time to expiration in years
F	Forward level of underlying
K_0	First strike below F
K_i	Strike price of the i-th out-of-money option
ΔK_i	$\frac{1}{2} \cdot (K_{i+1} - K_{i-1})$
R	Risk-free rate
$Q(K_i)$	Midpoint of bid-ask spread for option with strike K_i

Following the Chicago Board Options Exchange methodology, Bugge et al. (2016) calculated the implied volatility estimate σ for two chosen maturities, a near-term and

[3]The uncertainty data is accessible at https://github.com/ringdal/novix (Ringdal, Martin, 2020)

next-term maturity. The two maturities represent the options expiring before and after the desired 30-day horizon. The authors select a subset of options to include in the calculation by the procedure below for each maturity. To determine the forward level from the option prices, first they identify the strike with the smallest absolute difference in the put-call price and then apply the formula:

$$F = Strike + e^{RT} \cdot |CallPrice - PutPrice| - |CallPrice - PutPrice| \tag{3.6}$$

Bugge et al. (2016) define the K_0 as the first strike below F, and the option pair with strike K_0 is considered at-the-money. Next, they only consider at-the-money call options with strikes $K_i > K_0$ and the put options with strikes $K_i < K_0$. Then, they discard all options with a zero-bid price and all options following two zero bid prices in a row. The authors attain the 30-day volatility estimate from a linear interpretation between the near-term and the next term results,

$$NOVIX = 100 * \sqrt{\left(T_1\sigma_1^2\left[\frac{N_{T2} - N_{30}}{N_{T2} - N_{T1}}\right] + T_1\sigma_1^2\left[\frac{N_{30} - N_{T1}}{N_{T2} - N_{T1}}\right]\right) * \frac{N_{365}}{N_{30}}} \tag{3.7}$$

where "the subscripts 1 and 2 represent the near-term and next-term options, respectively. The NOVIX is calculated using a time precision of a minute, where T is the time to expiration in years quoted as minutes to expiration over minutes in a year. The remaining time terms are:

N_{T1} = Number of minutes to settlement of near-term options

N_{T2} = Number of minutes to settlement of next-term options

N_{30} = Number of minutes in 30-days

N_{365} = Number of minutes in a year

"(Bugge et al., 2016)

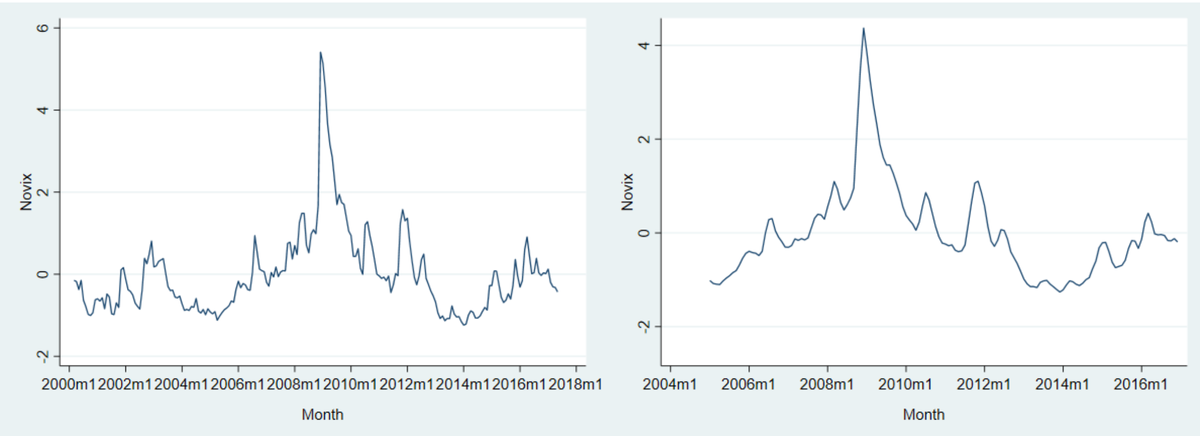
In Figure 3.11a and Figure 3.11b, the NOVIX is plottet for the years 2000-2017 and 2005-2016. We see that the implied volatility on the Norwegian Equity Market increases to global events such as the 9/11 terrorist attack and the global financial crisis in 2008. There are not many Norway-isolated spikes in the index, and in fact, the NOVIX correlates with 0.92 with the VIX index. The high correlation between the indices is the main reason for the exclusion of the VIX-index, as the NOVIX and the VIX mainly will measure the same type of uncertainty.

Table 3.6: Correlation matrix VIX Novix

	VIX	Novix
Vix	1.000	
Novix	0.9259	1.000

Source: Estimations of authors.

Figure 3.11: NOVIX



(a) NOVIX, 2000-2017 **(b)** NOVIX, 2005-2016

Source: (Bugge et al., 2016)

3.3.4 American macroeconomic uncertainty

US-based uncertainty shapes global uncertainty (Cuaresma et al., 2019) . Therefore, we utilise the macroeconomic uncertainty measure from Kyle Jurado, Sydney C. Ludvigson, and Serena Ng's (2015) paper *Measuring Uncertainty* , measure global macroeconomic uncertainty.[4]

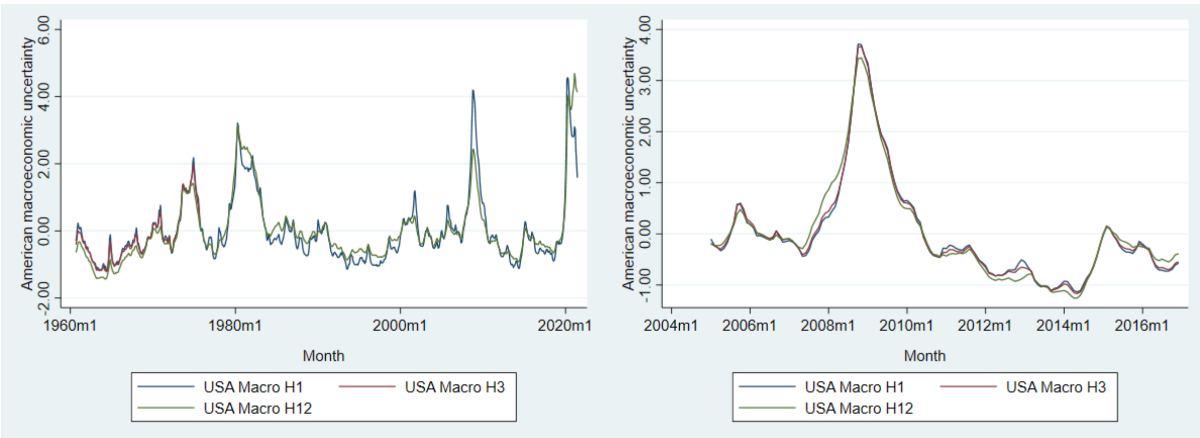
The uncertainty measure originates from a dataset that consist of 132 mostly macroeconomic time series, including: "Employment and hours, real retail, manufacturing and trade sales, consumer spending, housing starts, inventories and inventory sales rations, order and unfilled orders, compensation and labour costs, capacity utilisation measures, price indexes, bond, and stock market indexes and foreign exchange measures" (Jurado

[4]The uncertainty data is frequently updated and accessible at https://www.sydneyludvigson.com/data-and-appendixes (Ludvigson, Sydney C, 2021)

et al., 2015). Jurado et al. (2015) creates the macroeconomic uncertainty measure by separating the unforecastable from forecastable factors in each time series, because only unforecastable variation should be associated with uncertainty (Aastveit et al., 2017). In other words, their uncertainty measure is not based on the volatility of the variables, but on how predictable the economy is at a given time. The uncertainty measure is created at three different horizon's: h = 1; 3; and 12 months. For the analysis we will only analyse the macroeconomic time series at the 1 month horizon.

From figures 3.12a and 3.12b we can identify four large episodes of uncertainty. The first episode is around the 1973 oil crisis and the 1970-recession in America. The second episode is situated around the recession of 1981–82, and the final two correspond to the global financial crisis in 2008 and the Covid-19 crisis in 2020. We can also note the macroeconomic stability during "The great moderation" from 1980 - 2000 (Federal Reserve History, 2021) (Jurado et al., 2015).

Figure 3.12: American macroeconomic uncertainty



(a) American macroeconomic uncertainty, 1960-2021

(b) American macroeconomic uncertainty, 2005-2016

Source: (Jurado et al., 2015)

3.3.5 Norwegian uncertainty topics using machine learning

Given that our pricing dataset contains Norwegian producer price data, it is essential to have uncertainty measures that cover Norway-specific uncertainty. To this end, we have utilised the uncertainty data from Vegard Larsen's article (2017) *Components of uncertainty.*[5]

[5] The uncertainty data is frequently updated and available at a daily frequency at https://www.vegardlarsen.com/index.php/ui (Larsen, 2021)

In the article, Larsen creates measures of uncertainty using a latent Dirichlet allocation model (LDA model). He generates uncertainty themes from "Dagens Næringsliv" and creates measures of uncertainty by counting the number of uncertainty terms within each article in each theme; then, he controls for the varying amount of news coverage by tracking the number of words in each theme,

$$v_i = \text{number of uncertainty terms in article } i. \tag{3.8}$$

then he controls for the varying amount of news coverage by tracking the number of words in each article.

$$w_i = \text{number of total words in article } i. \tag{3.9}$$

The aggregate uncertainty measure is as follows:

$$\Upsilon_t^{Agg} = \sum_{i \,\epsilon \text{ day t}} (\frac{v_i}{w_i}) \tag{3.10}$$

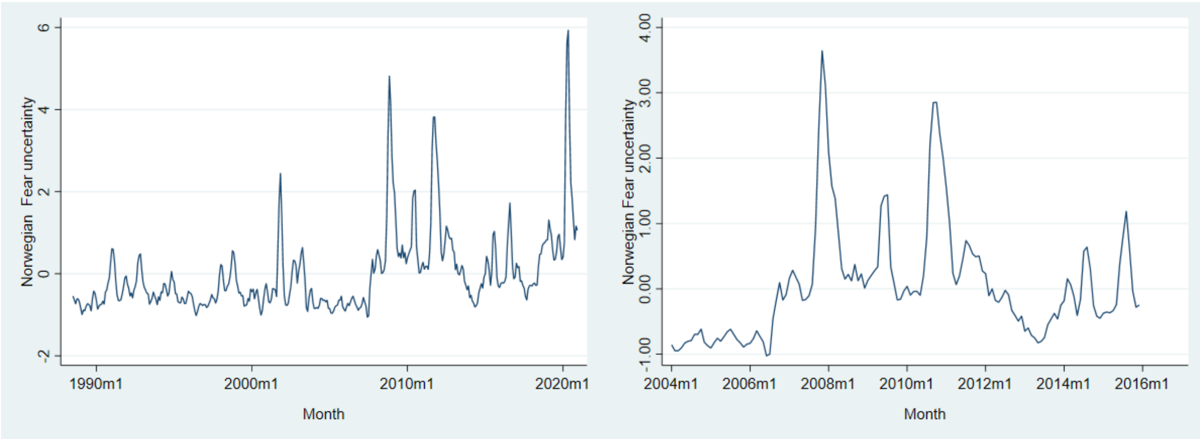
Following these calculations, the uncertainty is quantifies by the count of uncertainty terms within the different types of News. The result is 80 various uncertainty measures, and we have extracted three of those. These topics are Monetary policy, Macroeconomics, and Fear. We chose these measures because they are the topics with the highest uncertainty frequency and because they are the most relevant for our research. In Table 3.7 we show the most important words in each of the topics.

Table 3.7: Uncertainty topics in *Components of uncertainty*

Topic	First words
Fear	fear, emergency, hit, severe, financial crisis, scared
Monetary Policy	interest rate, central bank, euro, german, inflation, point
Macroeconomics	economy, budget, low, unemployment, high, increase

In Figure 3.13a and Figure 3.13b we have plotted the Fear uncertainty in Norway. This uncertainty measure is the frequency of uncertainty terms within news classified as Fear (Larsen, 2017). Fear uncertainty is especially high during crises, and it is easy to detect the financial crisis, the Greek government-debt crisis and the Covid-19 crisis.

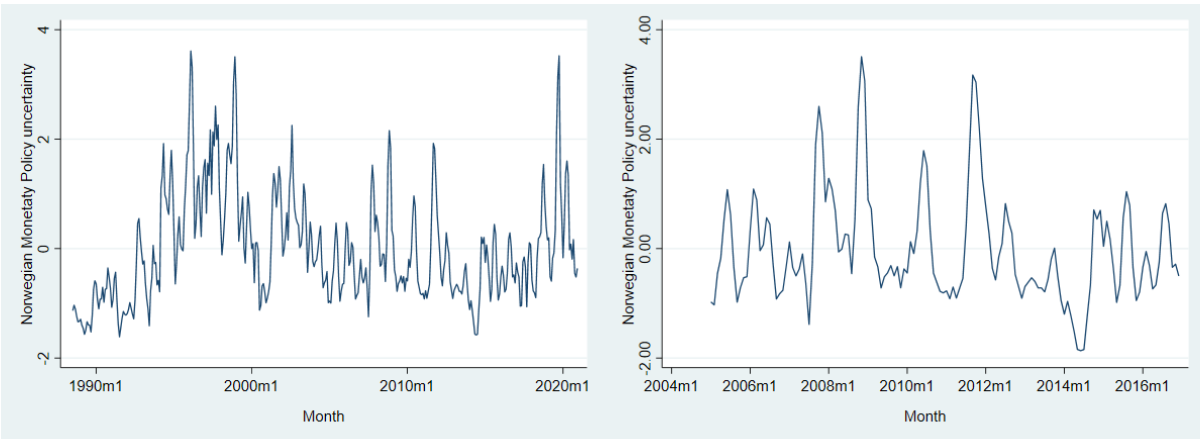
Figure 3.13: Fear uncertainty



(a) Norwegian Fear uncertainty, 1988-2020 **(b)** Norwegian Fear uncertainty, 2005-2016
Source: (Larsen, 2021)

In Figure 3.14a and Figure 3.14b we have plotted the Monetary policy uncertainty in Norway. This uncertainty measure is high when the monetary policy regime changes and when a new central bank governor assumes office (Larsen, 2017). This is evident from the figures, where uncertainty was high in the late 1990s. This corresponds to Svein Gjedrem being appointed as a new central bank governor, and the Norges Bank's monetary policy change from fixed exchange rate policy to inflation targeting (Norges Bank, 2021c). Monetary policy uncertainty also captures the global financial crisis and the Covid-19 crisis.

Figure 3.14: Monetary Policy uncertainty

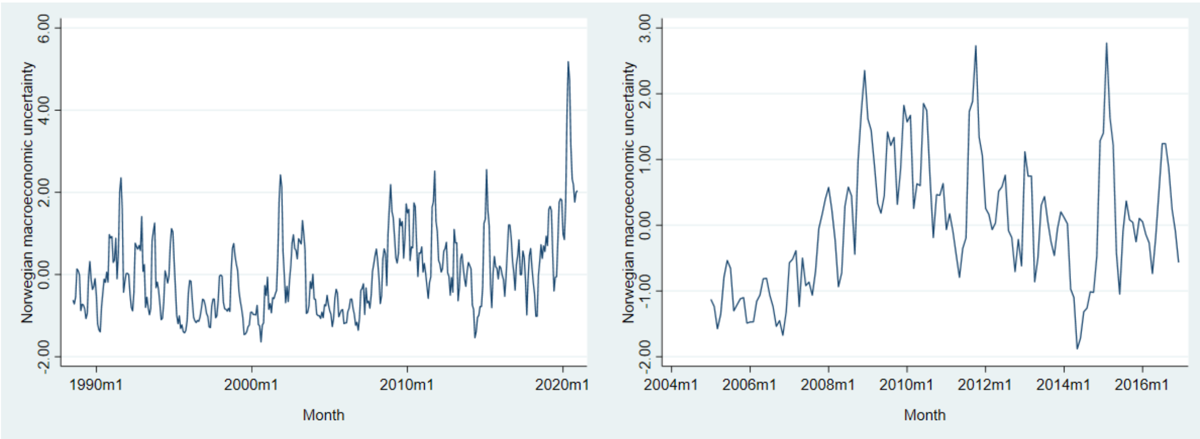


(a) Norwegian Monetary Policy uncertainty, 1988-2020 **(b)** Norwegian Monetary Policy uncertainty, 2005-2016
Source: (Larsen, 2021)

In Figure 3.15a and Figure 3.15b we have plotted the Macroeconomic uncertainty in

Norway. This uncertainty measure captures well-known episode in Norway's history. For instance, the Macroeconomic uncertainty is high during the Norwegian Banking crisis and the EU-debate in the 1990s (Larsen, 2017). This uncertainty measure corresponds with Norwegian crises, as depicted by Grytten and Hunnes (2010). Furthermore, the global financial crisis, Brexit and the Covid-19 crisis are all easy to detect.

Figure 3.15: Norges Bank Macroeconomic uncertainty uncertainty



(a) Norwegian Macroeconomic uncertainty uncertainty, 1988-2020

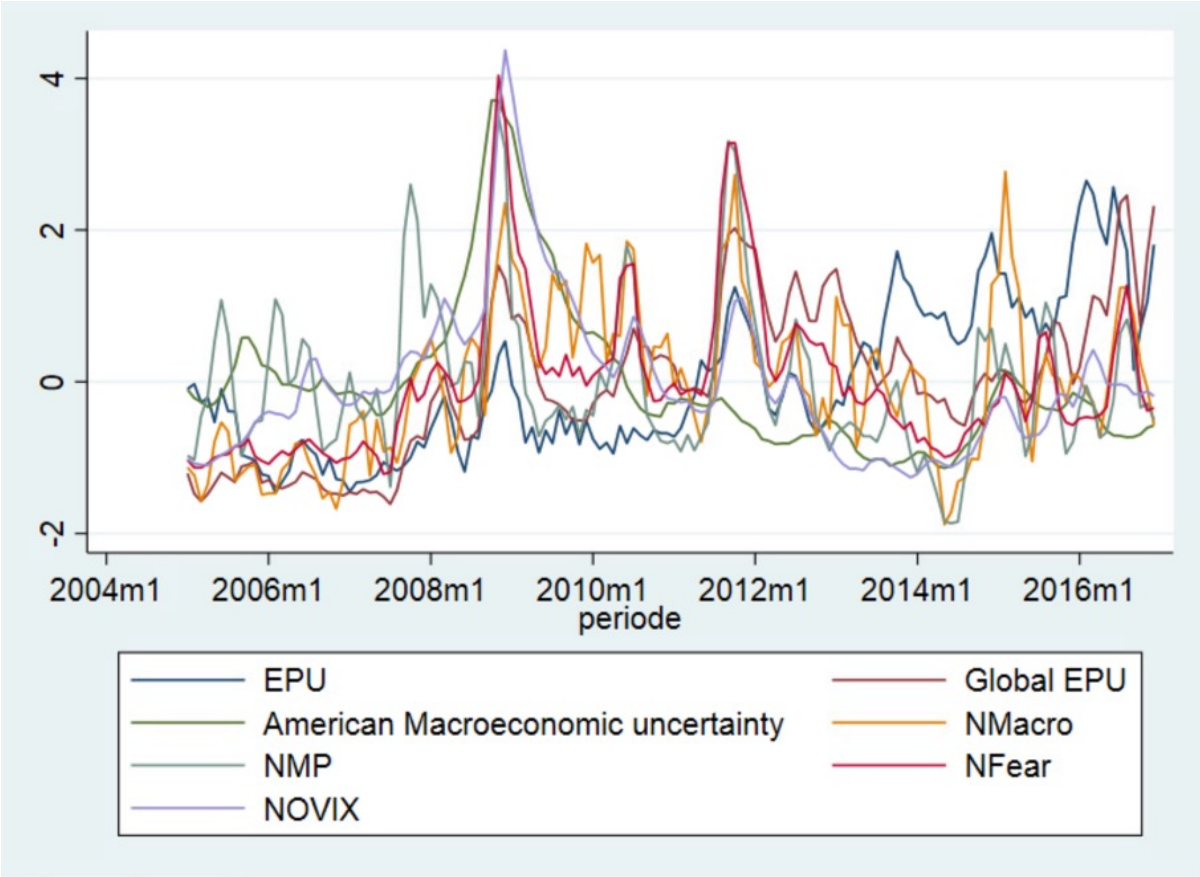
(b) Norwegian Macroeconomic uncertainty uncertainty, 2005-2016

Source: (Larsen, 2021)

3.3.6 Combining and comparing the uncertainty measures

To compare the different uncertainty measures against each other and analyse their effect on producer prices, we standardised the indices by subtracting the mean and dividing by the standard deviation. In Figure 3.16 we have plotted all the uncertainty measures against each other. In figures A2.4 to A2.14 in the Appendix, all uncertainty measures are plotted against the different price adjustments in the analysis.

Figure 3.16: All uncertainty measures



Source: Estimations of authors

To further compare the uncertainty measures we decide to run a correlation test. The correlation matrix is found in Table 3.8.

Table 3.8: Correlation matrix of uncertainty measures

	NOVIX	GlobalEPU	EPU	NMacro	NMonetary	NFear	USAMacro
NOVIX	1.000						
GlobalEPU	0.5935	1.000					
EPU	-0.1595	0.2757	1.000				
NMacro	0.2442	0.6121	0.5314	1.000			
NMonetary	0.0016	0.2952	0.5182	0.4921	1.000		
NFear	0.1828	0.7180	0.6885	0.7379	0.6859	1.000	
USAMacro	-0.2955	-0.0316	0.8260	0.3304	0.3670	0.4491	1.000

Note: This table presents the correlation between the uncertainty measures used in the multinomial logistic regression model.

Source: Estimations of authors.

From the correlation matrix, we see the correlation between Norwegian Fear uncertainty and Global EPU is 0.7180, implying that they are highly correlated. Further, we find that the correlation between EPU and macroeconomic uncertainty and EPU is 0.8260. While some of these numbers might seem too high and others too low, the results are not unexpected. The different measures convey different types of uncertainty. Some of them might detect the same uncertainty at the same events, while some of the events will not affect other measures. We would expect American Macroeconomic uncertainty and Global EPU to be more correlated. However, it seems that different forces are affecting the uncertainties. A reason for this is the severe effect of the global financial crisis and the insignificant effects of both the European debt crisis and the oil price crisis on the American Macroeconomic uncertainty compared to the other indices.

4 Methodology

4.1 The Multinominal logistic model

The complexity of the dataset and the diverse nature of our explanatory variables makes investigating the effect uncertainty has on price fluctuations a challenging task. Eventually, we land on the multinominal logistic model, as this model do not assume normality, linearity, or homoscedasticity (Starkweather and Moske, 2011). There will never be a model that picks up all relevant information. Still, when considering the research question, this model will assist us in our search for a connection between uncertainty and pricing behaviour.

The multinominal logistic model assume that the data are case-specific. Each independent variable have a single value for each case. Multinominal logistic regression can be used when the dependent variable is nominal and has more than two categories (Liu, 2016). The dependent variable in our model is $UD_{ijk,t}$. The dependent variable is a discrete variable that equals 1 if the price of a product increases from one month to another, -1 if the price of a product decreases from one month to another, and 0 if the price is unchanged, as shown in equation 4.1 . The independent variables are the different uncertainty measures, mentioned in Section 3.

$$UD_{ijk,t} = \begin{cases} 1 & \text{if } P_{ijk,t} > P_{ijk,t-1} \\ 0 & \text{otherwise} \\ -1 & \text{if } P_{ijk,t} < P_{ijk,t-1} \end{cases} \tag{4.1}$$

In the multinominal logistic model, we start with specifying the probability of each possible outcome as a function of the x's. Furthermore, there are mainly two methods for interpretation; a discrete change in the probabilities and factor change in the odds (Long and Long, 1997). In this thesis, we will use the discrete change interpretation. Our multinominal logistic model include three discrete outcomes: negative change, no change, and positive change. Positive and negative price changes are different. Firms tend to behave differently when increasing prices compared to decreasing prices (Ball and Mankiw, 1994). In section section 3, we find indicators that this applies to our dataset, and we want to see if and how uncertainty affects positive and negative price adjustments differently.

The marginal effects on the probability of these outcomes put up against the impact of uncertainty are our main results of interest. We include several variables to control for other factors that might interfere with our results. Our multinomial logistic model is :

$$UD_{ijl,t} = \alpha + \beta U_{ijk,t} + \phi x_{ijk,t} + \epsilon_{ijk,t} \tag{4.2}$$

The different uncertainty indices are included in U. The coefficients for the uncertainty indices are denoted with β, indicate the effect of uncertainty on the probability of price changes of products. Further, we have included the control variables represented with vector x.

4.1.1 Control variables

To analyse the control variables effect on producer prices, we first transform the data to the monthly level. Then we standardised the variables by subtracting the mean and dividing by the standard deviation. The variables we decide on are:

- Brent crude oil price. (The World Bank , 2021)
- Norges Bank's policy rate (Norges Bank, 2021b)
- The unemployment rate in Norway ((SSB, 2021)

We believe that the three control variables affect price-setting in Norway, and we assume that they might detect effects that otherwise would be unobserved. For instance, the Brent crude oil price impacts Norway's economic activity and the cost levels for Norwegian firms (Cappelen et al., 2014). Norges Bank's policy rate will affect loan cost and reflect Norges Bank's expectations of the Norwegian economic development (Bernhardsen, 2012; Norges Bank, 2018) . Lastly, the unemployment rate in Norway will affect producer prices in Norway through the classic economic relationship between low unemployment and high wages and vice versa (Goolsbee et al., 2016).

We include these controls because of their connection with the uncertainty measures. We want to include control variables that control for exogenous effects on price adjustments, not directly associated with an increase or decrease of uncertainty. For instance, in a recession, the Brent crude oil price might fall, the unemployment rate in Norway might rise, and Norges Bank might lower their policy rate (Cappelen et al., 2014). This will probably affect domestic pricing, and we want to isolate the effect of uncertainty. If we exclude the control variables, we would likely overestimate the uncertainty effect on price adjustments. Price adjustments are incredibly complex, and it is impossible to control for all the affecting factors. We do, however, believe that we control for some of the most important ones.

From figure 3.1 and figure 3.4, we find abnormal price setting activity in both January and February. Further we believe there to be clear seasonal trends over months, quarters and years. To control for seasonality, we have decided to include a both yearly and monthly dummy variables.

With our dataset, measuring the effect of uncertainty can be challenging due to the differences among the producers and their area of operations. The pricing dataset contains price information from several sectors, relying on various inputs and outputs in their day-to-day operations. These inputs and outputs might not respond equally to the same types of uncertainty, as their operations don't rely on the same factors. For that reason, it is essential to adjust for this in our empirical model and remove the unobserved differences within our price data set to fully see the effect of uncertainty without worrying about the differences within. To further control for product specific differences, we include dummy variables for product sections at the HS2 level, as well as clustering the standard errors at the product level.

4.1.2 Monthly price change with lags

With our data set, we expect given the relationship between producers price setting and our uncertainty measures, that there will be situations where the effect takes time to materialise.

To analyse this, we have chosen to use a distributed lag equation to utilise the dynamics of uncertainty's effect on the pricing behaviour among Norwegian producers. The multinomial logistic regression model for n lags is:

$$UD_{ijl,t} = \alpha + \beta U_{ijk,t-n} + \phi x_{ijk,t} + \epsilon_{ijk,t} \tag{4.3}$$

Intuitively there would be a lagged effect on uncertainty on price setting, as it takes time for companies to decide whether to change the price, given the delayed nature (price stickiness and price rigidity) of price decisions. It also involves extra cost, as discussed in the literature review regarding price setting.

4.1.3 Multicollinearity

We are concerned that some of our uncertainty measures detect the same uncertainty effects and create a multicollinearity problem when conducting our analysis. Multicollinearity can be a problematic factor when interpreting how the individual independent variables affect the dependent variable (Wooldridge, 2015). To examine the multicollinearity problem, we first investigate the correlation matrix in Table 3.8. From the correlation matrix we find that some of the uncertainty measures were highly correlated. Therefore, we decided to run a variance inflation factor test (VIF-test) , illustrated in Table 4.1.

Table 4.1: VIF-test

Variable	VIF
Norwegian Fear uncertainty	8.24
Global Economic Policy uncertainty	5.71
NOVIX	5.40
American Macroeconomic uncertainty	4.27
Norwegian Monetary Policy uncertainty	2.34
Norwegian Macroeconomic uncertainty	2.32
Norwegian Economic Policy uncertainty	2.03
Mean VIF	4.33

Note: This table presents the VIF-test.

Source: Estimations of authors.

The results from the VIF-test confirm that there might be multicollinearity issues. This could decrease our model's efficiency, as the literature standard is to consider a VIF-value over 5 as a cause for concern (Paul, 2006). We do not want to remove any of our uncertainty measures because they all represent different uncertainty types and because multicollinearity in itself is not a problem. However, if we do not control for multicollinearity, then we will fail to detect the true effect of the measures, we fear that the different uncertainty measures can “steal” efficiency from each other. This is a problem because multicollinearity will undermine the statistical significance of the uncertainty measures (Mansfield and Helms, 1982).

We decide on running regressions on the explanatory variables one by one instead of as one merged explanatory variable. We do this to reduce the problem of multicollinearity. Therefore, we will run seven regressions and calculate the probability of each uncertainty measure's effect on the probability of positive, negative, and no price adjustments.

5 Analysis

The results of the multinominal logistic model can be interpreted through the marginal effects regression tables. We chose to discard the coefficients for the multinomial logistic model, because the coefficients do not convey any meaningful information. We are more interested in the marginal effect. The three columns of the multinomial logistic regression table report the marginal effects of the specified uncertainty measures on the probability of a positive (1), a negative (-1) and no (0) price adjustment. The results from marginal effects can be interpreted in the following way: A one percentage point increase in an uncertainty measure lead to a increased or decreased probability of a price adjustment, ceteris paribus. The marginal effect regression tables display the statistical significance levels, marked at the 95%, the 99% and the 99.9%. For example, from Table 5.1, a one percentage increase in Global Economic Policy Uncertainty decreases the probability of a positive price adjustment by -0.008 percentage point, statistical significant at the 99.9% significance level.

Based on former studies, we expected some statistically significant correlation between the different uncertainty measures and the price fluctuations within Norwegian Production companies. However, from the literature review we know that price-setting and uncertainty follow different patterns. As said before, whereas price-setting behaviour seems to follow a seasonal trend, uncertainty shocks are, by definition, random.

5.1 Marginal effects of uncertainty on general prices, prices with frequent changes and prices with infrequent changes

Table 5.1: Marginal effects of uncertainty on prices

Marginal effects (dy/dx)			
Variable	Type of price adjustment		
	Positive adjustments	**Negative adjustments**	**No adjustments**
Economic Policy Uncertainty	-0.000	0.001	-0.000
	(0.002)	(0.002)	(0.002)
Global Economic Policy Uncertainty	-0.008***	0.008***	0.001
	(0.002)	(0.002)	(0.002)
Norwegian Stock Market Uncertainty	-0.008**	0.009***	-0.001
	(0.003)	(0.002)	(0.003)
Norwegian Macroeconomic Uncertainty	-0.001	0.002	-0.001
	(0.001)	(0.001)	(0.001)
Norwegian Monetary Policy Uncertainty	-0.002	0.004***	-0.002
	(0.001)	(0.001)	(0.001)
Norwegian Fear Uncertainty	-0.005**	0.005**	0.000
	(0.002)	(0.001)	(0.002)
American Macroeconomic Uncertainty	-0.002	0.000	0.002
	(0.002)	(0.002)	(0.003)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: We included the Economic Policy Uncertainty Index, the NOVIX, the Macroeconomic Index from Jurado et al. (2015), and the Fear, Monetary Policy and Macroeconomic uncertainty indices from Larsen (2017). The control variables are: The unemployment rate in Norway, Norges Bank's policy rate, the Brent oil price as well as monthly, yearly and product-section dummy variables. Robust standard errors in the parenthesis.

Source: Estimations of authors based on PPI data.

Table 5.2: Marginal effects of uncertainty on prices with frequent changes

Marginal effects (dy/dx)			
Variable	Type of price adjustments		
	Positive adjustments	**Negative adjustments**	**No adjustments**
Economic Policy Uncertainty	-0.001	0.002	-0.001
	(0.002)	(0.002)	(0.002)
Global Economic Policy Uncertainty	-0.011***	0.008***	0.003
	(0.003)	(0.002)	(0.002)
Norwegian Stock Market Uncertainty	-0.011***	0.010***	0.001
	(0.003)	(0.003)	(0.003)
Norwegian Macroeconomic Uncertainty	-0.001	0.002	-0.001
	(0.002)	(0.001)	(0.002)
Norwegian Monetary Policy Uncertainty	-0.005***	0.004**	0.001
	(0.001)	(0.001)	(0.001)
Norwegian Fear Uncertainty	-0.007***	0.005**	0.002
	(0.002)	(0.002)	(0.002)
American Macroeconomic Uncertainty	-0.001	0.001	0.000
	(0.003)	(0.002)	(0.003)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: We included the Economic Policy Uncertainty Index, the NOVIX, the Macroeconomic Index from Jurado et al. (2015), and the Fear, Monetary Policy and Macroeconomic uncertainty indices from Larsen (2017). The control variables are: The unemployment rate in Norway, Norges Bank's policy rate, the Brent oil price as well as monthly, yearly and product-section dummy variables. Robust standard errors in the parenthesis.

Source: Estimations of authors based on PPI data.

Table 5.3: Marginal effects of uncertainty on prices with infrequent changes

Marginal effects (dy/dx)			
Variable	Type of price adjustments		
	Positive adjustments	**Negative adjustments**	**No adjustments**
Economic Policy Uncertainty	0.003	-0.001	-0.002
	(0.002)	(0.001)	(0.002)
Global Economic Policy Uncertainty	0.002	0.001*	-0.003
	(0.002)	0.001)	(0.002)
Norwegian Stock Market Uncertainty	0.004**	0.001	-0.005*
	(0.002)	(0.001)	(0.002)
Norwegian Macroeconomic Uncertainty	0.001	0.001**	-0.002
	(0.001)	(0.000)	(0.001)
Norwegian Monetary Policy Uncertainty	0.004***	0.001***	-0.005**
	(0.002)	(0.001)	(0.002)
Norwegian Fear Uncertainty	0.003**	0.001*	-0.004*
	(0.001)	(0.000)	(0.002)
American Macroeconomic Uncertainty	-0.000	0.000	0.000
	(0.001)	(0.000)	(0.001)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: We included the Economic Policy Uncertainty Index, the NOVIX, the Macroeconomic Index from Jurado et al. (2015), and the Fear, Monetary Policy and Macroeconomic uncertainty indices from Larsen (2017). The control variables are: The unemployment rate in Norway, Norges Bank's policy rate, the Brent oil price as well as monthly, yearly and product-section dummy variables. Robust standard errors in the parenthesis.

Source: Estimations of authors based on PPI data.

5.1.1 Analysis

Table 5.1 presents the marginal effects of uncertainty on general price adjustments, Table 5.2 presents the marginal effects of uncertainty on prices with frequent price changes, and Table 5.3 presents the marginal effects of uncertainty and on prices with infrequent price adjustments. We have decided to analyse these measures together because they exhibit similarities in the uncertainty measures that are statistically significant. Throughout the analysis, the same four uncertainty measures tend to have a statistically significant effect (Global Economic Policy Uncertainty, Norwegian Stock Market Uncertainty and Norwegian Fear Uncertainty). This might be because these measures are all related to international events and, NOVIX especially, with stock market volatility, there might be a direct linkage to costs.

Positive price adjustments

Starting with the effect of uncertainty on the probability of positive price adjustments, we find some statistically significant results. We reject that Global EPU, Norwegian Stock Market Uncertainty and Norwegian Fear Uncertainty do not affect positive price adjustments for general prices and prices with frequent changes. For prices with frequent changes we can also reject that Norwegian Monetary Policy does not affect positive price adjustments. There are no statistically significant results for the rest of the uncertainty measures, meaning that we cannot reject that EPU and Norwegian and American Macroeconomic Uncertainty do not affect positive price adjustments at the 95% significance level. The results can be interpreted as a rise in the specific explanatory variable, leading to a lower probability of positive price adjustments. The similarities convey that the driving forces of uncertainty for price adjustments for frequent changes are similar to the general price changes.

These results differ from the effect of uncertainty for the probability of positive price adjustments for prices with infrequent changes. Here, we can reject that the Norwegian Stock Market Uncertainty, Norwegian Monetary Policy and Fear Uncertainty do not affect the probability of positive price adjustments for products with infrequent changes at the 95% significance level. All the marginal effects have positive values, which can be interpreted as a rise in uncertainty, which leads to a higher probability of positive price adjustments. For Norwegian and Global Economic Uncertainty and Norwegian and American Macroeconomic Uncertainty, we fail to reject that they do not affect the probability of positive price adjustments at the 95% significance level.

Negative price adjustments

For the probability of negative price adjustments for infrequent, frequent, and general price changes, the same four uncertainty measures have a statistically significant effect. We now see that Norwegian Monetary Policy Uncertainty also exhibits statistically significant marginal effects of uncertainty on general prices and prices with infrequent changes. The Marginal effects have a positive value. These results can be interpreted as follows; an increase in the above-mentioned uncertainty measures will increase the probability of negative price adjustments. There are no statistically significant results for the rest of the uncertainty measures.

No price adjustments

For the probability of zero price adjustment, there are only statistically significant effects for prices with infrequent changes. Meaning that, for frequent and general price changes, we cannot reject that any of the uncertainty measures do not affect zero price adjustments at the 95% significance level. For prices with infrequent changes, we can reject that the Norwegian Stock Market Uncertainty and Norwegian Monetary Policy at the 95% level, and Norwegian Fear Uncertainty at the 99% level do not affect the probability of a zero price adjustments.

5.2 Marginal effects of lagged uncertainty on price adjustments

Table 5.4: Marginal effects of lagged uncertainty on prices

Marginal Effects				
	0 Lags	1 Lag	3 Lags	12 Lags
Positive price adjustments				
Economic Policy Uncertainty	-0.000	0.000	0.002	-0.003*
	(0.002)	(0.002)	(0.004)	(0.003)
Global Economic Policy Uncertainty	-0.008**	-0.009**	-0.005	-0.004*
	(0.001)	(0.002)	(0.002)	(0.002)
Norwegian Stock Market Uncertainty	-0.008**	-0.006	-0.008	-0.006***
	(0.003)	(0.003)	(0.003)	(0.002)
Norwegian Macroeconomic Uncertainty	-0.001	-0.006***	-0.005**	-0.002
	(0.001)	(0.002)	(0.002)	(0.002)
Norwegian Monetary Policy Uncertainty	-0.002	-0.003*	-0.001	- 0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Norwegian Fear Uncertainty	-0.005**	-0.005**	-0.003	-0.003**
	(0.001)	(0.002)	(0.002)	(0.001))
American macroeconomic Uncertainty	-0.002	-0.004	-0.007**	-0.003**
	(0.002)	(0.002)	(0.003)	(0.002)
No price adjustments				
Economic Policy Uncertainty	-0.001	-0.002	-0.008***	0.012***
	(0.002)	(0.002)	(0.002)	(0.003)
Global Economic Policy Uncertainty	0.000	-0.001	-0.002	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)
Norwegian Stock Market Uncertainty	-0.001	-0.004	0.001	0.012***
	(0.003)	(0.002)	(0.003)	(0.002)
Norwegian Macroeconomic Uncertainty	-0.001	0.002	0.000	0.005***
	(0.002)	(0.001)	(0.002)	(0.002)
Norwegian Monetary Policy Uncertainty	-0.002	-0.001	-0.003**	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)
Norwegian Fear Uncertainty	-0.000	-0.001	-0.003	0.008***
	(0.002)	(0.001)	(0.002)	(0.002))
American macroeconomic Uncertainty	0.002	0.001	0.004	0.012***
	(0.003)	(0.003)	(0.003)	(0.003)
Negative price adjustments				
Economic Policy Uncertainty	0.001	0.002	0.006***	-0.009***
	(0.002)	(0.002)	(0.003)	(0.002)
Global Economic Policy Uncertainty	0.008**	0.010***	0.007***	-0.004*
	(0.003)	(0.002)	(0.002)	(0.002)
Norwegian Stock Market Uncertainty	0.009***	0.010***	0.007**	-0.006***
	(0.002)	(0.002)	(0.002)	(0.002)
Norwegian Macroeconomic Uncertainty	0.002	0.004**	0.005**	-0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
Norwegian Monetary Policy Uncertainty	0.004***	0.004***	0.004***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Norwegian Fear Uncertainty	0.005***	0.006***	0.006***	-0.005***
	(0.001)	(0.001)	(0.001)	(0.001)
American Macroeconomic Uncertainty	0.001	0.002	0.003	-0.009
	(0.002)	(0.002)	(0.002)	(0.001)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Wee included the Economic Policy Uncertainty Index, the NOVIX, the Macroeconomic Index from Jurado et al. (2015), and the Fear, Monetary Policy and Macroeconomic uncertainty indices from Larsen (2017). The control variables are: The unemployment rate in Norway, Norges Bank's policy rate, the Brent oil price as well as monthly, yearly and product-section dummy variables. Robust standard errors in the parenthesis.

Source: Estimations of authors based on PPI data.

5.2.1 Analysis

From tables 5.4 presents the marginal effects of the lagged uncertainty measures on the probability of price adjustments. As discussed in the literature review, prices often behave "sticky", meaning that they are reluctant to change. The presence of price stickiness and price rigidity makes it necessary to include lags in our explanatory variables.

Positive price adjustments

For the effect of uncertainty with zero months lag on the probability of positive and negative price adjustments, the results are the same as in Table 5.1. We include the zero-lag row in this analysis for comparison reasons. We want to see how the lagged uncertainty measures affect prices over time, and we find zero as a natural starting point. We will start this analysis with the lagged effect on positive price adjustments.

For the one month lagged effect of uncertainty on the probability for positive price adjustments, we can reject that Global EPU, Norwegian fear Uncertainty and Norwegian Stock Market Uncertainty have an statistically insignificant effect on the probability of positive price adjustments in one month at respectively the 99%, the 99.9% significance level. We notice the marginal effects are almost the same with one lag compared to zero lags, as the drivers of the one month uncertainty marginal effect on price adjustments are the same as for the zero month effect. We believe that these results explain that the lagged effect of uncertainty has not further influenced the pricing decisions relative to the starting point.

At three lags, we find that Norwegian and American Macroeconomic uncertainty are statistically significant at the 99% significance level. With an increased Norwegian and American Macroeconomic Uncertainty, the probability of positive price adjustments decreases in three months. We cannot reject that the Norwegian or Global EPU, Norwegian

Stock Market Uncertainty, Norwegian monetary policy Uncertainty and Norwegian Fear Uncertainty do not affect positive prices at three lags at the 95%, significance level. We see that the effect of uncertainty on positive price adjustment is diminishing, with fewer of the uncertainty measures having a statistically significant effect. We do, however, not believe that the effect that we see is different from zero and one month lags.

At twelve months lag, almost all the uncertainty measures are statistically significant, and all the marginal effects are negative. The interpretation is that an increase in the uncertainty measures will decrease the probability of positive price adjustments in twelve months. We cannot reject that the Norwegian Macroeconomic Uncertainty does not affect positive prices at twelve lags at the 95%, significance level.

Negative price adjustments

For the effect of uncertainty with one month lag on the probability of negative price adjustments, we can reject that Global Economic Policy Uncertainty, Norwegian Stock Market Uncertainty, Norwegian Macroeconomic Uncertainty, Norwegian Monetary Policy Uncertainty, and Norwegian Fear Uncertainty has an statistically insignificant effect on the probability of negative price adjustments in one month at the 99.9% significance level. An increase in the above mentioned uncertainty measures contributes to a higher probability of negative price adjustments in one month. We cannot reject that the other uncertainty measures do not affect negative prices at one lag at the 95% significance level.

While only two of the uncertainty measures were statistically significant for positive price adjustment at the three-month lag, almost all the uncertainty measures are statistically significant for the probability of negative price adjustments. As we saw in Figure 3.3, negative price changes are less influenced by seasonality, making them more exposed to uncertainty. We see that uncertainty's three months lagged effect on prices follows the same pattern as the zero and one month effect. We do not believe that the underlying explanations for price adjustments have changed. However, the fact that almost all the measures are statistically significant implies that the effect of uncertainty on negative price adjustments is more prevalent over time. We cannot reject that American Macroeconomic Uncertainty do not affect negative prices at three lags at the 95% significance level.

At twelve months lag, we can reject that almost any of the uncertainty measures have an statistically insignificant effect on the probability of negative price adjustments at the 99.9% significance level. We notice that for the 12-month lag, both the probability for positive and negative price adjustments fall with an increase in uncertainty. We cannot reject that the other uncertainty measures do not affect negative prices at twelve lags at the 95% significance level.

No price adjustments

Several factors can explain the observed statistical significance in the 12-months lag for no price change, but we will discuss the two we deem most important. First, from figures 3.5 and A2.3, we see that the median number of price changes per year for all the HS4 product sections is 0. So that would suggest that most products do not change the price at all during a 12-month interval. The second is more linked to uncertainty and pricing theory, mainly the “wait and see”-approach, and as Zbaracki et al. (2004) found, many companies tend to adjust their prices as a response to competitors adjustments. Putting these together, we have a theory of why the statistical significance seem to strengthen. When there are so many products with no price adjustments, the regression might pick up the lack of movement as a pattern, and thereby declaring statistical significance.

5.3 Discussion of results

Price-setting theory is ambiguous and there are a lot of different theories developed to explain the fluctuations we observe. We know that price rigidity and price stickiness complicate pricing decisions and that the most influential impact on price is cost (Blinder et al., 1998).

Short term uncertainty appears to have an effect on negative price adjustments in several of the explanatory variables in our regression. We see a lower probability of increasing prices and a higher likelihood of negative price changes. As Bloom (2014) mentions in his paper, uncertainty seems to damage short-run growth. There have not yet been provided conclusive evidence of this, but there is evidence of uncertainty reducing output, investment, hiring, consumption, and trade.

Increased uncertainty leads to a lower probability of positive price adjustments, which can be explained through the risk aversion channel of uncertainty. An increase of uncertainty can raise precautionary savings for consumers, lowering consumption and decreasing growth. With reduced growth comes fewer incentives to raise prices (Bloom, 2014).

Increased uncertainty leads to a higher probability of negative price, which can be explained with the real options channel of uncertainty influencing growth. In the real options theory, higher uncertainty will increase the option to wait for consumers and producers. This will decrease demand. Following classical economic theory, to raise demand, the producers have to lower their prices (Goolsbee et al., 2016).

We find evidence of both higher savings (lower demand) and lower investments (option value becomes higher) when looking at figures 1.2a and 1.2b . We see there that business investments in Norway fell during the Covid-19 crisis and that precautionary savings increased during the global financial crisis, during the uncertainty in the mid-2010s and the Covid-19 crisis. Following these findings, risk aversion and real options seem to be present during the uncertainty-induced period in Norway, making our explanations credible.

For prices with infrequent changes, we see that uncertainty increases both the probability of negative and positive price adjustments. Risk aversion and the real options channel of uncertainty influencing growth can again be the explanation uncertainty increases the probability of negative price adjustments. We find this explanation unlikely, as we would not expect uncertainty to also increase the probability of positive price changes if this explanation was correct. Further, we assume that the producers of products with frequent price changes can continuously adjust prices to meet lower or higher demand. In comparison, products with infrequent price changes tend to adjust prices less than once a year, with the main driving force being renegotiation of contracts (Alvarez et al., 2006).

The reason for uncertainty causing a higher probability of positive price adjustments can be explained by the growth options and the Oi-Hartman-Abel Effects channels of uncertainty influencing growth. From the growth options theory, if firms can control for bad outcomes, uncertainty can increase positive outcomes. This can increase investments and growth (Bar-Ilan and Strange, 1996). From the Oi-Hartman-Abel Effects, an increase in uncertainty can increase the size of the potential outcome (Bloom, 2014). It might be that products with infrequent price changes consist of, for example, research and development-intensive firms. If this were the case, then we would not expect uncertainty to increase the probability of negative price changes. Therefore, we find this explanation unlikely.

A more probable reason for uncertainty causing a higher probability of price adjustment for prices with infrequent can be explained by the menu cost theory. Following the menu cost theory, some companies rarely change prices, but when they do they tend to change prices on several products at once (Alvarez et al., 2006). Heightened uncertainty will probably create an incentive to adjust prices, and thus being an important factor for both positive and negative price adjustments. The price adjustment and uncertainty relationship can also be explained through the Calvo model. As previously discussed in the literature review, Calvo introduced a model that showed how firms change price after receiving a random signal (Shock) (Calvo, 1983). We see some evidence that these random signals could result from known uncertainty shocks, leading to a price adjustment.

Another reason that the same source of uncertainty can be a catalyst for both positive and negative price adjustments can be explained with mark up pricing. As we saw from Nick Bloom's work earlier, the effect of uncertainty might adjust prices both ways depending on companies operating market. Some producers might reduce prices to make up for a decreasing demand. At the same time, others are forced to increase prices as critical production material gets more expensive as uncertainty rises (Bloom, 2014).

When we compare our results to the formerly mentioned works by Canales et al. (2021) and Bachmann et al. (2019), we see that they alter slightly. The Canales study investigates the effect on a developing country, thought to be more sensitive towards global uncertainty and with less anchored financial institutions (Canales et al., 2021). Bachmann et al. (2019) present result similar to ours, they find that some price adjustments can be explained by what they call idiosyncratic business volatility. They also find that the absolute price changes are mainly driven by price decreases. As they use data from Germany, it makes sense that the effect of uncertainty would produce similar consequences as in Norway.

6 Conclusion

Several uncertainty shocks have hit the economy throughout the last decade. The European debt crisis, the 2010s oil glut and Brexit all caused severe uncertainty in the global landscape. The latest uncertainty shock came as a result of the Covid-19 pandemic. In the wake of the pandemic, consumption, investments, employment and exports have all declined, while the uncertainty measures have gone through the roof (Baker et al., 2020). Since the global financial crisis in 2008 researchers have extensively analysed the effect of uncertainty, and there is evidence that the economic decline in recessions has been worsened by uncertainty (Bloom, 2014; Bloom et al., 2018).

With the knowledge that uncertainty affects key economic metrics, we wanted to investigate if uncertainty affects price-setting adjustments for production companies. The relationship between uncertainty and price-setting is unexplored and in thesis we wanted to help close the gap. Armed with a dataset containing micro-data on the Norwegian PPI during a period of several uncertainty shocks, we aimed to investigate if uncertainty had a causal impact on the price-setting behaviour among Norwegian Production companies. We address this through the following research question:

Are there evidence of uncertainty influencing producer prices in Norway?

To answer the research question, we first started looking at the price data. We analyse how price adjustments develop. We find signs of trends based on seasonality, differences in positive and negative prices, and differences in prices with frequent and infrequent price changes.

We created and analysed different uncertainty measures, and compared them to the pricing data. Our research quickly revealed the differences between the patterns of uncertainty and price fluctuations. The uncertainty indexes we constructed illustrated something obvious, uncertainty shocks don't follow a specific pattern. We wanted to analyse if the uncertainty shocks can be a explanatory factor affecting the frequency of price changes.

We investigated the relationship between price change frequency and uncertainty by using a multinomial logisitc model. We controlled for the Brent crude oil price, Norges Bank's policy rate and the unemployment rate in Norway, due to these being exogenous factors affecting prices directly or indirectly.

The result from the analysis is a statistically significant effect of uncertainty on the probability of price changes. Our findings indicate that uncertainty and prices are counter-cyclical. An increase in uncertainty will increase the probability of a negative price change and decrease the probability of a positive price change. We also found evidence of this effect increasing over time. We explain this with risk aversion and an increased value for the option to wait. For products with infrequent price changes the picture differs. We found that uncertainty can be a catalyst for both positive and negative price adjustments. We explained this with menu cost and the Calvo model. Our results coincide with the existing literature. Uncertainty leads to a decline in key macroeconomic variables, and our findings suggest that this also applies to price adjustments of producer prices. Our results are important, because they show a clear relationship between uncertainty and price-setting for producer prices. This is important when including transmission effects of uncertainty in macroeconomic models.

The PPI dataset consists of pricing information from a broad spectrum of Norwegian Production companies, distributed over several different sectors. For further research, we think it could be interesting to sort this dataset by sectors and investigate how and if uncertainty impact the differences between them. That could give valuable insight into how different sectors are affected by uncertainty and are especially important in the times we live in now. For example, this potential insight could assist official institutions when they are allocating emergency funding as a result of the Covid-19 recession.

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Appendix

A1 Data

Table A1.1: HS sections

Section. #	Section name
1	Live animals; animal product
2	Vegetable products
3	Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes
4	Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactured tobacco substitutes
5	Mineral products
6	Products of the chemical or allied industries
7	Plastics and articles thereof; rubber and articles thereof
8	Raw hides and skins, leather, fur, skins and articles thereof; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silk-worm gut)
9	Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basket ware and wickerwork
10	Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard; paper and paperboard and articles thereof
11	Textiles and textile articles
12	Footwear, headgear, umbrellas, sun umbrellas, walking-sticks, seat-sticks, whips, riding-crops and parts thereof; prepared feathers and articles made therewith; artificial flowers; articles of human hair
13	Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware
14	Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal, and articles thereof; imitation jewellery; coin
15	Base metals and articles of base metal
16	Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers; television image and sound recorders and reproducers, and parts and accessories of such articles
17	Vehicles, aircraft, vessels and associated transport equipment
18	Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof
19	Arms and ammunition; parts and accessories thereof
20	Miscellaneous manufactured articles
21	Works of art, collectors' pieces and antiques

Note: This table presents the different product sections in the dataset.

Table A1.2: Descriptive statistics over HS sections

Section	Number of firms	Number of products	Share of dataset	Frequency Mean	Frequency Median
1	14.70	58.98	4.08%	41.18	29.41
2	3.99	16.97	1.17%	20.30	10.53
3	2.37	7.53	0.52%	32.99	11.89
4	41.88	243.66	16.84%	34.50	16.08
5	9.24	23.26	1.61%	26.86	10.17
6	33.10	133.00	9.19%	25.34	7.63
7	23.36	83.14	5.74%	28.19	8.39
8	2.51	11.84	0.82%	6.38	3.50
9	35.18	126.52	8.74%	34.61	15.79
10	14.68	45.48	3.14%	29.20	12.90
11	17.06	67.11	4.64%	12.15	6.29
12	1.88	4.60	0.13%	2.30	0.00
13	22.15	89.24	6.17%	21.97	8.42
14	4.33	12.33	0.85%	15.50	8.39
15	41.42	155.58	10.75%	22.57	7.37
16	54.74	219.31	15.15%	12.21	6.99
17	5.63	29.15	2.01%	11.51	10.87
18	7.00	34.56	2.39%	17.23	6.29
20	22.63	87.58	6.05%	24.65	9.09

Note: This table presents the descriptive statistics for the different HS sections .

Table A1.3: Descriptive statistics over price adjustment measures

	Obs	Mean	Std.Det
Zero price changes	154 143	0	0
Positive price changes	30 343	1	0
Negative price changes	20 278	-1	0
Zero price changes for frequent prices	94 173	0	0
Positive price changes for frequent prices	27 415	1	0
Negative price changes for frequent prices	19 613	-1	0
Zero price change for infrequent prices	59 970	0	0
Positive price changes for infrequent prices	2 928	1	0
Negative price changes for infrequent prices	665	-1	0
Price data	204 764	0.0492	0.4948

Note: This table presents the descriptive statistics for the different price adjustment measures

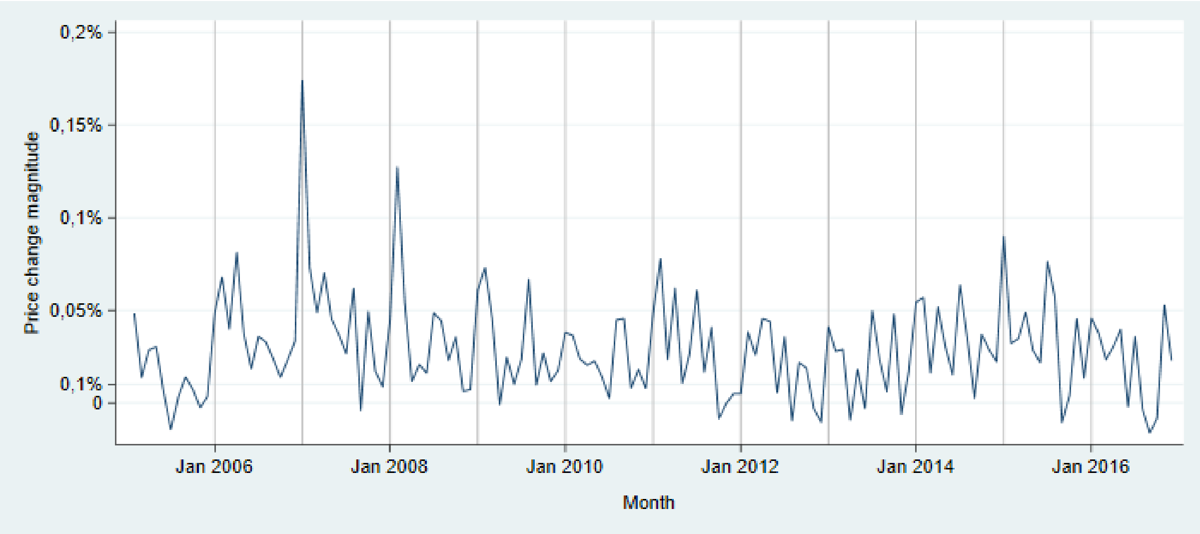
Table A1.4: Descriptive statistics over uncertainty measures

Uncertanty Measure	Mean	Std.Dev	Min	Max
EPU	-0.062	0.985	-1.464	2.653
Global EPU	-0.073	1.000	-1.612	2.458
NOVIX	0.008	1.009	-1.261	4.371
Norwegian Macroeconomic uncertainty	-0.037	1.008	-1.881	2.770
Norwegian Monetary Policy uncertainty	0.012	1.009	-1.864	3.507
Norwegian Fear uncertainty	-0.029	1.009	-1.219	4.038
American Macroeconomic uncertainty	0.030	1.009	-1.136	3.715

Note: This table presents the descriptive statistics for the different uncertainty measures

A2 Graphs

Figure A2.1: Monthly price change

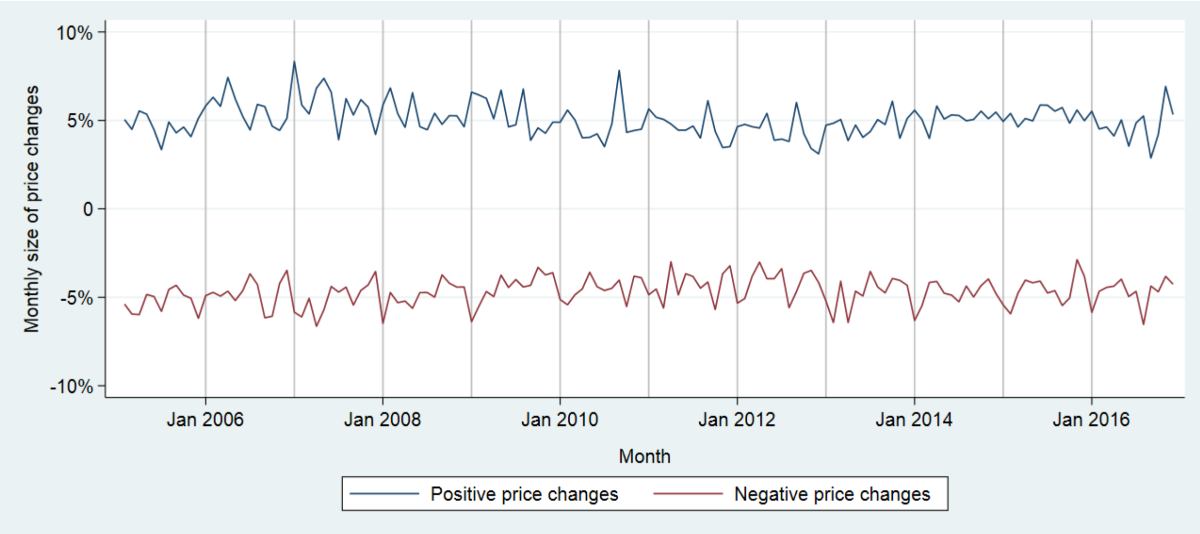


Note: This figure illustrate how the average monthly price change for products develops over time. With equation:

$$\Upsilon_{ijk} = \frac{P_{ijk,t} - P_{ijk,t-1}}{P_{ijk,t-1}} \tag{.1}$$

Source: Estimations of authors

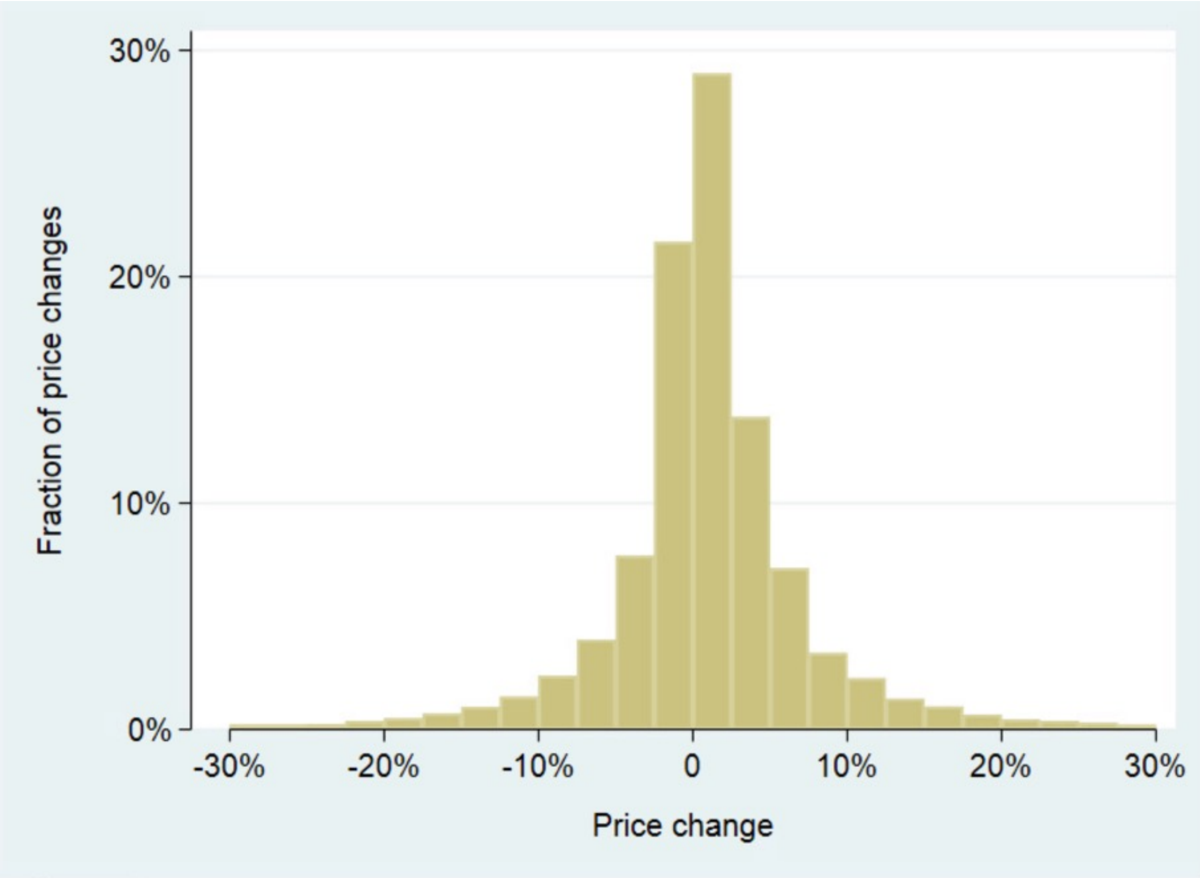
Figure A2.2: Monthly size of price changes



Note: We utilise the $UD_{ijk,t}$ variable and find the average percentage monthly price adjustment for products with positive changes and the average percentage monthly price adjustment for products with negative changes.

Source: Estimations of authors

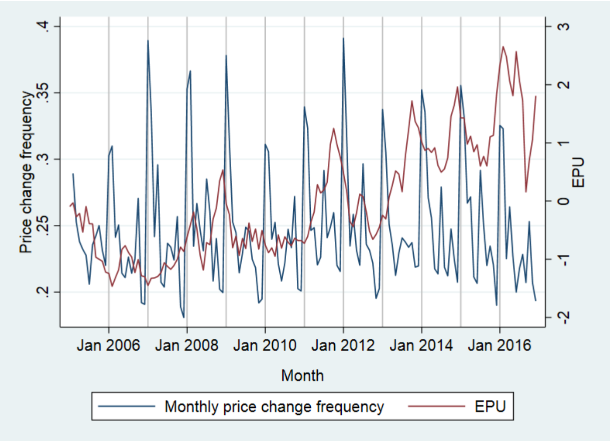
Figure A2.3: Fraction of price changes



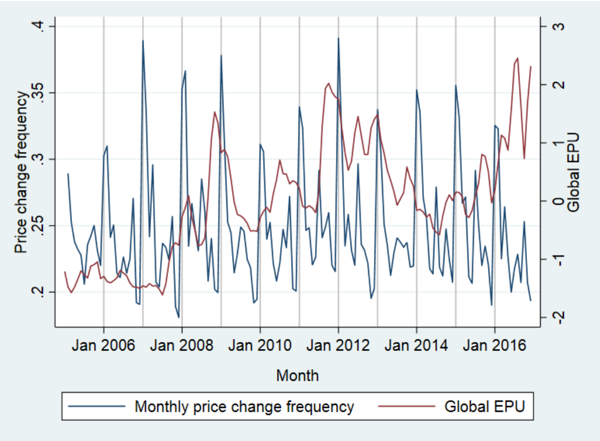
Note: The fraction of price changes

Figure A2.4: Price change frequency and uncertainty measures

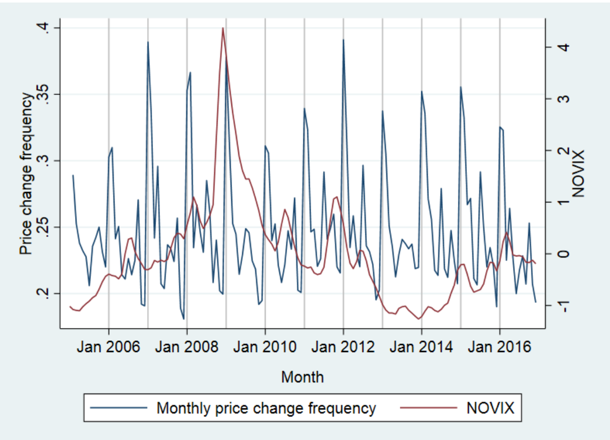
(a) EPU



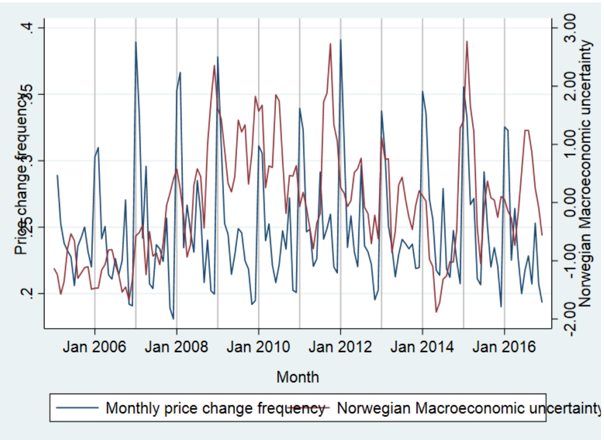
(b) GEPU



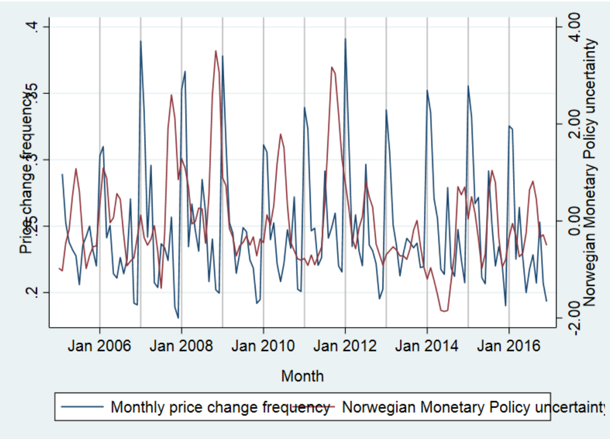
(c) NOVIX



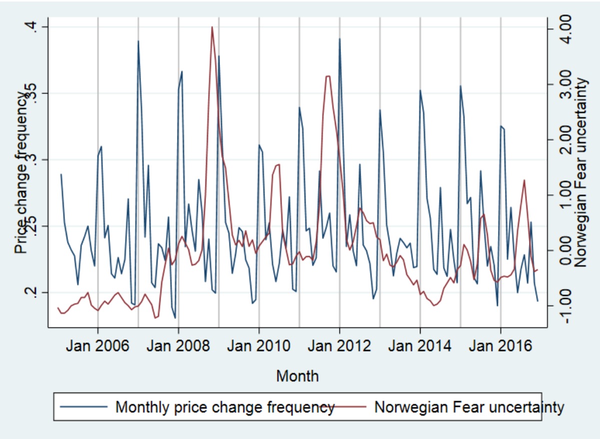
(d) Norwegian Macroeconomic uncertainty



(e) Norwegian MP uncertainty



(f) Norwegian Fear uncertainty



(g) American Macroeconomic uncertainty

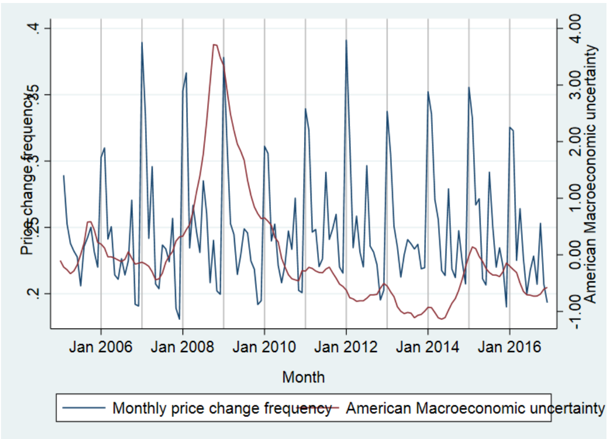
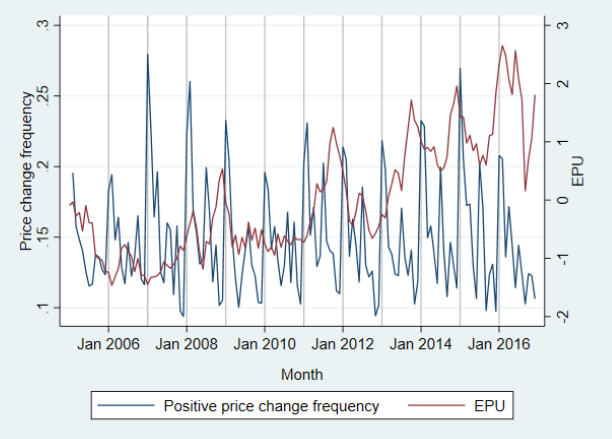
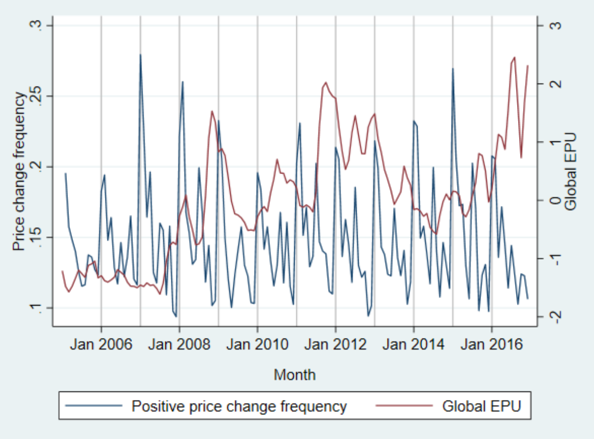


Figure A2.5: Price change frequency for positive price changes and uncertainty measures

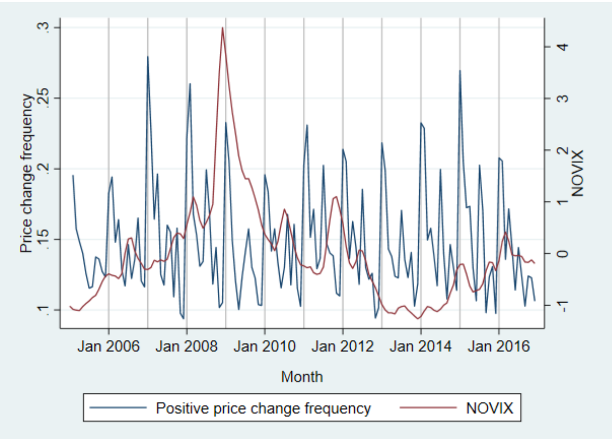
(a) EPU



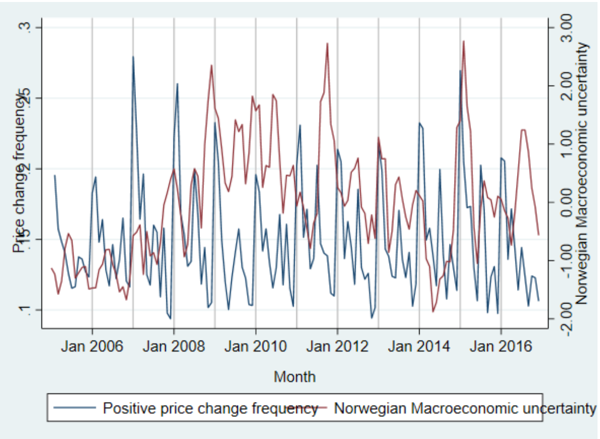
(b) GEPU



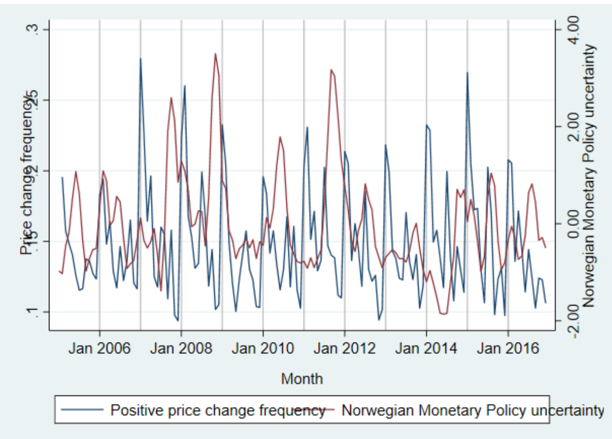
(c) NOVIX



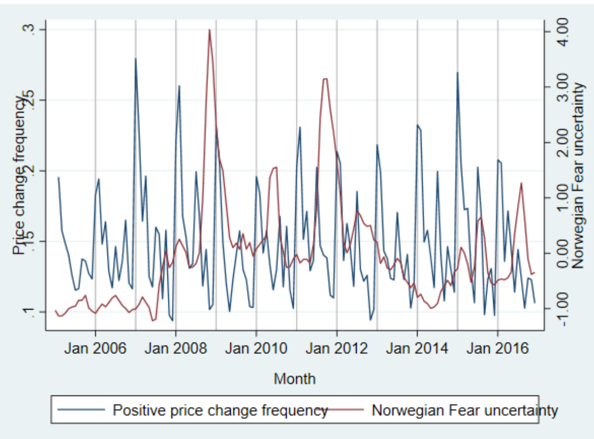
(d) Norwegian Macroeconomic uncertainty



(e) Norwegian MP uncertainty



(f) Norwegian Fear uncertainty



(g) American Macroeconomic uncertainty

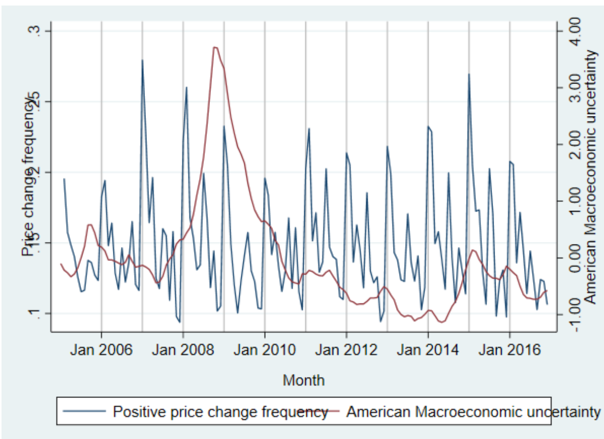
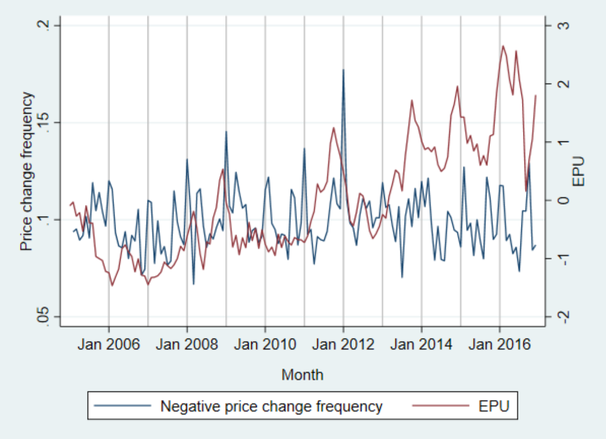
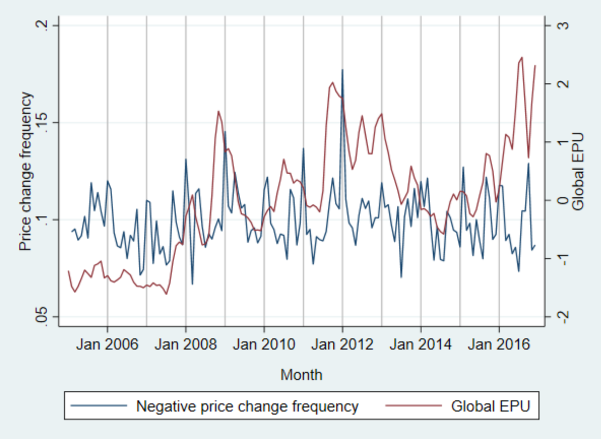


Figure A2.6: Price change frequency for negative price change and uncertainty measures

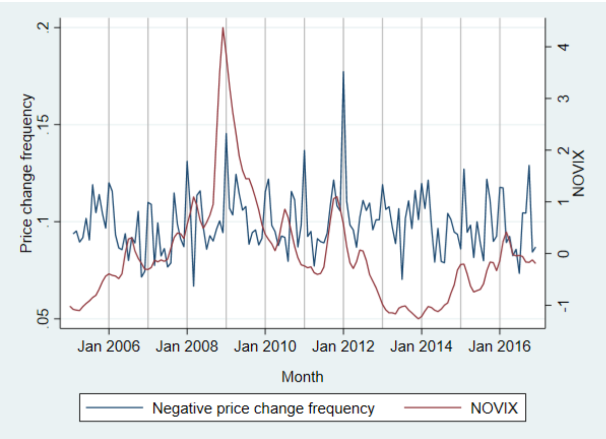
(a) EPU



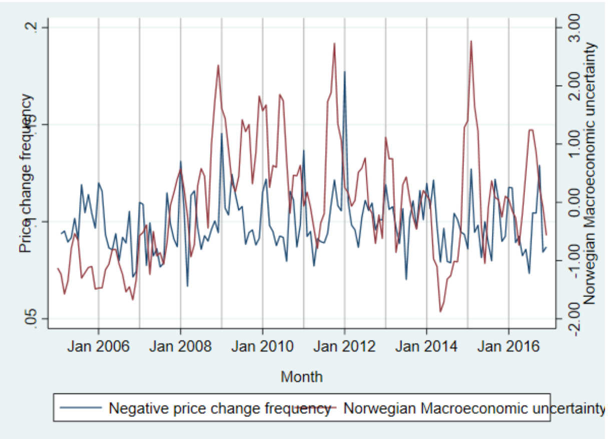
(b) GEPU



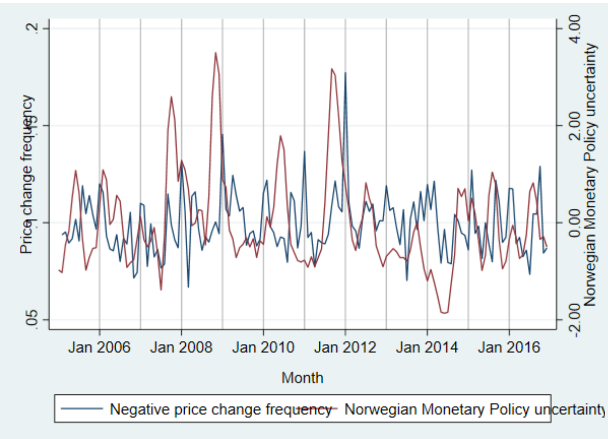
(c) NOVIX



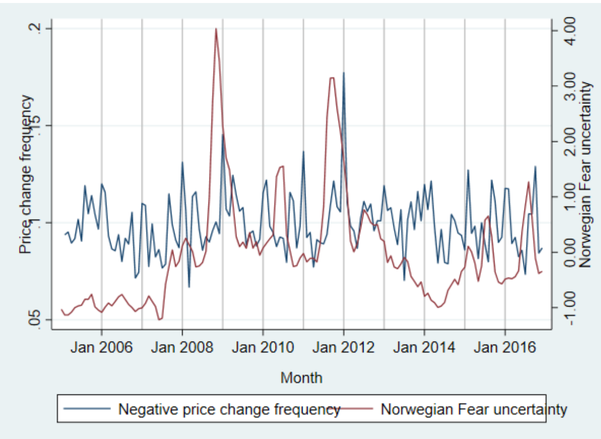
(d) Norwegian Macroeconomic uncertainty



(e) Norwegian MP uncertainty



(f) Norwegian Fear uncertainty



(g) American Macroeconomic uncertainty

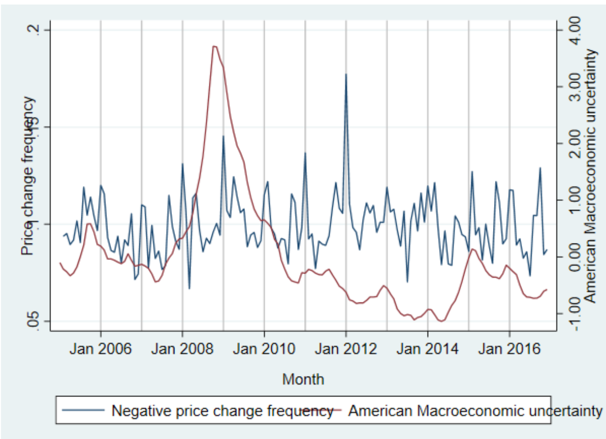
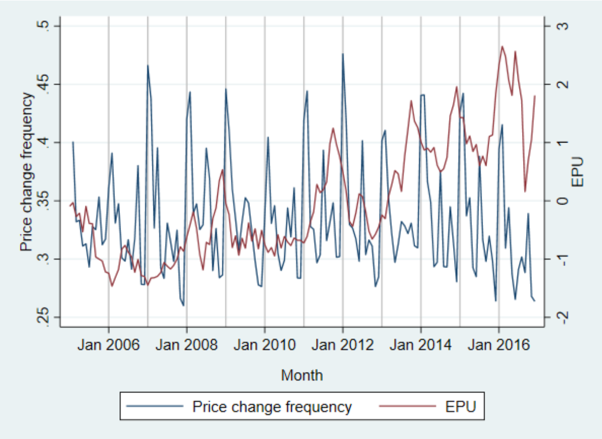
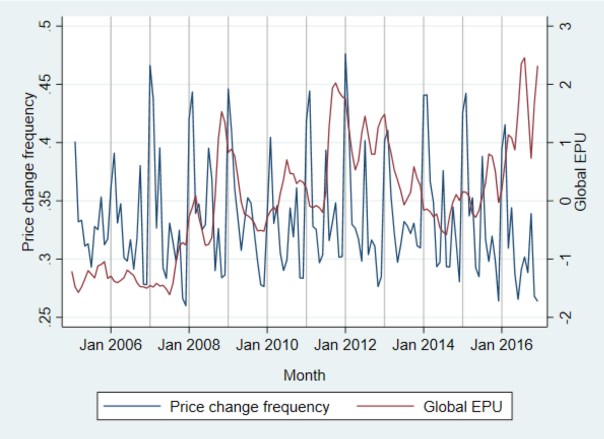


Figure A2.7: Price change frequency for with frequent price changes and uncertainty measures

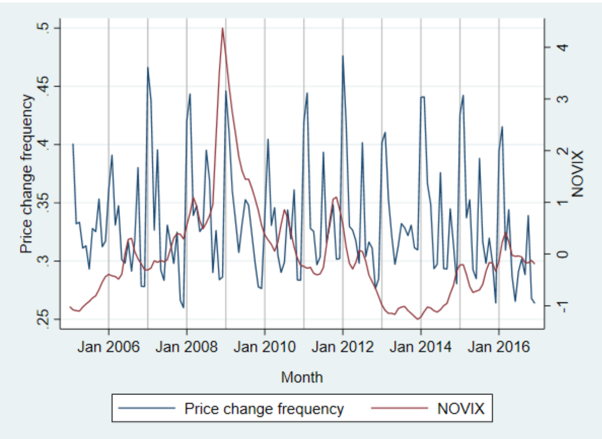
(a) EPU



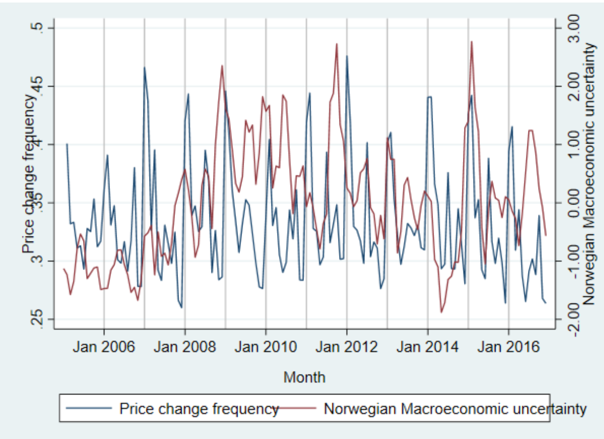
(b) GEPU



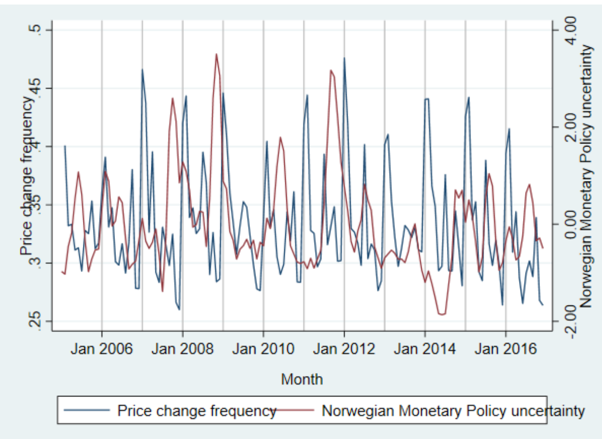
(c) NOVIX



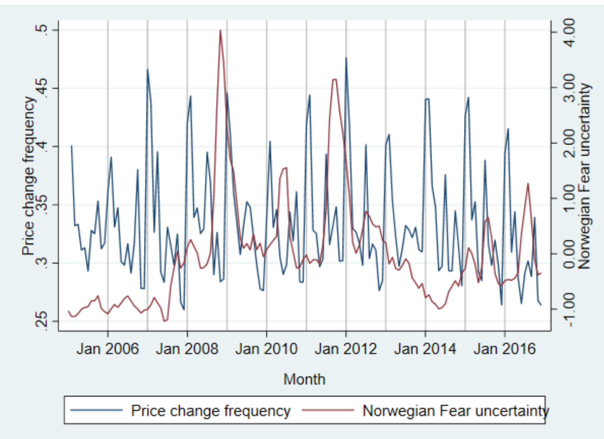
(d) Norwegian Macroeconomic uncertainty



(e) Norwegian MP uncertainty



(f) Norwegian Fear uncertainty



(g) American Macroeconomic uncertainty

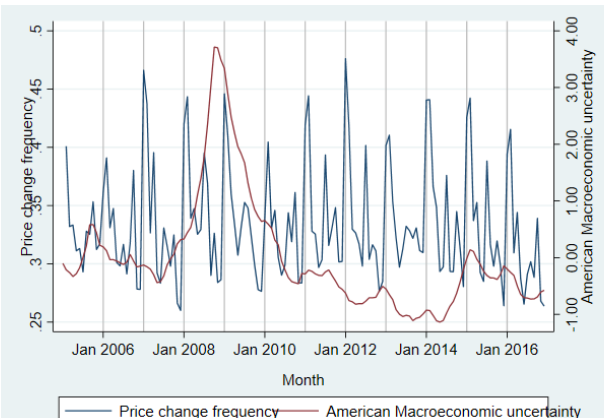
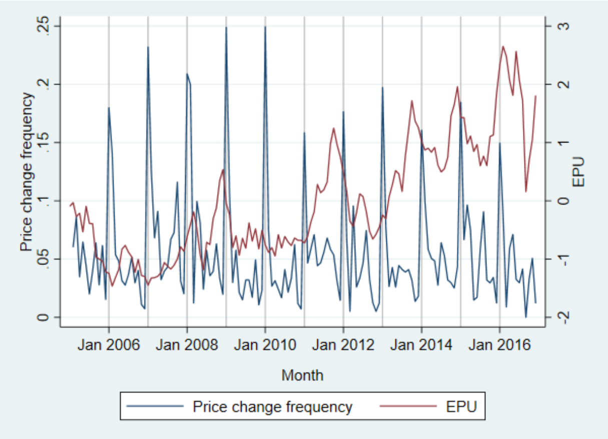
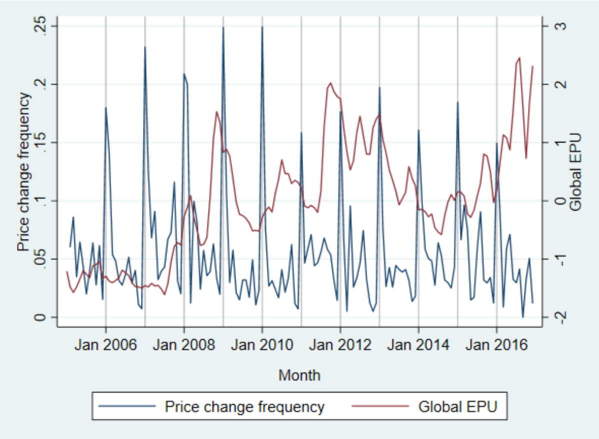


Figure A2.8: Price change frequency for with infrequent price changes and uncertainty measures

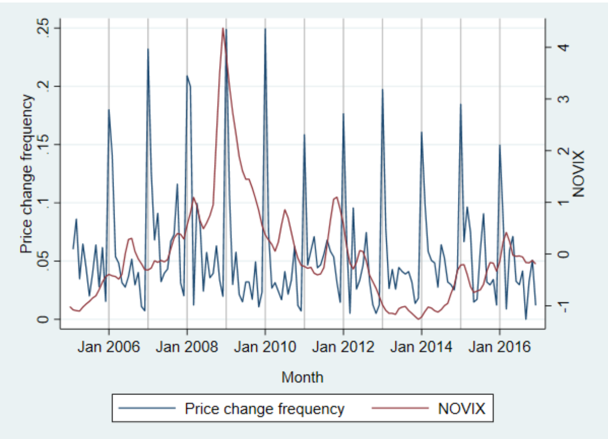
(a) EPU



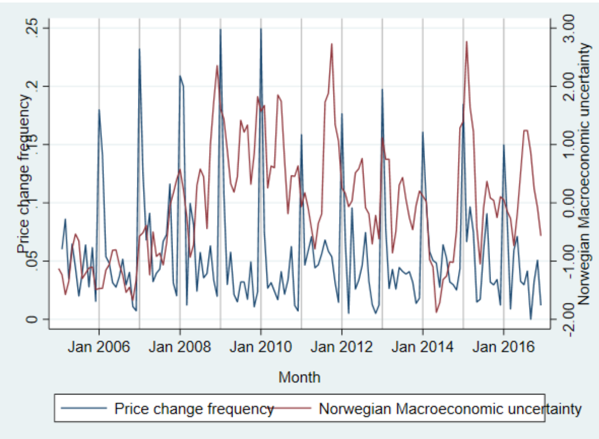
(b) GEPU



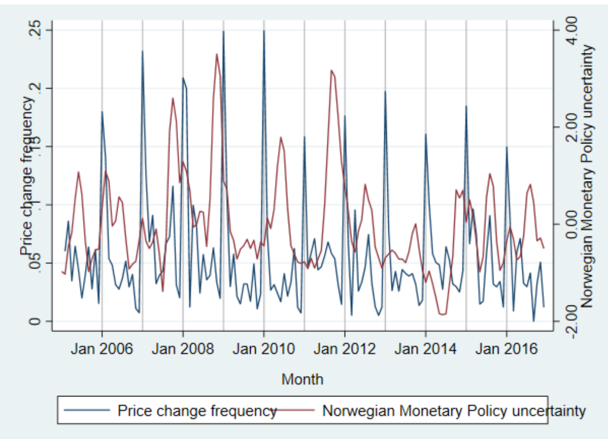
(c) NOVIX



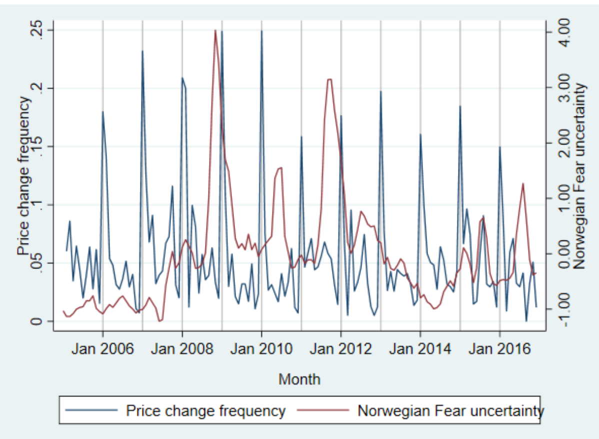
(d) Norwegian Macroeconomic uncertainty



(e) Norwegian MP uncertainty



(f) Norwegian Fear uncertainty



(g) American Macroeconomic uncertainty

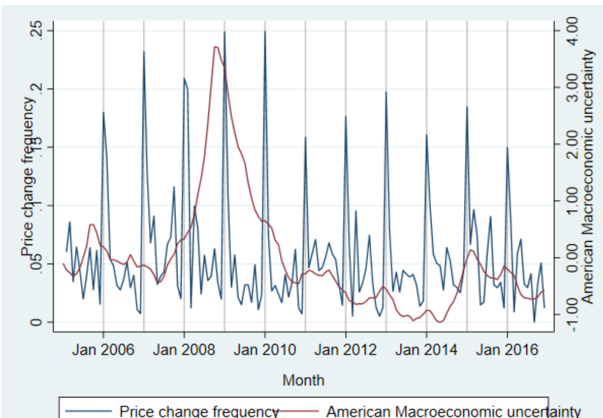
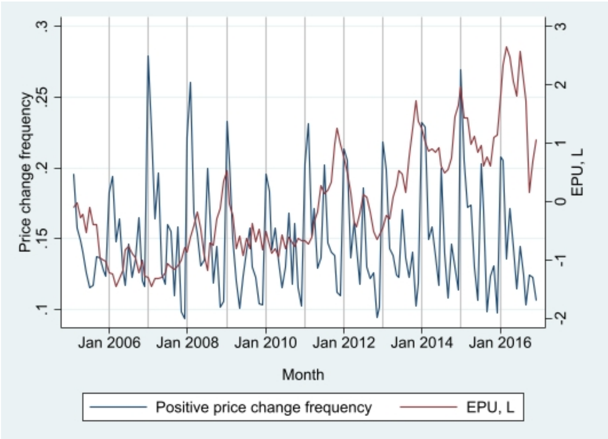
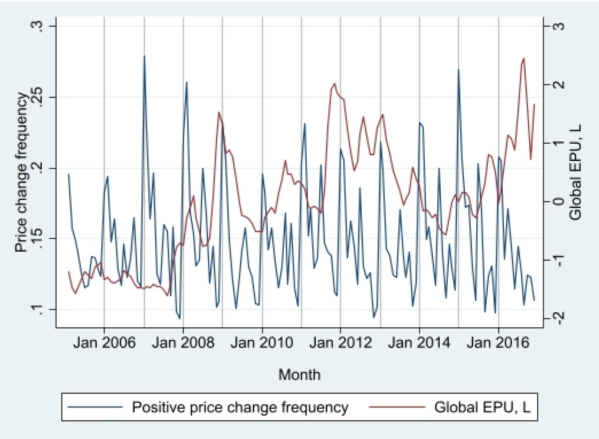


Figure A2.9: Price change frequency for with 1 month lagged positive price changes and uncertainty measures

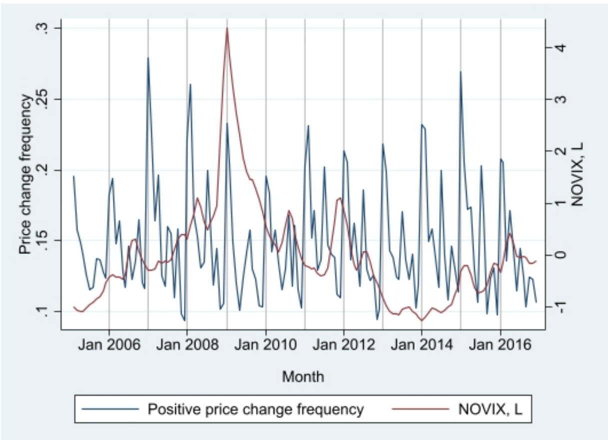
(a) EPU



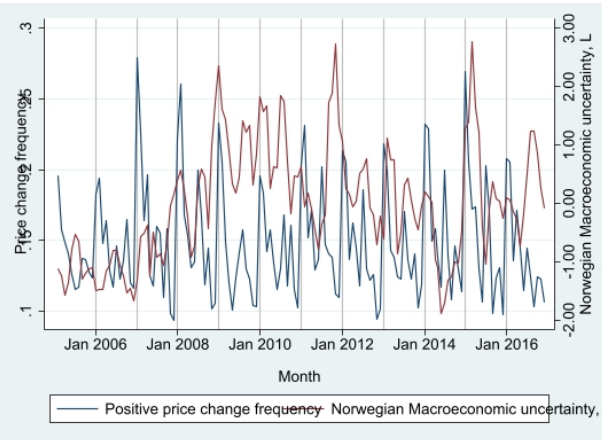
(b) GEPU



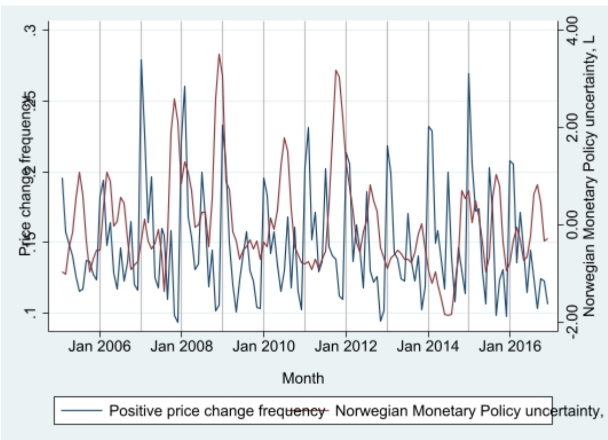
(c) NOVIX



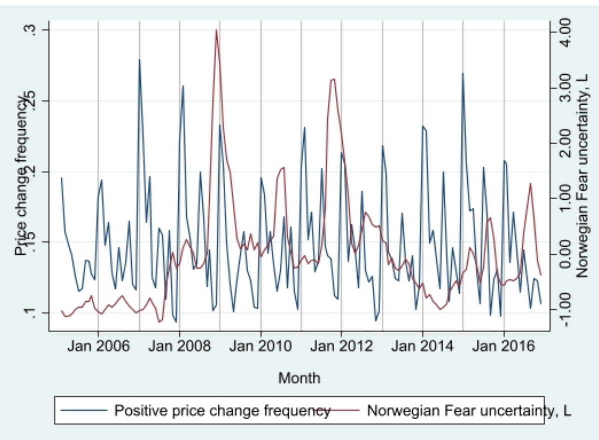
(d) Norwegian Macroeconomic uncertainty



(e) Norwegian MP uncertainty



(f) Norwegian Fear uncertainty



(g) American Macroeconomic uncertainty

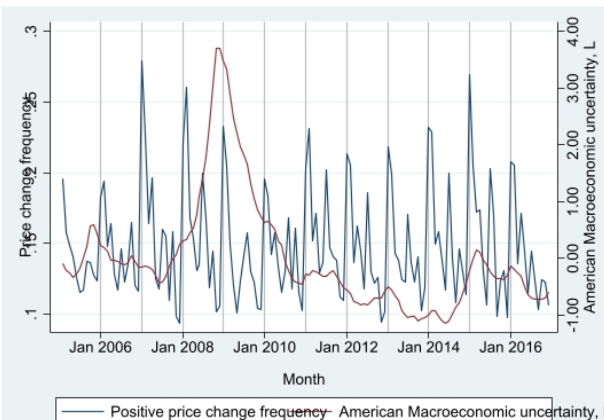
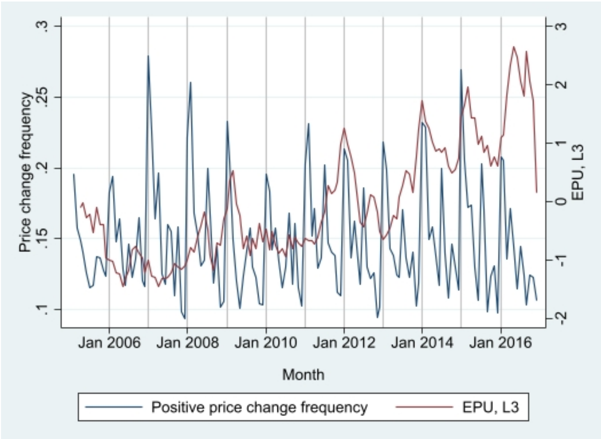
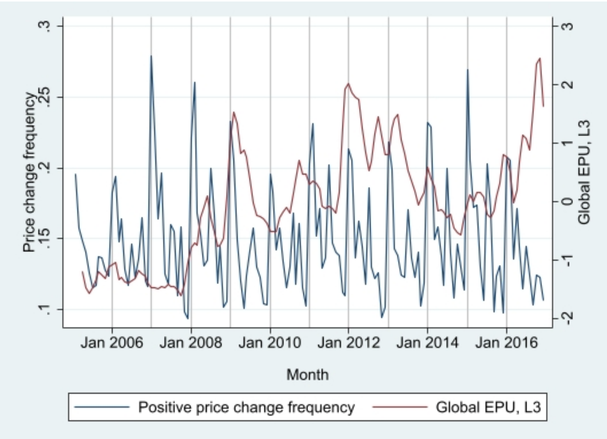


Figure A2.10: Price change frequency for with 3 month lagged positive price changes and uncertainty measures

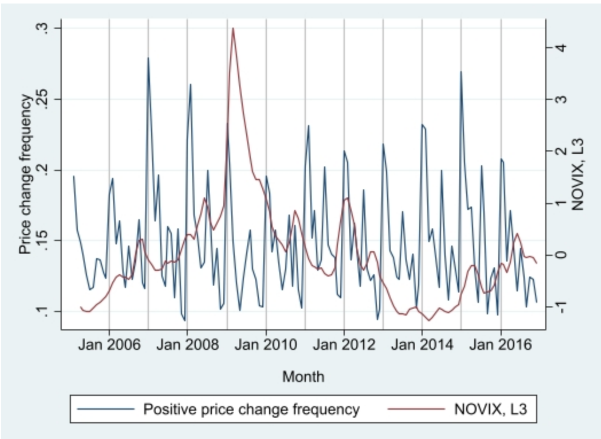
(a) EPU



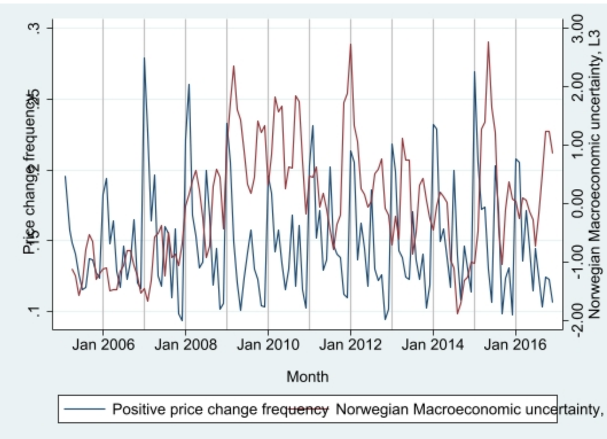
(b) GEPU



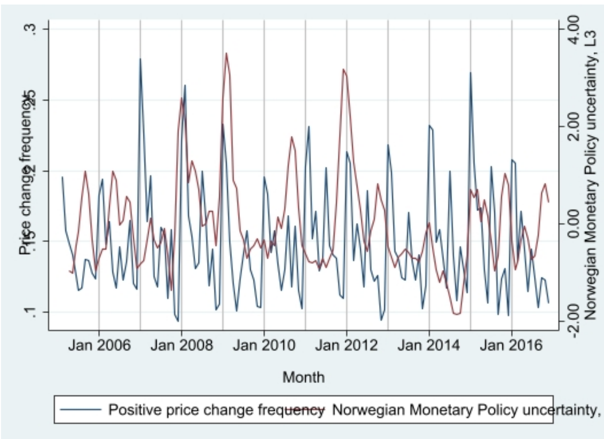
(c) NOVIX



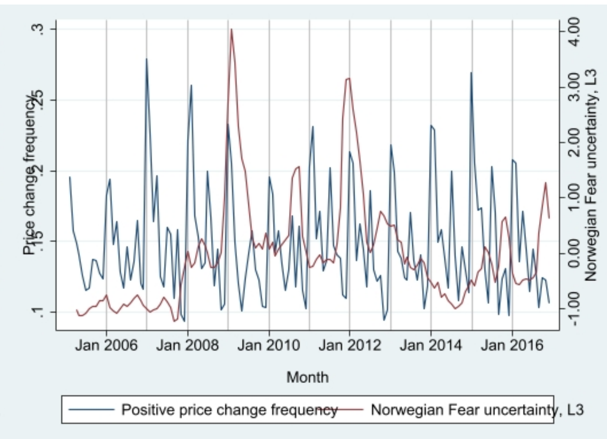
(d) Norwegian Macroeconomic uncertainty



(e) Norwegian MP uncertainty



(f) Norwegian Fear uncertainty



(g) American Macroeconomic uncertainty

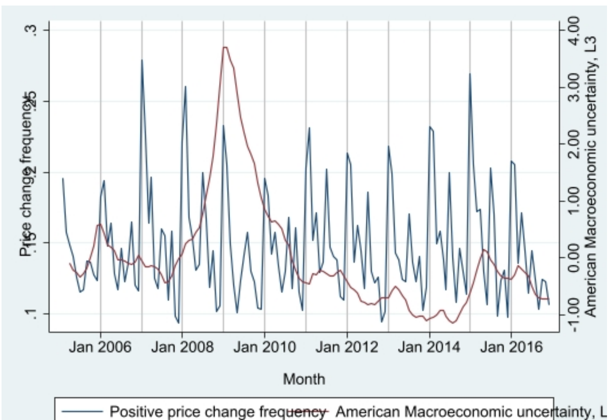
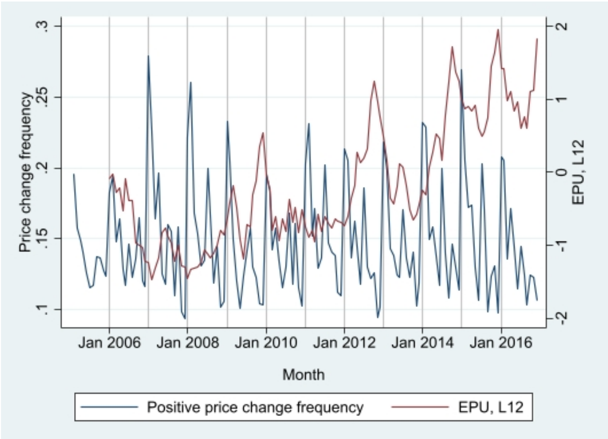
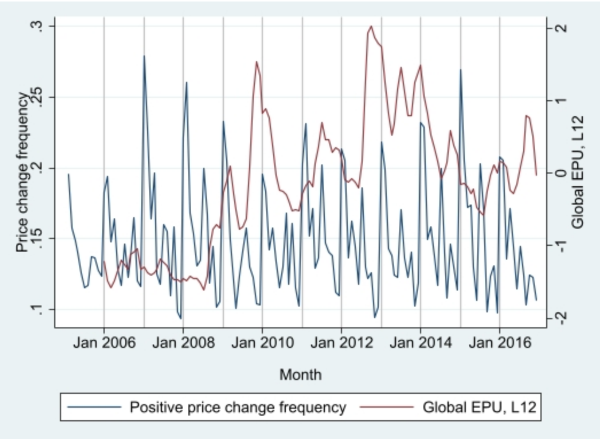


Figure A2.11: Price change frequency for with 12 month lagged positive price changes and uncertainty measures

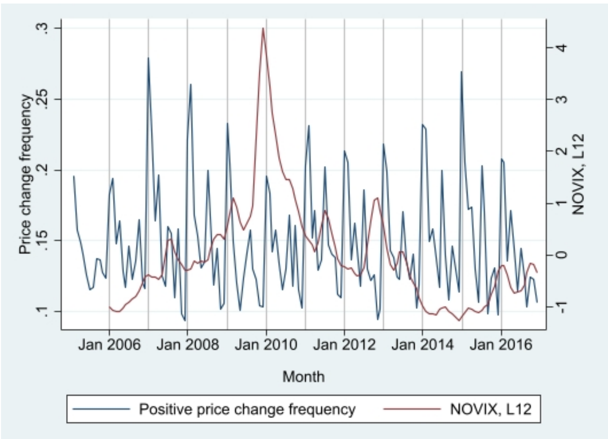
(a) EPU



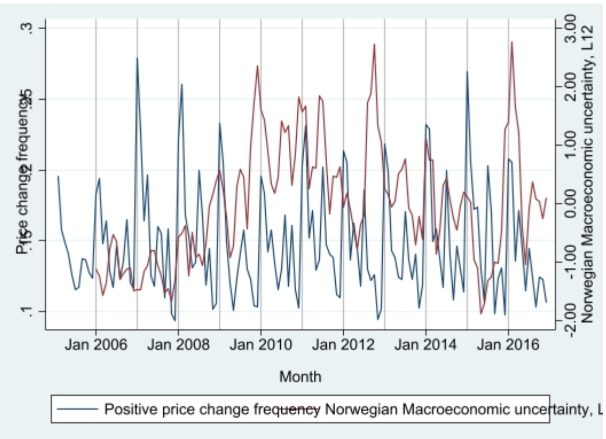
(b) GEPU



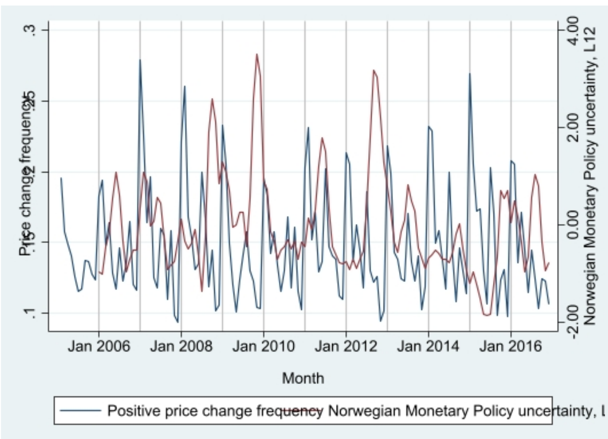
(c) NOVIX



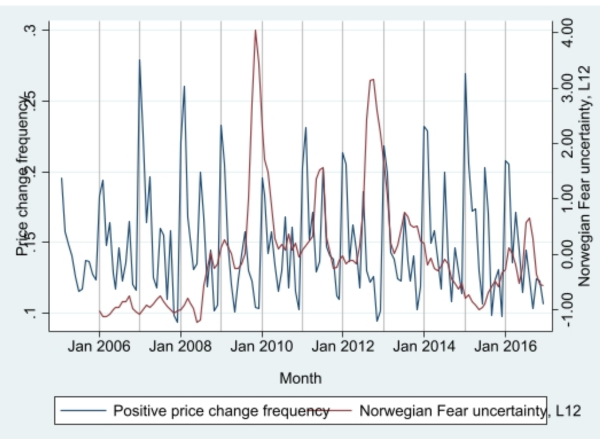
(d) Norwegian Macroeconomic uncertainty



(e) Norwegian MP uncertainty



(f) Norwegian Fear uncertainty



(g) American Macroeconomic uncertainty

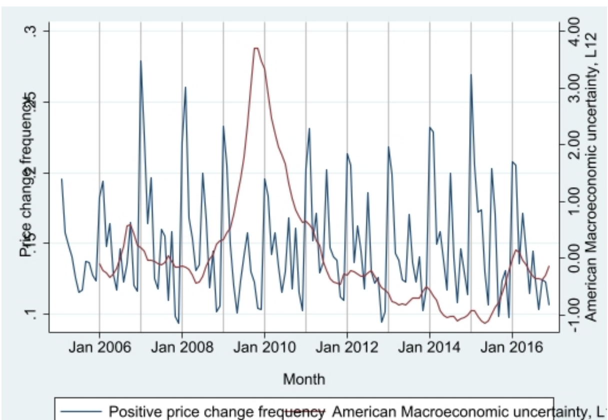
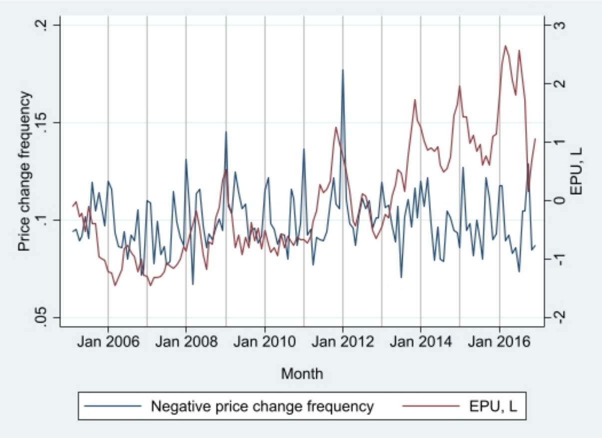
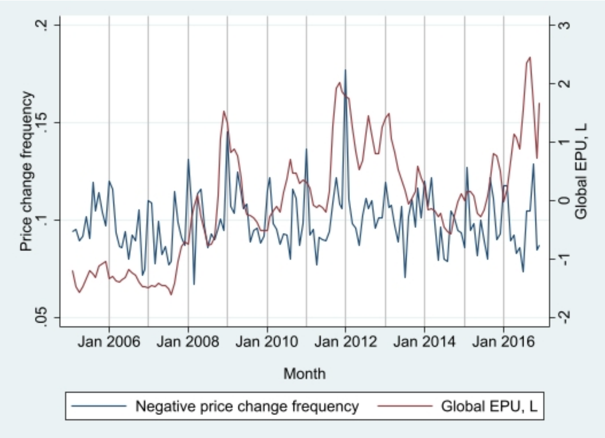


Figure A2.12: Price change frequency for with 1 month lagged negative price changes and uncertainty measures

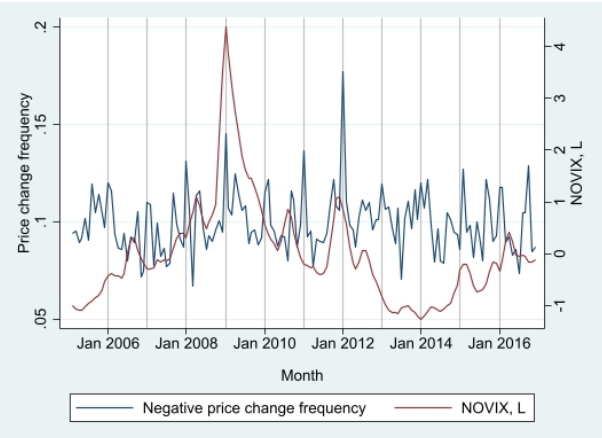
(a) EPU



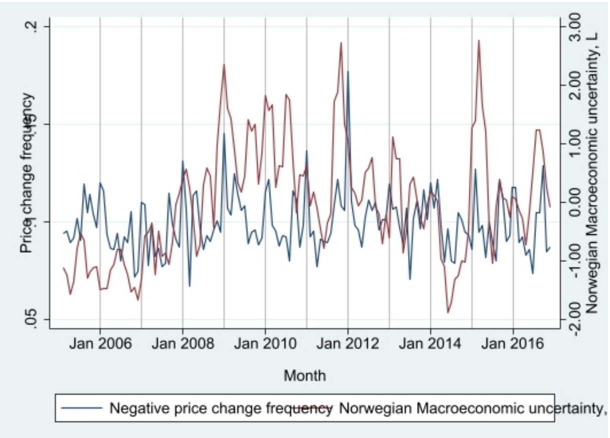
(b) GEPU



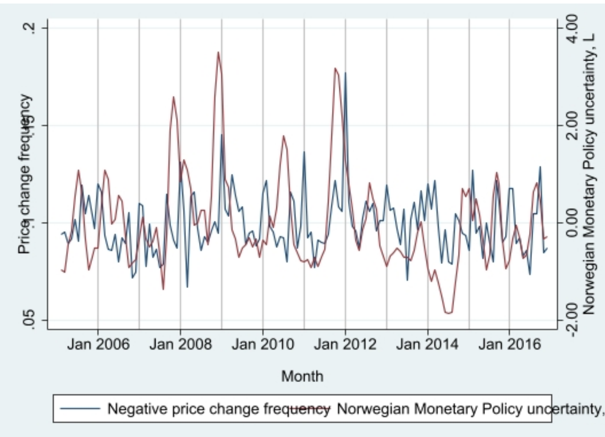
(c) NOVIX



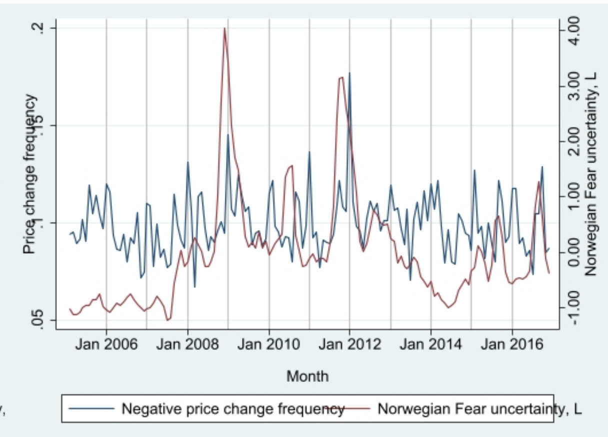
(d) Norwegian Macroeconomic uncertainty



(e) Norwegian MP uncertainty



(f) Norwegian Fear uncertainty



(g) American Macroeconomic uncertainty

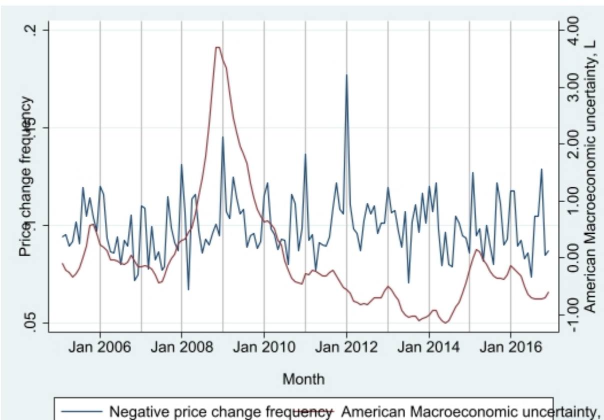
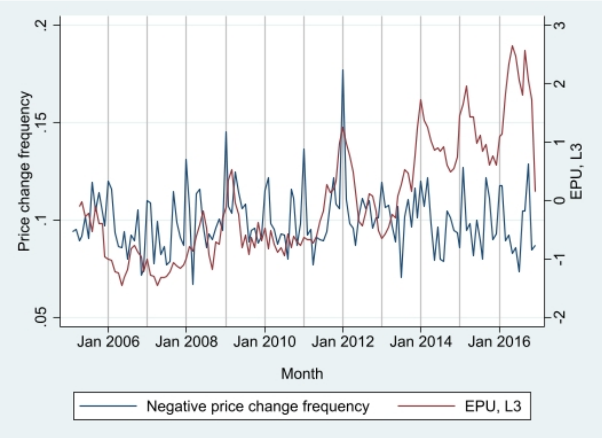
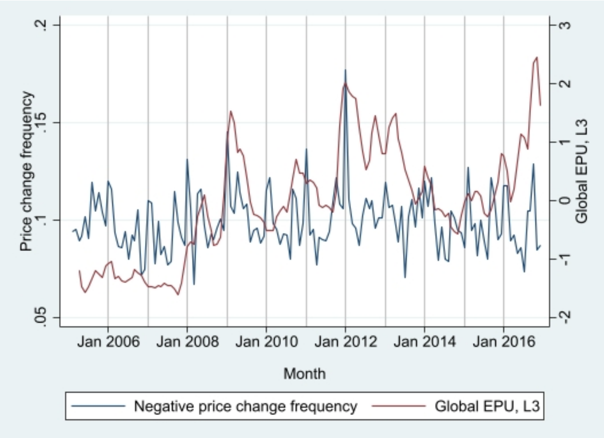


Figure A2.13: Price change frequency for with 3 month lagged negative price changes and uncertainty measures

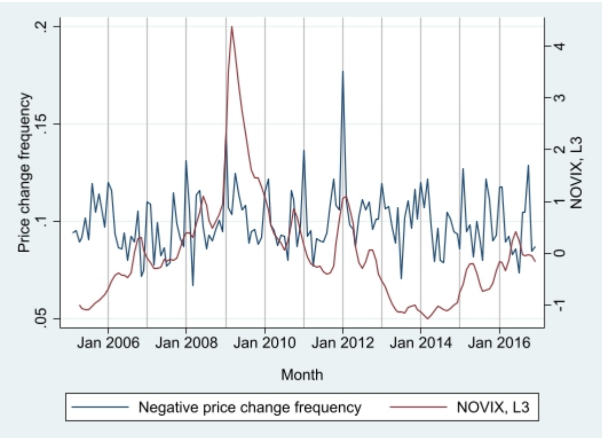
(a) EPU



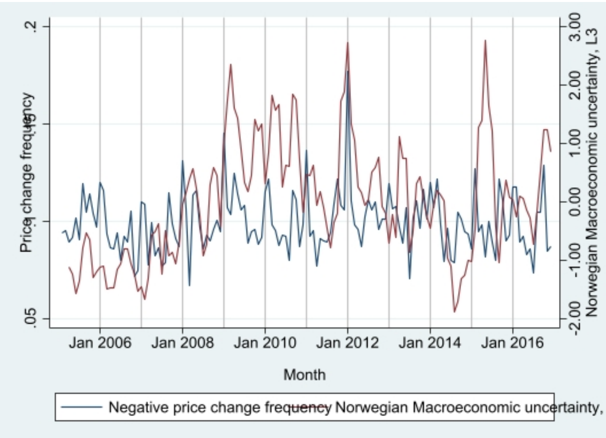
(b) GEPU



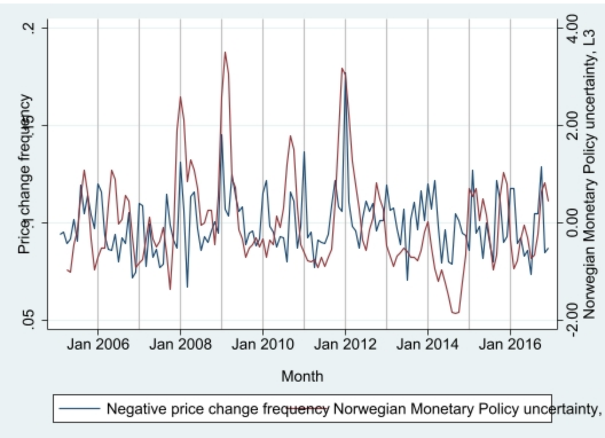
(c) NOVIX



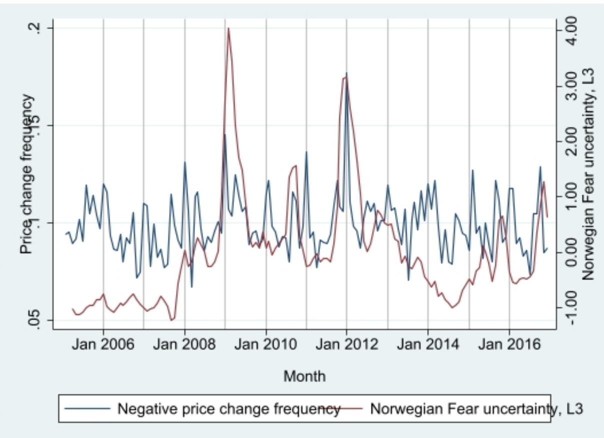
(d) Norwegian Macroeconomic uncertainty



(e) Norwegian MP uncertainty



(f) Norwegian Fear uncertainty



(g) American Macroeconomic uncertainty

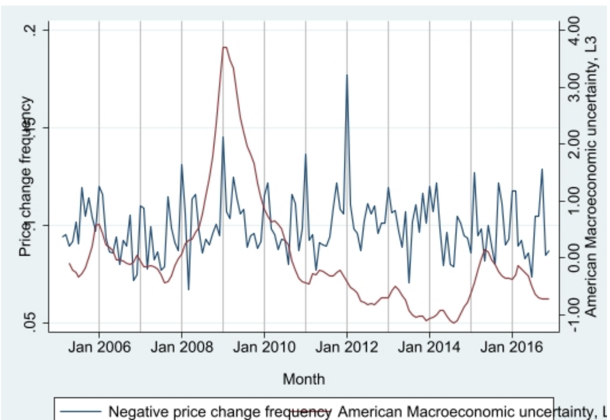
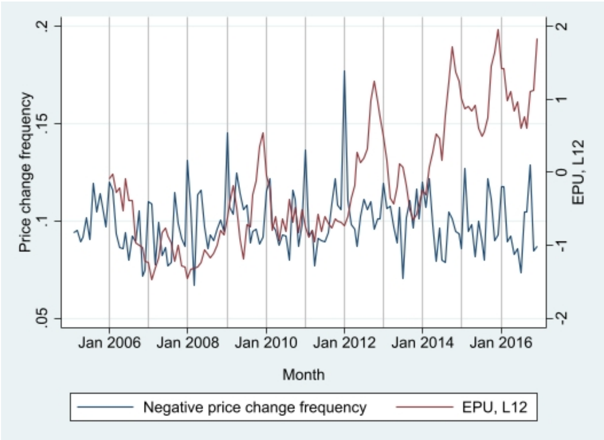
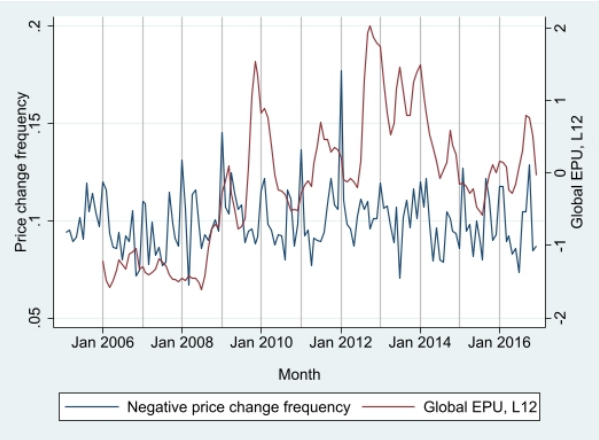


Figure A2.14: Price change frequency for with 12 month lagged negative price changes and uncertainty measures

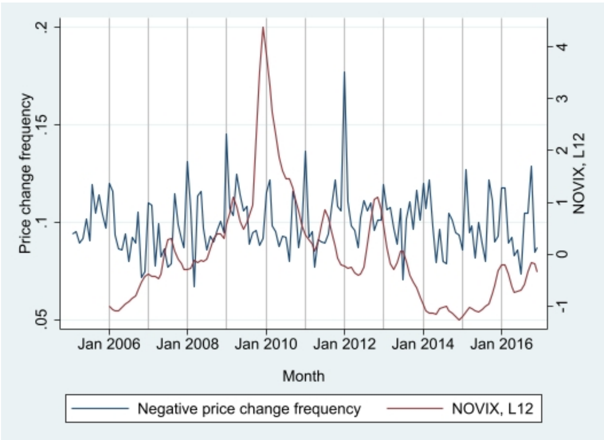
(a) EPU



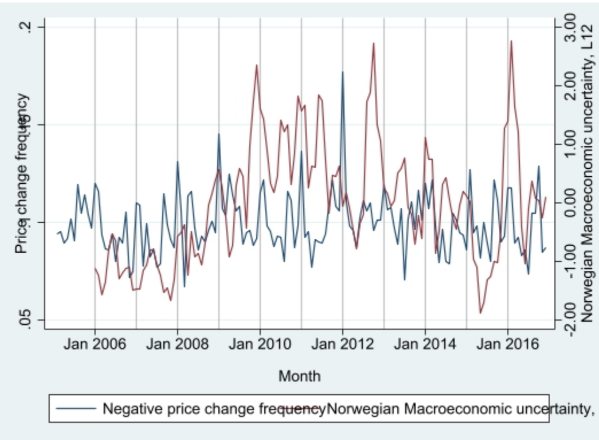
(b) GEPU



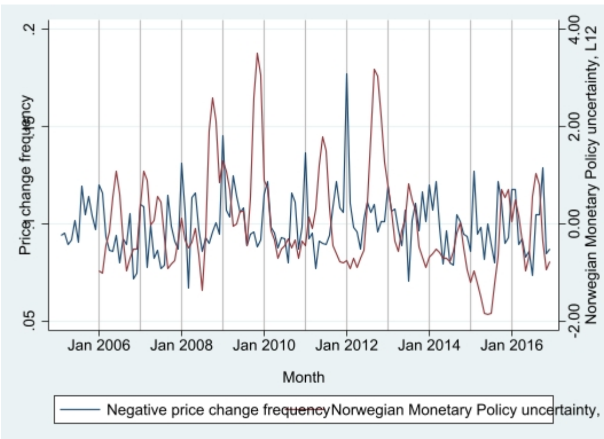
(c) NOVIX



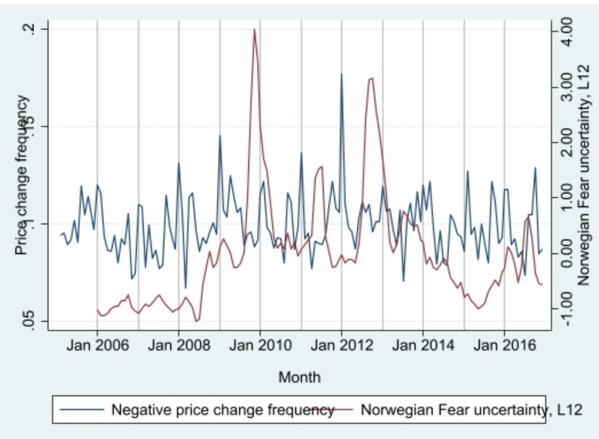
(d) Norwegian Macroeconomic uncertainty



(e) Norwegian MP uncertainty



(f) Norwegian Fear uncertainty



(g) American Macroeconomic uncertainty