Master thesis

# Empirical properties of Norwegian inflation expectations from 2002-2015

Submitted by

Anette Borge

Norwegian University of Science and Technology

Department of Economics
Supervisor: Gunnar Bårdsen
Norway, June 2016

# Preface

This thesis is submitted in partial fulfilment of the requirements for the degree MSc. at the Norwegian University of Science and Technology. I would like to thank my supervisor Professor Gunnar Bårdsen for excellent guidance and valuable comments and explanations during my work with this thesis. The proofreading done by Linda Stokke and Jake Lamb is also greatly appreciated.
Any errors that remain in this thesis are my sole responsibility.

Trondheim, May 2016

Anette Borge

# Contents

# List of Figures

# List of Tables

# 1 Introduction

Inflation expectations from surveys have been the subject of economic research for more than 40 years. One of the oldest surveys available in the U.S., The Livingston Survey, was started in 1946 and is today conducted by the Federal Reserve Bank of Philadelphia. Surveys have been used to answer numerous research questions, as to test rational-expectations theory, to analyse formation of inflation expectations, to use in empirical research in macroeconomics and to use in a variety of other studies (Croushore 2010). However, there is next to no published research based on Norwegian inflation expectations surveys. This thesis therefore aims to analyse the properties and a possible application of inflation expectations from the expectations survey[1] of the central bank of Norway[2].

The Norwegian government adopted in March 2001 an inflation target for the monetary policy in Norway. The target is low and stable inflation, with annual consumer price inflation of approximately 2.5 % over time. Inflation expectations influence wage demands and this further affects the prices businesses set. As expectations of future inflation may themselves influence the actual inflation, confidence in the inflation target could contribute to stabilising the inflation around its target (Norges Bank 2004). Hence, Norges Bank is emphasising that households, businesses, the workers' and employers' organizations and those trading in the financial markets have confidence in the inflation remaining low and stable (ibid).

A survey of expectations might give an insight in these expectations. Norges Bank is having a survey of expectations conducted each quarter, where representatives of four different groups are asked about their expectations of different macroeconomic sizes. The groups represented in Norges Bank's survey are households, business executives, labor organizations and economists, and it is these groups' inflation expectations from the survey that is the starting point of this thesis. Norges Bank's expectations survey hence also provides the opportunity to compare the forecasting qualities of four different groups.

The main purpose of this thesis is threefold. First I will compare the four mentioned groups' inflation expectations to the actual inflation rate, evaluating which group is the best forecaster, and whether there is any significant difference between the groups' forecast

[1] Forventningsundersøkelsen
[2] Henceforth referred to as Norges Bank or NB.

errors. Both their 12- and 24-month inflation forecasts are evaluated, in addition to test their forecasts for rationality (i.e. if their forecasts are unbiased and efficient).
Second, since there's evidently differences in the expectations of the groups, regression analyses will be conducted in order to evaluate whether the groups' 12-month inflation expectations are influenced by different macroeconomic variables. Each group would in all likelihood want to use the best model as possible for predicting the inflation rate, but they might have different motivations, and hence be influenced by different information. Gramlich's (1983) analyses on the Livingston and Household Information Survey are the basis of the similar analyses done in this thesis.
Lastly, due to different motivations and thereby input, the expectations might entail information not present in a simple wage-price model used for predicting inflation. Hence, the expectations are used in the regression analyses of a reduced form model of inflation, testing whether the model is improved and how the expectations might influence actual inflation. This thesis will analyse whether some groups' inflation expectations are more important in predicting inflation than others, and possibly how they affect the actual inflation rate differently.

The outline of this thesis is as follows. First, the properties of the inflation expectations from Norges Banks expectations survey are presented and evaluated. That includes different measures of forecast errors, testing whether the expectations are unbiased and efficient, in addition to finding whether there's a significant difference between the forecast errors using the Diebold-Mariano test. Before the regression analyses, chapter 3 will address the empirical approach, including conditions of OLS-estimation, the time series properties of the variables used, and accordingly the concepts of cointegration and error correction models. The fourth part of this thesis concerns how the group's expectations are formed, while the fifth chapter presents the wage-price model and the regression analyses of the reduced form inflation model with and without expectations. The conclusion is presented in section 6, and additional presentations of the dataset, results and relevant concepts is found in the appendices.

## 2 Inflation expectations and their properties

As defined by Pesaran and Weale (2006), expectations are subjectively held beliefs by individuals about uncertain future outcomes or the beliefs of other individuals in the market place. Such expectations are an essential part of the decision making process made by households, firms, as well as private and public institutions. Consumers are basing their decisions of how much labor to supply and how much to save on their economic outlook, on their stream of future wages and returns on savings. Similarly, firms base their investment choices on their forecasts of future income and profitability. When individuals form their expectations, they must try to forecast what will occur in the future[3], for instance what paths prices and interest rates will take. In addition expectations of the future price development can itself play a part in the actual price development. This is important for Norges Bank when implementing a goal of low and stable inflation, as outlined in their monetary policy (Epinion 2015).

According to Kershoff and Smit (2002), nearly all central banks that have adopted inflation targeting monetary policy frameworks consult inflation expectations surveys. Norges Bank adopted an inflation targeting framework in 2001, and their expectations survey was conducted for the first time the following year. The reason why these central banks are consulting inflation expectations surveys, is to both forecast inflation and to evaluate the credibility of their inflation fighting-policies (ibid). Inflation expectations surveys are providing information about whether people are making accurate forecasts. Moreover, whether they are using all relevant information to predict the future outcome. If this is not the case, it becomes equally difficult for authorities to alter the expectations in order to influence the economy. Inflation expectations surveys might therefore be a good indicator of what the public thinks of the authorities' policies.

How expectations are formed can be divided into three lines of thought (Kershoff & Smit 2002), namely the adaptive expectations, the rational expectations and a mix of the two. The adaptive expectations hypothesis asserts that expectations of future inflation are based on some distributed lags of past values of inflation. If this was the case, inflation expectations surveys could be a waste of time as the results would contain no additional information other than that provided by past inflation (ibid). When the groups are using

[3]Hence, the terms expectation and forecast are used interchangeably.

all relevant information to forecast inflation, and hence are not systematically making errors, they are said to be rational (Pesaran & Weale 2006). Rational forecasts are thus entailing two characteristics; they have to be unbiased and they have to employ all relevant information available.

Studies from the early 1980s of inflation forecasts in surveys taken over the previous 20 years, found that the forecasts systematically underpredicted inflation (Croushore 1996). This stood in contrast to economic theory, so it was suggested that either those who surveyed the forecasters weren't collecting the proper data or the forecasters were irrational in their beliefs about inflation (ibid) and many economists hence stopped paying attention to inflation forecasts from surveys. However, later reviews indicate that sharp rises in oil prices during the 70s had a large role to play in the forecasting errors, and including data after 1980 provides much better forecasts (ibid).

Norges Banks' expectations survey contains the inflation forecasts of four groups. In addition to testing for rationality in the forecasts, the focus will also be whether the forecasts are accurate, and whether some forecasters might be more accurate than others. A forecast can be unbiased and still highly inaccurate, as large positive and negative errors cancel each other out; therefore the accuracy of the different forecast groups also needs to be evaluated.

## 2.1 The survey of expectations and actual inflation rates

### 2.1.1 Executing the survey of expectations

The survey of expectations is conducted by Epinion[4] and commissioned by Norges Bank each quarter. In the survey representatives for economists, central labor organizations, executives in trade and industry and households are questioned on expectations on the price-, wage-, exchange rate- and interest rate-development in Norway[5]. The survey was first conducted in February 2002, and has today been conducted more than fifty times. It is conducted quarterly with the first survey during February, the second during May, the third during August and the fourth during November. The representatives of economists, labor organizations, and executives are invited to participate through emails,

[4]Earlier the survey has been performed by TNS Gallup (2002-2008) and Opinion (2009-2014) respectively

[5]The abbreviations E, W, B and H will be used for economists, central labor organizations, executives in trade and industry and households respectively.

where the survey is conducted online using the data collection software IBM-SPSS. The representatives of households are interviewed over telephone in Epinion's CATI-centre. The sample size varies among the groups, where economists and labor organizations have roughly 50 and 40 representatives each, executives have 513 representatives, and 1000 respondents represent households[6].

This thesis focuses on the inflation expectations of the different groups of representatives, for 12 and 24 months ahead respectively. The questions from the survey that are the basis for the analyses are for the economists, labor organizations and executives the following:

- What do you think the general price increase on goods and services will be in 12 months, measured with the 12 month's increase in the Consumer Price Index (CPI)?
- What do you think the general price increase on goods and services will be in 2 years, measured with the 12 month's increase in the Consumer Price Index (CPI)?

Households have been given the following questions:

- Do you think that the prices on goods and services (measured by the Consumer Price Index) in the next 12 months will be higher, the same or lower than today?
- Approximately how much higher/lower, measured in percent?
- How much do you think the prices on goods and services (measured by the Consumer Price Index) will increase annually in the next 2-3 years, measured in percent?

Norges Bank's observations range from the first quarter in 2002 until the fourth quarter in 2015 and have been collected from each of the four named groups above. It is important to notice that the observations used in this dataset are mean values from the samples that have been used to conduct the survey each quarter, so that the variation in the inflation expectations within each group has not been possible to make use of. The descriptive statistics that are presented in table 1 are therefore based on observations of the mean values each quarter.

[6]The sample sizes might also vary between the different surveys, and the numbers reported here are from no. 3/2015 (Epinion 2015)

Table 1: Descriptive statistics for inflation expectations

| Variable | Observations | Mean | Standard deviation | Min. value | Max. value |
|---|---|---|---|---|---|
| 12 month expectations | | | | | |
| H12m | 54 | 2.96 | 0.432 | 2.1 | 4.2 |
| B12m | 56 | 2.45 | 0.409 | 1.6 | 3.7 |
| W12m | 56 | 2.14 | 0.403 | 1.4 | 3.3 |
| E12m | 56 | 2.07 | 0.322 | 1.6 | 3.2 |
| 24 month expectations | | | | | |
| H24m | 56 | 4.12 | 0.469 | 1.0 | 4.9 |
| B24m | 56 | 3.17 | 0.412 | 2.3 | 4.2 |
| W24m | 56 | 2.44 | 0.301 | 1.9 | 3.1 |
| E24m | 56 | 2.34 | 0.205 | 2.0 | 2.9 |

### 2.1.2 Actual and expected inflation

The actual inflation is measured as growth in the consumer price index (CPI)[7]. Mean values of the observations of the CPI in Norway (set to 1 in 2013) from the corresponding quarters[8] as the survey of expectations was conducted has been collected, and the observations range from 1972 to 2015. The 12 month rate of inflation has then been calculated using:

$$infl12_t = \frac{CPI_t - CPI_{t-4}}{CPI_{t-4}} \cdot 100 \tag{2.1.1}$$

and correspondingly, the 24 month rate of inflation has been calculated using:

$$infl24_t = \frac{CPI_t - CPI_{t-8}}{CPI_{t-8}} \cdot 100 \tag{2.1.2}$$

where

$infl12_t$ is the 12 month inflation rate at time t

$infl24_t$ is the 24 month inflation rate at time t

$CPI_t$ is the CPI at time t

$CPI_{t-4}$ is the CPI one year ago (four periods equals four quarters)

[7] The price index used in this thesis is the regular consumer price index, without any adjustment for tax changes or removal of energy products, that causes large variations.

[8] As the data from Statistics Norway is given as monthly observations.

$CPI_{t-8}$ is equivalently CPI two years ago

The first observation of 12 month inflation rate is from the first quarter of 1973, which was the 12 month price growth until this time. The first observation of the 24 month inflation rate was from the first quarter of 1974. Table 2 shows a summary of the descriptive statistics of the 12- and 24 month growth in CPI from the first quarter of 1973/74 until the third quarter of 2015, giving 171 and 167 observations respectively.

In 2001 the Norwegian government set an inflation goal for the monetary policy, where the goal is an annual growth in the consumer prices that over time should be close to 2.5%. Behind all the observations after 2001 there is in other words an inflation target affecting both the expectations and how Norges Bank sets the interest rate and thereby affecting future inflation. Prior to the inflation target, the inflation rates have varied a lot, as can be seen by the minimum and maximum values in table 2.

Table 2: Descriptive statistics for actual inflation

| Variable | Observations | Mean | Standard deviation | Min. value | Max. value |
|---|---|---|---|---|---|
| $infl12$ | 171 | 4.64 | 3.56 | -1.39 | 14.6 |
| $infl24$ | 167 | 9.61 | 7.24 | -0.40 | 28.1 |

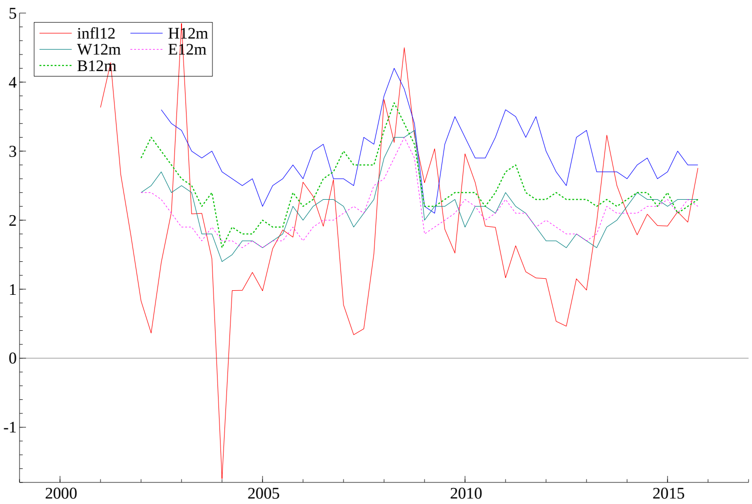



Figure 1: Expectations of inflation in 12 months

Figure 1 and 2 shows the different groups' 12 and 24 month inflation expectations, with actual inflation (infl12 and infl24) incorporated as the red line. The actual inflation rates have a longer time series than the expectations, and hence only the samples from 2002-2015 are shown in the figure. From the figure it appears that the households and executives in both of the time horizons expect higher inflation than the remaining two groups. Over time there is less variation in the inflation expectations than in actual inflation, which may be an indicator that the government's inflation goal as reliable to the participants of the survey[9]. This is particularly noticeable in figure 1 in respect of extreme values (in actual inflation rate). During the financial crisis in 2008, there is a 'shock' in the expectations giving them a peak between 3 and 4% in the 12 month forecasts, while the 24 month forecasts seem to be relatively unaffected by it. The actual 12 month inflation rate is displaying a negative value in the first quarter of 2004 in figure 1. The drop in CPI was due to declining electricity prices after having experienced a positive shock in 2003[10] (Statistics Norway 2004).

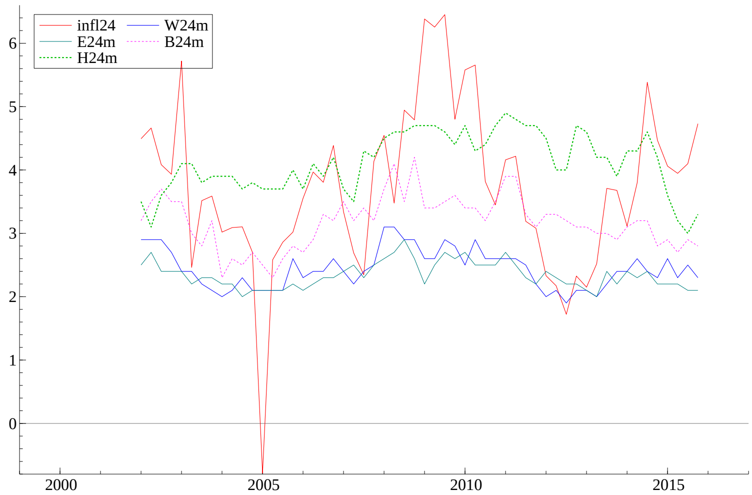



Figure 2: Expectations of inflation in 24 months

## 2.2 Comparison of the forecasting accuracies

To decide which group's inflation forecasts best coincides with the actual inflation observed, different measures of forecast accuracy are used: root mean squared error (RMSE), mean absolute error (MAE) and Theil's U-Statistic. Both RMSE and MAE compare expected inflation to actual inflation, while Theil's U-Statistic compares the forecasts to

[9]It may also, however, be a consequence of not having the real variation of the survey. As mentioned this dataset only contains the mean values - and extreme observations also has been removed prior to calculating these values.

[10]The electricity prices were 30.8 % below the price level the preceding year.

'naive' benchmarks[11]. The error measure is desired to be as close to zero as possible: The RMSE is the most widely used measure in the literature (Akay 2016) and is the mean of the squares of all the errors. The RMSE is thus penalising large errors, and therefore MAE is also included, as MAE measures the average absolute forecast error.
The formulas for the different accuracy measures are:

$$RMSE_{e_{t+h,t}} = \sqrt{\frac{1}{T}\sum_{t=0}^{T} e^2_{t+h,t}} \tag{2.2.1}$$

$$MAE_{e_{t+h,t}} = \frac{1}{T}\sum_{t=0}^{T} e_{t+h,t} \tag{2.2.2}$$

$$U_{hm} = \frac{\sqrt{\sum_{t=0}^{T}\left(\frac{e_{t+h,t}}{\pi_t}\right)^2}}{\sqrt{\sum_{t=1}^{T}\left(\frac{\pi_t - \bar{\pi}}{\pi_t}\right)^2}} \tag{2.2.3}$$

$$U_{nc} = \frac{\sqrt{\sum_{t=0}^{T}\left(\frac{e_{t+h,t}}{\pi_t}\right)^2}}{\sqrt{\sum_{t=1}^{T}\left(\frac{\pi_t - \pi_{t-h}}{\pi_t}\right)^2}} \tag{2.2.4}$$

Where:

t denotes time and T is the total number of observations.

$\pi_{t+h}$ is the actual inflation h steps ahead

$\pi_{t+h,t}$ is the expected inflation h steps ahead at time t

$e_{t+h,t} = \pi_{t+h} - \pi_{t+h,t}$ is the forecast error

$\bar{\pi}$ is the historical mean forecast

$\pi_t$ is the inflation at time t

$\pi_{t-h}$ is the inflation at time t-h

While RMSE and MAE measure how accurate the different forecasts are compared to one another, Theil's U-statistic are comparing the forecasts with a 'naive' model. If

[11] Here, two kinds of benchmarks are used, $U_{hm}$ uses the historical mean forecast as benchmark, whereas $U_{nc}$ uses a 'no change' forecast as benchmark

the U-statistics are below 1, the chosen group's forecasts are doing better than the naive forecasts. If U = 1, they are equally (in)accurate, and a U-statistic bigger than 1 indicates that the naive forecast is superior to the survey forecasters.

The different measures of forecast accuracy are displayed in table 3, and judging by the RMSE, the economists have the most accurate 12 month forecasts, followed by the labor organizations. The households' group are the most inaccurate in the 12 month forecast, but this changes in the 24-month forecast. In the 'long' run, households and executives are the most accurate. These results are also confirmed by the MAE, but the two measures rate executives and households differently in the 2-year forecast, indicating that the difference between the two is minimal.

Table 3: Different measures of forecast accuracy

| Group | RMSE | MAE | $U_{hm}$ | $U_{nc}$ |
|---|---|---|---|---|
| 12 months | | | | |
| Households | 1.65 | 1.37 | 1.63 | 0.10 |
| Labor organizations | 1.15 | 0.86 | 1.04 | 0.64 |
| Executives | 1.20 | 0.91 | 1.20 | 0.73 |
| Economists | 1.10 | 0.80 | 0.92 | 0.56 |
| | | | | |
| 24 months | | | | |
| Households | 1.49 | 1.15 | 1.12 | 0.77 |
| Labor organizations | 1.84 | 1.48 | 0.77 | 0.53 |
| Executives | 1.46 | 1.18 | 0.95 | 0.65 |
| Economists | 1.89 | 1.55 | 0.78 | 0.53 |

The values of Theil's U-statistics are not very intuitive, meaning that one can't say how much better 0.77 is compared to 0.78. However, it is interesting to see how the different forecasters score compared to the naive benchmark (i.e. a good forecaster should be better than a naive benchmark). Using the 'no change'-model as the naive model, all forecasters are doing better than the benchmark (in both the 12- and 24-month horizon).

In the 12-month forecasts, only economists are doing better than the historical mean model, while only households' forecasts are inferior to the same benchmark when expanding the forecast to two years. Looking at the data this seems to be caused by a combination of some great outliers in the households' forecast errors and simultaneous small errors made by the other groups[12]. Theil's U-statistics are therefore not always the most appropriate criterion for evaluating forecasts, but together with the other two measures it gives a good indication of the ranking between the different forecasters. Especially in the 12 month forecasts, economists seem to be the best forecasters according the most of the measures.

## 2.3 Testing the rationality of the forecasts

In addition to the measures above, the different group's forecasts can be evaluated through tests of unbiasedness and efficiency. Both are characteristics of rational expectations, and can be evaluated using the same equation. Rational expectations have been studied by several researchers after John Muth first introduced the hypothesis in 1961, asserting that expectations of an economic variable are based on all available information (cited in Colling et al. 1992). In addition to testing the hypothesis of Muth (1961), a reason for evaluating the rationality and efficiency of individuals' forecasts concerns the accuracy of the forecasts themselves and wether they could have been improved (Stekler 2007). If ex post rationality studies show that the forecasters were biased or not included available information at the time the forecast was made, then, in principle, the accuracy of the ex ante predictions could have been improved if this information had been taken into account (ibid).

One usually differentiates between two main concepts of rationality, namely weak and strong rationality (Stekler 2007). Weak rationality indicates that the forecasts are unbiased, while strong rationality indicates that the forecasts are efficient. That is, they are unbiased in addition to the forecast errors being uncorrelated with any other information known at the time the forecasts are prepared.

The basis for equation (2.3.1) used for testing of both weak and strong rationality, was first suggested by Henri Theil in 1966 (cited in Croushore 2006), and has later been discussed by among others Clements (2005), whose description is the basis for this section. The equation is as follows:

$$\pi_{t+1} = \alpha + \beta\pi_{t+1|t} + \epsilon_{t+1}, \quad t = 1, \ldots, T \tag{2.3.1}$$

[12]Households expected for instance a two year inflation rate of 4.1% in the first quarter of 2003, while the actual two year inflation rate was negative in the first quarter of 2005.

The joint null hypothesis $\alpha = 0$ and $\beta = 1$ entails unbiasedness, as (2.3.1) then indicates:

$$E_t(\pi_{t+1}) = \alpha + \beta E_t(\pi_{t+1|t}) \Leftrightarrow E_t(\pi_{t+1} - \pi_{t+1|t}) = 0$$

The joint null on $\alpha$ and $\beta$ is a sufficient but not a necessary condition for unbiasedness. The necessary and sufficient condition is $\alpha = (1-\beta)E(\pi_{t+1|t})$, and was introduced by Holden and Peel in 1990 (cited in Stekler 2007).
An alternative to testing the joint null hypothesis $(\alpha, \beta) = (0,1)$, is to test whether $\tau$ in the forecast error

$$e_{t+1,t} = \tau + \epsilon_{t+1} \tag{2.3.2}$$

is significantly different from 0 using the reported t-statistic.

Using The Livingston Survey, estimates of equation (2.3.1) on the mean forecasts tend to reject the hypothesis of rationality (Figlewski & Wachtel 1981). These studies were however based on small data sample, and Stekler (2007) notes that there is conflicted findings, depending on the data used and the appropriateness of econometric methodology that is employed[13].

The reason why (2.3.1) can also be used to evaluate efficiency, is by checking that forecasts and their errors are uncorrelated (Clements 2005). If there's a systematic relationship between them, this can be used to help predict future errors, and hence improve the forecasts - indicating that they're not efficient. From (2.3.1), we have

$$e_{t+1,t} = \pi_{t+1} - \pi_{t+1|t} = \alpha + (\beta - 1)\pi_{t+1|t} + \epsilon_{t+1} \tag{2.3.3}$$

The correlation between the forecast error and forecast is then given by

$$E(\pi_{t+1|t}e_{t+1,t}) = \alpha E(\pi_{t+1|t}) + (\beta - 1)E(\pi^2_{t+1|t}) + E(\pi_{t+1|t}\epsilon_{t+1,t}) \tag{2.3.4}$$

The expression in (2.3.4) equals zero when $\alpha = 0$ and $\beta = 1$, so the unbiasedness test can also be used to evaluate whether the forecasts are efficient. This can also be done by the t-test using (2.3.2), as the null hypothesis then gives $e_{t+h|t} = \epsilon_{t+1}$, making the correlation term of (2.3.4)$= E(\pi_{t+1|t}\epsilon_{t+1,t}) = 0$. In order for the tests to indicate rationality, the error

[13] Some tests were based on the assumption that the forecasts were made 6 and 12 months into the future, while they in fact were 8 and 14 months into the future.
An alternative methodology other than using equation 2.3.1, was to use variants of the autoregressive approach, to test whether the outcomes and forecasts was generated by the same model (Stekler 2007).

terms cannot be serially correlated. Autocorrelation in the error terms indicates that past forecast errors, which are known and relevant information at the time the current forecast is generated, are not included into the current forecast. Hence, autocorrelation in the error terms are incompatible with both weak and strong rationality.

### 2.3.1 Results from tests of rationality

As presented above, a test of rationality in the expectations takes equation (2.3.1) or (2.3.2) as a basis, testing whether $(\alpha, \beta)$ = (0,1) in (2.3.1) or if $\tau = 0$ in (2.3.2). Potential autocorrelation in the error term also influences the usual formulas for estimating variances, making the standard inference methods invalid. To correct for autocorrelation, standard errors robust for heteroscedasity and autocorrrelation (HACSE) has been used when autocorrelation is present. The results of estimating (2.3.1) is presented in table 4 and 5.

Table 4: Test of rationality in 12 month forecasts (F-test)

| | H12m | E12m | B12m | W12m |
|---|---|---|---|---|
| Constant ($\alpha$) | 3.155 (2.80) | 0.820 (0.93) | 0.741 (0.87) | 1.849 (2.87) |
| $\beta$ | -0.455 (1.10) | 0.483 (1.17) | 0.438 (1.16) | -0.020 (0.06) |
| $R^2$ | 0.041 | 0.025 | 0.032 | 0.000 |
| AR 1-4 test (p-value) | 0.001** | 0.001** | 0.003** | 0.001** |
| F-statistic (p-value) | 0.000** | 0.138 | 0.000** | 0.003** |
| HACSE-F-test (p-value) | 0.000** | 0.225 | 0.015* | 0.009** |
| Reject unbiasedness hypothesis | Yes | No | Yes | Yes |

NOTES: 12 month inflation (infl12) is the endogenous variable, estimating (2.3.1) making the fourth lag of the expectations the explanatory variable. Robust (absolute) t-ratios in parentheses. F-test of the linear restriction $H_0$: ($\alpha$, $\beta$) = (0,1). The AR-test is explained in appendix B.
(**) for p-value $\leq$ 0.01, (*) for p-value $\leq$ 0.05.

Table 5: Test of rationality in 24 month forecasts (F-test)

| | H24m | W24m | B24m | E24m |
|---|---|---|---|---|
| Constant ($\alpha$) | 4.789 (2.05) | 4.371 (2.65) | 3.796 (2.72) | 5.369 (2.46) |
| $\beta$ | -0.265 (0.49) | -0.281 (0.40) | -0.035 (0.07) | -0.714 (0.72) |
| $R^2$ | 0.008 | 0.005 | 0.000 | 0.013 |
| AR 1-4 test (p-value) | 0.000** | 0.000** | 0.000** | 0.000** |
| F-test (p-value) | 0.002** | 0.000** | 0.006** | 0.000** |
| HACSE-F-test (p-value) | 0.020* | 0.000** | 0.000** | 0.000** |
| Reject unbiasedness hypothesis | Yes | Yes | Yes | Yes |

NOTES: 24 months inflation (infl24) is the endogenous variable, estimating (2.3.1) making the eighth lag of the expectations the explanatory variable. Robust (absolute) t-ratios in parentheses. F-test of the linear restriction $H_0$: ($\alpha$, $\beta$) = (0,1)

The t-test using equation (2.3.2), is based on a more restrictive model, leading to larger 'unexplained' variance (estimated by the residuals) and hence lower t-values that will more likely keep the null hypothesis of unbiasedness and efficiency. Therefore the results from the F-test are presented here, while the results of the t-test can be found in table 21 in appendix G.4. When using the F-test, it is only the null hypothesis of the economists in the 12 month forecast that cannot be rejected at a 5 % significance level, indicating unbiased expectations. The autocorrelation in the error terms of all groups indicates that none of the groups are rational forecasters, making use of all available information (including past errors); however, the expectations of economists can still be described as unbiased. Using the t-test, also the null hypothesis of labor organizations (12 months forecast), executives and households (both in the 24 month forecasts) could not be rejected.

## 2.4 Diebold-Mariano tests

A Diebold-Mariano (DM)[14] test can give us the answer to whether the differences between the groups' forecast accuracies we have found earlier are significant or if it is just pure luck. The DM test takes the losses associated with the forecast errors of two different forecasts as a basis for the test. Assuming a quadratic loss function, the time-t quadratic

[14]Proposed by F. Diebold and R. Mariano (1995).

loss would be $L(e_t) = e_t^2$, and the time-t loss differential between forecasts 1 and 2 (for instance forecasts of households and economists) is then $d_{12t} = L(e_{1t}) - L(e_{2t})$. An important requirement of the DM-test is that the loss differential is covariance stationary (Diebold 2015), so DM assumes:

$$\begin{aligned}
&E(d_{12t}) = \mu, \quad \forall t \\
&cov(d_{12t}, d_{12(t-\tau)}) = \gamma(\tau), \quad \forall t \\
&0 < var(d_{12t}) = \sigma^2 < \infty
\end{aligned} \tag{2.4.1}$$

The null hypothesis is given as $E(d_{12t}) = 0$, indicating equal predictive accuracy (i.e. the expected loss is the same). Under the assumptions in (2.4.1), the test statistic is given as

$$DM_{12} = \frac{\bar{d_{12}}}{\hat{\sigma}_{\bar{d_{12}}}} \xrightarrow{d} N(0,1) \tag{2.4.2}$$

Where

$\bar{d_{12}} = \frac{1}{T}\sum_{t=1}^{T} d_{12t}$ is the sample mean loss differential

$\hat{\sigma}_{\bar{d_{12}}}$ is a constant estimate of the standard deviation of $\bar{d_{12}}$

If the DM-assumptions hold, the N(0,1) limiting distribution of the test statistic in equation (2.4.2) must hold. To test whether two forecasts are significantly different, one must use an asymptotic z-test of the hypothesis that the mean of the loss differential is zero. If there appears to be serial correlation in the forecast errors, this must be taken into account by either calculating the standard error in the denominator robustly or by regressing the loss differential on an intercept, allowing for AR(p)-disturbances (Diebold 2015).

To execute the DM-test, the quadratic loss function was used as illustrated above. This means regressing the loss differential of two forecasts on a constant, and testing whether the constant is significantly different from zero[15]. Starting with the twelve month-forecasts, households are apparently the least accurate forecasters and will be used as a benchmark; are the other groups significantly more accurate in their 12-month forecasts?

The test results in table 6 indicate that households are significantly less accurate than all the other groups. Economists are significantly more accurate than labor organizations in second place, but there is not a significant difference between economists and executives

[15] A simple approach is therefore to recognise that $DM$ is a $t$-statistic for the hypothesis of a zero population mean loss differential (Diebold 2015).

Table 6: Diebold-Mariano tests for 12 month forecasts

| | | | $\overline{d}$ | t-value | p-value |
|---|---|---|---|---|---|
| Economists | v. | Households | -1.664 | -3.228 | 0.000** |
| Labor organisations | v. | Households | -1.443 | -3.171 | 0.000** |
| Executives | v. | Households | -1.307 | -4.332 | 0.000** |
| Economists | v. | Labor organisations | -0.221 | -2.040 | 0.049* |
| Economists | v. | Executives | -0.356 | -1.534 | 0.131 |
| Labor organisations | v. | Executives | -0.135 | -0.804 | 0.425 |

The critical value of the t-test is 2.009. HACSE is used to estimate t-values where autocorrelation is present

in third place. This may however be due to autocorrelation in the loss differential between economists and executives, giving the constant a lower t-value (using HACSE) than the mean value of the loss differential between economists and labor organizations. The loss differential between the second and third place is not significant.

With regard to the 24 month forecasts in table 3, the groups of economists seem to be the least accurate forecast group (judging by the RMSE), and is therefore used as a benchmark to test whether the other groups are significantly better.

Table 7: Diebold-Mariano tests for 24 month forecasts

| | | | $\overline{d}$ | t-value | p-value |
|---|---|---|---|---|---|
| Executives | v. | Economists | -1.441 | -2.27 | 0.028* |
| Households | v. | Economists | -1.345 | -1.18 | 0.244 |
| Labor organizations | v. | Economists | -0.161 | -1.32 | 0.194 |
| Executives | v. | Labor organizations | -1.279 | -2.04 | 0.047* |
| Households | v. | Labor organizations | -1.184 | -1.05 | 0.298 |
| Executives | v. | Households | -0.095 | -0.17 | 0.863 |

The critical value of the t-test is approximately 2.009. HACSE is used to estimate t-values where autocorrelation is present

Only executives are significantly better than economists according to the DM-tests in table 7. In addition executives are significantly better than labor organizations in third place. Using the quadratic loss function, there are hence not any significant differences between the forecasting accuracies of households, labor organizations and economists in the 24 month forecasts.

# 3 Empirical approach

Before conducting the regression analyses presented in the next chapters, this chapter will discuss the empirical approaches and the time series properties of the variables. The estimations are done with ordinary least squares (OLS) method, using *PcGive 14.0* (Doornik & Hendry 2009*b*). The analyses conducted are based on quarterly time series data[16] from approximately 1990 or 2002 to 2015 for different expectations- and macroeconomic variables.

## 3.1 OLS-estimation

The empirical analyses in this thesis are regression models for each of the groups in the survey from Norges Bank explaining their expectations, in addition to different versions of a reduced form model for inflation. The models will be presented more thoroughly in the next chapters, while this chapter discusses the general estimation method.

### 3.1.1 Estimation problems related to the use of OLS

In order for the coefficients in the estimated models to be unbiased and consistent, a number of conditions must be met. These conditions concern the error term in the regression model, and are described in Wooldridge (2013), and summarized as the following assumptions[17]:

The first assumption states that the time series process should follow a model that is linear in its parameters. Furthermore, there can be no perfect collinearity among the regressors; that is, no independent variable is constant nor a perfect linear combination of others. The third assumption requires observations that the models estimated are to be based on a random sample, indicating that

$$E(\epsilon_t|\mathbf{X}) = 0, \qquad t = 1, 2, \ldots, n \tag{3.1.1}$$

$\mathbf{X}$ denotes the collection of all independent variables for all time periods.

[16] Time series show variation for each variable over time.

[17] The simple time series model $y_t = \beta_0 + \beta_1 x_{1t} + \beta_2 x_{2t} + \cdots + \beta_k x_{kt} + \epsilon_t$ is the basis for the following explanations.

The error term at time t, $\epsilon_t$ is in other words uncorrelated with each explanatory variable in every time period. The explanatory variables are then strictly exogenous. This assumption puts no restriction on correlation in the independent variables, or in the error terms across time, it only states that the value of the error term is unrelated to the independent variables in all time periods. When the error term might be correlated with a past value of an exogenous variable, the lagged observation of the exogenous variable should be included in the model. Feedback from the error term to the future value of the exogenous variable is always an issue. When these first three assumptions are fulfilled, the OLS estimators are unbiased conditionally on **X**, and therefore unconditionally as well: $E(\hat{\beta}_j) = \beta_{Xj},\ j = 0, 1, \ldots, k$.

A fourth assumption is based on homoscedasticity, meaning that the variance of the error term, conditional on **X** is the same in all time periods:

$$Var(\epsilon_t|\mathbf{X}) = var(\epsilon_t) = \sigma^2, \qquad t = 1, 2, \ldots, n$$

When this assumption does not hold, the errors are said to be heteroscedastic.
An assumption special for time series data requires that the errors in two different time periods conditional on **X** are uncorrelated, namely there is no serial correlation in the error term. Under these five preceding assumptions, the OLS estimators are the best linear unbiased estimators (BLUE) conditional on **X**. Lastly the errors must be independent of **X** and independently and identically distributed as Normal$(0, \sigma^2)$. These last three assumptions are important in order for the inference testing to give exact results.

## 3.2 Time series properties

### 3.2.1 Stationarity

Whether a variable is stationary or not, has important implications for the econometric analyses. A variable is strictly stationary if for any values of $j_1, j_2, j_3, \ldots, j_n$, the joint distribution of $(y_{t+j1}, y_{t+j2}, y_{t+j3}, \ldots, y_{t+jn})$ depends only on the intervals separating the dates $(j_1, j_2, j_3, \ldots, j_n)$ and not on the date itself, $t = 1, 2, ..., \infty$. If neither the mean, variance, nor the covariances depend on the date t, then the process for $y_t$ is said to be covariance (weakly) stationary.

If one or all of the conditions for weakly stationarity does not hold, the variable is non-stationary, containing a deterministic or/and stochastic trend. If the trend is deterministic, the variable's time series process depends on the time index $t$, whereas a stochastic trend indicates that the time series process only depend on past values of itself and Gaussian white noise errors. When a variable contains a stochastic trend, it can be expressed as:

$$y_t = y_{t-1} + v_t \tag{3.2.1}$$

with $v_t \sim i.i.d.\ N(0, \sigma^2)$.
The process of $y_t$ is referred to as a random walk. For a random walk, the effect of a shock does not die out, it persists forever. This can be shown using recursive substitution:

$$\begin{aligned} y_t &= y_{t-1} + v_t \\ &= y_{t-2} + v_{t-1} + v_t \\ &= y_{t-3} + v_{t-2} + v_{t-1} + v_t \\ &\vdots \\ y_t &= \sum_{j=0}^{t-1} v_{t-j} + y_0 \end{aligned}$$

If $y_0$ is taken to be zero, the random walk can be written as:

$$y_t = \sum_{j=0}^{t-1} v_{t-j} \tag{3.2.2}$$

demonstrating that each shock, $v_{t-j}$ contributes its full value to $y_t$, having a permanent effect on the series. The impact of a change in an initial shock in period $t-k$ on $y_t$ is 1, and hence we say that the series contains a unit root .
Accordingly, the mean and variance of the random walk-process is:

$$E[y_t] = 0 \tag{3.2.3}$$

$$var(y_t) = \sigma^2 t \tag{3.2.4}$$

where the variance depends on the time index t, making $y_t$ non-stationary. When the series contains a unit root it can be described as difference-stationary, because by taking first difference of the random walk you get:

$$y_t - y_{t-1} = v_t \tag{3.2.5}$$

$$\Delta y_t = v_t \tag{3.2.6}$$

where $\Delta y_t$ is stationary. If a variable $y_t$ can be made approximately stationary by differencing it once, it is integrated of first order, $I(1)$. Stationary variables are thus integrated of order zero, $I(0)$. In general, the order of integration $d$ is the number of differences needed to make the series stationary.

Doing regression analyses with variables that are non-stationary might induce spurious regressions, as two variables that are moving in the same direction over time might seem to be causing the change in each other even when they are not. Therefore, it is preferred to work with stationary time series. A series containing a deterministic trend can be made stationary by removing the trend[18], while a series containing a stochastic trend is made stationary by differencing it. To determine if there is a trend in the series, and what kind of trend it is, figures of the time series of the relevant variables are examined. When a time series does not seem to be stationary (i.e. the series does not have a constant mean), an Augmented Dickey-Fuller (ADF) test is used to test whether an unit root is present.

The different inflation rates and expected inflation rates are not included in figure 3, but with respect to figure 1 and 2, the series of expectations seem to be stationary. Unit root in the time series can also be detected through evaluating the sample autocorrelation and partial autocorrelation functions, as shown in figure 4. If the series contains a unit root, its sample autocorrelation function (acf) will tend to decrease very slowly. This is because a random walk fails to revert to any population mean, so that any given sample path will tend to wander above or below its sample mean for long periods of time, leading to very large positive sample autocorrelations, even at long displacements (Diebold 2007, p.296). The sample partial autocorrelation function (pacf) on the other hand, will decrease quickly: It will tend to be very large and close to one when displacement=1, but will tend to be smaller and decay quickly thereafter (ibid).

Testing for a unit root using the ADF-test, examines whether a series is a random walk against the alternative that it is (trend-)stationary. Assuming an autoregressive (AR)

[18] The trend can be removed by for instance including a time trend in the regression (Wooldridge 2013).

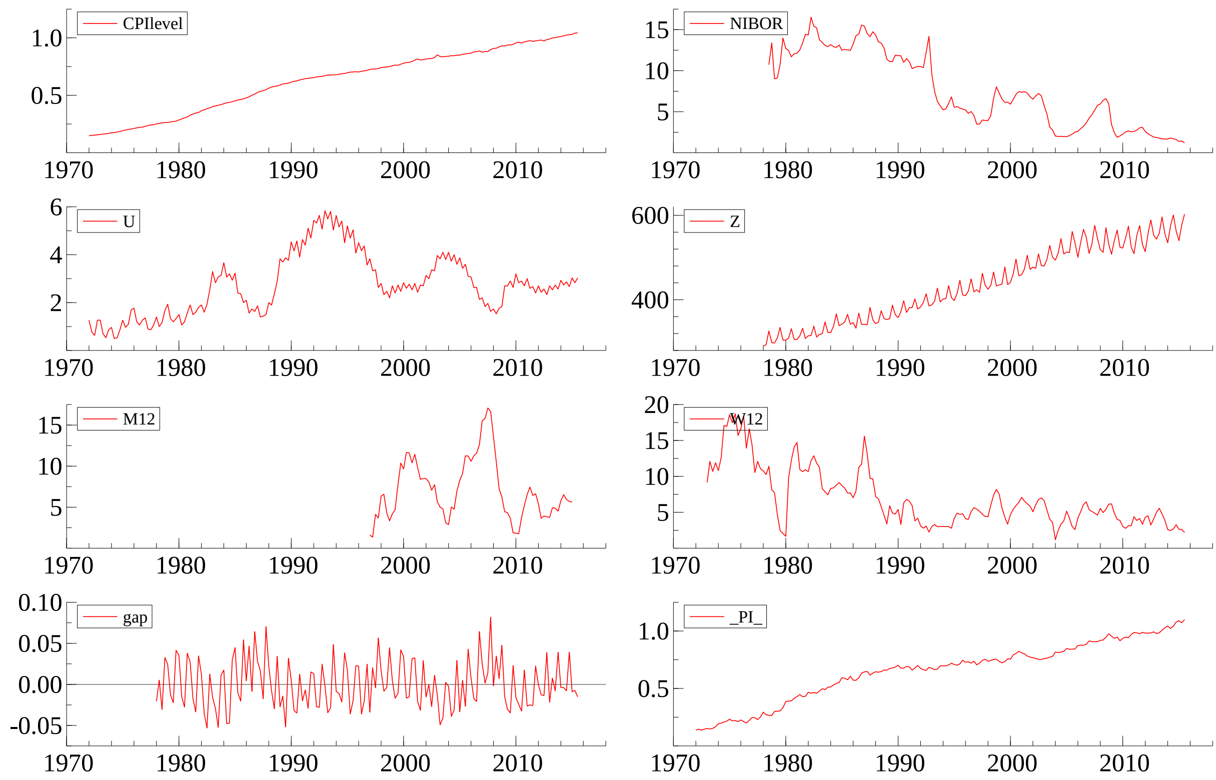



Figure 3: Time series from the dataset

process with one lag (AR(1)):

$$y_t = \phi y_{t-1} + v_t \tag{3.2.7}$$

The error term is assumed to be white noise ($v_t \sim i.i.d.\ N(0, \sigma^2)$). If $\phi = 1$, (3.2.7) is expressing a random walk, but if $\phi < 1$ (3.2.7), it is stationary. (3.2.7) can be rewritten as:

$$\Delta y_t = \mu y_{t-1} + v_t \tag{3.2.8}$$

where $\mu = \phi - 1$. To test for a unit root, one simply tests if:

$$H_0 : \mu = 0$$
$$\text{against } H_1 : \mu < 0$$

If $\mu = 0$, $y_t$ is integrated of order one[19], $y_t \sim I(1)$. If $\mu < 0$, $y_t \sim I(0)$, that is, stationary.

[19] $y_t$ could also be integrated of a higher order, so the ADF-test will also be conducted on the differenced versions of $y_t$, when a unit root seem to be present.

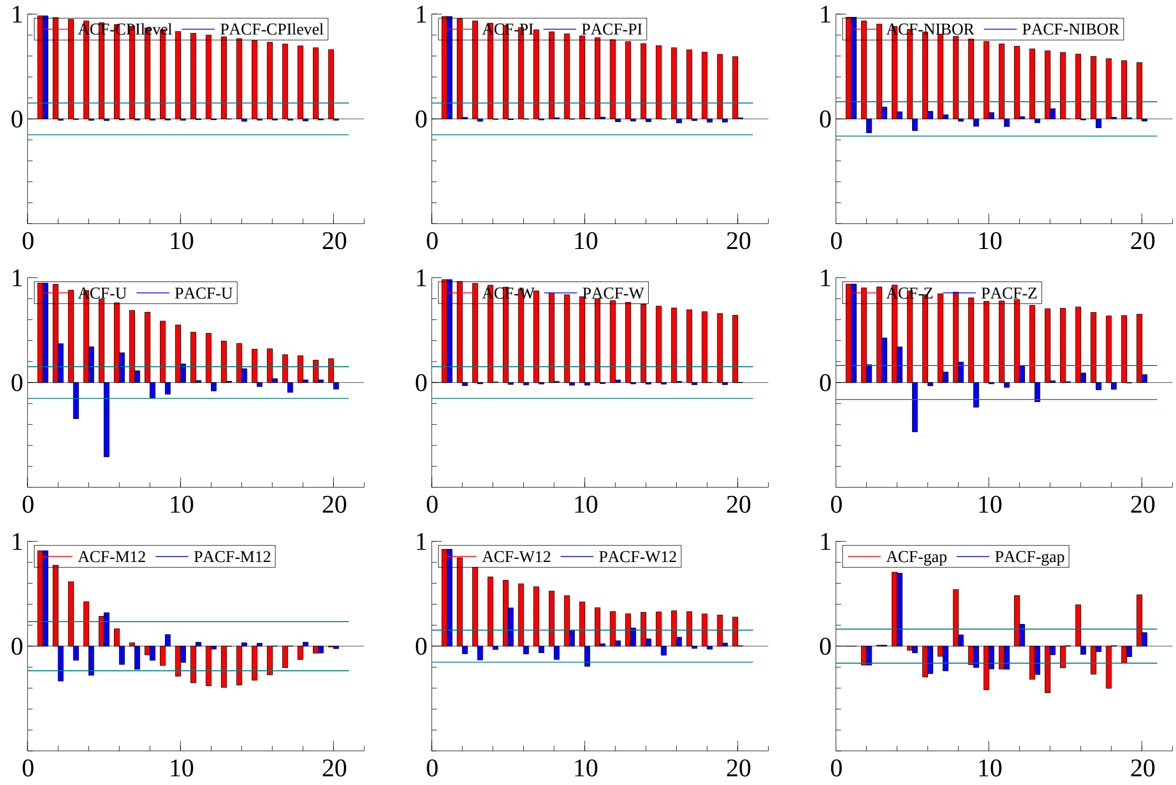



Figure 4: Sample autocorrelation and partial autocorrelation functions

The test is in other words the t-test for $H_0$:

$$\hat{t}_{DF} = \frac{\hat{\mu}}{SE(\hat{\mu})} \tag{3.2.9}$$

Where $SE(\hat{\mu})$ is the standard error of $\hat{\mu}$.
The test statistic will not follow the usual t-distribution under the null hypothesis, because of the implied non-stationarity. Critical values are hence derived from simulation experiments, and will be given automatically in the software-output for unit-root testing.

The tests are only valid if $v_t$ is white noise. If $v_t$ in (3.2.8) is autocorrelated, the test is 'oversized', meaning that the proportion of times a correct null hypothesis is incorrectly rejected would be higher than nominal size used. To ensure that no autocorrelation is present in $v_t$ (due to autocorrelation in $\Delta y_t$), $p$ lags of $\Delta y_t$ are included - consequently the test is called 'augmented' DF-test and is written

$$\Delta y_t = \mu y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta y_{t-i} + v_t \tag{3.2.10}$$

Determining the optimal number of lags of $\Delta y_t$ can be based on the frequency of the data, using four lags if the data is quarterly for instance. Another possibility is the use of information criteria, using the number of lags minimalizing the value of an information criterion. In addition it is also possible to add a constant term or trend variable in (3.2.10). When a constant is included, the null hypothesis is a random walk with drift, and the alternative hypothesis is stationarity; however, including a trend variable makes the alternative hypothesis stationarity with a deterministic time trend. Therefore, including a time trend in the test is only appropriate for time series that is obviously trending in one direction. The null hypothesis of a unit root is rejected in both cases, if the test statistic is more negative than the critical value.

With regard to figure 3, only the variable *gap* seems to be stationary, and hence the ADF-test will be conducted on the eight other variables. $CPI$, $Z$ and $PI$ are clearly trending, and seem to be I(1)-processes. This is also observed in figure 4, where past shocks seem to stay in the system. As most of the apparent non-stationary variables seem to be trending, the ADF-test with deterministic time trend as the alternative hypothesis will be conducted on them.
The variables are differenced once, and the number of lags of the dependent variable is decided using Akaike's information criterion (AIC)[20], with a maximum of six lags.

Table 8: Results from ADF-tests

| Variable | Constant | | Constant and trend | |
|---|---|---|---|---|
| | $\mu$ | $\hat{t}_{DF}$ | $\mu$ | $\hat{t}_{DF}$ |
| CPI | 0.998 [2] | -0.25 | 0.711 [0] | -3.28 |
| $\Delta cpi$ | 0.853 [3] | -1.91 | | |
| $\Delta cpi$ after 1990 | -0.169 [3] | -4.98** | | |
| M12 | 0.851 [6] | -3.27** | | |
| NIBOR | 0.936 [1] | -2.47 | 0.877 [1] | -3.21 |
| $\Delta NIBOR$ | 0.265 [0] | -8.99** | | |
| PI | 1.008 [0] | 0.41 | 0.818 [0] | -2.46 |
| $\Delta pi$ | 0.109 [6] | -5.03** | | |
| W12 | 0.821 [4] | -1.86 | 0.870 [4] | -3.03 |
| $\Delta W12$ | 0.091 [0] | -6.15** | | |
| U | 0.918 [5] | -2.36 | 0.973 [6] | -2.11 |
| $\Delta U$ | 0.608 [6] | -5.22** | | |
| Z | 0.930 [3] | -2.05 | 0.876 [3] | -1.13 |
| $\Delta z$ | -0.990 [5] | -4.34** | | |

[20]AIC is explained in appendix A.3

The critical DF-value at 5% significance level is approximately -2.91 when a constant is included, and -3.41 when both a constant and a trend variable are included. When testing the level-variables for a unit root without a trend, $M12$ is the only variable that rejects the null hypothesis of a unit root. When the alternative hypothesis is stationarity with a deterministic time trend, none of the tested variables rejects the null hypothesis of a unit root. For the variables including a unit root, $Nibor$ and $W12$ might appear to be problematic as they appear with their unit roots in a later model explaining inflation expectations. Despite this, as long as the error term is stationary (i.e. the OLS-conditions are still met), the non-stationarity of the variable won't have too big consequences.

Taking the log difference of the non-stationary variables, should make them stationary in both mean and variance, which were the conditions of weak stationarity. The model for predicting inflation contains log differenced versions of CPI, PI and Z, in addition to a differenced U. According to table 8, the three latter are stationary. The null hypothesis of a unit root in $\Delta cpi$ is not rejected, and from figure 5 the series of $\Delta cpi$ seems to stabilising after approximately 1990. Conducting the ADF-test using observations after 1990, successfully rejects the hypothesis of a unit root. Hence, when estimating the model using $\Delta cpi$ as the endogenous variable, only observations from and after 1990 is used.

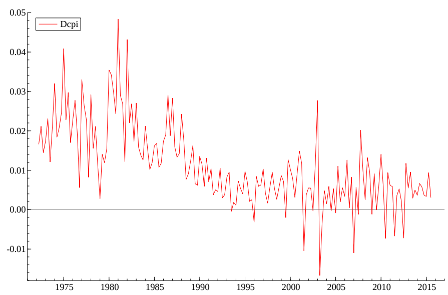



Figure 5: Time series of log differenced CPI

### 3.2.2 Seasonality

In figure 3, another property is detectable in the time series of the productivity $z$. Seemingly the values of the observations varies between the quarters, which indicates presence of seasonality. In a time series model containing $z$, this should be corrected for. Therefore, the model containing $z$ presented later, will include dummies for three quarters in addition to the constant term, to correct for seasonality. Following the Frisch-Waugh-Lovell

(FWL) theorem this should be equivalent to seasonally adjusting all the variables in the model of interest individually, using the residuals from regressions against the seasonal dummies (see appendix D).

## 3.3 Cointegration and Error Correction Models

When variables contain a unit root, the use of such variables may as mentioned earlier lead to spurious regressions. Therefore, they should be differenced before they are used in linear regression models (Wooldridge 2013). Despite this, the notion of cointegration makes the use of I(1)-variables in regressions potentially meaningful, and avoids the problem of no long-run solution in a pure first difference model. If $\{y_t, : t = 0, 1. \dots\}$ and $\{x_t : t = 0, 1, \dots\}$ are two I(1)-processes, it is possible that for some $\beta \neq 0$, $y_t - \beta x_t$ is an I(0)-process; with a constant mean and constant variance, autocorrelation that only depends on the time distances between any two in the series, and is asymptotically uncorrelated (ibid). If such a $\beta$ exists in a dynamic linear model with stationary disturbances (like $y_t = \beta x_t + u_t$), the Granger representation theorem states that the variables are cointegrated of order (1, 1) (Engle & Granger 1987).

An error correction model is a model using combinations of first differenced and lagged levels of cointegrated variables. The model used for predicting inflation presented in chapter 5 is an error correction model, with the error correction term $ecm_t$. The error correction term consists of a set of variables that are cointegrated (i.e. the linear combination of them is stationary). Many time series that are non-stationary 'move together' over time, meaning that the series are bound by some relationship in the long run (Brooks 2014). The error correction term can therefore be interpreted as correcting towards a long-run equilibrium. Consider this simple autoregressive distributed lag (ARDL) model with one lag of each variable:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \beta_1 x_t + \beta_2 x_{t-1} + u_t \tag{3.3.1}$$

where $u_t$ is assumed to be white noise. By subtracting $y_{t-1}$ on both sides, and by adding and subtracting $\beta_1 x_{t-1}$ on the right hand side, we get an error correction model:

$$\Delta y_t = \alpha_0 + (\alpha_1 - 1) y_{t-1} + (\beta_1 + \beta_2) x_{t-1} + \beta_1 \Delta x_t + u_t \tag{3.3.2}$$

$$\Delta y_t = \alpha_0 - (1 - \alpha_1) \left[ y_{t-1} - \frac{\beta_1 + \beta_1}{1 - \alpha_1} x_{t-1} \right] + \beta_1 \Delta x_t + u_t \tag{3.3.3}$$

In the long run all the differenced variables will be zero, as the variables converge upon some long term value, no longer changing, leaving us with the error correction term (using asterisks to indicate long term value):

$$\begin{aligned} 0 &= y^* - \frac{\beta_1 + \beta_1}{1 - \alpha_1} x^* \\ y^* &= \frac{\beta_1 + \beta_2}{1 - \alpha_1} x^* \end{aligned} \tag{3.3.4}$$

Equation (3.3.4) gives the steady-state or long-run equilibrium of the model, hence the error correction term in equation (3.3.3) is the deviation from the long run equilibrium last period. If $y_{t-1} > \frac{\beta_1 + \beta_2}{1 - \alpha_1} x_{t-1}$, the error correction term will have a negative effect on the change in $y_t$ working to push $y_t$ back to its long-run equilibrium. $(1-\alpha_1)$ describes the speed of adjustment back to the equilibrium. If $\alpha_1$ is close to 1, $y_t$ is strongly influenced by last period's value and will take a long time to come back to its equilibrium ($1 - \alpha_1$ is low). If $\alpha_1$ is low however, the speed of adjustment is much larger.

As $CPI$, $PI$, $U$ and $Z$ are all I(1)-processes, it is therefore of interest to find whether these variables are cointegrated, and can be used in an error correction term $ecm_t$ in the reduced form model for inflation. In order to estimate the parameters in the cointegrated system, the Johansen-method based on a vector autoregressive model (VAR), is used. This method gives the opportunity to test hypotheses about the cointegrating relationship between the consumer price index and the other variables. This is further explained in section 5.1.1.

# 4 Expectations formation

Descriptive statistics of the expected inflation for the four different groups in Norges Bank's Survey of expectations presented in table 1 indicate that the range of inflation expectations differs among the groups. Therefore, in addition to rating the best forecasters of the survey done earlier, this chapter will analyse whether relevant macroeconomic variables affect the group's inflation expectations differently.

## 4.1 The Livingston Survey and results from American data

When it comes to earlier studies on inflation expectations, one will have to look outside of Norway, since studies of Norwegian data as the starting point are scarce. A survey that is central in several research papers on inflation expectations, is The Livingston Survey, an American survey of economist's expectations conducted twice a year (in June and December)[21]. The survey contains economist's predictions of 18 different variables describing macroeconomic data, including growth in the consumer price index (CPI)[22] (Federal Reserve Bank of Philadelphia 2014).

Gramlich (1983), compares the formation of inflation expectations from The Livingston Survey with surveys for households[23] and businesses. Comparing their expected (calculated) inflation rates to actual inflation rates, Gramlich (1983) found that both of the groups' inflation forecasts rejected the unbiasedness hypothesis (estimating an equation like (2.3.1) and testing whether $(\alpha,\ \beta) = (0,1)$ using an F-test with observations from 1956 to 1980). By using only observations from 1970 to 1980 to estimate (2.3.1), he finds that he cannot reject the joint hypothesis for households, indicating unbiased forecasts. In general he finds that forecast made by households were slightly more rational than forecasts by economists or businesses forecasts. In addition to the test of rationality, he sorts the households after income (high and low) and education (high and low)[24], and compares the different groups forecasting errors using measures like mean (absolute) error, root mean square error, and Theil's U-statistics. This comparison strengthened the

[21] The Livingston Survey is named after Joseph Livingston, who started the survey in 1946, but since 1990 the survey has been conducted by the Federal Reserve Bank of Philadelphia.

[22] In the Livingston Survey, the respondents are asked about expected level in CPI, which is then used to calculate expected inflation.

[23] Conducted each quarter since 1948 by Michigan's Institute for Social Research (ISR).

[24] Concentrating on observations from only five quarters in 1978-79.

results that non-economists seem to forecast slightly more rationally, and is the reverse result of the tests conducted on Norwegian data in this thesis - where economists are the best forecasters for the yearly inflation rate.

To explain the expectations formation of households and economists, Gramlich (1983) uses a modified adaptive equation model that includes current and past economic variables in addition to current and past rates of price change:

$$p^e = f(A(L)p, B(L)\mathbf{Z}) \tag{4.1.1}$$

where

$p^e$ is the expected rate of inflation

A and B refer to polynomials in the lag operator L[25].

p is the rate of inflation

**Z** is a vector of variables plausibly related to inflation. Gramlich uses the variables

m - rate of growth of the money supply

w - rate of change of wages

f - a fiscal impact variable, representing budget deficits

$(Y - Y^*)$ - the output gap, alternatively U - the unemployment rate

S - dummies for shocks; a dummy for price shocks, a dummy for wage-price controls and a dummy for when Republican presidents were in office

From Gramlich's analyses (Gramlich 1983) it turns out that both economists and households are strongly influenced by current and past inflation rates, as well as current and past rates of growth of money supply. In addition, households are also influenced by budget deficits (f), the presence of a Republican president, and wage-price controls, whereas none of these are significant for economists. As a result it seems that households believed government policy could influence inflation, while economists, who were closer to the setting of government anti-inflation policy[26], had less faith in it.

[25] The lag operator is explained in appendix A.2.

[26] Regarding the wage-price controls in the U.S. in the 1970s.

## 4.2 Variables in the models of expectations

In the model for explaining inflation expectations, Gramlich's article (Gramlich 1983) presented above is used as the point of departure. The variable we seek to explain, is the different groups' inflation expectations; H12m, B12m, W12m and E12m respectively; why are some forecasters better than others and why are are actual inflation not influenced by every group's expectations? These are in percentage form, as explained in section 2.1.

The main explanatory variable in explaining inflation forecasts is actual inflation, calculated as in equation (2.1.1), and hence will also be in percentage form. This also applies for money supply growth ($M12$) and wage growth ($W12$), where the variables are rates of annual growth. The money supply used was M2, and its exact definition can be found in appendix A.1. The yearly growth of the money supply is calculated equivalently as the inflation rate in (2.1.1):

$$M12 = \frac{M2_t - M2_{t-4}}{M2_{t-4}} \cdot 100 \tag{4.2.1}$$

Where M2 is the quarterly money stock of 'intermediate money' M2. An increased growth rate of money supply is expected to increase inflation expectations; if the money supply increases it might lower the value of money, hence leading to inflation.

To calculate the yearly growth rate in wages, a wage index for the average hourly earnings for mainland Norway is used with 1988 set as the basis year (=1). The growth rate is calculated as the money supply above, and also expected to affect the expected inflation in the same way, as increased wages leads to increased production costs and hence increased prices for the consumers. The variable representing the output gap, $gap$ is defined as the natural logarithm of Norwegian mainland GDP's deviations from trend. The trend is calculated using the Hodrick-Prescott filter with $\lambda = 1600$ [27]. A positive output gap means that demand is higher than supply and will lead to higher prices. The observations for $W$ and $gap$ are given quarterly.

In addition Gramlich (1983) has used variables such as fiscal influences, a government dummy, a shock dummy and a dummy for wage-price controls. The latter is not relevant here, as wage-price controls not have been an issue in Norway in the time period of interest. The fiscal impact variable $F$ which in Gramlich (ibid) is representing budget deficits, has also not been included in the final analyses. The price shock term $SCK$

[27] A more detailed description is given in appendix C.

used here is based on the rate of change of the average of the export and import price deflator, taking the value 1 when the rate of change is positive (indicating that import price deflator has grown more than the export price deflator). A price shock is expected to lead to increased expected inflation as such a shock leads to imported inflation.

The dummy variable *gov* has the value 1 when there's a 'conservative' majority in the government, otherwise it has the value of 0. Conservatives usually front increased competition in the market, which may lead to lower prices for the consumers and thereby lower inflation expectations. I have also chosen to include a dummy variable for the financial crisis, based on figure 2.1.1, where a jump is observed the inflation expectations. Hence, the dummy variable $CR$ takes the value 1 in the last quarter of 2007 and in each quarter of 2008.

In addition to Gramlich's variables (Gramlich 1983) I have also included the three month Norwegian Interbank Offered Rate ($Nibor$) as an explanatory variable (measured in percent). Nibor is intended to reflect the interest rate level lenders require for unsecured money market lending in NOK with delivery two days after trade (Finance Norway 2013), and should be a good indicator of the market rates. Interest rates on different debt instruments will affect individuals' plans for the future, and might also influence what they think of the future price levels. Higher interest rates will lower inflation expectations as consumers will have less money left over after repaying their debts, leading to less demand[28].

Table 9: Overview of expected effects of variables in models explaining expectations

| Variable | Expected sign in (4.3.1) |
|---|---|
| infl12 | + |
| M12 | + |
| W12 | + |
| Nibor | - |
| gap | + |
| CR | + |
| SCK | + |
| GOV | - |

[28]Higher interest rates are also likely to make it more attractive to save rather than spend money - also lowering demand.

## 4.3 The formation of 12 month inflation expectations

As economists' 12 month expectations are the only unbiased expectations of the four groups, there's a possibility that they are using different information to forecast inflation than the other groups. This section summarizes how the expectations of the different groups are influenced by different economic variables that might also affect inflation. The analyses use Gramlich (1983) as a starting point, presented in section 4.1, and the regression models are estimated using Autometrics[29]. The expectations equation used, is

$$X12m = f(\mathrm{A(L)infl12}, \mathrm{B(L)}M12, \mathrm{C(L)}W12, \mathrm{D(L)}Nibor, gap, \mathrm{S}), \qquad X = H, B, E, W \tag{4.3.1}$$

where $infl12$, $M12$, $W12$, $Nibor$ and $gap$ are the variables introduced above, together with the shock dummies compiled in S. Distributed lags are estimated for the first three explanatory variables, $gap$ is included with its first lag and the shock dummies enters contemporaneously in the models.

The observations are quarterly, and all equations were estimated using OLS[30]. First, general models that include 8 lags of the explanatory variables have been estimated in order to conduct F-tests of the overall significance of the lags. Then, Autometrics is used to specify the models, with a significance level of 5 % for reduction. The results of the final models (i.e. their static long-run equations) are presented in table 19, while the test results from the F-tests are reported in table 20. Both tables can be found in appendix G.

#### 4.3.0.1 Households

When testing the overall significance of the distributed lags of the mentioned explanatory variables, only the overall effect of Nibor was found to be significant in households' model

[29]Autometrics is a feature of PcGive providing automatic model selection given a chosen significance level of reduction (Doornik & Hendry 2009*a*).

[30]Estimation problems related to OLS are presented in section 3.1.1.

of inflation expectations. The specified model is given as[31]:

$$
\begin{aligned}
\text{H12m} = \; & \underset{(0.166)}{2.463} + \underset{(0.0315)}{0.1363}\ \text{infl12}_t + \underset{(0.0357)}{0.1048}\ \text{infl12}_{t-8} \\
& - \underset{(0.0147)}{0.07308}\ \text{M12}_{t-6} - \underset{(0.0349)}{0.08459}\ \text{W12}_{t-1} + \underset{(0.0366)}{0.112}\ \text{W12}_{t-6} \\
& + \underset{(0.0377)}{0.2826}\ \text{NIBOR}_t - \underset{(0.0616)}{0.3166}\ \text{NIBOR}_{t-2} + \underset{(0.0536)}{0.4238}\ \text{NIBOR}_{t-4} \\
& - \underset{(0.0353)}{0.1995}\ \text{NIBOR}_{t-7} - \underset{(0.0787)}{0.316}\ \text{gov}_t
\end{aligned}
\tag{4.3.2}
$$

Equation (4.3.2) shows that the wage growth rate and Nibor both have positive and negative effects on inflation expectations over time. If the wage growth rate increases by one percentage point, the inflation expectations of households will increase by 0.03 percentage points over the next one and a half year (the sum of the lags are presented in table 19); however, the sum of the lags is not significant. The overall effect of Nibor is positive, though two of the lags are working in the negative direction. The actual inflation rate works as expected, increasing expected inflation rate with 0.24 percentage points over the next two years by one percentage point increase. The growth of money supply has a negative effect on the inflation expectations of households. If the growth of money supply increases by one percentage point, the inflation expectations of households will decrease by 0.07 percentage points over the next 18 months. The only dummy variable influencing households' expectations is the government dummy, which reduces the inflation expectations by 0.32 percentage points when there's a conservative' government.

#### 4.3.0.2 Labor organizations

In the general model for inflation expectations of labor organizations the distributed lag of the inflation rate and Nibor are both significant, while the money and wage growth rates' distributed lags are not. The specified model estimated using Autometrics is as

[31] Standard errors reported in parentheses.

follows:

$$
\begin{aligned}
\text{W12m} \;=\; & \underset{(0.0797)}{1.586} + \underset{(0.0194)}{0.1795}\ \text{infl12}_t + \underset{(0.0193)}{0.1434}\ \text{infl12}_{t-1} \\
& + \underset{(0.0162)}{0.05677}\ \text{infl12}_{t-5} - \underset{(0.00626)}{0.01092}\ \text{M12}_{t-5} - \underset{(0.0167)}{0.06681}\ \text{W12}_t \\
& - \underset{(0.0166)}{0.0905}\ \text{W12}_{t-2} + \underset{(0.0348)}{0.3609}\ \text{NIBOR}_t - \underset{(0.0403)}{0.1992}\ \text{NIBOR}_{t-1} \\
& + \underset{(0.0269)}{0.1512}\ \text{NIBOR}_{t-4} - \underset{(0.0183)}{0.1251}\ \text{NIBOR}_{t-6} + \underset{(0.0373)}{0.1362}\ \text{SCK}_t
\end{aligned}
\tag{4.3.3}
$$

According to equation (4.3.3), also labor organizations' inflation expectations are influenced by the actual inflation rate. The inflation rate has a consistent and positive effect on the inflation expectations, where the sum of the coefficients is 0.38. This implies that a one percentage point increase in the inflation rate will increase the expected inflation of labor organizations by 0.38 percentage points during approximately 15 months (as the 'highest' lag is 5 periods/quarters ago). Both the growth of money supply and the wage growth rate are working in the opposite direction as expected, but the sum of their lags is not significant. Nibor is not working constantly in the same direction, but the sum of its lags is positive. Labor organizations are the only group whose expectations are influenced by price shocks: When the import price index rises more than the export price index, labor organizations expect 0.2 percentage points higher inflation.

#### 4.3.0.3 Executives

Table 20 shows the results from the F-test, where the overall effect of the distributed lags of only Nibor can be said to be significant in the model. In the specified model given by

(4.3.4), $Infl12$, $W12$ and $Nibor$ all have significant lags, while $M12$ has fallen out:

$$\begin{aligned} \text{B12m} = \ & \underset{(0.125)}{1.261} + \underset{(0.0192)}{0.06705}\ \text{infl12}_t + \underset{(0.0211)}{0.06239}\ \text{infl12}_{t-8} \\ & + \underset{(0.0215)}{0.07824}\ \text{W12}_{t-3} + \underset{(0.0214)}{0.1027}\ \text{W12}_{t-6} + \underset{(0.0224)}{0.07824}\ \text{W12}_{t-8} \\ & + \underset{(0.0396)}{0.3003}\ \text{NIBOR}_t - \underset{(0.0461)}{0.2133}\ \text{NIBOR}_{t-1} + \underset{(0.0277)}{0.08199}\ \text{NIBOR}_{t-4} \\ & - \underset{(0.0221)}{0.1913}\ \text{NIBOR}_{t-7} - \underset{(0.0436)}{0.1628}\ \text{gov}_t \end{aligned} \qquad (4.3.4)$$

In contrast to the two preceding groups, the expectations of executives are negatively influenced by Nibor. A one percentage point increase in interest rate will over time lead to 0.02 percentage points lower expected inflation. The inflation rate is also here working positively; when the actual inflation rate increases with one percentage point, the inflation expectations of executives will increase with 0.13 point. An increase in the wage growth rate also has a positive effect, as a one percentage point increase will increase inflation expectations with 0.26 percentage points over the next two years. As with households, executives are also negatively influenced by a 'conservative' government in their expectations. Their expectations will be reduced by 0.16 percentage points when there's a change in government to a more conservative one.

#### 4.3.0.4 Economists

The best forecasters of inflation do not really stand out regarding what variables are affecting their inflation expectations compared to the other groups, but there are a few differences. In the general model, only the distributed lags of the interest rate, Nibor, is overall significant. The specified model is expressed as:

$$
\begin{aligned}
\text{E12m} = \; & \underset{(0.113)}{1.301} + \underset{(0.0156)}{0.06603}\ \text{infl12}_{t-3} + \underset{(0.0152)}{0.04348}\ \text{infl12}_{t-4} \\
& - \underset{(0.00963)}{0.0952}\ \text{M12}_{t} + \underset{(0.0145)}{0.079}\ \text{M12}_{t-2} - \underset{(0.015)}{0.05138}\ \text{M12}_{t-5} \\
& + \underset{(0.0131)}{0.04705}\ \text{M12}_{t-6} + \underset{(0.0149)}{0.07322}\ \text{W12}_{t-2} + \underset{(0.0167)}{0.06531}\ \text{W12}_{t-5} \\
& + \underset{(0.017)}{0.1091}\ \text{W12}_{t-8} + \underset{(0.0202)}{0.2092}\ \text{NIBOR}_{t} - \underset{(0.0216)}{0.153}\ \text{NIBOR}_{t-2} \\
& - \underset{(0.0239)}{0.119}\ \text{NIBOR}_{t-5} - \underset{(0.0211)}{0.0503}\ \text{NIBOR}_{t-7} + \underset{(0.076)}{0.3408}\ \text{CR}_{t}
\end{aligned}
\tag{4.3.5}
$$

Correspondingly to the models of households and labor organizations, the growth in money supply works negatively, but the other variables are here working as expected. The inflation rate is having a positive effect, where a one percentage increase in the inflation rate over the next year will increase economists' inflation expectations with 0.11 percentage points. A one percentage point increase in the wage growth rate will over the next two years increase expectations by 0.25 percentage points. The effect of Nibor is not working constantly over time, but the sum of the lags is negative, indicating that a one percentage point in the interest rate reduces inflation expectations by 0.11 percentage points during the next 21 months. Economists are the only group significantly influenced by the financial crisis, increasing their inflation expectations by 0.34 percentage points.
Despite this, the model estimated for economists does not seem to be a good model for explaining their inflation expectations, as there is a problem of autocorrelation in the residuals[32]. The problem is removed by including a lagged variable of the endogenous variable, $E12m_{t-1}$, which doesn't seem to have too big consequences in the long-run model ($E12m^B$ in table G.3), as the coefficients are approximately the same.

In summary, the inflation expectations of all groups have not been constantly and 'correctly'[33] influenced by the same variables, except for the actual inflation rate, which influenced all the groups' expectations positively. None of the groups' expectations was influenced by the output gap, while only the economists' expectations were influenced

[32]Hence, the standards errors and t-values reported in equation (4.3.5) are HACSE.
[33]Correctly in the sense that they work as expected.

by the financial crisis. The growth rate in money supply has both positive and negative effect over time for three of the groups, but it did not have any effect on executives. The wage growth rate on the other hand, influenced all the groups' expectations, but only labor organizations were influenced negatively. Labor organizations are also the only group influenced by price shocks. The two 'worst' forecast groups from table 3, are also the ones influenced by the parties in government. These analyses have in other words not revealed any major differences in the information sets used by the groups.

In the previous chapter, ADF-tests revealed that $Nibor$ and $W12$ are I(1)-variables. This did however not seem to affect the residuals of the models, as the results from ADF-tests conducted on them implied stationarity (see table 16 in appendix G). A graphical analysis of the parameter stability in the models is presented in section 5.2 and appendix G.5 after the remaining regression analyses are completed.

# 5 Wage-Price system as basis for predicting inflation

To predict inflation, I use a theoretical model of wage-price adjustment originally set out by Layard and Nickell (1986) and Layard et al. (1991), based on theories of imperfect competition in goods and labor markets. The model of Layard and Nickell (1986) has later been adapted by among others Kolsrud & Nymoen (1998) and Bårdsen et al. (1997), where the latter is the basis for the model presented in this thesis. The reason for using a system, is the mutual dependence between prices and wages. Wages are negotiated with an eye on past and expected inflation, while prices are influenced by costs and particularly labor costs. Hence, predicting inflation using such a system, can be an equivalent to the predictions of the representatives of labor organizations from the expectations survey.

The wage-price system can be summed up in three equations[34]:

$$\begin{aligned}\Delta w_t =& c_1 + \alpha_{12,0}\Delta q_t + \alpha_{11}(L)\Delta w_t + \alpha_{12}(L)\Delta q_t + \beta_{12}\Delta z_t \quad (5.0.1)\\ &- \beta_{14}(L)\Delta U_t - \gamma_{11} ecm^b_{t-r} + \beta_{16}(L)\Delta p_t + \epsilon_{1t}\\ \Delta q_t =& c_2 + \alpha_{21,0}\Delta w_t + \alpha_{22}\Delta q_t + \alpha_{21}(L)\Delta w_t + \beta_{21}(L)gap_t \quad (5.0.2)\\ &- \beta_{22}\Delta z_t - \gamma_{22} ecm^f_{t-r} + \epsilon_{2t}\\ p_t =& (1-\zeta)q_t + \zeta pi_t \quad (5.0.3)\end{aligned}$$

where

Lower case letters indicate the natural log of the corresponding upper-case variable names[35]:

$W_t$ - nominal wage rate

$Q_t$ - product price index

$Z_t$ - labor productivity

$U_t$ - aggregated unemployment rate[36]

[34]Tax rate variables are often included in such systems, but ignored in this framework.

[35]The advantage of using natural logarithms of variables, is that the assumptions underlying the regression analysis are better met. A log transformation of strictly positive variables can mitigate, if not eliminate problems of heteroskedacity or skew-ness of the variables' conditional distributions (Wooldridge 2013).

[36]Since the unemployment rate is measured in percent, the natural log is not used on U.

$P_t$ - consumer price index

$gap_t$ - output gap

$PI_t$ - import price index

$\epsilon_{it},\ i = 1, 2$ - error terms, assumed to fulfil the assumptions listed in section 3.1.1 (i.e. it is white noise).

$\alpha_{ij}(L) = \alpha_{ij,1}L + \cdots + \alpha_{ij,(r-1)}L^{(r-1)},\ i = 1, 2,\ j = 1, 2.$

$\beta_{1j}(L) = \beta_{1j,0} + \beta_{1j,1}L + \cdots + \beta_{1j,(r-1)}L^{(r-1)},\ j = 2, 4, 5, 6$

$\beta_{2j}(L) = \beta_{2j,0} + \beta_{2j,1}L + \cdots + \beta_{2j,(r-1)}L^{(r-1)},\ j = 1, 2, 5$

$r$ is the order of lag polynomials and might vary between the variables, and hence determined empirically.

Equation (5.0.1) gives the relationship between wage growth and changes in producer and consumer prices, past changes in the wage rate, productivity and the unemployment rate. In addition the error correction term represents deviations from desired wage level given by:

$$ecm_t^b = w_t - d_{11}p_t - d_{12}z_t + d_{13}pi_t + d_{15}U_t$$

Equation (5.0.2) gives the relationship between product price inflation and past inflation, current and past wage growth, the output gap and productivity. The error correction term represents the deviations from the equilibrium price:

$$ecm_t^f = p_t - \rho_{21}w_t + \rho_{22}z_t - \rho_{23}pi_t$$

Equation (5.0.3) says that the consumer prices is influenced by both product prices and import prices. $0 < \zeta < 1$ where $\zeta$ reflects the openness of the economy.

By differencing (5.0.3), solving it for $\Delta q_t$ and substituting out in (5.0.1) and (5.0.2), we end up with a simultaneous wage-price system[37]:

$$\begin{aligned}\Delta w_t =& c_{11} + a_{11}(L)\Delta w_t + a_{12,0}\Delta p_t - a_{12}(L)\Delta p_t + a_{13}(L)\Delta z_t \\ & - a_{14}(L)\Delta pi_t - a_{15}(L)\Delta U_t \\ & - \gamma_{11}[w - d_{11}p - d_{12}z + d_{13}pi + d_{15}U]_{t-1} + e_1\end{aligned} \tag{5.0.4}$$

$$\begin{aligned}\Delta p_t =& c_{22} + b_{21}(L)\Delta p_t + a_{22,0}\Delta w_t - a_{22}(L)\Delta w_t + a_{23}(L)gap_t \\ & - b_{24}(L)\Delta z_t + b_{25}(L)\Delta pi_t \\ & - \gamma_{22}[p - \rho_{21}w_t + \rho_{22}z - \rho_{23}pi]_{t-1} + e_2\end{aligned} \tag{5.0.5}$$

Since this is a simultaneous model, equation (5.0.5) can't be estimated on its own. $e_2$ will be correlated with $\Delta w_t$ as $\Delta p_t$ and thereby $e_2$ influences $\Delta w_t$ in equation (5.0.4). Substituting $\Delta w_t$ and $w_t$ from (5.0.4) into (5.0.5) (still ignoring the identification of the parameters), gives us a reduced form model, appropriate for predicting inflation[38]:

$$\begin{aligned}\Delta cpi_t =& c_{21}(L)\Delta cpi_t + \upsilon_{21}(L)gap_t + \upsilon_{22}(L)\Delta z_t + \upsilon_{23}(L)\Delta pi_t \\ & - \upsilon_{24}(L)U_t - d_{22}[p + \theta_{21}z - \theta_{22}pi - \theta_{23}U]_{t-1} \\ & + \mu + \theta_{25}D_{1t} + \theta_{26}D_{2t} + \theta_{27}D_{3t} + e_{22t}\end{aligned} \tag{5.0.6}$$

where

$$c_{21}(L) = c_{21,1}L + c_{21,2}L^2 + \cdots + c_{21,(r-1)}L^{(r-1)}$$

$$\upsilon_{2i}(L) = \upsilon_{2i,0} + \upsilon_{2i,1}(L) + \cdots + \upsilon_{2i,(r-1)}L^{(r-1)},\ i = 1, 2, 3$$

$D_{it},\ i = 1, 2, 3$ are quarterly dummies, for the three first quarters of the year.

This model is an error correction model, where $p_{t-1} + \theta_{21}z_{t-1} - \theta_{22}pi_{t-1} - \theta_{23}U_{t-1} = ecm_{t-1}$ is the error correction term. The error correction term will be explained more in the next section. The quarterly dummies are included in order to correct for seasonality as explained in section 3.2.2.

The model given in (5.0.6), does however not contain information about inflation expectations, which might be relevant to the actual inflation rate. The expectations of

[37] The identification of parameters is here disregarded, as the main aim is to find the variables used in a model for predicting inflation.

[38] Setting $\Delta p_t = \Delta cpi_t$

interest contain information not included in the model above, be it the Nibor, growth in money supply or different shock dummies. As shown in the previous chapter, also the wage growth rate may work indirectly through inflation expectations of the groups. The expectation variables are divided by four to find the expected quarterly inflation rate, indicating an assumption of similar expectations for each quarter of a year.

## 5.1 Estimation results

In order to find out whether any of the groups' expectations are relevant for predicting inflation, the following general model is the starting point for Autometrics:

$$\begin{aligned}\Delta cpi_t =& c_{21}(L)\Delta cpi_t + \upsilon_{21}(L)gap_t - \upsilon_{22}(L)\Delta z_t + \upsilon_{23}(L)\Delta pi_t \\ &+ \upsilon_{24}(L)\Delta U_t - d_{22}[p + \theta_{21}z - \theta_{22}pi + \theta_{24}U]_{t-1} \\ &+ \mu + \theta_{25}D_{1t} + \theta_{26}D_{2t} + \theta_{27}D_{3t} + \theta_{2X9}(L)\left(\frac{X12m_t}{4}\right) + e_{22t}\end{aligned} \tag{5.1.1}$$

Where four lags[39] of the differenced variables and the first lag of $gap_t$ are included. When it comes to the expectations variables, four lags are included, indicating that also the 12 months inflation expectations of the groups until a year ago, might influence the quarterly inflation rate this quarter. Six general models are used, one for each group and then one model including all four groups, in addition to the original model without expectations.

### 5.1.1 Estimating the error correction term using the Johansen-method

For a VAR, Johansen (1992) showed how to estimate cointegrating relations in a partially modelled system, and how weak exogeneity is a crucial assumption for making inference on the cointegrating relations. This section will present a cointegrated VAR and the underlying assumptions required in order to test hypothesis on the cointegrated vector in the model, following Harbo et al.(1998).

The vector error correction model (VECM) is a representation of a cointegrated VAR[40] and used as a starting point. With the wage-price system in mind, the VECM is here

[39]The lag length was decided when the error correction term was estimated using Autometrics in the next section.
[40]A VECM gives the opportunity to evaluate both the long term and short term effects.

two-dimensional and has a cointegrating rank of r:

$$\Delta X_t = \alpha\beta' X_{t-1} + \sum_{i-1}^{k-1} \Gamma_i \Delta X_{t-i} + \mu + \delta D_{jt} + \epsilon_t \tag{5.1.2}$$

Where $X_t$ is a $(2 \cdot 2)$ vector of variables at time $t = 1, \ldots, T$, and $\{\epsilon_t\}_{t=1}^{T}$ is independent and distributed as $N_2(0, \Omega)$. $\mu$, $\delta$ and $\epsilon_t$ are $(2 \cdot 1)$ vectors, while $\alpha$ and $\beta$ are $(2 \cdot r)$ matrices and $\Gamma_1, \ldots, \Gamma_{k-1}$ are $(2 \cdot 2)$ matrices. The covariance matrix $\Omega$ is positive definite and symmetric. The linear term in the VAR model of Harbo et al. (1998) is here replaced by deterministic variables (seasonal dummies), for $j = 1, 2, 3$. $\alpha\beta' X_{t-1}$ is the error correction term, where $\beta'$ contains the r cointegrating vectors and $\alpha$ contains the r adjustment vectors.

$X_t$ is assumed to be an I(1)-variable, and (5.1.2) is simplified by setting $k = 2$:

$$\Delta X_t = \alpha\beta' X_{t-1} + \Gamma_1 \Delta X_{t-1} + \mu + \delta D_{jt} + \epsilon_t \tag{5.1.3}$$

$X_t$ can be decomposed into $Y_t$ and $Z_t$, where $Y_t$ is of dimension $p_1$ and $Z_t$ of dimension $p_2$: $X_t' = (Y_t', Z_t')$. The system can now be expressed as:

$$\begin{pmatrix} \Delta Y_t \\ \Delta Z_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \begin{pmatrix} \beta_1 & \beta_2 \end{pmatrix} \begin{pmatrix} Y_{t-1} \\ Z_{t-1} \end{pmatrix} + \begin{pmatrix} \Gamma_{11} & \Gamma_{12} \\ \Gamma_{21} & \Gamma_{22} \end{pmatrix} \begin{pmatrix} \Delta Y_{t-1} \\ \Delta Z_{t-1} \end{pmatrix} + \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + \begin{pmatrix} \delta_{j1} \\ \delta_{j2} \end{pmatrix} D_{jt} + \begin{pmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{pmatrix} \tag{5.1.4}$$

The covariance matrix is hence given as $\Omega = \begin{pmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{pmatrix}$. Then the partial or conditional model for $\Delta Y_t$ is defined by the equation

$$\begin{aligned} \Delta Y_t =& \omega \Delta Z_t + (\alpha_1 - \omega\alpha_2)\beta' X_{t-1} + (\Gamma_{11} - \omega\Gamma_{21})\Delta X_{t-1} \\ &+ (\mu_1 - \omega\mu_2) + (\delta_{j1} - \omega\delta_{j2}) D_{jt} + \epsilon_{ct} \end{aligned} \tag{5.1.5}$$

where $\omega = \Omega_{12}\Omega_{22}^{-1}$ and $\epsilon_{ct} = \epsilon_{1t} - \omega\epsilon_{2t}$. The condtitional model for $\Delta Z_t$ is given by the equation

$$\Delta Z_t = \alpha_2 \beta' X_{t-1} + \Gamma_{22} \Delta X_{t-1} + \mu_2 + \delta_{2j} D_{jt} + \epsilon_{2t} \tag{5.1.6}$$

In order to conduct inference on $\beta$ in (5.1.5), $\alpha_2$ must equal 0. That is, there cannot be any information about $\beta$ in the marginal model of $\Delta Z_t$, making $Z_t$ weakly exogenous. It follows that equation (5.1.6) does not contain an error correction term, so that the variables $Z_t$ do not react to disequilibrium. If $\alpha_2 \neq 0$, inference on $\beta$ in the conditional model will be inefficient and difficult because the asymptotic distributions of the test statistics derived from the conditional model involve nuisance parameters (Harbo et al. 1998).
Equation (3.3.3) can be interpreted as a conditional model, with $\beta' X_{t-1} = y_{t-1} - \frac{\beta_1 + \beta_2}{1-\alpha_1} x_{t-1}$. By assuming that the cointegrating rank is 1, and that the variables in the marginal model are weakly exogenous, we can conduct inference on the cointegrating relationship in equation (3.3.3).

Model (5.1.1) can be understood as a conditional model for inflation, so the explanatory variables have to be weakly exogenous in order for inference on the error correction term to be valid. The error correction term is conditioned upon the explanatory variables from model (5.0.6) without expectations. Using a system to estimate the error correction term, revealed that the import price index is not weakly exogenous, which might lead to bias in the estimates. However, the estimates should be super consistent, as the variables all are I(1) (Engle & Granger 1987). The estimation results of the system can be found in appendix E.

The cointegrating vector found by using a marginal model for $\Delta cpi$, and is expressed as[41][42]:

$$ecm_{t-1} = cpi_{t-1} - \underset{(0.12)}{0.70} pi_{t-1} - \underset{(0.14)}{0.14} z_{t-1} + \underset{(0.01)}{0.03} U_{t-1} \tag{5.1.7}$$

and gives the long term relationship between the consumer price index, the import price index and unemployment rate. Productivity $z$ is according to this sample not having a long term effect on the consumer price index, as its coefficient is not significantly different from zero. Since the consumer price and import price indexes are in natural logs, the coefficient of $pi$ can be interpreted as elasticity. If the import price index increases by 1 %, the consumer price index will increase with 0.7 %. As Norway is a small open economy, imported inflation is not a surprising result.
By a one percentage point increase in the unemployment rate, the consumer price index will decrease by 3%. The unemployment rate is from (5.0.4) expected to have a negative effect on wages, as increased unemployment reduces the bargaining power' of employees

[41] Standard errors in parentheses.
[42] Estimation period is from 1990:1-2015:3, as $\Delta cpi$ only is stationary after 1990.

in wage negotiations (Blanchflower & Oswald 1994). Reduced wages will further lead to less demand, and therefore lower prices.

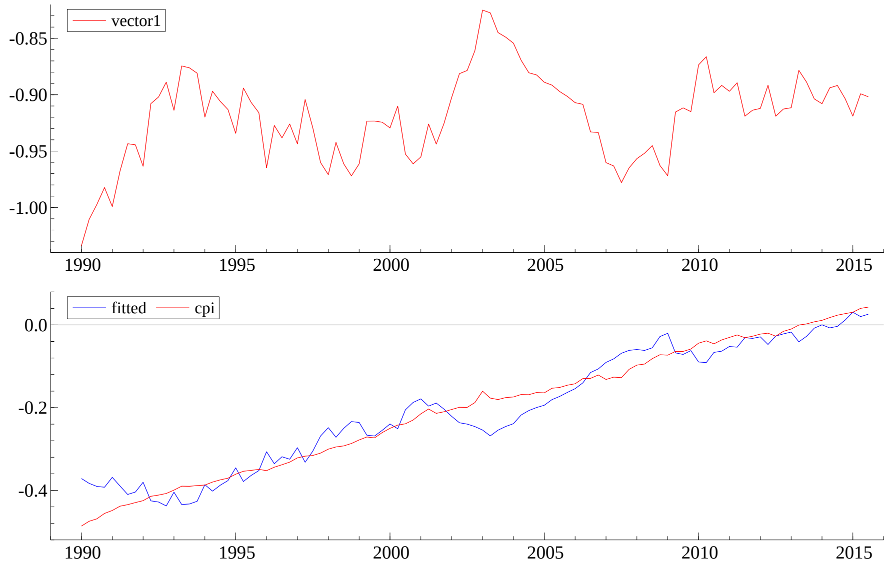



Figure 6: Cointegration vector and cointegrating relationship

The upper part of figure 6 shows the estimated cointegration vector. The vector is during the early 90s stabilising around one value[43], but from 2002 till 2003 there seems to be a large increase in the consumer price index leading to a shock in the vector. However, with the exception of the shock the vector seems to be stable, indicating a cointegrating relationship. The lower part of the figure has resolved the vector in the actual consumer price index (red line) and the estimated value from the cointegrating vector (blue line). The two lines are on the whole following each other, supporting the existence of a cointegrating relationship. Also here, the deviation around 2003 is noticeable, as the actual consumer price index is much higher than the estimated value from the vector.

The deviation in 2002-2003 is due to a large increase in the prices of electricity, giving a rise in the CPI of 5 percent (Statistics Norway 2003). The prices of electricity in January 2003 were 82.5 percent higher than the corresponding period in 2002 (ibid). The electricity prices are also the reason why the vector is stabilising at a higher level after 2010 (Statistics Norway 2010); the 12-month growth from February 2009 was 21.5 percent just in the electricity prices. Thus, the fluctuations in the vector seems to be largely due to fluctuations in the electricity prices.

[43] An ADF-test (with a constant) yields a t-statistic of -7.328 (with 1 lag), indicating that the error correction term is stationary.

The cointegration vector was estimated using impulse dummies for extreme outliers, which takes the value 1 in the quarter where a shock occurs, 0 else. These dummies can capture large changes in the consumer price index not properly explained by the model. Such extreme outliers might lead to a rejection of the normality assumption (Brooks 2014), therefore it is advisable to avoid them by for instance including impulse dummies. Autometrics includes these dummies when large residuals are discovered. As explained above, there are some deviations, but only a dummy for the first quarter of 2003 was significant when estimating the cointegrating vector using the conditional model for $\Delta cpi$.

### 5.1.2 Error correction model

The error correction model, given in (5.1.1), is estimated using Autometrics. Insignificant lags are excluded, and impulse dummies are included in order to get a well-specified model. In order to test whether expectations may improve the reduced form model for inflation, the model is first estimated without expectations[44]:

$$\begin{aligned}
\Delta \text{cpi} \;=\;& \underset{(0.117)}{0.3816}\ \Delta \text{cpi}_{t-1} + \underset{(0.0217)}{0.04498}\ \Delta \text{pi}_{t-3} - \underset{(0.024)}{0.0717}\ \Delta \text{pi}_{t-4} \\
& + \underset{(0.00211)}{0.005766}\ \Delta \text{U}_{t-4} + \underset{(0.0218)}{0.04339}\ \Delta \text{z}_{t-3} + \underset{(0.0216)}{0.05888}\ \Delta \text{z}_{t-4} \\
& + \underset{(0.0255)}{0.07253}\ \text{gap}_{t-1} - \underset{(0.162)}{0.4955}\ \text{ecm}_{t-1} + \underset{(0.000725)}{0.003014} \\
& - \underset{(0.0036)}{0.01903}\ \text{D}_{1t} - \underset{(0.00384)}{0.01407}\ \text{D}_{2t} - \underset{(0.00313)}{0.01949}\ \text{D}_{3t} \\
& + \underset{(0.00412)}{0.02338}\ \text{I:2003(1)}_t - \underset{(0.00488)}{0.03055}\ \text{I:2003(2)}_t
\end{aligned} \tag{5.1.8}$$

The estimated error correction model, shows that the import price index, unemployment rate, productivity and output gap all have significant short run effects. $\Delta pi$ is however significant with two lags with different signs, and the short run effect of unemployment is positive. In order to simplify the interpretation of the short run dynamics, a reparameterisation is conducted which requires that each variable in steady-state is dated at their longest lag. This should give the short run parameters an implicit dynamic multiplier

[44]The estimation period is from 1990:2-2015:3.

interpretation in addition to simplifying the dynamics since short-run terms often drop out by reparameterisation (Bårdsen et al. 2007). The reparameterisation yields[45]:

$$ecm(t) = p_t - \underset{(0.12)}{0.70} pi_{t-5} - \underset{(0.14)}{0.14} z_{t-5} + \underset{(0.01)}{0.03} U_{t-5} \tag{5.1.9}$$

In addition, since there is two significant effects of $\Delta pi$ with different signs, the variable $\Delta_3\Delta_4 pi = (\Delta pi_{t-3} - \Delta pi_{t-4})$ is created and replaces the two original $\Delta pi$'s. This new variable allows the interpretation of the possible effect of the acceleration in the growth rate of the import price index. The re-estimation of the model did however not result in any major changes in the model, expressed as (1):

$$\begin{aligned} \Delta\text{cpi} = \; & \underset{(0.11)}{0.3501}\ \Delta\text{cpi}_{t-1} + \underset{(0.0154)}{0.05709}\ \Delta_3\Delta_4\text{pi}_t + \underset{(0.00209)}{0.005967}\ \Delta\text{U}_{t-4} \\ & + \underset{(0.0217)}{0.04305}\ \Delta\text{z}_{t-3} + \underset{(0.0215)}{0.06001}\ \Delta\text{z}_{t-4} + \underset{(0.0254)}{0.0737}\ \text{gap}_{t-1} \\ & - \underset{(0.157)}{0.4626}\ \text{ecm(t)} + \underset{(0.000722)}{0.003048} - \underset{(0.00359)}{0.01884}\ \text{D}_{1t} \\ & - \underset{(0.00382)}{0.01387}\ \text{D}_{2t} - \underset{(0.00312)}{0.01968}\ \text{D}_{3t} + \underset{(0.0041)}{0.0236}\ \text{I:2003(1)}_t \\ & - \underset{(0.00471)}{0.02955}\ \text{I:2003(2)}_t \end{aligned} \tag{5.1.10}$$

Of the mis-specification tests listed in table 10 (column (1)), only the null hypothesis of normally distributed error terms is rejected. Figure 11 in appendix G.2, shows that the density of the residuals is leptokurtic. The scaled residuals in the lower part of figure 7, have some observations outside ±2 standard errors[46]. Impulse dummies capturing the effect of a positive and negative shock in the two first quarters of 2003 are therefore included in the model[47].

In model (5.1.10), the import price index, unemployment rate and productivity all have significant effects in their differenced form. An increased quarterly inflation rate the previous quarter from 0.5% to 1% [48], will lead to 35% higher quarterly inflation this

[45] The cointegration vector is denoted ecm(t) to indicate that the variables included might have different lags.

[46] Figure 7 shows the scaled residuals in a model not including impulse dummies.

[47] Both shocks were due to changes in electricity prices (Statistics Norway 2003a, b)

[48] According to the descriptive statistics given in table 15 in appendix G.1 the mean quarterly inflation

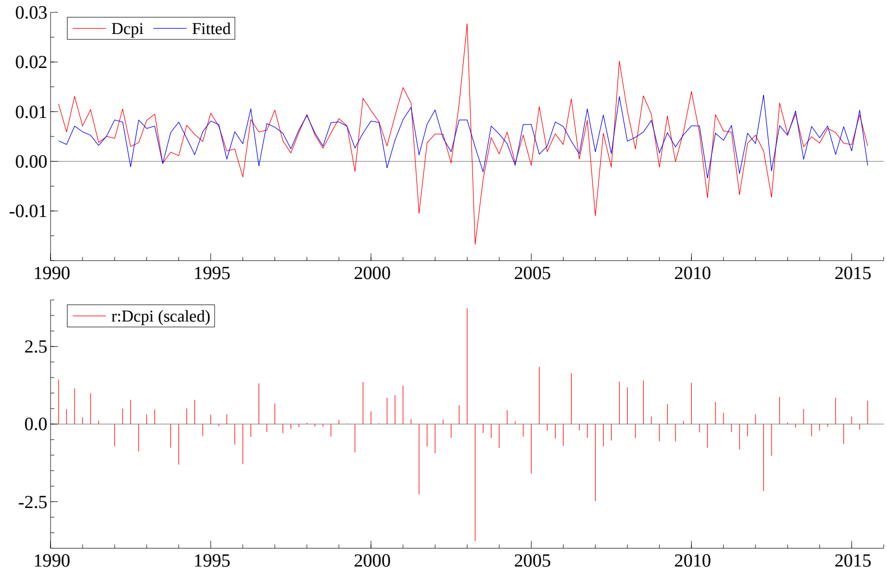



Figure 7: Error correction model without expectations and impulse dummies

quarter. As mentioned, the import price index was originally significant at its third and fourth lag with different signs. Using $\Delta_3\Delta_4 pi$, the effect is 0.06, indicating that a higher growth rate in the import price index three quarters ago than that of four quarters ago, results in a positive effect on the consumer price. Hence an accelerating growth in the import price index is influencing the consumer prices positively.

An increase of 1% in the quarterly growth rate of productivity will over the following year lead to 0.1% higher quarterly inflation rate. If the unemployment rate increases from 0 to 0.5 percentage point, the quarterly inflation rate will over the year increase with 0.3%. This is a surprising result and inconsistent with the long-run effect, which is negative. A reparameterisation of the model did not change the effect of the growth in the unemployment rate.

An increase in the output gap of 1% in the preceding quarter, will lead to 0.07% higher quarterly inflation rate. The error correction term has a high adjustment rate, of 0.46, indicating that 46% of the deviations from the long run consumer price in the preceding quarter will be corrected for in this quarter. The deterministic dummies indicates that the fourth quarter has higher quarterly price growth, as the seasonal dummies are negative. The impulse dummies correct for a large positive and negative residual in the first and second quarter of 2003 respectively.

rate is 0.5%.

The purpose of this model is to analyse whether it is improved by including the expectations of any of the groups presented earlier in the thesis. When the group's expectations are included, only the observations from 2002 and after is used, restraining the model. In addition, when expectations are included, the error correction term will be fixed, in order to evaluate what happens to the long run equilibrium of the model. The models including households', labor organizations', executives' and economists' inflation expectations are as follows[49]:

With inflation expectations of households (2):

$$\begin{aligned}\Delta\text{cpi} \;=\; & \underset{(0.00219)}{0.01294}\ \Delta\text{U}_{t-1} + \underset{(0.0229)}{0.0592}\ \text{gap}_{t-1} + \underset{(0.00386)}{0.022}\ \text{H12m4}_t \\ & - \underset{(0.00383)}{0.01548}\ \text{H12m4}_{t-3} - \underset{(0.148)}{0.1786}\ \text{ecm}_{t-1}\end{aligned} \tag{5.1.11}$$

With inflation expectations of labor organizations (3):

$$\begin{aligned}\Delta\text{cpi} \;=\; & -\underset{(0.168)}{0.9564}\ \Delta\text{cpi}_{t-1} - \underset{(0.126)}{0.654}\ \Delta\text{cpi}_{t-2} - \underset{(0.131)}{0.5271}\ \Delta\text{cpi}_{t-3} \\ & - \underset{(0.122)}{0.2068}\ \Delta\text{cpi}_{t-4} + \underset{(0.0034)}{0.01403}\ \Delta\text{U}_t + \underset{(0.00314)}{0.01415}\ \Delta\text{U}_{t-1} \\ & + \underset{(0.00826)}{0.05838}\ \text{W12m4}_t - \underset{(0.00721)}{0.02841}\ \text{W12m4}_{t-3} + \underset{(0.24)}{0.4499}\ \text{ecm}_{t-1}\end{aligned} \tag{5.1.12}$$

With inflation expectations of economists (4):

$$\begin{aligned}\Delta\text{cpi} \;=\; & -\underset{(0.143)}{0.4318}\ \Delta\text{cpi}_{t-1} + \underset{(0.0032)}{0.01191}\ \Delta\text{U}_t + \underset{(0.0237)}{0.09629}\ \Delta\text{z}_t \\ & - \underset{(0.0269)}{0.1118}\ \Delta\text{z}_{t-3} - \underset{(0.00469)}{0.0264}\ \text{D}_{3t} + \underset{(0.0159)}{0.07665}\ \text{E12m4}_t \\ & - \underset{(0.0158)}{0.06344}\ \text{E12m4}_{t-1} + \underset{(0.238)}{0.4902}\ \text{ecm}_{t-1}\end{aligned} \tag{5.1.13}$$

[49] $X12m4 = \dfrac{X12m}{4}$ for $X = H, B, E, W$.

With inflation expectations of executives (5):

$$\begin{aligned}\Delta\text{cpi} \;=\; & -\underset{(0.165)}{0.4084}\ \Delta\text{cpi}_{t-1} + \underset{(0.0362)}{0.08116}\ \Delta\text{z}_t - \underset{(0.00397)}{0.008169}\ \text{D}_{2t} \\ & -\underset{(0.00449)}{0.01438}\ \text{D}_{3t} + \underset{(0.00202)}{0.01067}\ \text{B12m4}_t + \underset{(0.288)}{0.4329}\ \text{ecm}_{t-1}\end{aligned} \tag{5.1.14}$$

The first noticeable feature of the models including inflation expectations, in addition to all expectations having significant effects, is that three of them is containing an error correction term with a positive coefficient, indicating that the models are not converging in the long run. In fact, only the model containing households' expectations has a error correction term with a negative coefficient, but this is not significant. Thus, the models containing expectations do not seem to have a long run equilibrium. Because of the difference in number of observations, an LR-test of whether the restrictions in model (1) are valid, will not be possible. The best model of the five presented are however according to two of the three information criteria[50] in table 11, the model without expectations, model (1). Only Schwarz's Bayesian information criterion find the model using households' expectations better, but this is also the information criterion that embodies a stiffer penalty term for additional parameters than the two others. When the error correction term was removed from models (2)-(5), the information criteria remained unchanged with two of them choosing the original model (see appendix F).

As a final test of whether expectations might improve the current reduced-form for inflation, a model including inflation expectations of all groups is estimated (6):

$$\begin{aligned}\Delta\text{cpi} \;=\; & -\underset{(0.00171)}{0.01154}\ \Delta\text{U}_{t-2} - \underset{(0.00986)}{0.04272}\ \text{B12m4}_t + \underset{(0.0108)}{0.03251}\ \text{B12m4}_{t-4} \\ & -\underset{(0.00919)}{0.02502}\ \text{W12m4}_{t-4} + \underset{(0.00608)}{0.01243}\ \text{H12m4}_t - \underset{(0.00547)}{0.02688}\ \text{H12m4}_{t-3} \\ & +\underset{(0.0116)}{0.03887}\ \text{E12m4}_t + \underset{(0.0112)}{0.02772}\ \text{E12m4}_{t-3} - \underset{(0.127)}{0.2034}\ \text{ecm}_{t-1}\end{aligned} \tag{5.1.15}$$

In model (6), the expectations of all groups are significant. Of the variables from the

[50] The information criteria are Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SC) and the Hannan-Quinn criterion (HQIC). The difference between them is how they punish loss of degrees of freedom (Brooks 2014). See appendix A.3.

original model, only the second lag of the differenced unemployment rate is significant. The unemployment rate now has a negative effect as in the long-run, indicating that an increase of half a percentage point in the unemployment rate, will decrease the quarterly inflation rate with 0.5% over the following six months. The error correction term is not significant in the model, and when it is not fixed, the differenced unemployment rate becomes significant with different effects at different lags. The differenced productivity also becomes significant in the model without the restrained error correction term (see equation (F.1.5) in appendix F).

The expectations of executives and households are both significant with different effects at different lags. An increase in the inflation expectations of executives seem to initially decrease the quarterly inflation rate, but the decrease will over the following year become smaller. The total effect of a one percentage point increase in the 12 month inflation expectations of executives, is an decrease in the quarterly inflation rate with 0.25%. Household's inflation expectations have initially a positive effect, but the effect becomes negative over time. An increase of household's 12 month inflation expectations of one percentage point will hence over the following 9 months decrease the quarterly inflation rate with $1.4 \times 0.25 = 0.35\%$. Labor organizations inflation expectations also have a negative effect on the quarterly inflation rate: If their 12-month inflation expectations increase with half a percentage point, the quarterly inflation rate will decrease with $2.5 \times 0.125 = 0.31\%$. If the 12-month inflation expectations of economists increase with half a percentage point, the quarterly inflation rate will over the following 9 months increase with $6.7 \times 0.125 = 0.84\%$.

In other word, if the inflation expectations of executives, labor organizations or households increases, this will lead to a decline in the actual inflation rate. Economists' increased inflation expectations on the other hand are having a positive effect on the actual inflation rate. Most of the 'traditional' variables in the wage-price system are falling out of the model when inflation expectations are included, in addition to the long-run equilibrium. There are in other words few similarities between the model (1) and model (6).

Table 11: Selection of model based on information criteria

| Model | AIC | HQ | SC |
|---|---|---|---|
| (1) | -8.15< | -8.01< | -7.81 |
| (2) | -8.01 | -7.94 | -7.82< |
| (3) | -7.58 | -7.45 | -7.24 |
| (4) | -7.50 | -7.38 | -7.20 |
| (5) | -7.15 | -7.06 | -6.92 |
| (6) | -8.31< | -8.18< | -7.97< |

Table 10: Reduced form-model for inflation

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| T | 102 | 49 | 51 | 51 | 51 | 49 |
| Sigma | 0.004 | 0.004 | 0.005 | 0.005 | 0.006 | 0.003 |
| log-likelihood | 428.44 | 201.22 | 202.29 | 199.21 | 188.32 | 212.71 |
| | | | | | | |
| AR 1-5 test | 1.58 (0.17) | 1.19 (0.33) | 0.31 (0.87) | 1.05 (0.39) | 0.27 (0.90) | 0.63 (0.64) |
| ARCH 1-4 test | 0.77 (0.54) | 3.03 (0.03)* | 0.61 (0.66) | 0.34 (0.85) | 2.34 (0.07) | 1.74 (0.16) |
| Normality test | 7.67 (0.02)* | 1.28 (0.53) | 7.07 (0.03)* | 1.79 (0.41) | 6.95 (0.03)* | 4.56 (0.10) |
| Hetero test | 1.52 (0.11) | 0.57 (0.82) | 0.83 (0.65) | 1.79 (0.16) | 1.09 (0.39) | 0.57 (0.89) |
| RESET23 test | 1.14 (0.32) | 1.97 (0.15) | 2.70 (0.08) | 3.60 (0.04)* | 0.57 (0.57) | 3.38 (0.04)* |

T is the sample size. Log-likelihood is the value of a log-likelihood function evaluated at the estimated values of coefficients, and can be used to compare restricted and unrestricted versions of a model.

Table 10 shows that all of the models have their faults. However, using the information criteria again to choose the 'best' model, all three criteria choose the model with the expectations of all groups. Hence, these analyses indicates that inflation expectations did seem to improve the reduced-form model for predicting inflation. In the appendices estimated models not restraining the error correction term are reported, and there a version of model (6) without the error correction term is also rejecting all the mis-specification null hypotheses.

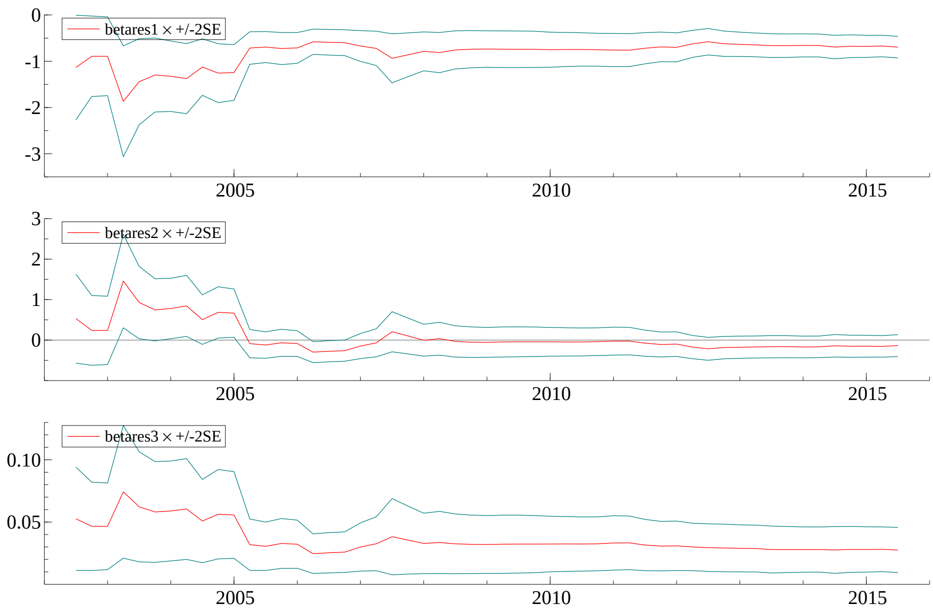
To sum up, it seems that whether the reduced-form inflation model is improved by including expectations, is dependent on whether one wants a long-run equilibrium of the model. Expectations seem to improve the model, but at the same time it only contains short run effects. As there is an inflation target in Norway (indicating a long-run steady-state), the removal of the error correction term appears to be unfortunate.

## 5.2 Parameter stability

In conclusion graphical analyses of the parameter stability, of the estimated regression models in this and the foregoing chapter, in addition to the cointegration vector respectively, are performed. If the parameters in the models are stable over time, the models might be generalised to be used on samples outside of those used in this thesis. Using recursive estimation a visual impression of how stable the parameters appears to be, can be retrieved (Brooks 2014).

Recursive estimation is made by using a sub-sample of the data, estimating the regression, then sequentially adding one observation at a time and re-running the regression until the end of the sample (Brooks 2014). Models containing expectations only have approximately 50 observations, so the sub-sample is 10 observations. For model (5.1.10) and the cointegration vector given in (5.1.7), the subsamples consists of 50 observations (as they are estimated from 1990). It is reasonable to expect that the parameter estimates produced near the start will appear rather unstable, since there's few observations underlying the regression estimates (ibid). Over time however, the instability should settle down as more observations are added, to indicate parameter stability.

Figure 8: Recursive estimates of the cointegration vector.




Note: Turquoise bands specifies ±2 standard errors for the parameter estimates

Figure 8 shows the result from the recursive estimation of the cointegration vector given in (5.1.7). The results indicate that they are stable. The estimates are all close to zero, but the upper and lower figures are significantly different from zero (lower and higher respectively). The figure in the middle is for the parameter of z, and is not significantly different from zero, as in the model. There are some instability in the figures to start with, but they are increasingly stable over time. This also is the case for the other regression models, graphed in appendix G.5; there are instabilities in the parameters at the start of the sample period, but the instabilities diminish as the sample grows.

# 6 Conclusion

This thesis has been divided in to three parts, each examining different properties of Norwegian inflation expectations. The expectations survey from Norges Bank has also given the opportunity to compare the inflation forecasting abilities of different groups with different motivations in the Norwegian society. The first part of this thesis evaluated the forecasting accuracies of these groups and tested whether any of the groups were rational in their forecasts. The second part analysed whether a sample of macroeconomic variables could explain the dissimilarity in the group's inflation forecasts. Lastly, the third part included a reduced form inflation model, testing whether the inflation expectations could be used in the model. Hence, this thesis is contributing to a new insight into the inflation expectations from Norges Bank's expectations survey.

Regarding the 12 month inflation forecasting accuracy, the group of economists was the most accurate, while households were the worst forecasters. Considering that economists are the 'professional' forecasters and households the amateurs, the forecasting accuracies are as expected. In the 24 month inflation forecasts, the results list was turned upside-down, but there were only significant differences between executives and labor organizations and economists respectively. Testing for rationality in the inflation forecasts, only economists kept the null hypothesis of rationality in the 12 month forecasts. There was however a problem of autocorrelation in the forecasting errors, indicating that the forecasts could not claim to be rational - as previous forecasting errors obviously was not taken into consideration when making new forecasts. Although the 12 month inflation forecasts of economists proved to be inefficient, they could nevertheless be classified as unbiased.

Analysing which macroeconomic variables influenced the 12 month inflation forecasts of the different groups, yielded very different results in the sense that only the 12 month inflation rate influenced all four groups consistently in a positive direction. Several of the macroeconomic variables had both positive and negative effects on inflation expectations over time, hence their long-run effects were considered. The only obvious property of economists' inflation forecasts that separated them from the rest, is that none of the other groups were significantly influenced by a dummy for the financial crisis in 2007-08. Hence, the information set that was expected to be different for economists and the other groups, proved to be more similar than anticipated regarding the variables used in this thesis. The economists' model for inflation expectations was in addition also the only model that was troubled with autocorrelated residuals. On the other hand, the two worst 12 month inflation forecasters were also the two only groups influenced by a dummy for 'conservative' government in charge.

The third part considered a reduced form model for inflation, originated from a wage-price system, testing whether inflation expectations from the expectations survey conducted by Norges Bank could improve the model. Including inflation expectations removed the long-run equilibrium estimated using the Johansen-method and decreased the number of observations substantially. Using information criteria, a model including all group's inflation expectations was found to be better than the original model. Whether the model was improved therefore became a weighing of the importance of a long-run equilibrium in the model - and considering the inflation target of Norges bank, the importance of a steady state of prices appeared not to be negligible.

The research on inflation expectations is far from complete, and for Norwegian survey data several possibilities remain. As stated earlier, only the mean responses from the survey are used in the analyses conducted in this thesis. Further analyses could make use of the individual responses if possible, in the groups where the respondents are not random as in the case for households, in a panel data context. In addition to evaluate variations over time, this would offer the possibility to also analyse the variation among the respondents.

An alternative extension of the analyses conducted in this thesis, is to compare the inflation expectations to other measures of the consumer price index that are less volatile, like CPI adjusted for tax changes (KPI-JA) or CPI without energy products (KPI-JE) or both (KPI-JAE). As this thesis only estimated the reduced form model for inflation, a natural extension would also be to estimate the whole wage-price system to analyse how the inflation expectations are working in the system.

# References

Akay, T. (2016), 'All SPSS: Common forecast accuracy measures', `http://www.allspss.com/Appendixpdf/Technical%20Appendix%201%20Common%20Forecast%20Accuracy%20Measures.pdf`. [Accessed 29-02-2016].

Bjørnland, H. C. & Thorsrud, L. A. (2014), *Applied Time Series for Macroeconomics*, Gyldendal.

Blanchflower, D. G. & Oswald, A. J. (1994), *The Wage Curve*, Massachusetts Institute of Technology. p. 38.

Brooks, C. (2014), *Introductory Econometrics for Finance*, 3 edn, Cambridge.

Bårdsen, G., Fisher, P. & Nymoen, R. (1997), Business cycles: real facts or fallacies?, *in* S. Strøm, ed., 'Ragnar Frisch Centenary Conference', Cambridge University Press.

Bårdsen, G., Hurn, S. & McHugh, Z. (2007), 'Modelling wages and prices in australia', *Economic Record* **83**, 143–158.

Clements, M. P. (2005), *Evaluating Econometric Forecasts of Economic and Financial Variables*, Palgrave macmillan. p. 4-45.

Colling, P. L., Irwin, S. H. & Zulauf, C. R. (1992), 'Weak- and strong-form rationality tests of market analysts' expectations of usda 'hogs and pigs' reports', *Review of Agricultural Economics* **14**(2), 263–270.

Croushore, D. (1996), 'Inflation forecasts: How good are they?', Business Review - Federal Reserve Bank of Philadelphia.

Croushore, D. (2006), 'An evaluation of inflation forecasts from surveys using real-time data', Working Paper NO. 06-19. Federal Reserve Bank of Philadelphia.

Croushore, D. (2010), 'Philadelphia fed forecasting surveys: Their value for research', Business Review - Federal Reserve Bank of Philadelphia.

Diebold, F. X. (2007), *Elements of Forecasting*, Thomson South-Western.

Diebold, F. X. (2015), 'Forecasting in economics, business, finance and beyond', `http://www.ssc.upenn.edu/~fdiebold/Teaching221/Forecasting.pdf`. Accessed 12-01-2016.

Diebold, F. X. & Mariano, R. S. (1995), 'Comparing Predictive Accuracy', *Journal of Business and Economic Statistics* **13**, 253–265.

Doornik, J. A. & Hendry, D. F. (2009*a*), *Empirical Econometric Modelling - PcGive$^{TM}$ 14: Volume I*, Timberlake Consultants.

Doornik, J. A. & Hendry, D. F. (2009*b*), *Modelling Dynamic Systems - PcGive$^{TM}$ 13: Volume II*, Timberlake Consultants Ltd.

Engle, R. F. & Granger, C. W. J. (1987), 'Co-Integration and Error Correction: Representation, Estimation and Testing', *Econometrica* **55**(2), 251–276.

Epinion (2015), 'Forventningsundersøkelse for Norges Bank 4. Kvartal 2015'.

Federal Reserve Bank of Philadelphia (2014), 'Livingston survey documentation'.

Figlewski, S. & Wachtel, P. (1981), 'The formation of inflationary expectations', *The Review of Economics and Statistics* **63**(1), 1–10.

Finance Norway (2013), 'Rules for the calculation and publication of Norwegian money market rates, Nibor', `https://www.fno.no/globalassets/nibor-og-nowa-mm/nibor-rules/nibor-rules.pdf`.

Gramlich, E. M. (1983), 'Models of Inflation Expectations Formation: A Comparison of Household and Economist Forecasts', *Journal of Money, Credit and Banking* **15**(2), 155–173.

Harbo, I., Johansen, S., Nielsen, B. & Rahbek, A. (1998), 'Asymptotic Inference on Cointegrating Rank in Partial Systems', *Journal of Business & Economic Statistics* **16**(4), 155–173.

Johansen, S. (1988), 'Statistical analysis of cointegration vectors', *Journal of Economic Dynamics and Control* **12**, 231–254.

Johansen, S. (1992), 'Cointegration in partial systems and the efficiency of single-equation analysis', *Journal of Econometrics* **52**(3), 389–402.

Kershoff, G. & Smit, B. (2002), 'Conducting Inflation Expectation Surveys in South Africa', *South African Journal of Economics* **70**(3), 205–212.

Kolsrud, D. & Nymoen, R. (1998), 'Unemployment and the open economy wage-price spiral', *Journal of Economic Studies* **25**(6), 450–467.

Layard, R. & Nickell, S. (1986), 'Unemployment in Britain', *Economica* **53**(210), S121–S169.

Layard, R., Nickell, S. & Jackman, R. (1991), *Unemployment*, 2 edn, Oxford University Press. 2005.

Lovell, M. C. (2008), 'A Simple Proof of the FWL Theorem', *The Journal of Economic Education* **39**(1), 88–91.

Norges Bank (2004), 'Norges banks skriftserie nr. 34: Norske finansmarkeder - pengepolitikk og finansiell stabilitet', `http://www.norges-bank.no/upload/import/publikasjoner/skriftserie/34/hele_heftet_34.pdf`.

Pesaran, M. & Weale, M. (2006), Survey expectations, *in* G. Elliot, C. Granger & A. Timmermann, eds, 'Handbook of Economic Forecasting', 1 edn, Vol. 1, Elsevier B.V., chapter 14, pp. 715–770.

Statistics Norway (2003*a*), 'Konsumprisindeksen, 15. februar 2003', `http://www.ssb.no/priser-og-prisindekser/statistikker/kpi/maaned/2003-03-10`. [Accessed 13-05-2016].

Statistics Norway (2003*b*), 'Konsumprisindeksen, 15. mai 2003', `http://ssb.no/priser-og-prisindekser/statistikker/kpi/maaned/2003-06-10`. [Accessed 13-05-2016].

Statistics Norway (2004), 'Elektrisitetspriser gir kraftig kpi-fall', `https://www.ssb.no/priser-og-prisindekser/statistikker/kpi/maaned/2004-02-10`. [Accessed 24-05-2016].

Statistics Norway (2010), 'Konsumprisindeksen, 15. februar 2010', `https://www.ssb.no/priser-og-prisindekser/statistikker/kpi/maaned/2010-03-10`. [Accessed 14-05-2016].

Stekler, M. (2007), The rationality and efficiency of individuals' forecasts, *in* M. Clements & D. Hendry, eds, 'A Companion to Economic Forecasting', Blackwell Publishing Ltd., chapter 10, pp. 220–240.

Wooldridge, J. M. (2013), *Introductory Econometrics: A Modern Approach*, South Western, Cengage Learning.

# A Definitions

## A.1 The variables

| | |
|---|---|
| $CPI$ | Consumer Price Index. 2013 = 1 |
| $CR$ | Dummy for the financial crisis; takes the value 1 in the last quarter of 2007 and all quarters of 2008, 0 else. |
| $gap$ | Log of Norwegian mainland GDP (market value) deviations from trend (the original GDP variable is in fixed prices). The trend is calculated using the Hodrick-Prescott filter with $\lambda = 1600$. |
| $gov$ | Dummy for 'conservative' government. Takes the value 1 when 'conservative' parties are in government, 0 else. |
| $M2$ | The sum of Norwegian currency and overnight deposits in circulation, deposits with maturity of maximum two years and deposits redeemable at notice of maximum three months. |
| $Nibor$ | Three month Norwegian Interbank Offered Rate, percent. |
| $SCK$ | Dummy for price shock. Takes the value 1 when the import price deflator has grown more than the export price deflator. |
| $PI$ | Import price index. 2013 = 1 |
| $U$ | Registered unemployment rate |
| $W$ | Wage per hours in mainland Norway. Index, 1988 = 1. |
| $X12m$ | The expected 12 month inflation rate, for $X = H, B, W, E$ |
| $X24m$ | The expected 24 month inflation rate, for $X = H, B, W, E$ |
| $Z$ | Productivity. Output at basic values divided by total hours worked (for mainland Norway). Fixed prices. |

## A.2 The lag operator

In time series the lag operator L transforms an observation at time $t$ to period $t-1$:

$$Ly_t = y_{t-1}$$

If L is raised to the power of $-1$, the series is transformed one period forward; $L^{-1}y_t = y_{t+1}$. Generally, the lag operator can be to arbitrary integer powers $k$ such that:

$$L^k y_t = y_{t-k}$$
$$L^{-k} y_t = y_{t+k}$$

It can also be used to express the first difference of a series:

$$(1-L)y_t = y_t - y_{t-1} = \Delta y_t$$

The lag operator can be used to describe any differences of a series, like for instance $(1-L^4)y_t = y_t - y_{t-4}$. The whole expression $(1-L)$ can also be raised to any power. The second difference of a time series is for for example defined as

$$\Delta^2 y_t = \Delta(\Delta y_t) = \Delta y_t - \Delta y_{t-1} = (1-L)^2 y_t$$

A polynomial of lag operators is called a lag operator, defined as $\phi(L)$, where

$$\phi(L) = (1 - \phi_1 L - \phi_2 L^2 - \cdots - \phi_p L^p)$$

where p is the lag order. An example of the use of the lag polynomial is as follows:

$$\begin{aligned}
\phi(L)y_t &= \left(1 - \sum_{i=1}^{p} \phi_i L^i\right) y_t \\
&= (1 - \phi_1 L - \phi_2 L^2 - \cdots - \phi_p L^p) y_t \\
&= y_t - \phi_1 y_{t-1} - \phi_2 y_{t-2} - \cdots - \phi_p y_{t-p}
\end{aligned}$$

### A.3 Information Criteria

Information criteria are metrics that can be used to select the best fitting from a set of competing models, as they embody a term which is a function of the residual sum of squares, in addition to some penalty for including extra parameters (Brooks 2014). The model chosen will be the one minimising one or more of the information criteria.
The information criteria mentioned in this thesis are expressed as:

Akaike's information criterion (AIC): $AIC = ln(\sigma^2) + \frac{2k}{T}$.

Hannan-Quinn criterion (HQ): $HQ = ln(\sigma^2) + \frac{2k}{T} ln(ln\ T)$

Schwarz-Bayesian criterion (SC): $SC = ln(\sigma^2) + \frac{k}{T} ln\ T$

$\sigma^2$ is the residual variance, $T$ is the number of observations and $k$ is the total number of parameters. Additional parameters will lower the residual variance, but the information criteria also have penalties for the loss of degrees of freedom from extra parameters. The difference between these model is how they punish additional parameters.

## B Misspecification tests

After estimating regression models, PcGive provides a testing sequence on the residual, for a range of null hypotheses of interest. The residual should be white noise in order for a model to be well-specified, and this is decided based on the test-results presented by PcGive[51]. The rejection of the null hypotheses in the tests implies:

i. AR test: Autocorrelation in the residuals.

ii. ARCH-test: The variance of the residuals is autocorrelated.

iii. Normality-test: The residuals are not normally distributed.

iv. Hetero test: The residuals are heteroscedastic.

v. RESET23-test: The model is mis-specified.

[51] PcGive presents test-statistics and the corresponding p-values, hence a p-value lower than 0.05 indicate that the null hypothesis is rejected at the 5% significance level.

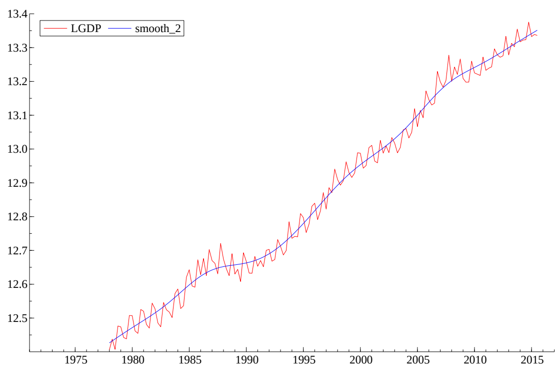
# C Hodrick-Prescott (HP) filter

The HP-filter is a common approach to extract business cycles (Bjørnland & Thorsrud 2014). The filter extracts a stochastic trend, $(g_t)$, which for a given value of $\lambda$, moves smoothly over time and is uncorrelated with the cycle. The idea is that it shall emphasise the true business cycle frequencies, and downplay the other frequencies, generally on the grounds that these represent noise rather than business cycles. The filter is the solution to the following problem:

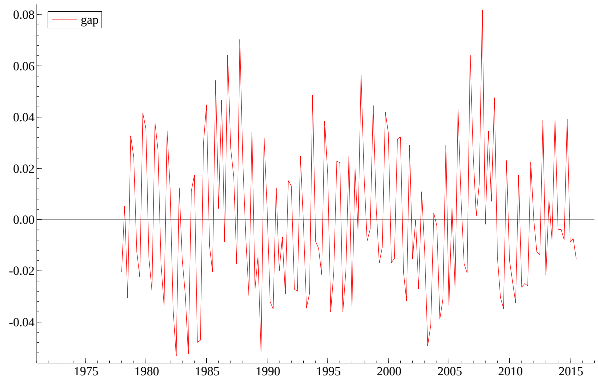
$$\min_{[g_t]} \sum_{t=1}^{T} \left[ (y_t - g_t)^2 + \lambda[(g_{t+1} - g_t) - (g_t - g_{t-1})]^2 \right] \qquad \text{(C.0.1)}$$

Where $\lambda$ is a constant, called the smoothing parameter, determining the smoothness of the filtered series. $\lambda$ 'penalises' the acceleration of the growth component. Kydland and Prescott have argued that $\lambda = 1600$ is a reasonable choice for quarterly data (ibid), and is therefore used in estimating the trend in Norwegian mainland GDP ($y_t$ in (C.0.1)) in this thesis. Figure 10a displays the logarithm of Norwegian mainland GDP and a trend fitted to the data using the HP-method with $\lambda = 1600$, and figure 10b displays the deviation of GDP from the trend, the output *gap*.

Figure 9: Hodrick-Prescott filter: $\lambda = 1600$




(a) Natural log of mainland GDP and HP-trend




(b) Output gap:
The deviation of GDP from the HP-trend

# D Proof of the Frisch-Waugh-Lovell Theorem

In section 3.2.2, the FWL theorem was used as an argument for adding quarterly dummies to the model of inflation instead of seasonally adjusting the endogenous variable and the regressors. Here a proof of the FWL theorem will be given, following Lovell (2008).

Suppose one is fitting by least squares the variable on a set of k' explanatory variables plus dummies for all four quarters (no intercept):

$$Y_t = d_i D_{it} + b_1 X_{1t} + b_2 X_{2t} + \cdots + b_{k'} X_{k't} + e_t \qquad i = 1, 2, 3, 4 \tag{D.0.1}$$

The alternative to estimating (D.0.1) is to use a two-step procedure to seasonally adjust all the variables, ending up with the equation:

$$Y_t^* = b_1^* X_{1t}^* + b_2^* X_{2t}^* + \cdots + b_{k'}^* X_{k't}^* + e_t^* \tag{D.0.2}$$

Here, the asterisks indicate that the variables are 'cleansed' of the effect of the dummy variables:

$$\begin{aligned} Y_t^* &= \bar{Y} + e_t^y \\ X_{jt}^* &= \bar{X}_j + e_{jt}^x, \qquad j = 1, \ldots, k' \end{aligned} \tag{D.0.3}$$

Where $e_t^y$ and $e_{jt}^x$ are the least squares residuals obtained from the auxiliary regressions:

$$Y_t = c_{y1} D_{1t} + c_{y2} D_{2t} + c_{y3} D_{3t} + c_{y4} D_{4t} + e_t^y \tag{D.0.4}$$

$$X_{jt} = c_{j1} D_{1t} + c_{j2} D_{2t} + c_{j3} D_{3t} + c_{j4} D_{4t} + e_{it}^x \qquad j = 1, \ldots, k' \tag{D.0.5}$$

Then $b_j^* = b_j$ for $j = 1, \ldots, k'$ and $e_t^* = e_t$.

Using two well-known numerical properties of the method of least squares, the FWL theorem can easily be derived:

(I) The residuals from a least-squares regression are uncorrelated with the explanatory variables.

(II) The coefficients of a subset of the explanatory variables in a regression equation will be zero if those variables are uncorrelated with both the dependent variable and the other explanatory variables.

**Proof**

Substituting equation (D.0.4) and (D.0.5) into equation (D.0.1) yields:

$$\begin{aligned} e_t^y =& b_1 e_{1t}^x + \cdots + b_{k'} e_{k't}^x + (b_1 a_{11} + b_2 a_{21} + \cdots + b_{k'} a_{k'1} + d_1 - a_{y1}) D_{1t} + \ldots \\ &+ (b_1 a_{14} + \ldots b_{k'} a_{k'4} + d_4 - a_{y4}) D_{4t} + e_t \end{aligned} \tag{D.0.6}$$

The auxiliary regressions of (D.0.4) and (D.0.5) are both fitted by least squares, Property (I) implies that the residuals $e_t^y$ and $e_{jt}^x$ are uncorrelated with the quarterly dummies. Therefore, all the regression coefficients of the dummies in (D.0.6) are zero, thanks to property (II), meaning that the same $b_j$ are obtained when the dummies are dropped from the regression, namely

$$e_t^y = b_1 e_{1t}^x + b_2 e_{2t}^x + \cdots + b_{k'} e_{k't}^x + e_t \tag{D.0.7}$$

Adding the identity $\bar{Y} = b_1 \bar{X}_1 + b_2 \bar{X}_2 + \cdots + b_{k'} \bar{X}_{k'}$ to equation (D.0.7) yields:

$$\bar{Y} + e_t^y = b_1(\bar{X}_1 + e_{1t}^x) + b_2(\bar{X}_2 + e_{2t}^x) + \cdots + b_{k'}(\bar{X}_{k'} + e_{k't}^x) + e_t \tag{D.0.8}$$

which by equation (D.0.3) is equation (D.0.2), hence establishing that the least squares coefficients $b_j^*$ of equation (D.0.2) are identical to the $b_j$ of equation (D.0.1), and that $e_t^* = e_t$

# E Results from system estimation

In order to estimate the error correction term, a system of the relevant variables is estimated, using the Johansen (1988) technique to test for cointegrating relationships. With (5.1.2) as a starting point, setting $\mathbf{X}_t = [\ cpi\ pi\ z\ U\ ]'_t$, the cointegrated VAR can be written:

$$\Delta \mathbf{X}_t = \mu + \delta D_{jt} + \alpha\beta' \mathbf{X}_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta \mathbf{X}_{t-i} + \sum_{i=1}^{k} \kappa_i S_{t-i} + \epsilon_t \tag{E.0.1}$$

Where $S_t$ is a shift dummy for 2003:2-2003:1. The lag length $k$ is set to 5, using Autometrics. The system is estimated over the period 1990:1-2015:3, and the cointegration rank is tested using the trace test introduced by Johansen (1988). Setting $\alpha\beta' = \Pi$ in equation (E.0.1), the Johansen test is based on the $\Pi$-matrix, which is interpreted as the long-run coefficient matrix. The results are presented in table 12.

Table 12: Rank tests

| Hypothesis | Test | p-value |
|---|---|---|
| $r = 0$ | 64.23 | 0.00** |
| $r \leq 1$ | 20.43 | 0.41 |
| $r \leq 2$ | 6.29 | 0.67 |
| $r \leq 3$ | 0.30 | 0.58 |

The rank tests indicate one cointegrating relationship, assumed to be the price steady state, expressed as $cpi = -\theta_{21} z + \theta_{22} pi - \theta_{24} U$. In order to test whether the explanatory variables are weakly exogenous, the system is estimated. Imposing rank=1, the long-run coefficient matrix consists of two vectors:

$$\underbrace{\begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \end{pmatrix}}_{\alpha} \underbrace{\begin{pmatrix} \beta_1 & \beta_2 & \beta_3 & \beta_4 \end{pmatrix}}_{\beta'} \begin{pmatrix} cpi \\ pi \\ z \\ U \end{pmatrix}_{t-1} \tag{E.0.2}$$

The joint hypotheses to test is that of weak exogeneity in the explanatory variables;

$\alpha_2 = \alpha_3 = \alpha_4 = 0$, in addition to setting $\beta_1 = 1$. This results in the following vectors:

$$\begin{pmatrix} \underset{(0.01)}{-0.06} \\ 0 \\ 0 \\ 0 \end{pmatrix} \begin{pmatrix} 1 & \underset{(0.14)}{-0.58} & \underset{(0.16)}{-0.24} & \underset{(0.01)}{0.03} \end{pmatrix} \begin{pmatrix} cpi \\ pi \\ z \\ U \end{pmatrix}_{t-1} \tag{E.0.3}$$

Where standard errors are in parentheses. The test statistic[52] for the imposed restrictions is 22.82 with a p-value of 0.001, indicating that the restrictions are not valid. Removing the restriction of $\alpha_2 = 0$, yields:

$$\begin{pmatrix} \underset{(0.01)}{-0.05} \\ \underset{(0.06)}{0.25} \\ 0 \\ 0 \end{pmatrix} \begin{pmatrix} 1 & \underset{(0.10)}{-0.63} & \underset{(0.12)}{-0.20} & \underset{(0.01)}{0.03} \end{pmatrix} \begin{pmatrix} cpi \\ pi \\ z \\ U \end{pmatrix}_{t-1} \tag{E.0.4}$$

With a test statistic of 2.46 and a p-value of 0.29, these are valid restrictions, but reveals that the import price index is not weakly exogenous in this sample. As mentioned in section 5.1.1, this might lead to bias in the estimates, but they should still be super-consistent.

[52] $LR = -2(L_r - L_u) \sim \chi^2(m)$, where L is the log-likelihood function of the restricted and unrestricted model respectively and $m$ is the number of restrictions.

# F More on the error correction model

## F.1 Models with inflation expectations and unrestrained error correction term

Households (2'):

$$\begin{aligned}\Delta\text{cpi} &= -\underset{(0.101)}{0.1855}\ \Delta\text{cpi}_{t-1} + \underset{(0.00212)}{0.01266}\ \Delta\text{U}_{t-1} + \underset{(0.0239)}{0.07437}\ \text{gap}_{t-1} \\ &\quad + \underset{(0.00575)}{0.009679} + \underset{(0.00541)}{0.0167}\ \text{H12m4}_t - \underset{(0.00534)}{0.0221}\ \text{H12m4}_{t-3}\end{aligned} \tag{F.1.1}$$

Labor organizations (3'):

$$\begin{aligned}\Delta\text{cpi} &= -\underset{(0.132)}{0.7193}\ \Delta\text{cpi}_{t-1} - \underset{(0.12)}{0.5705}\ \Delta\text{cpi}_{t-2} - \underset{(0.12)}{0.3981}\ \Delta\text{cpi}_{t-3} \\ &\quad + \underset{(0.00346)}{0.01274}\ \Delta\text{U}_t + \underset{(0.00311)}{0.01341}\ \Delta\text{U}_{t-1} + \underset{(0.00844)}{0.05643}\ \text{W12m4}_t \\ &\quad - \underset{(0.00721)}{0.03253}\ \text{W12m4}_{t-3}\end{aligned} \tag{F.1.2}$$

Economists (4'):

$$\begin{aligned}\Delta\text{cpi} &= -\underset{(0.143)}{0.4318}\ \Delta\text{cpi}_{t-1} + \underset{(0.0032)}{0.01191}\ \Delta\text{U}_t + \underset{(0.0237)}{0.09629}\ \Delta\text{z}_t \\ &\quad - \underset{(0.0269)}{0.1118}\ \Delta\text{z}_{t-3} + \underset{(0.238)}{0.4902}\ \text{ecm}_{t-1} - \underset{(0.00469)}{0.0264}\ \text{D}_{t3t} \\ &\quad + \underset{(0.0159)}{0.07665}\ \text{E12m4}_t - \underset{(0.0158)}{0.06344}\ \text{E12m4}_{t-1}\end{aligned} \tag{F.1.3}$$

Executives (5'):

$$\Delta \text{cpi} = \underset{(0.13)}{-0.2523}\ \Delta \text{cpi}_{t-1} - \underset{(0.129)}{0.2633}\ \Delta \text{cpi}_{t-2} + \underset{(0.0255)}{0.06025}\ \Delta \text{z}_t - \underset{(0.0283)}{0.06793}\ \Delta \text{z}_{t-3} - \underset{(0.00457)}{0.01616}\ \text{D}_{3t} + \underset{(0.00213)}{0.01166}\ \text{B12m4}_t \tag{F.1.4}$$

Expectations of all groups (6'):

$$\Delta \text{cpi} = \underset{(0.00276)}{0.008413}\ \Delta \text{U}_{t-1} - \underset{(0.00248)}{0.008782}\ \Delta \text{U}_{t-2} + \underset{(0.017)}{0.04971}\ \Delta \text{z}_t + \underset{(0.0183)}{0.06009}\ \Delta \text{z}_{t-2} - \underset{(0.0101)}{0.03667}\ \text{B12m4}_t + \underset{(0.00952)}{0.03513}\ \text{B12m4}_{t-3} + \underset{(0.00585)}{0.01593}\ \text{H12m4}_t - \underset{(0.00542)}{0.02373}\ \text{H12m4}_{t-3} - \underset{(0.00633)}{0.01123}\ \text{W12m4}_{t-4} + \underset{(0.013)}{0.05733}\ \text{E12m4}_t - \underset{(0.0107)}{0.0248}\ \text{E12m4}_{t-1} \tag{F.1.5}$$

Table 13: Mis-specification tests of alternative models

| | (2') | (3') | (4') | (5') | (6') |
|---|---|---|---|---|---|
| T | 49 | 51 | 51 | 51 | 49 |
| Sigma | 0.004 | 0.005 | 0.005 | 0.006 | 0.003 |
| log-likelihood | 203.73 | 199.39 | 199.21 | 189.55 | 217.38 |
| | | | | | |
| AR 1-5 test | 1.87 (0.13) | 0.48 (0.75) | 1.05 (0.39) | 0.57 (0.69) | 0.97 (0.44) |
| ARCH 1-4 test | 2.22 (0.08) | 0.81 (0.53) | 0.34 (0.85) | 0.51 (0.72) | 0.50 (0.73) |
| Normality test | 2.86 (0.24) | 3.31 (0.19) | 1.79 (0.41) | 6.07 (0.05)* | 1.34 (0.51) |
| Hetero test | 0.87 (0.57) | 1.25 (0.28) | 1.50 (0.16) | 1.30 (0.26) | 0.89 (0.60) |
| RESET23-test | 0.16 (0.85) | 2.84 (0.07) | 3.60 (0.04)* | 1.02 (0.37) | 1.08 (0.35) |

Table 14: Selection of alternative models based on information criteria

| Model | AIC | HQ | SC |
|---|---|---|---|
| (1) | -8.15 | -8.01 | -7.81 |
| (2') | -8.07 | -7.98 | -7.84 |
| (3') | -7.54 | -7.44 | -7.28 |
| (4') | -7.50 | -7.38 | -6.97 |
| (5') | -7.20 | -7.11 | -7.20 |
| (6') | -8.42$<$ | -8.26$<$ | -8.00$<$ |

# G Figures and tables

## G.1 Descriptive statistics

Table 15: Descriptive statistics

| Variable | Obs | Mean | Std.dev | Min. | Max |
|---|---|---|---|---|---|
| $CPI$ | 175 | 6.27 | 2.70 | 1.48 | 1.04 |
| $CR$ | 176 | 0.002 | 0.17 | 0.00 | 1.00 |
| $gap$ | 151 | 0 | 0.029 | -0.05 | 0.08 |
| $gov$ | 176 | 0.35 | 0.48 | 0 .00 | 1.00 |
| $M12$ | 73 | 7.07 | 3.68 | 1.36 | 3.68 |
| $PI$ | 175 | 6.52 | 2.57 | 1.38 | 1.10 |
| $SCK$ | 60 | 0.47 | 0.50 | 0.00 | 1.00 |
| $U$ | 175 | 2.72 | 1.27 | 0.50 | 5.83 |
| $W$ | 175 | 143.6 | 91.32 | 19.26 | 329.89 |
| $W12$ | 171 | 6.85 | 4.00 | 1.18 | 18.71 |
| $Z$ | 151 | 435.7 | 89.365 | 290.6 | 602.68 |
| $\Delta cpi$ | 103 | 0.005 | 0.006 | -0.01 | 0.03 |
| $\Delta pi$ | 103 | 0.005 | 0.02 | -0.04 | 0.05 |
| $\Delta U$ | 103 | -0.007 | 0.40 | -0.97 | 0.87 |
| $\Delta z$ | 103 | 0.005 | 0.06 | -0.09 | 0.11 |

Table 16: ADF-tests on the residuals from models explaining inflation expectations

| | $\mu$ | $\hat{t}_{DF}$ |
|---|---|---|
| $e_H$ | -0.56 [1] | -7.30** |
| $e_W$ | -0.07 [0] | -7.30** |
| $e_E$ | -0.03 [0] | -6.61** |
| $e_B$ | -0.21 [1] | -6.00** |

NOTES: Subscript indicates the model in which the residual originates.

Table 17: Correlation matrix of variables in model for explaining expectations

| | H12m | W12m | E12m | B12m | infl12 | M12 | W12 | Nibor | gap | CR | gov |
|---|---|---|---|---|---|---|---|---|---|---|---|
| H12m | 1.00 | | | | | | | | | | |
| W12m | 0.64 | 1.00 | | | | | | | | | |
| E12m | 0.65 | 0.84 | 1.00 | | | | | | | | |
| B12m | 0.71 | 0.83 | 0.83 | 1.00 | | | | | | | |
| infl12 | 0.31 | 0.69 | 0.53 | 0.45 | 1.00 | | | | | | |
| M12 | 0.06 | 0.25 | 0.21 | 0.44 | -0.03 | 1.00 | | | | | |
| W12 | 0.25 | 0.42 | 0.24 | 0.54 | 0.41 | 0.35 | 1.00 | | | | |
| Nibor | 0.58 | 0.69 | 0.59 | 0.79 | 0.36 | 0.47 | 0.68 | 1.00 | | | |
| gap | 0.14 | 0.25 | 0.34 | 0.29 | 0.06 | 0.39 | 0.10 | 0.21 | 1.00 | | |
| CR | 0.53 | 0.68 | 0.77 | 0.67 | 0.45 | 0.32 | 0.27 | 0.62 | 0.40 | 1.00 | |
| gov | -0.28 | -0.19 | -0.30 | -0.40 | -0.11 | -0.19 | -0.23 | -0.12 | -0.20 | -0.25 | 1.00 |
| SCK | -0.18 | 0.07 | -0.02 | 0.02 | -0.14 | -0.05 | 0.08 | -0.04 | 0.05 | -0.14 | 0.10 |

## G.2 Residuals in error correction model

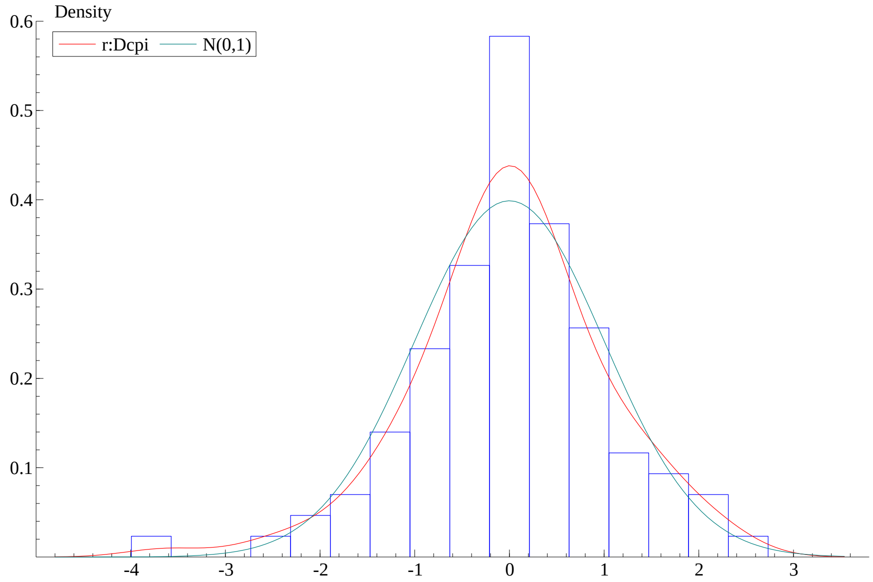



Figure 11: Estimated residual density with histogram for error correction model without expectations (model (5.1.10))

Table 18: Correlation matrix of the variables in inflation model

| | $\Delta cpi$ | $\Delta pi$ | $\Delta w$ | $\Delta z$ | $\Delta U$ | gap | cpi | pi | w | z | U | H12m4 | W12m4 | E12m4 | B12m4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\Delta cpi$ | 1.00 | | | | | | | | | | | | | | |
| $\Delta pi$ | 0.001 | 1.00 | | | | | | | | | | | | | |
| $\Delta w$ | 0.05 | -0.35 | 1.00 | | | | | | | | | | | | |
| $\Delta z$ | -0.20 | -0.25 | -0.02 | 1.00 | | | | | | | | | | | |
| $\Delta U$ | -0.15 | 0.11 | 0.16 | 0.11 | 1.00 | | | | | | | | | | |
| gap | 0.38 | 0.19 | -0.19 | -0.63 | -0.42 | 1.00 | | | | | | | | | |
| cpi | 0.06 | -0.01 | -0.06 | -0.07 | 0.06 | 0.11 | 1.00 | | | | | | | | |
| pi | 0.02 | 0.08 | -0.03 | -0.10 | 0.03 | 0.20 | 0.95 | 1.00 | | | | | | | |
| w | 0.02 | -0.04 | -0.02 | -0.05 | 0.06 | 0.12 | 0.99 | 0.96 | 1.00 | | | | | | |
| z | -0.15 | -0.07 | -0.23 | 0.48 | -0.09 | 0.003 | 0.60 | 0.62 | 0.62 | 1.00 | | | | | |
| U | -0.16 | 0.07 | -0.11 | 0.10 | 0.24 | -0.54 | -0.45 | -0.58 | -0.50 | -0.40 | 1.00 | | | | |
| H12m4 | 0.24 | -0.01 | 0.18 | -0.06 | 0.01 | 0.14 | 0.04 | -0.01 | 0.02 | -0.10 | -0.36 | 1.00 | | | |
| W12m4 | 0.19 | 0.05 | 0.14 | -0.04 | 0.04 | 0.25 | 0.04 | 0.08 | 0.02 | -0.01 | -0.49 | 0.64 | 1.00 | | |
| E12m4 | 0.25 | 0.17 | 0.08 | -0.04 | 0.03 | 0.34 | 0.25 | 0.32 | 0.25 | 0.14 | -0.65 | 0.65 | 0.84 | 1.00 | |
| B12m4 | 0.14 | 0.01 | 0.17 | -0.02 | -0.02 | 0.29 | 0.02 | 0.08 | 0.03 | -0.02 | -0.67 | 0.71 | 0.83 | 0.83 | 1.00 |

## G.3 Explaining expectations of inflation

Table 19: Equations explaining the groups' inflation expectations (long-run)

| Explanatory variables | H12m | W12m | B12m | E12m | $E12m^B$ |
|---|---|---|---|---|---|
| Constant | 2.46 (14.8) | 1.60 (19.9) | 1.26 (10.1) | 1.30 (11.5) | 1.31 (10.2) |
| A(L)infl12 | 0.24 (4.94) | 0.38 (14.3) | 0.13 (4.23) | 0.11 (6.53) | 0.13 (7.53) |
| B(L)m12 | -0.07 (4.96) | -0.01 (1.74) | | -0.02 (2.64) | -0.02 (1.77) |
| C(L)W12 | 0.03 (0.46) | -0.16 (7.07) | 0.26 (5.68) | 0.25 (6.78) | 0.22 (5.57) |
| D(L)Nibor | 0.19 (4.23) | 0.19 (10.2) | -0.02 (0.80) | -0.11 (5.06) | -0.11 (4.05) |
| $CR$ | | | | 0.34 (4.48) | 0.38 (4.39) |
| $gov$ | -0.32 (4.02) | | -0.16 (3.73) | | |
| $SCK$ | | 0.14 (3.65) | | | |
| | | | | | |
| $R^2$ | 0.839 | 0.954 | 0.928 | 0.956 | 0.950 |
| T | 51 | 51 | 51 | 51 | 51 |
| Sigma | 0.201 | 0.102 | 0.123 | 0.082 | 0.088 |
| AR 1-4 test | 1.93 (0.13) | 1.15 (0.35) | 1.74 (0.16) | 3.36 (0.02)* | 1.78 (0.16) |
| Normality test | 3.76 (0.15) | 0.70 (0.70) | 0.24 (0.89) | 0.52 (0.77) | 1.38 (0.50) |
| Hetero test | 0.85 (0.64) | 1.15 (0.36) | 0.87 (0.62) | 0.80 (0.71) | 1.30 (0.26) |
| RESET23 test | 0.44 (0.65) | 3.14 (0.05) | 3.22 (0.05) | 0.03 (0.97) | 0.64 (0.53) |

NOTES: Mean response, quarterly observations, 2003-2015. Absolute t-ratios in parentheses. For distributed lags the sum of the significant coefficients are given, with the absolute t-ratio for the sum. Lags are all for eight quarters.

Table 20: Results from F-tests of the overall significance of distributed lags

| Explanatory variables | H12m | W12m | B12m | E12m |
|---|---|---|---|---|
| A(L)infl12 | 1.41 (0.30) | 11.1 (0.00)*** | 0.64 (0.74) | 2,62 (0.07) |
| B(L)m12 | 1.41 (0.30) | 0.82 (0.62) | 0.46 (0.87) | 2.54 (0.08) |
| C(L)W12 | 2.26 (0.11) | 1.53 (0.26) | 1.38 (0.31) | 1.51 (0.27) |
| D(L)Nibor | 3.44 (0.03)** | 6.16 (0.00)*** | 4.02 (0.02)** | 7.39 (0.00)*** |

NOTES: p-values in parentheses.

## G.4 Test of rationality in forecasts

Table 21: Testing rationality (t-test)

| | Households | | Labor organizations | | Executives | | Economists | |
|---|---|---|---|---|---|---|---|---|
| | Er12m | Er24m | Er12m | Er24m | Er12m | Er24m | Er12m | Er24m |
| Constant | -1.16 | -0.48 | -0.26 | 1.24 | -0.59 | 0.47 | -0.19 | 1.32 |
| t-value | -6.87 | -2.35 | -1.64 | 6.22 | -3.96 | 2.35 | -1.26 | 6.73 |
| AR 1-4 test | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| t-HACSE | -4.74 | -1.43 | -1.18 | 3.70 | -2.87 | 1.40 | -0.93 | 4.08 |
| Reject $H_0$ | Yes | No | No | Yes | Yes | No | No | Yes |

$Er12 = infl12 - X12m_{t-4}$ and $er24 = infl24 - X24m_{t-8}$, X = H, B, W, E are the forecast errors, and are regressed on a constant, testing whether the constant is significantly different from zero using a t-test. With approximately 50 observations and a 5% significance level, the critical (absolute) value is set to 2.

## G.5 Graphic analyses of parameter stability

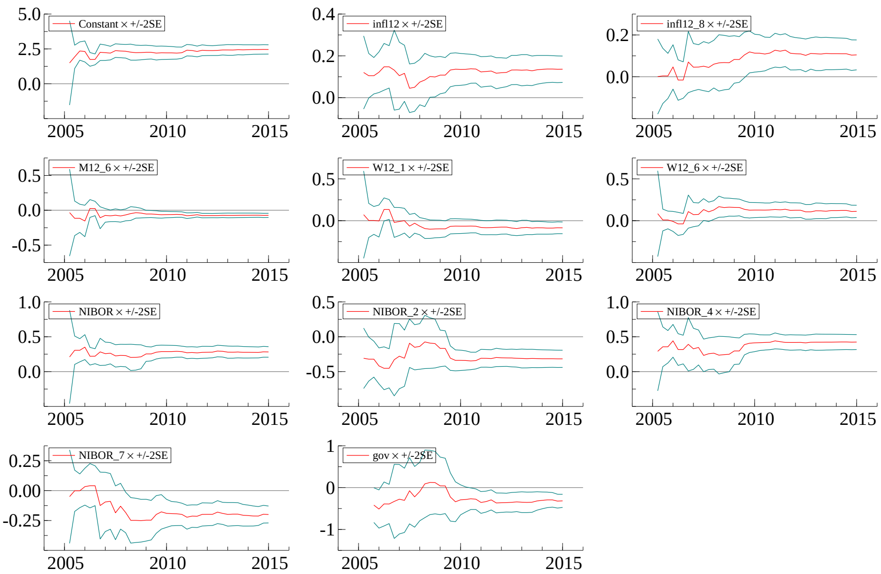



Figure 12: Recursive estimates of model (4.3.2)

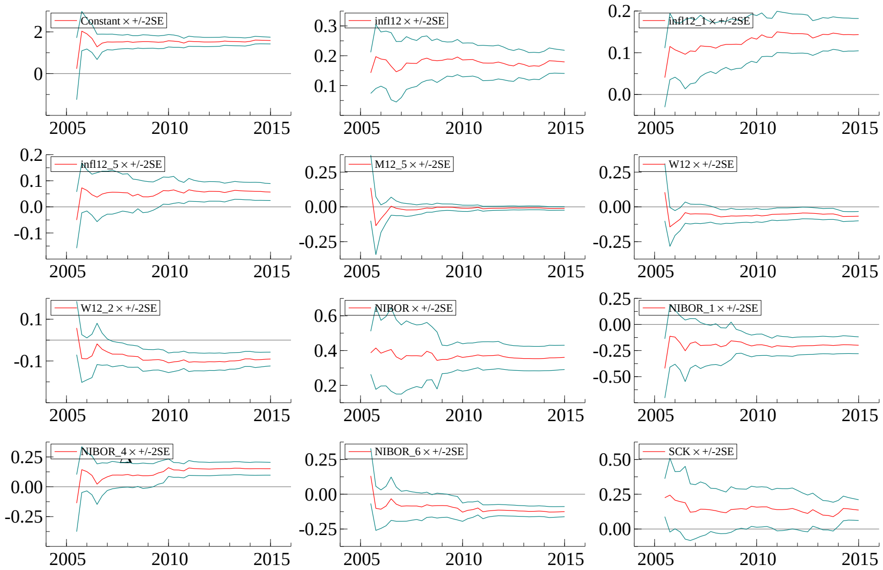



Figure 13: Recursive estimates of model (4.3.3)

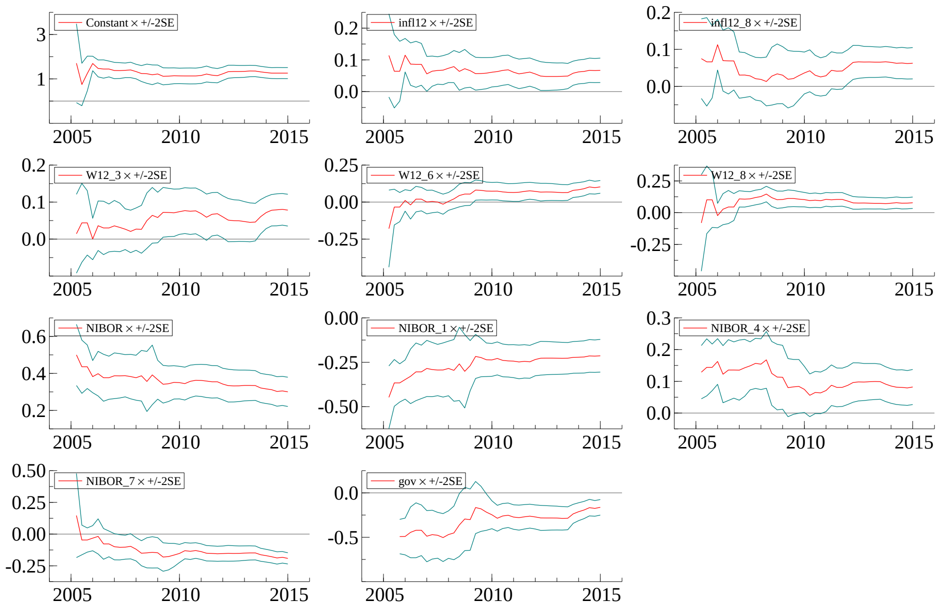



Figure 14: Recursive estimates of model (4.3.4)

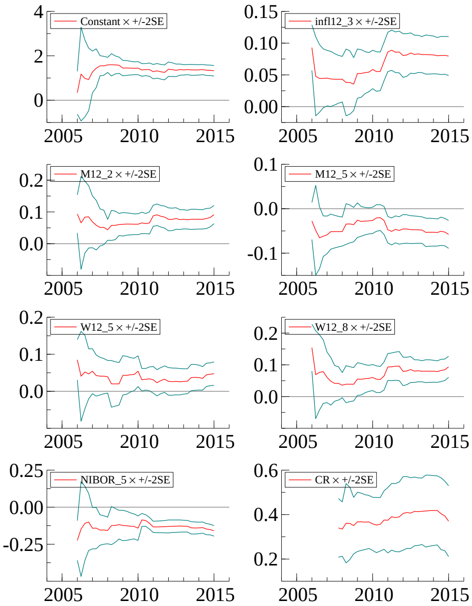


Figure 15: Recursive estimates of model (4.3.5)

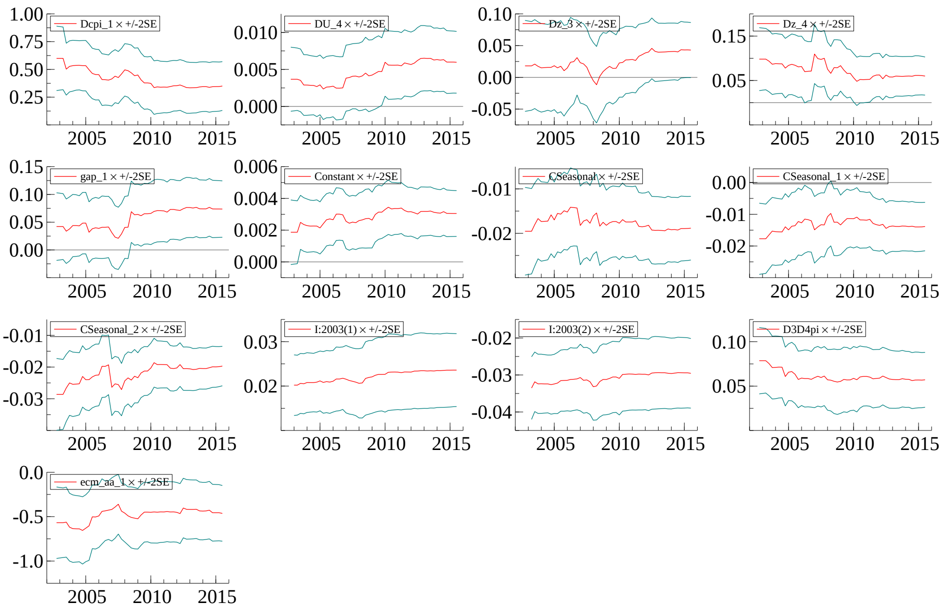


Figure 16: Recursive estimates of model (5.1.10)

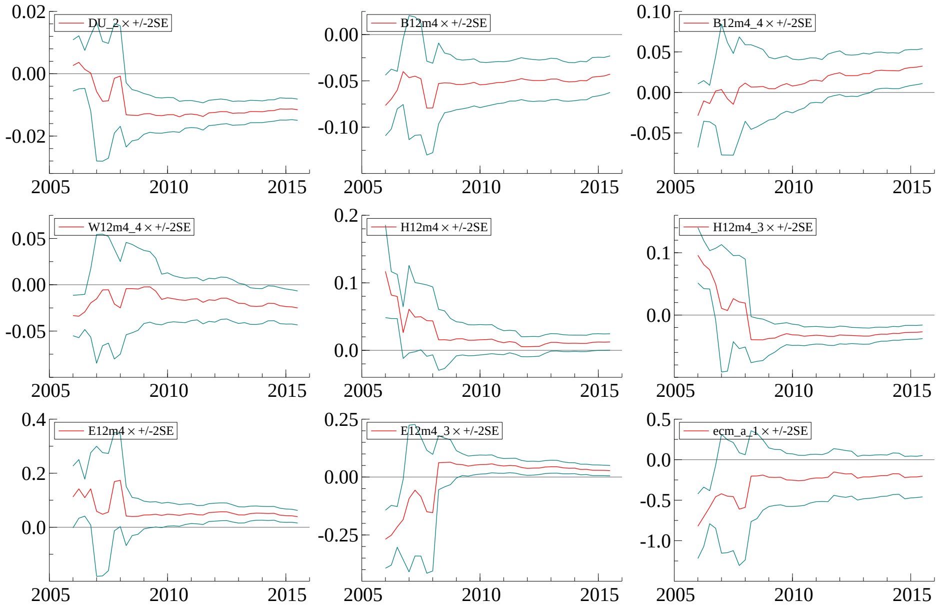



Figure 17: Recursive estimates of model (5.1.15)