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The New Keynesian Phillips Curve

Estimating the New Keynesian Phillips curve using survey expectations

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The usual disclaimer applies: all errors and inconsistencies are my own responsibility.

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Executive summary

The purpose of this thesis has been to estimate the New Keynesian Phillips curve relation using Norwegian data, and more precisely using survey expectations as instruments for the expected inflation term in the NPC to see how this would influence the results. As a comparison to the survey estimates I have estimated a replication of the Galí and Gertler (1999) study.

The estimations using both survey expectations and the Galí and Gertler instruments turned out to be significant, and with the size and sign of the coefficients as expected. Based on my estimation the Galí and Gertler instruments provide a better fit model of the NPC than using survey expectations, however both methods are valid to estimate the NPC.

Table of content

EXECUTIVE SUMMARY	3
1 INTRODUCTION.....	6
2 THE LITERATURE	8
2.1 THE HISTORICAL DEVELOPMENT OF THE PHILLIPS CURVE	8
2.2 THE NEW KEYNESIAN FRAMEWORK.....	10
3 THE BASELINE MODEL	11
3.1 DERIVING THE BASELINE MODEL.....	11
3.2 <i>Marginal cost in the model</i>	19
4 THE DATA.....	21
4.1 INFLATION	22
4.2 THE OUTPUT GAP	25
4.3 WAGE INFLATION.....	29
4.4 UNIT LABOR COSTS	31
4.5 COMMODITY PRICE INFLATION.....	33
4.5.1 <i>Making short term indexes from the sub-indexes</i>	34
4.5.2 <i>Making short term indexes into a chained index</i>	36
4.5.3 <i>Commodity price inflation</i>	38
4.6 LONG-SHORT INTEREST SPREAD	40
4.7 SURVEY FROM THE CENTRAL BANK OF NORWAY	42
4.7.1 <i>The economy experts</i>	43
4.7.2 <i>Labor unions: Employer and employee organizations</i>	44
4.7.3 <i>Business leaders</i>	45
4.7.4 <i>Households</i>	47
4.7.5 <i>Shortcomings in the survey</i>	48
5 ANALYSIS.....	49
5.1 THE METHODOLOGY	49
5.1.1 <i>Instrument variables regression</i>	49
5.1.2 <i>Generalized Methods of Moments</i>	50
5.1.3 <i>Deviation from steady state</i>	51
5.1.4 <i>Comparing non-nested models</i>	52
5.2 RESULTS.....	53
5.2.1 <i>Survey expectations instruments, 2002-2010</i>	53
5.2.2 <i>NPC without survey instruments, 1996-2010</i>	56
5.3 DISCUSSION OF THE RESULTS	59
5.3.1 <i>Variability in survey expectations</i>	59
5.3.2 <i>The inflation measure</i>	61
5.3.3 <i>Some remarks about the analysis</i>	64
6 THE CONCLUSION	66
REFERENCES	67
APPENDIX A: SURVEY QUESTIONS USED IN THE THESIS.....	70

Figures

FIGURE 1: PERFECT COMPETITION AND MONOPOLISTIC COMPETITION.....	16
FIGURE 2: THE 12-MONTH GROWTH IN CPI. 1980-2010	24
FIGURE 3: CPI. 10-YEAR MOVING AVERAGE ¹⁾ AND VARIATION ²⁾ . 1980-2011	25
FIGURE 4: GDP FIXED AND GDP TREND. HP-FILTER, SMOOTHING PARAMETER $\lambda = 40\,000$	27
FIGURE 5: THE OUTPUT GAP	29
FIGURE 6: WAGE INFLATION	30
FIGURE 7: THE LABOR INCOME SHARE	32
FIGURE 8: SHORT-TERM INDEX AND CPI SUB-INDEX FOR AGRICULTURAL PRODUCTS.....	35
FIGURE 9: COMMODITY PRICE INDEX: NORWEGIAN PRODUCED GOODS ONLY, AND NORWEGIAN PRODUCED GOODS AND IMPORTS. 1979=100	38
FIGURE 10: COMMODITY PRICE INFLATION	39
FIGURE 11: CPI INFLATION AND THE TWO COMMODITY INFLATION MEASURES. PER CENT	40
FIGURE 12: THE LONG-SHORT INTEREST SPREAD	42
FIGURE 13: ACTUAL INFLATION AND INFLATION EXPECTATIONS BY THE ECONOMY EXPERTS.....	44
FIGURE 14: ACTUAL INFLATION AND INFLATION EXPECTATIONS FROM THE LABOR UNIONS SECTOR.....	45
FIGURE 15: ACTUAL INFLATION AND INFLATION EXPECTATIONS BY BUSINESS LEADERS	46
FIGURE 16: ACTUAL INFLATION AND INFLATION EXPECTATIONS FROM ECONOMY EXPERTS AND HOUSEHOLDS	47
FIGURE 17 ACTUAL INFLATION AND INFLATION EXPECTATIONS FROM ALL THE SECTORS IN THE SURVEY	61
FIGURE 18: CONSUMER PRICES. 12-MONTH CHANGE. JANUARY 2003 – FEBRUARY 2011	62

Tables

TABLE 1: SHORT-TIME INDEX FOR AGRICULTURAL GOODS	35
TABLE 2: NPC ESTIMATES WITH SURVEY EXPECTATIONS AS INSTRUMENTS, 2002-2010	53
TABLE 3: NPC ESTIMATES WITH SURVEY EXPECTATIONS AS INSTRUMENTS, HOUSEHOLDS EXCLUDED, 2002-2010	54
TABLE 4: NPC ESTIMATES WITH GALÍ AND GERTLER INSTRUMENTS, 1996 – 2010.....	56
TABLE 6: NPC ESTIMATES WITH GALÍ AND GERTLER INSTRUMENTS, 2002-2010	58

1 Introduction

Inflation dynamics is a widely debated subject in modern macroeconomics. Since New Zealand started with inflation targeting as their monetary policy regime in 1988, several other countries has adopted the regime, and amongst them, Norway. Understanding the inflation dynamics in the short run has implications for how to conduct monetary policy and is thus of great interest. One of the objectives has been the New Keynesian Phillips curve (NPC). The NPC is a widely debated theory of inflation dynamics in the short run, and the conclusions about whether the NPC is a good approximation of short-run inflation dynamics are differing.

One way to test the NPC is to use forwarded actual inflation as a proxy for expected inflation. Another approach is that of Roberts (1995). He used survey expectations as proxy for the expected inflation term in the estimation the NPC and compared this to estimates using forwarded actual inflation, and found that using survey expectations improved the fit of the NPC. As an explanation for why the survey expectations would make a more precise model, he said: “(..) *survey response may be better measures of peoples expectations than are realized future prices*” (Roberts 1995, p. 976). Galí and Gertler presented a paper in 1999 testing the NPC theory on US and EU data. They concluded that the NPC was a good first approximation of short-run inflation dynamics. Their results have later been subject to further research, and the conclusions have been conflicting¹. Norwegian studies of the NPC have often ended in a rejection of the NPC, or inconclusive results².

In the thesis I have estimated the NPC relation using both survey expectations and the same variables as Galí and Gertler (1999)³ as instruments for the expected inflation term. The NPC estimates proved to be significant for all of the instrument sets, although the impact from the variables have differed somewhat. Overall, the model that fits Norwegian data the best when testing the NPC theory are the instrument variables used in the Galí and Gertler (1999) paper. My results are contradictory to

¹ For a discussion of the Galí and Gertler (1999) findings, see for example Fuhrer (1997), and Galí, Gertler and López-Salido (2001)

² Se for example Bårdsen et. al (2002), Boug et. al (2006) and Nymoene et. al. (2008)

³ The instrument set in this thesis consist of lags of CPI inflation, labor income share, output gap, wage inflation, long-short interest spread and commodity inflation.

the findings of Roberts (1995). His findings from using surveys showed that using survey expectations had a better fit than using forwarded actual inflation as proxies for the expected inflation term in the NPC. On the other hand, my findings coincided with his result in the respect that it did not matter much whose expectations were used as instruments. I did not find significant differences when using the survey expectations from different sectors as instruments, although excluding the inflation expectations from the household sector made a slightly better model fit.

In the following, I will go through some of the literature regarding the New Keynesian Phillips curve and its origin in section 1. In section 2 the NPC baseline model will be derived. Section 3 is an assessment of the different variables used in the estimation. The data collection and a description of the different variables will be assessed in before we move on to the analysis in section 4. In the analysis part, a brief introduction to the methodology will be given before we move in to the results and the discussion of the results. In the end I will give some remarks about the thesis.

2 The literature

2.1 The historical development of the Phillips curve

Alban William Phillips, who later gave the name to the Phillips curve, first introduced the Phillips curve in 1958 through the article: “ *The relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861-1957*” (Phillips, 1958). Phillips analyzed yearly data from the British economy in the years 1861-1957 and found a non-linear inverse relationship between the unemployment rate and the growth rate of nominal wages. His findings were that the growth rate of wages was high when unemployment was low, and vice versa, but that the growth rate increased more when unemployment was low than it decrease when unemployment was high. The explanation of the negative correlation was that when unemployment was low, employers would bid up the price of labor to get the workforce they needed, resulting in higher overall wages. Workers were on the other hand not willing to work for decreasing wages when unemployment was high. The Phillips curve suggested that there was a trade-off between wage growth and unemployment. Samuelson and Solow found similar results using U.S. data, but they altered/modified the relation by trading nominal wage growth with the inflation rate. This is the relation that is associated with the name the Phillips curve today. The Phillips curve that described the relation between inflation and unemployment is described by:

$$\pi = \pi^e + \beta(\bar{u} - u)$$

where π and π^e is inflation and expected inflation, and u and \bar{u} are the actual- and steady state unemployment rate, respectively. If expected inflation and the steady state unemployment rates are fixed, we find the inverse relationship between inflation and the unemployment rate. A lower unemployment rate than the steady state unemployment rate would lead to higher inflation. The inverse relation between unemployment and the inflation rate implied by the Phillips curve suggested that governments could lower the unemployment rate by accepting higher inflation for a period at the cost it entails. Governments could achieve this by increasing their demand to excess demand, thus causing inflation, but also lowering the inflation rate.

The theory was accepted by many researchers, resulting in a general belief that the government could easily reduce unemployment at the cost of inflation. Given the time periods prior to 1958 when the article was presented, the Phillips curve relation was plausible, not only on British data, but also in other countries. However, thru the 1970s the economic climate changes, and challenged the Phillips curve relation. Several countries experience both high inflation and high unemployment at the same time, called stagflation⁴, which violated the Phillips curve theory. Instead of the predicted negative correlation, countries now experienced a positive correlation between unemployment and inflation.

One of the problems with the Phillips curve is that inflation expectations must be fixed for the relation and the trade-off to be valid. However, it is not realistic that individuals will have fixed inflation expectations. If the government for example were running high inflation by increasing their demand for a longer period to lower the unemployment rate, the individuals in the economy would, after getting used to the higher inflation level, be likely to alter their inflation expectations to fit the new inflation level. This would lead to higher inflation expectations even though the unemployment rate was still the same. This was one of the arguments put forward by Milton Friedman (1968) against the original Phillips curve.

Friedman also criticized the Phillips curve for using nominal variables, and argued that it is the real variables (i.e. real wages) that influence economic behavior, not nominal variables (nominal wages). As a response to the Phillips curve by Samuelson and Solow, Friedman (and Phelps) brought forward the term “natural rate of unemployment” which is the unemployment rate to witch we have no inflationary or deflationary pressure. The insight of a natural rate of unemployment motivated the NAIRU-model⁵. Friedman (1968) emphasized that this natural rate is not a fixed rate for all times, but could change given the economic environment at the time.

⁴ Stagflation is a term for an economic environment that experiences both inflation and stagnation at the same time. Many countries suffered from stagflation in the 1970s.

⁵ NAIRU is an acronym for Non-accelerating rate of unemployment, which is the rate of unemployment that neither increase or decrease inflation

2.2 The New Keynesian framework

The NPC is an improved version of the NAIRU-model, and it is based on a micro foundation, meaning that aggregated supply and aggregated demand is a result of firms maximizing profit and households maximizing utility given their budget constraint. This gives rise to an optimization of behavior for individuals, called agents, in the economy. The NPC is based on a loss function, and the calculation is thus based in a micro foundation. The micro foundation is one of the main features in the New Keynesian framework, and was initiated by Kydland and Prescott (1982)⁶. Their influence in modern macroeconomic modeling, especially the micro foundation in macroeconomic modeling earned them the Nobel price in 2004⁷.

The New Keynesian framework, which the NPC is founded on, is a belief that there are nominal rigidities in wages and prices in the short run. Given nominal rigidities in the short run, government and monetary policy can influence real economic variables in the economy, helping production reach an optimal level in the short run. Another feature is the belief in rational expectations. The individuals make optimal decisions based on their information set at the time. The optimal behavior will change as they get new information. Given rational expectations, the individuals will not make systematic mistakes.

The key elements in the NPC used in the thesis are monopolistic competition, nominal rigidities and short run non-neutrality of monetary politics (Galí 2008). Monopolistic competition means that firms, represented by private agents, set individual prices on goods and inputs on their differentiated goods. The agents exhibit maximizing behavior given a loss function. The second element in the NPC is that the agents experience nominal rigidities. There are constraints imposed on price adjustments, either by constraints on frequencies on price adjustments, or because they experience costs when changing prices. Menu costs are cost firms experience when changing the prices, as for example costs of physically changing the prices-tags or changes in magazines that go out to the public. The constraints on when firms can

⁶ Kydland and Prescott was rewarded the Nobel Price in 2004 based on their contribution to micro founded macroeconomic modeling. Readers are directed to the original paper, Kydland and Prescott (1982): "Time to build and aggregate fluctuations".

⁷ For a brief introduction to the works of Kydland and Prescott and the rationale for the Nobel Price, see the article: "Nobelprisen tildelt intertemporal makroøkonomi" in Økonomisk Forum, Nr.8, 2004 by Espen Henriksen and Kjetil Storsletten

adjust the prices are in this model in line with the Calvo price model (1983) of staggered prices. Only a fraction of firms can adjust their prices in any given period, the remaining firms must wait until next period or periods after. The third main element in the NPC is a result of the nominal rigidities. Since firms are experiencing nominal rigidities, the monetary policy is non-neutral in the short run. The change in interest rates, imposed by either monetary policy or changes in money supply, is not matched one-by-one in expected inflation giving rise to changes in the real interest rate. This has effect on the real economy since the agents in the economy, both firms and households, will alter their behavior.

The main difference between the old Phillips curve and the New Keynesian Phillips curve of today is different forcing variables. The former unemployment growth rate has been replaced by the real marginal costs⁸, and the NPC is forward looking. The NPC expresses that inflation today is affected by real marginal costs and expected future inflation.

3 The baseline model

In this section I will derive the baseline model as it is used in Galí and Gertler (1999). This model has the standard New Keynesian framework with a micro foundation.

3.1 Deriving the baseline model

In the baseline model, agents are assumed to optimize behavior given their preferences and budget constraints. The optimization problem we wish to minimize is the discounted deviation from the optimal prize, p_{t+k} . Future prices are not known at the time of optimization, therefore we need to replace actual prices with expectations. The loss function we wish to minimize can be shown as:

⁸ It is also common to use a measure of output gap instead of real marginal costs, but as Galí and Gertler (1999) showed, this can make spurious result. See Galí and Gertler (1999) for a discussion of the use of marginal costs as driving variable.

$$L = \frac{1}{2} E_t \sum_{k=0}^{\infty} \beta^k (p_{i,t+k} - p_{t+k}^*)^2$$

$$L = (p_{i,t} - p_t^*) + \theta \beta E_t (p_{i,t} - p_{t+1}^*) + \theta^2 \beta^2 E_t (p_{i,t} - p_{t+2}^*)^2 + \dots$$

$$L = \sum_{k=0}^{\infty} \theta^k \beta^k (p_{i,t} - p_{t+1}^*)^2 \quad (1)$$

, where $p_{i,t+1}$ is the price for a representative firm, denoted i , at time t , and p_t^* is the optimal price at time t , hence the expression in the paranthesis displays deviations from optimal price at their respective time periods. As shown above, the deviations are squared, hence both the upside and downside deviations from optimal price are treated equally as losses. The parameter θ is the set probability that a firm must keep its prices for the next period, and β is the discount factor that calculates the present value of future losses of deviations from optimal prices.

The intuition is that, starting at time t , we want to minimize deviations from optimal price (p^*), and we take into consideration the ability to either change the price or not during a period. The first term ($p - p^*$) is, for the representative firm i , the difference of the price at time t (p) and the optimal price at time t (p^*). The following terms represent the future expected deviations from optimal price in their representative years. Since we are assuming the Calvo (1983) pricing model, every firm has a fixed probability ($1 - \theta$) that it can change the price during that period, and thus a fixed probability of θ that it must keep its price unchanged throughout the period. As hown in Eq. (1), the deviation from the optimal price is due to the fact that we have this fixed probability of not being able to change the prices throughout the period. With fully flexible prices, we would not have had this problem since then the firms would have been able to change their prices to the optimal price as the real marginal costs change. Since we have the fixed probability of some firms not being able to change their prices during a period, the actual price may deviate from the optimal price during that period. The loss function we wish to minimize is hence the expected discounted deviations from optimal price from this period and periods to come:

$$L = \frac{1}{2} E_t \sum_{k=0}^{\infty} \theta^k \beta^k (p_{i,t} - p_{t+k}^*)^2 \quad (2)$$

The first order condition (F.O.C) is obtained by differentiating Eq. (2) conditional on the price at time t :

$$\frac{\partial L}{\partial p_{0,t}} = 2 * \frac{1}{2} E_t \sum_{k=0}^{\infty} \theta^k \beta^k (p_{i,t} - p_{t+k}^*) * 1 = 0$$

$$\frac{\partial L}{\partial p_{0,t}} = \sum_{k=0}^{\infty} \theta^k \beta^k E_t p_{i,t} - \sum_{k=0}^{\infty} \theta^k \beta^k p_{t+k}^* = 0$$

Since $E_i p_{i,t} = p_{i,t}$, we get:

$$p_{i,t} \sum_{k=0}^{\infty} \theta^k \beta^k - \sum_{k=0}^{\infty} \theta^k \beta^k E_t p_{t+k}^* = 0 \quad (3)$$

Eq. (3) is the F.O.C. for optimal price at time t . In the following, the subscript i will be omitted since we assume that all firms are equal, hence the equations are based on a representative firm. By using the expression for an infinite geometric series, $\sum_{k=0}^{\infty} \theta^k \beta^k = \frac{1}{1-\theta\beta}$, we can rewrite the optimal price function at time t (Eq.3) to:

$$p_t^{optimal} \frac{1}{1-\theta\beta} - \sum_{k=0}^{\infty} \theta^k \beta^k E_t p_{t+k}^* = 0.$$

Rearranging and multiplying this by $(1 - \theta\beta)$, gives us the new optimal price function:

$$p_t^{optimal} = (1 - \theta\beta) \sum_{k=0}^{\infty} \theta^k \beta^k E_t p_{t+k}^* \quad (4)$$

Further we find the optimal price in the next period, i.e. the F.O.C. for period $t + 1$. Since the prices in the next period is unknown we need to use an expectation-term, which gives us:

$$E_t p_{t+1}^{optimal} = (1 - \theta\beta) \sum_{k=0}^{\infty} \theta^k \beta^k E_t p_{t+1+k}^*$$

Multiply this equation by $\theta\beta$ and rearrange the equation gives the expected optimal price at time $t + 1$:

$$\theta\beta E_t p_{t+1}^{Optimal} - \theta\beta(1 - \theta\beta) \sum_{k=0}^{\infty} \theta^k \beta^k E_t p_{t+1+k}^* = 0 \quad (5)$$

Eq. (5) sums up to zero, thus we can add Eq. (5) to the right side of Eq. (4). The term $(1 - \theta\beta)$ is a common factor; hence the expression can be written as $p_t^{Optimal} = (1 - \theta\beta)[\sum_{k=0}^{\infty} \theta^k \beta^k E_t p_{t+k}^* - \theta\beta \sum_{k=0}^{\infty} \theta^k \beta^k E_t p_{t+1+k}^*] + \theta\beta E_t p_{t+1+k}^{Optimal}$. The expression in the brackets equals p_t^* , which gives:

$$p_t^{Optimal} = (1 - \theta\beta)p_t^* + \theta\beta E_t p_{t+1}^{Optimal} \quad (6)$$

The aggregated price level is given by:

$$p_t = (1 - \theta)p_t^{Optimal} + \theta p_{t-1} \quad (7)$$

Where $(1 - \theta)$ is the fixed probability of firms that are able to change their prices to the optimal price during the period, and θ is the fixed probability of the firms that need to keep the same price as last period regardless of changes in marginal costs. The aggregated price level for period $t + 1$ can be found by using an expectation-term since we do not know the actual price in the next period:

$$E_t p_{t+1} = (1 - \theta)E_t p_{t+1}^{Optimal} + \theta p_t$$

Solving for $E_t p_{t+1}^{Optimal}$, gives the expected optimal price in period $t + 1$:

$$E_t p_{t+1}^{optimal} = \frac{1}{1-\theta} E_t p_{t+1} - \theta p_t \quad (8)$$

Eq. (8) can then be put in expression for the optimal price at time t , namely Eq. (6):

$$p_t^{optimal} = (1 - \theta\beta)p_t^* + \frac{\theta\beta}{1-\theta} (E_t p_{t+1} - \theta p_t) \quad (9)$$

Eq. (9) is then put in the expression for the aggregated price level (Eq. (7)):

$$p_t = (1 - \theta) \left[(1 - \theta\beta)p_t^* + \frac{\theta\beta}{1-\theta} (E_t p_{t+1} - \theta p_t) \right] + \theta p_{t-1}$$

Solving by opening up the brackets and the parenthesis gives the equation that determines the price level:

$$p_t = (1 - \theta)(1 - \theta\beta)p_t^* + \theta\beta E_t p_{t+1} - \theta^2 \beta p_t + \theta p_{t-1} \quad (10)$$

Further, we assume imperfect competitive markets, i.e. the markets are influenced by monopolistic competition. In imperfect markets as monopolistic competition, the firms set their optimal price to cover expected marginal costs plus an extra premium that is computed by a share of the marginal cost. In nominal terms:

$$p_t^* = \frac{\varepsilon}{1-\varepsilon} MC_t^n$$

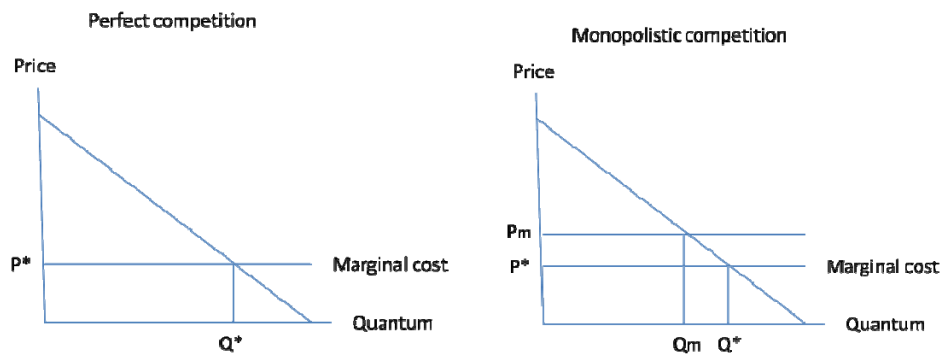
Here, MC_t^n is the nominal marginal costs and the $\frac{\varepsilon}{1-\varepsilon}$ is the premium.

Monopolistic competition occurs when firms have some form of market power, thus they have the opportunity of setting the price higher than needed to cover the marginal costs. There are few pure perfect markets, and it is common to believe all markets have some form of monopolistic competition, although in various degrees.

When firms are setting prices they must consider the expected future increase in wages and other factors that will affect their margins. Since the firms do not know the outcome of the wage settlement, they must use their expectation of the outcome. The firms facing some form of monopolistic power set a price a little higher than expected marginal costs; hence the price is the marginal cost plus a premium⁹. The effect of monopolistic competition is that the quantum produced is less and the price of the goods produced will be higher than what would have been the price under efficient market equilibrium. This also means that the firms have some spare capacity; they can increase production without having to increase their price. Hence, under monopolistic competition there are more flexibility than for a perfect market, and the firms are therefore less affected by changes in the marginal costs.

Figure 1 shows the economic effects of monopolistic and perfect competitive markets. Under perfect competition, the firms' prices will equal their marginal costs, while under monopolistic competition we experience a dead weight loss because the prices are set higher than marginal cost, i.e. not economically optimal.

Figure 1: Perfect competition and monopolistic competition



⁹ Read more about monopolistic competition and price setting decisions in Steigum (2006)

Taking logs of the expression above gives us:

$$p_t^* = \ln\left(\frac{\varepsilon}{1-\varepsilon}\right) + \ln MC_t^n \quad (11)$$

Defining $\mu = \ln\left(\frac{\varepsilon}{1-\varepsilon}\right)$ and $\ln MC_t^n = p_t + mc_t$, where mc_t is real marginal costs in log-form. This last expression comes from the fact that nominal marginal costs can be written as $MC_t^n = \frac{MC_t^n}{P_t} * P_t$. Since real marginal costs equal nominal marginal costs divided by the price, this expression makes us able to write Eq. (11) as:

$$p_t^* = \mu + p_t + mc_t \quad (12)$$

Using the expression above, Eq. (12), and inserting it in Eq. (10), we get:

$$p_t = (1 - \theta)(1 - \theta\beta)[\mu + p_t + mc_t] + \theta\beta E_t p_{t+1} - \theta^2\beta p_t + \theta p_{t-1} \quad (13)$$

Rearranging Eq. (13), gives:

$$\begin{aligned} p_t + \theta^2\beta p_t - \theta p_{t-1} \\ = (1 - \theta)(1 - \theta\beta)[\mu + mc_t] + (1 - \theta)(1 - \theta\beta)p_t + \theta\beta E_t p_{t+1} \end{aligned}$$

$$\begin{aligned} p_t - p_t(1 - \theta)(1 - \theta\beta) + \theta^2\beta p_t - \theta p_{t-1} \\ = (1 - \theta)(1 - \theta\beta)[\mu + mc_t] + \theta\beta E_t p_{t+1} \end{aligned}$$

$$\begin{aligned} p_t(1 - [(1 - \theta)(1 - \theta\beta)] + \theta^2\beta) - \theta p_{t-1} \\ = (1 - \theta)(1 - \theta\beta)[\mu + mc_t] + \theta\beta E_t p_{t+1} \end{aligned}$$

$$\begin{aligned}
p_t(1 - [1 - \theta\beta - \theta + \theta^2\beta] + \theta^2\beta) - \theta p_{t-1} \\
= (1 - \theta)(1 - \theta\beta)[\mu + mc_t] + \theta\beta E_t p_{t+1}
\end{aligned}$$

$$p_t(1 - 1 + \theta\beta + \theta - \theta^2\beta + \theta^2\beta) = (1 - \theta)(1 - \theta\beta)[\mu + mc_t] + \theta\beta E_t p_{t+1}$$

$$p_t(\theta\beta + \theta) - \theta p_{t-1} = (1 - \theta)(1 - \theta\beta)[\mu + mc_t] + \theta\beta E_t p_{t+1}$$

$$\theta p_t - \theta p_{t-1} + p_t\theta\beta = (1 - \theta)(1 - \theta\beta)[\mu + mc_t] + \theta\beta E_t p_{t+1}$$

$$p_t - p_{t-1} = \beta E_t p_{t+1} - p_t\beta + \frac{(1 - \theta)(1 - \theta\beta)}{\theta}[\mu + mc_t]$$

$$p_t - p_{t-1} = \beta[E_t p_{t+1} - p_t] + \frac{(1 - \theta)(1 - \theta\beta)}{\theta}[\mu + mc_t] \quad (14)$$

Since the variables are all in logs, the inflation is defined as $\pi_t = p_t - p_{t-1}$. Inserting this in Eq. (14) gives:

$$\pi_t = \lambda mc_t + \beta[E_t p_{t+1} - p_t] + \varphi$$

$$\text{Where: } \lambda \equiv \frac{(1 - \theta)(1 - \theta\beta)}{\theta} \text{ and } \varphi \equiv \mu \frac{(1 - \theta)(1 - \theta\beta)}{\theta}$$

Eq. (15) is the inflation-equation we wish to estimate. Galí and Gertler are using this expression in their study, but with the marginal cost parameter being percentage deviation from steady state. Making the expression being deviation from steady state, we can write (15) as:

$$\hat{\pi}_t = \lambda \widehat{mc}_t + \beta E_t \{\hat{\pi}_{t+1}\} \quad (15)$$

Where the $\hat{\cdot}$ subscript reflects deviation from steady state. By iterating Eq. (15) forward, we get:

$$\hat{\pi}_t = \lambda \sum_{k=0}^{\infty} \beta^k E_t \{\widehat{mc}_{t+k}\} \quad (16)$$

As shown in Eq. (17) the theory suggests that inflation, measured as price deviation from steady state, is the present value of future expected marginal costs.

3.2 Marginal cost in the model

Marginal costs are the increase in costs of producing one more unit. Producing an extra unit is profitable as long as the marginal revenue from producing one more unit is higher than the marginal cost. When marginal costs and marginal revenue is equal we have equilibrium, hence the optimal production. In competitive market equilibrium, the price would equal the marginal cost, and we would get optimal production.

Marginal costs are not observable because it differs across the aggregated firms, so the marginal cost of the representative firm in this model framework will not be observable. Marginal costs are thus calculated using other measures. In Galí and Gertler (1999) the labor income share is used as the measure of the firms real marginal costs. They consider a simple Cobb-Douglas production function:

$$Y_t = A_t K_t^{\alpha_k} N_t^{\alpha_n} \quad (17)$$

They assume that real marginal costs are given by the rate real wage divided by the marginal product of labor:

$$MC_t^r = \frac{W_t/P_t}{\partial Y_t / \partial N_t} \quad (18)$$

Eq. (18) is a standard expression from microeconomics, which is only a rewritten expression of the fact that in optimum, the real wage will equal the value of the last unit of labor, i.e. the marginal product of labor, MPL¹⁰.

Given Eq. (17) MPL is:

$$MPL = \frac{\partial Y_t}{\partial N_t} = A_t K_t^{\alpha_k} \alpha_n N_t^{\alpha_n - 1} = \alpha_n A_t K_t^{\alpha_k} \frac{N_t^{\alpha_n}}{N_t} = \frac{\alpha_n Y_t}{N_t} \quad (19)$$

Inserting Eq. (19) in Eq. (18) gives:

$$MC_t^r = \frac{W_t/P_t}{\alpha_n Y_t / N_t} = \frac{1}{\alpha_n} * \frac{W_t N_t}{Y_t P_t} = \frac{1}{\alpha_n} * S_t \rightarrow MC_t^r = \frac{S_t}{\alpha_n} \quad (20)$$

Where S_t is the labor income share, where $S_t = \frac{W_t N_t}{Y_t P_t}$. We can see from the Eq. (20) that real marginal costs are proportional with the labor income share. In the following, lower key letters displays the percentage deviation from steady state.

$$\widehat{mc}_t = s_t \quad (21)$$

Gali and Gertler (1999) then use the conditions above in their baseline model:

By inserting the relation in Eq. (21) in Eq. (15), gives:

¹⁰ Pindyck and Rubinfeld (2005)

$$\hat{\pi}_t = \lambda s_t + \beta E_t\{\hat{\pi}_{t+1}\} \quad (22)$$

Eq. (22) is therefore the relation used for estimating the NPC using survey expectations and the Galí and Gertler instrument

4 The data

Estimations of the NPC relation, Eq. (15), was performed by using different instrument sets for the expected inflation term. The first estimation used survey expectations as instruments for the expected inflation term, from a survey conducted by the Central Bank of Norway. This is a quarterly survey where one of the questions is the expected future inflation 12 months ahead. The four groups included in the survey are economy experts from academia, leaders in the labor unions, business leaders and the household sector. The second estimation used the instruments that Galí and Gertler (1999) used in their estimation, namely 4 lags of inflation, labor income share, output gap, wage inflation, long-short interest spread and commodity inflation¹¹.

The data used for the model that replicates the testing for the NPC by Galí and Gertler are quarterly data for Mainland-Norway for various series in the period 1978:1-2011:4. Data for wage inflation calculations starts from 1996:1, hence the time span of the Galí and Gertler instrument set is 1996:1-2010:4. The survey conducted by the Central Bank of Norway started in the first quarter of 2002, and is performed quarterly, therefore the time span of the survey-model is 2002:1-2010:4.

¹¹ Galí and Gertler (1999) used the percent change in the GDP deflator, while I have used the 12-month growth in the CPI as the inflation measure.

4.1 Inflation

The inflation variable, π_t , is the 12-month growth in the consumer price index (CPI). Ideally the 12-month growth in the CPI-ATE¹² or CPIXE¹³ should have been used as the inflation measure, but observations for CPI-ATE and CPIXE are only available from 2002:4 and 2008:3, respectively, and could therefore not be used, as the time periods would be too short for the analysis. The CPI is available on Statistics Norway's webpages, table 03013¹⁴.

Figure 2 shows the actual inflation measured by the CPI, over the period 1980-2010, and displays several distinct economic periods in Norway¹⁵. In 1980 and 1981 we see the aftermath of the revolution in Iran in 1979, and the following Iranian-Iraqi war in 1980 that resulted in a steep increase in the oil prices. The price of oil tripled during this period, giving the oil nation Norway increasing revenues to the state, which in turn gave rise to increasing inflation. The following years the inflation rate declined, until Norway again entered a new economic era, the so called "yap'e time", followed by high inflation¹⁶. Since the discovery of oil in Norway in the early 1970s and the oil crisis' in 1973 and 1979/1980 that both led to steep increases in the oil price, the revenue to the government had risen sharply. High government revenue from the oil fields together with low government set nominal interest rate gave rise to a credit boom (Grytten 2003). The banks were lending out large sums of money, and prices were rising, especially asset prices. The boom came to a sudden end when oil prices fell in 1986, leading to a sharp drop in government revenue, together with a tightening of monetary policy. The years to follow were characterized by banking crisis. The results were an increasing number of bankruptcies, increasing unemployment rates, and declining asset prices.

The 1990s started slow with the aftermath from the banking crisis, but after 1993-1994 the economy started to recover. The banking crisis was a Norwegian phenomenon and not an international banking crisis, which lead to a competitive

¹² CPI-ATE is CPI adjusted for tax changes and excluding energy products

¹³ CPIXE is CPI adjusted for tax changes and excluding temporary changes in energy prices

¹⁴ Statistics Norway, StatBank, table 03013: Konsumprisindex

¹⁵ For a brief overview of the distinct periods in the Norwegian business cycle 1980-2005, see Samfunnspeilet nr. 5-6, 2007, by Statistics Norway

¹⁶ In Norwegian the time period in the mid- to late 1980s was called "jappe-tiden", coming from the English acronym YAP, meaning Young Aspiring Professional.

advantage for Norwegian firms. We can see the expansionary phase in figure 2 as a slow and steady upturn in inflation.

In March 2001 Norway changed the monetary policy regime to inflation targeting. The inflation target was set to be 2,5 % growth in the consumer prices in the medium term¹⁷. After an increase in inflation in early 2002, reaching a top of inflation of 4,5 %, the central bank needed to increase the key policy rate to reduce the inflationary pressure. The Norwegian economy experienced a drawback in late 2002, early 2003. The drawback came as a result of both weak economy amongst Norway's trading partners, and a weakening in the Norwegian economy with low production and increasing unemployment¹⁸. The drawback in the economy resulted in a decreasing inflation. In addition, the water reservoirs were unusually full during 2003 leading to low energy prices. The Norwegian economy is sensitive to energy prices, and the sharp decline in energy prices during 2003 turned into a decline in the CPI. The next year, 2004, the energy prices were at its normal levels, thus making the 12-month growth from in CPI 2003-2004, high. Figure 2 displays a steep fall in CPI inflation in 2003 with a following increase in 2004, but as we now know, this was partly due to the unusually low energy prices in 2003. This shows how the CPI can be a poor measure of underlying inflation since it is affected by the energy prices that are very volatile (Nordbø 2008)¹⁹.

The weak economy during the early 2000s resulted in a lowering of the key policy rate. The central bank started to cut the key policy rate in December 2002, and kept cutting the rate at almost every board meeting until March 2004 in an attempt to boost the Norwegian economy²⁰. The attempt was successful and the inflation started to increase again from the low point in 2003. As mentioned above, some of the effect of the inflation came from the normalization of the energy prices. The increase in inflation however, lasted until the financial crisis hit in 2008. As we will see later, the inflation on Norwegian produced goods were higher than figure 2 indicates. Norway

¹⁷ Read more about the history of the Central Bank of Norway at their webpage, available from URL: <http://www.norges-bank.no/en/about/history/norges-banks-history/>

¹⁸ Speech by former Governor for the Central Bank of Norway, Svein Gjedrem, at Centre for Monetary Economics/Handelshøyskolen BI, June 3rd 2003, available at: *Penger og kreditt 2/03*, Norges Bank

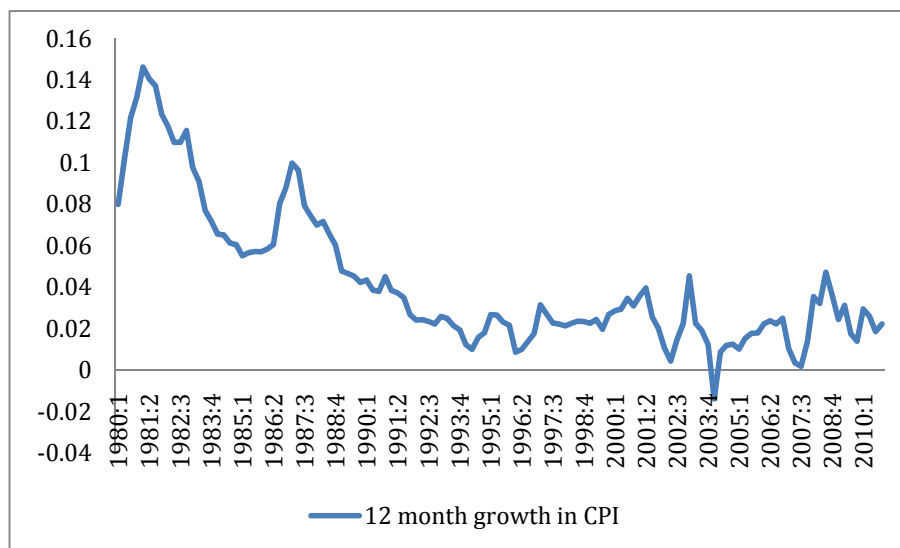
¹⁹ Read more about different inflation measures in Nordbø (2008) in *Norges Bank Staff Memo 2008/7*

²⁰ A summary of when changes have been made to the key interest rate is available at the Central Bank of Norway's webpages, available from URL: <http://www.norges-bank.no/en/price-stability/monetary-policy-meetings/key-policy-rate/key-policy-rate-monetary-policy-meetings-and-changes-in-the-key-policy-rate/>

experienced deflation on imported goods in this period, and since the CPI is a measure of the overall price level in the country, the deflation on imported goods pushed down the overall inflation.

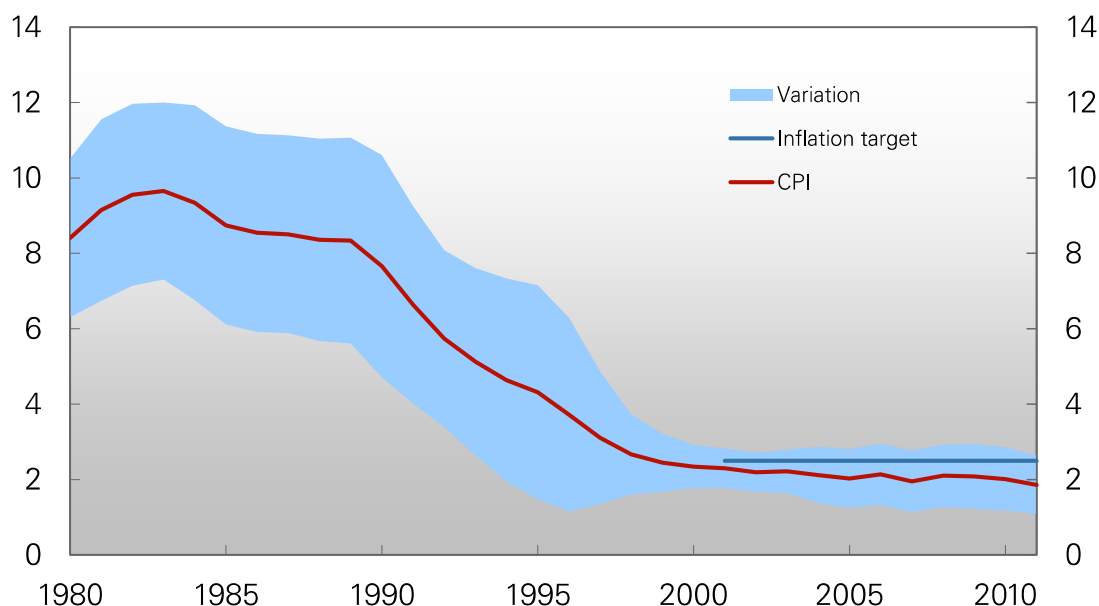
The effect of the financial crisis is clearly visible in figure 2 as a distinct drop in inflation. A note should be made that Norway did not experience disinflation in this period. Norway was not hit as hard as first expected, and as we can see from the figure, the inflation seems to have picked up after the crisis and is getting closer to the inflation target of 2,5 %.

Figure 2: The 12-month growth in CPI. 1980-2010



Overall from the time when the inflation targeting was set in effect in March 2001, Norway has experienced volatile inflation, but the variation has been less volatile than the inflation in the a priori decades. Using a 10-year average to smoothening the variability of inflation makes a better picture of the changes in the inflation volatility. As we see from figure 3, after the inflation targeting was set in effect the volatility in inflation has decreased. Intuitively this should make it easier for individuals in the economy to predict future inflation.

Figure 3: CPI. 10-year moving average¹⁾ and variation²⁾. 1980-2011



1) The moving average is calculated 10 years back

2) The band around the CPI is the variation in the CPI adjusted for tax changes and excluding energy products in the average period, measured by +/- one standard deviation

3) CPI projections in this *Report* form the basis for this estimate

Sources: Statistics Norway and Norges Bank

Source: The Central Bank of Norway²¹

4.2 The output gap

The output gap is a measure used to describe business cycles. It is a measure of whether the activity in the economy is higher or lower than a steady state activity level. The gross domestic product (GDP) is the value of total production output in the economy; accordingly it is an indicator of the overall activity. The steady state value of production is the level that gives steady state inflation, and is called potential output, or equivalently the trend level of production. The difference between actual output and the steady state output is the output gap, consequently it is an indication on how well the economy is doing compared to steady state. A positive output gap is an indicator of the pressure in the economy, and therefore an indicator on inflation-pressure. The problem with the output gap is that GDP levels are revised long after,

²¹ Monetary Policy Report 1/11, chart 1.10, page 12

making it a poor measure of the activity at the present time period. The output gap is defined as:

$$\text{Output gap} = \ln(GDP_{actual}) - \ln(GDP_{potential})$$

The data series used to calculate the output gap is GDP fixed for Mainland-Norway, measured by market value over the period 1978:1-2010:4²². The GDP series has been seasonally adjusted using X-12-ARIMA²³. The steady state level of production is not observable, and must be calculated to find the output gap. One way to calculate the steady state level, and consequently the output gap, is to use a Hodrick-Prescott (HP) filter²⁴. The HP-filter is a univariate method, i.e. a method that only uses information from the GDP series itself when calculating potential production. The method calculates potential production that minimizes the deviation of actual production from potential production.

$$\text{Min}\{y_t^*\}_{t=1}^T \{ \sum_{t=1}^T (y_t - y_t^*)^2 + \lambda \sum_{t=2}^{T-1} [(y_{t+1}^* - y_t^*) - (y_t^* - y_{t-1}^*)]^2 \} \quad (23)$$

where y_t is actual production (GDP) and τ_t is potential production (potential GDP). The first part of Eq. (23) is the difference between actual GDP and potential GDP, squared, in effect the output gap. Since it is squared both positive and negative deviations from the potential output are given the same weight. The second part of the equation is a measure on changes in the trend, thus also deciding the size of the output gap. The weight put on the second part is defined by the parameter λ . The value of λ decides how smooth we want the output trend to be: whether the trend should follow actual production (GDP) closely, or if it should be more of a linear trend. If $\lambda = 0$, only the first part of Eq. (23) is focused on when minimizing; hence the trend follows the actual production series exact, i.e. $\tau = \lambda$. If this were the case we would not have experienced business cycles since the output gap would be zero. The other extreme is if $\lambda = \infty$. In this case the first part of Eq. (23) lose all effect, and the trend would be linear. Clearly this is not realistic either. The output gap was made using the same smoothing parameter used by Statistics Norway, $\lambda = 40\,000$ (Bjørnland et. al. 2004).

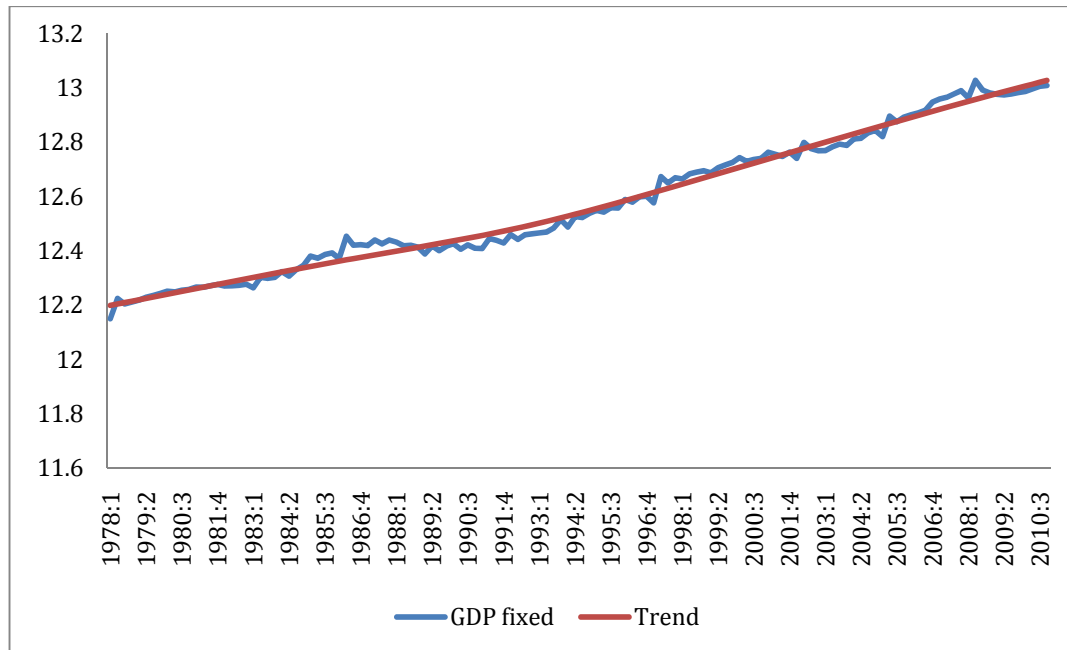
²² GDP fixed prices, market value. Statistics Norway, StatBank, table 06127: "Makroøkonomiske hovedstørrelser"

²³ X-12-ARIMA is available for download at U.S. Census Bureau, URL: <http://www.census.gov/srd/www/x12a/>

²⁴ Read more about the different measures of the output gap, and the features of the HP filter at Bjørnland et.al. (2004) in *Penger og Kreditt* 4/04

Figure 4 show the GDP compared to its trend level, calculated by the HP filter using a smoothing parameter of 40 000. The deviation between the GDP series and the trend GDP is the output gap.

Figure 4: GDP fixed and GDP trend. HP-filter, smoothing parameter $\lambda = 40\ 000$



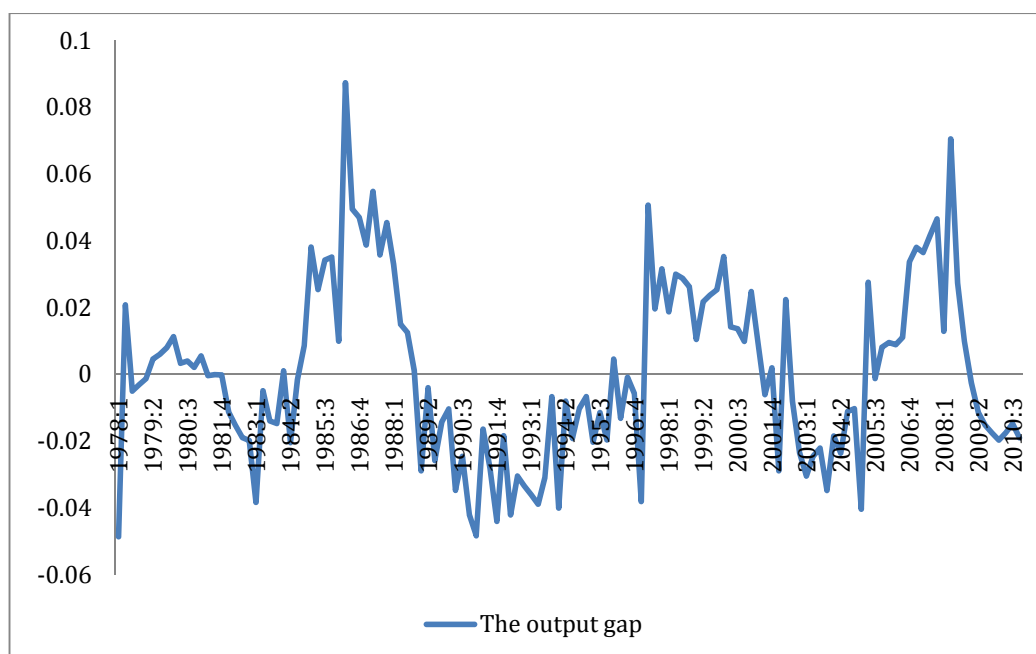
A disadvantage of calculating potential production and the output gap by the HP-filter is the endpoint issues²⁵. The filter is two-sided, which means that observations from both $t - 1$ and $t + 1$ are used when calculating the potential output at time t . At the beginning of the series we do not have any information of the value before the first observation, and in the end of the series we have no information about future production. Only current and future information is available for the computing the trend at the beginning of the series, and only past and current information is available for calculating the trend at the end of the series. In either fringe the trend is therefore more influenced by actual production than in the rest of the series. To remedy a part of the endpoint issues, a prediction of future GDP was made for the period 2011:1-2011:4 by using the forecasts of GDP growth presented by the Central Bank of

²⁵ Read more about issues regarding the HP filter in Sørensen & Whitta-Jacobsen (2005), ch.14

Norway in their Monetary Policy Report 2011/1. Since the GDP series ends at 2010:4, by using the predicted GDP values, the endpoint issue at the end of the series is smoothed out. The GDP series starts in 1978:1, and since the length of the data used in the analysis starts in 1996:1, also the endpoint issue in the beginning of the series is smoothed out. Another concern about the HP filter is a lack of theoretical foundation. The HP filter theory merely states that potential production is the trend, and that potential production is the production we would get if prices and wages had been fully flexible.

Figure 5 display the output gap predicted by the HP filter with a smoothing parameter of 40 000. We can clearly see the expansionary phase in the mid 1980s, and the following downturn from the banking crisis in the late 1980s that carried on into the early 1990s. Output spiked in 1986 and resulted in the highest positive output gap of the period 1978 to 2010. It is also distinctive how the banking crisis in the late 1980s affected the Norwegian economy for several years after, resulting in a negative output gap. The turning point after the crisis came in 1996, ten years after the oil price dropped and the banking crisis (Grytten 2003). The downturn because of the financial crisis in 2008 is also distinct with a sudden shift from positive to a negative output gap in the second half of 2008.

Figure 5: The output gap



Comparing the output gap in figure 5 to the inflation in figure 2 show that there is a strong link between the output gap and inflation. When there is pressure in the economy, production will increase, and thus leading to inflation. The output gap is a common indicator of inflationary pressure.

4.3 Wage inflation

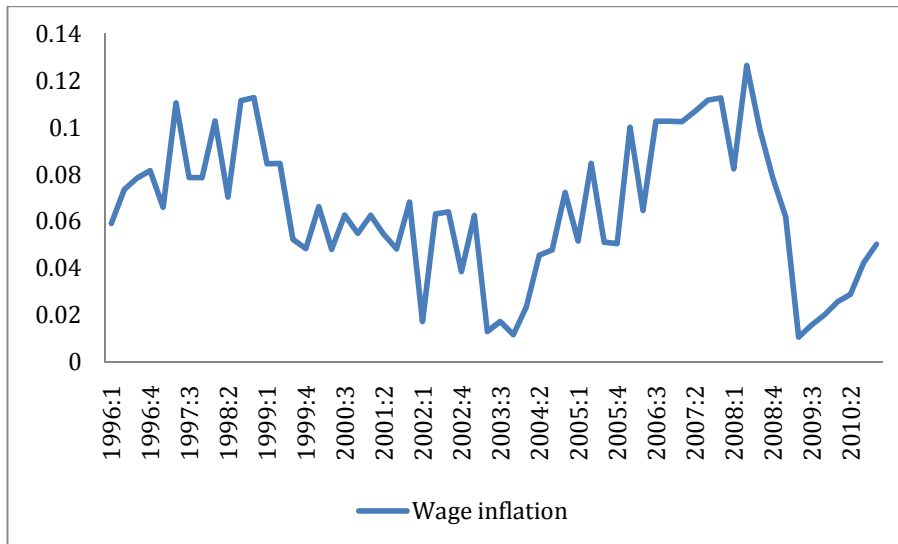
The wage inflation variable is calculated by taking the 12 month growth in the seasonally adjusted total wage cost series, over the period 1995:1-2010:4. The wage cost series is found in table 06173 at Statistics Norway's webpages²⁶.

Table 6 clearly shows the expansionary period from the mid-1990s up until the so-called *dot.com* and *9/11* crisis in the beginning of the 21st century. The increase in wages was low during the difficult years and had a low point in 2003. The growth in wage inflation was relatively steep from the low point in 2003 up until the financial

²⁶ Statistics Norway, table 06173: "lønn og sysselsetting, etter næring"

crisis hit. One of the explanations is the decreasing unemployment rate during this period. The unemployment rate was 3,5 % in 2005, but fell to 1,7 % in 2008²⁷. In 2008 the financial crisis hit, and as we can see from figure 6 wage inflation dropped sharply from 12,5 % to 1 % during the 12 months from mid-2008 until mid-2009.

Figure 6: Wage inflation



The theory of the original Phillips curve proclaimed a stable inverse relationship between the rate of unemployment and the wage inflation (Steigum 2006). Although this theory is rejected in its original form, the insight of the theory still stands regarding labor market theories.

Price inflation will make the income for the individuals in the economy pay for less than it otherwise would if the prices had stayed the same, i.e. the money lose purchasing power when the prices of goods and services increases. The loss of purchasing power of the paycheck workers receive for their work will in turn be compensated for by increasing the wages for the workers. To which scale the workers will be compensated for the price inflation, hence loss in purchasing power, depends on what labor unions agree upon during wage settlements. Former Governor of the

²⁷ Statistics Norway, StatBank, table 06900: “Registrerte arbeidsledige, etter kjønn. Årsgjennomsnitt (present) (k)”

Central Bank of Norway, Svein Gjedrem, pointed out that the low growth in wages during 2003 could be a result of 2003 being a year with midterm-negotiations and not the main settlement (Gjedrem 2003).

Amongst other issues as to how different types of work are valued in society, wage settlements depend largely on expected inflation. The increase in wages that worker unions and others are trying to settle on should in part reflect the loss of purchasing power caused by increasing prices. Since future inflation is not known, the labor unions on both the employers and the employees side must make their own prognosis on how they believe the prices will change in the short term, in effect settle on new wages that will close to fully compensate for inflation. In an economy with low unemployment, there is usually a shortage of skilled workers to be hired, and workers have greater bargaining power over the labor unions in wage settlements, making an upward pressure on wages. When the unemployment rate is high, the employers have the upper hand, thus making a downward pressure on wage growth.

4.4 Unit labor costs

The labor income share is a measure of unit labor costs, i.e. how much of the total production output in a country goes to paying for the production input labor. GDP Mainland-Norway is the measure of total output, and the total labor cost is the measure of the cost of the production input labor. The labor income share is used both as the measure of marginal costs, s_t , but it also used as an instrument variable as a measure of unit labor costs in the testing of the NPC. The labor income share is calculated by taking the percentage difference between wage cost and the gross domestic product; hence it is the relative cost of labor measured by total costs of labor compared to total income measured by the GDP.

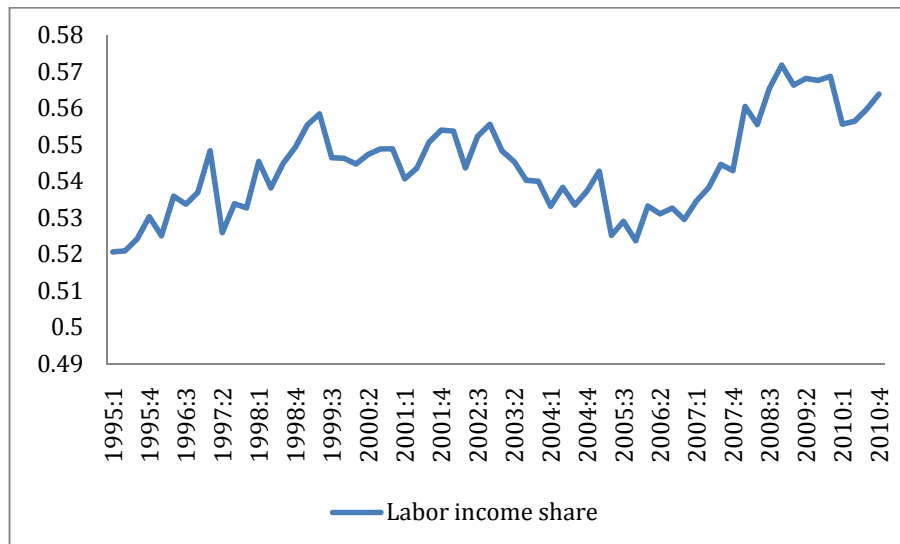
The wage cost series is total wage cost for Mainland-Norway, presented quarterly from 1995:1-2010:4, available from StatBank at Statistics Norway's webpages, table 06173²⁸. The wage cost series has been seasonally adjusted using X-12-ARIMA. The

²⁸ Statistics Norway, StatBank, table 06173: "Lønn etter sysselsetting, etter næring"

GDP series are seasonally adjusted GDP for Mainland-Norway in basic value, quarterly data from 1978:1-2010:4²⁹.

Figure 7 shows the relative cost of labor measured as total wage cost divided by total output (GDP). From the period 1995-2010, the wage share has increased from about 52 % to 57 %. The increase in unit labor cost has not been steep, but it shows that almost 60 % of total output from production goes to paying for the production input labor.

Figure 7: The labor income share



To get a better picture of the actual development, we need to look at both how wages and total output has developed in the same period. The wage inflation was high and increasing during the late 1990s, before it started to slow down in the early 2000 as shown by figure 6. From figure 7 we can see that unit labor costs was at its second highest in the end of the 1990s for the whole time period. The total production was low during the early start of the 1990s, cf. the output gap in figure 5. Total production was rising in the second part of the 1990s, but as we can see from chart 7, wage cost increase more than total production. During the difficulties in the early 2000s, labor unit cost sunk. At this time wage inflation was low, and is the most likely reason for

²⁹ Statistics Norway, StatBank, table 06128: “Makroøkonomiske hovedstørrelser. Sesongjustert”

unit labor cost decreasing at this point. Production was also suffering from the difficulties in the early 2000s.

There was pressure on labor unions not to demand higher wages since the economy was in a stall. When the economy started to pick up speed again, we experienced high wage inflation, and unit labor costs were again increasing. The low unemployment rate in this period increased labor unions positions, making wages increase. The unit labor costs have been increasing since the low point in 2005. The financial crisis in this chart is not easy to spot, which is to be expected since both wage costs and total production both dropped steeply in this period, making the relative relationship the same as before.

Using unit labor cost as an instrument for expected inflation is intuitive given the way unit labor cost affect total production through costs. When unit labor costs increase, a larger share of the value of total production are used to finance the production input factor labor. An increase in unit labor cost also means that the cost of labor has increased relative to output, i.e. the firm are getting less output per krone paid for labor than earlier. When the cost level of production increases relative to output, the prices are likely increase so the firm can finance the higher cost level and still keep its margins.

4.5 Commodity price inflation

The commodity price inflation is a measure of changes in prices on consumer goods that do not include rent and services. The consumer price index (CPI) for goods and services by delivery sector was used to calculate two commodity price inflation indexes: one index for inflation in Norwegian produced goods only, and another index that also includes inflation on imported goods. The CPI index for goods and services are divided into sub-indexes by delivery sector; “agricultural products”, “fish products”, “other consumer goods produced in Norway”, “imported consumer goods”, “rent” and “other services”, and their representative weights. Using all of the sub-indexes besides “rent” and “other services” makes up the commodity price index.

The CPI by delivery sector series is available at SSBs webpages, table 03363³⁰. Base year for the CPI by delivery sector is 1998 (1998=100).

4.5.1 Making short term indexes from the sub-indexes

Each of the sub-indexes is split into short term-indexes, where July each year is set to 100³¹. This allows for relative price differences over time, hence we are able to compare the years relative to each other. Setting July = 100 isolated each year's price changes, in other words variations in prices during year t do not affect variations in prices in year $t+1$, and so forth. Table 1 displays how the short-term index is made for the agricultural products. The same procedure has been done for each of the other sub-indexes; fish products, other consumer goods produced in Norway, and imported goods.

As we can see from table 1 and figure 8, the short-time index re-starts at the value of 100 each July; hence we can see how the prices have changed within each year without effects from the other years interfering. In figure 8 we can see the short-term index for agricultural products compared to the original agricultural products index, where the original index has the base value 1998=100.

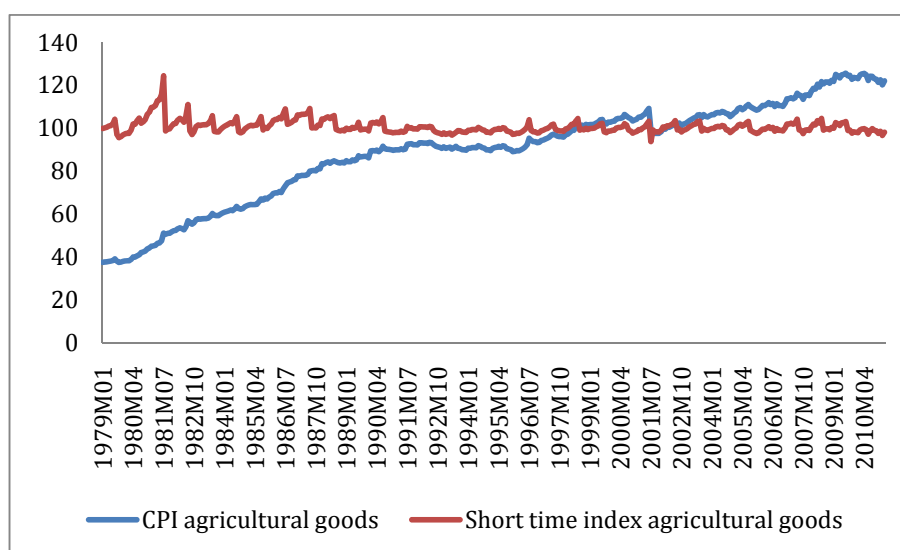
³⁰ SSB, table 03363: "Konsumprisindeks for varer og tjenester, etter leveringssektor (1998=100)"

³¹ Statistics Norway change the weights of the sectors in CPI in July each year, see Rodriguez & Haraldsen (2005) in *Økonomiske Analyser* 4/2005

Table 1: Short-time index for agricultural goods

Date	CPI agricultural goods	Calculation	Short term index (S.I)
December 2002	106,8	$\frac{CPI_{Dec02}}{CPI_{Dec02}} * 100 =$	100
January 2003	107,5	$\frac{CPI_{Jan02}}{CPI_{Dec02}} * 100 =$	100,655
February 2003	108,3	$\frac{CPI_{Feb02}}{CPI_{Dec02}} * 100 =$	101,404
:	:	:	:
July 2003	111	$\frac{CPI_{Jul02}}{CPI_{Dec02}} * 100 =$	103,933
August 2003	109,7	$\frac{CPI_{Aug02}}{CPI_{Jul02}} * 100 =$	98,829
September 2003	111,1	$\frac{CPI_{Sept02}}{CPI_{Jul02}} * 100 =$	100,090

Figure 8: Short-term index and CPI sub-index for agricultural products



4.5.2 Making short term indexes into a chained index

To make a chained index that will become the commodity price indexes, the short-term indexes first need to be weighted together. The short-term indexes for each delivery sector are weighted together by their representative weights given in Table 03362 by SSB. The weighted index for Norwegian produced goods is:

$$\frac{(s.i.agri * weight agri) + (s.i.fish * weight fish) + (s.i.other * weight other)}{weight agri + weight fish + weight other}$$

Here, *s.i.* = the short time index for the representative sectors. Adding imported goods to the formula makes the weighted index for Norwegian produced goods and imports imported goods, which is the basis for the second commodity price inflation variable.

The weighted short-term indexes make the basis for calculating the chained index for the commodity price inflation; one for Norwegian produced goods only and a second one that includes imported consumer goods. The chained index will re-index the weighted short-term indexes, in other words reversing the short-term indexing done in the first step, so we get a new index with base year 1979 = 100. When calculating the chained index, the index will be equivalent to the short-term index during the first year of the series until July the same year, and then it is re-indexed in August 1979 against July the same year (1979). In the following *ch* = chained index and *s.i.* = short-term index. The formula for making the chained index is:

$$ch.1979Aug = ch.1979July * \frac{s.i.1979Aug}{100}$$

$$ch.1979Sept = ch.1979July * \frac{s.i.1979Sept}{100}$$

:

$$ch.1980July = ch.1979July * \frac{s.i.1979July}{100}$$

$$ch.1980Aug = ch.1980July * \frac{s.i.1980Aug}{100}$$

:

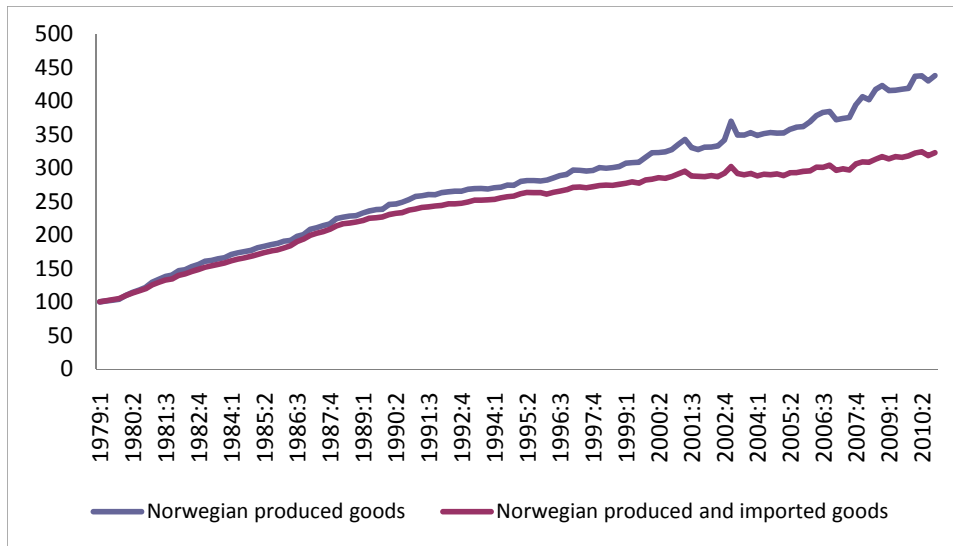
$$ch.1981July = ch.1980July * \frac{s.i.1981July}{100}$$

$$ch.1981Aug = ch.1981July * \frac{s.i.1981Aug}{100}$$

The chained index describes the historical development of the price of Norwegian produced goods in CPI, and the historical development of the price in Norwegian produced goods and imports in CPI. Each of the new indexes has base year 1979 = 100.

Figure 9 shows that the index of Norwegian produced goods is increasing at a higher rate than the index for Norwegian produced and imported goods, making it apparent that the price development of imported goods has dampened the development of the total price level. Intuitively this makes sense since Norway has experienced large revenues from the petroleum industry since oil was discovered in the 1970s, pushing up the prices on other domestic consumer goods. Imported inflation has been low since Norway has been able to import cheap goods from Asia and other countries, both because Asia are producing at a low cost level, but also because the Norwegian exchange rate has been high making the products relatively cheaper (Gustavson and Vinje 2009).

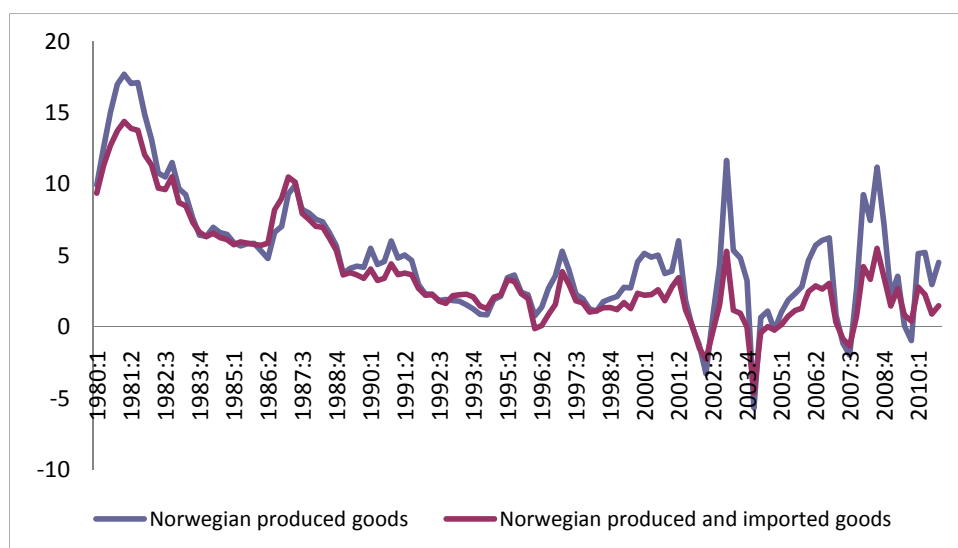
Figure 9: Commodity price index: Norwegian produced goods only, and Norwegian produced goods and imports. 1979=100



4.5.3 Commodity price inflation

Taking the 12-month growth in the chained indexes for Norwegian produced goods and Norwegian produced and imported goods gives the inflation in the two commodity variables. As shown in figure 10, the inflation in Norwegian produced goods is more volatile than the inflation when including the imported goods. It is also clear that the inflation in imported goods have dampened the inflationary pressure for Norwegian consumer goods. We can see that this is particularly true throughout the 2000s.

Figure 10: Commodity price inflation



The price development on consumer goods produced in Norway compared to imported goods has moved in opposite directions. Most of the imported goods have had a declining inflation or even deflation, while the Norwegian produced consumer goods has had a steeper inflation pattern.

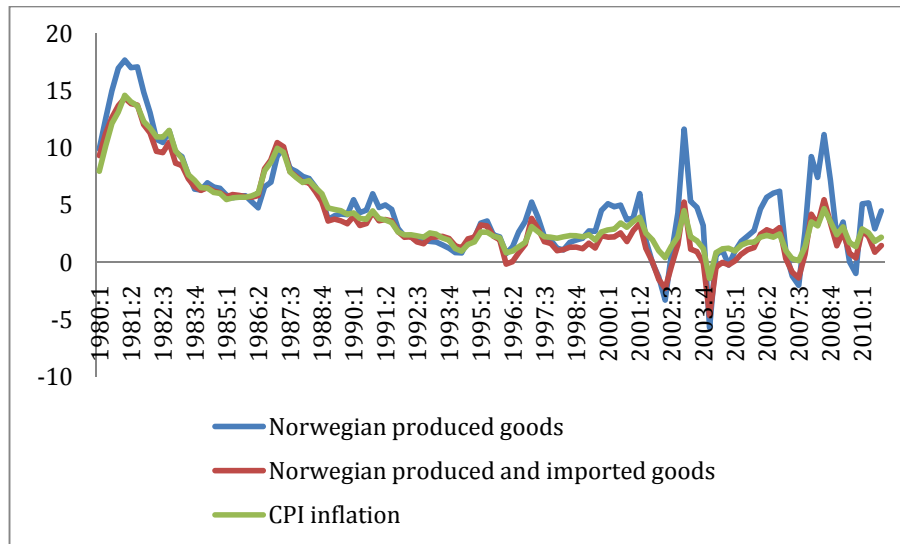
The cheap imports made it look as if the pressure in the Norwegian economy was less than it actually was. The Central Bank of Norway started their hike in the sight deposit rate in June 2005³². As we can see from figure 10, the inflation on commodity goods produced in Norway had been high in the years leading up to this, but using the index where imported goods are included show that the total inflation on commodity goods has been low. The commodity price inflation is not the measure of underlying inflation, but it gives an indication on price developments on Norwegian produced and imported goods.

The reason for using two different measures of the commodity price inflation is to see whether it makes a difference on the results on how well the NPC fit Norwegian data. It seems plausible that the commodity inflation variable that includes imports will make a better instrument for expected inflation than the variable without imported goods. As we can see from figure 11, the commodity variable that includes imports is

³² Historical changes in the sight deposit rate, available at the Central Bank of Norway's webpages, URL: <http://www.norges-bank.no/no/prisstabilitet/rentemoter/styringsrenten/styringsrenten-oversikt-over-rentemoter-og-endringer-i-styringsrenten/>

less volatile, and follows actual inflation better than the commodity variable with Norwegian produced goods only.

Figure 11: CPI inflation and the two commodity inflation measures. Per cent



4.6 Long-short interest spread

The long-short interest rate spread is the difference between the 10-year Government bond and the 3-month NIBOR³³. The 10-year Government bond and the 3-month NIBOR rates are available at the Central Bank of Norway's webpages³⁴.

If there are high inflation expectations in the long run, the individuals holding the long-term bonds want a high compensation for lending out the money, hence a higher interest rate. The rate of the 10-year Treasury bond largely depends on the economic outlook, both regarding risk and inflation. The 3-month NIBOR is the short time interest rate in the interbank market, and reflects the situation in the money market in the short run³⁵. A high spread between the short- and long-run interest rates is an indicator of future inflation expectations. Tighter monetary policy leads to rising

³³ NIBOR is the Norwegian Inter Bank Offered Rate

³⁴ 10-year Government bonds is available at URL: <http://www.norges-bank.no/en/price-stability/interest-rates/government-bonds-yield-monthly-average-of-daily-quotes/>. 3 month NIBOR is available at URL: <http://www.norges-bank.no/en/price-stability/interest-rates/nibor-nominal-interest-rate-monthly-average-of-daily-observations/>

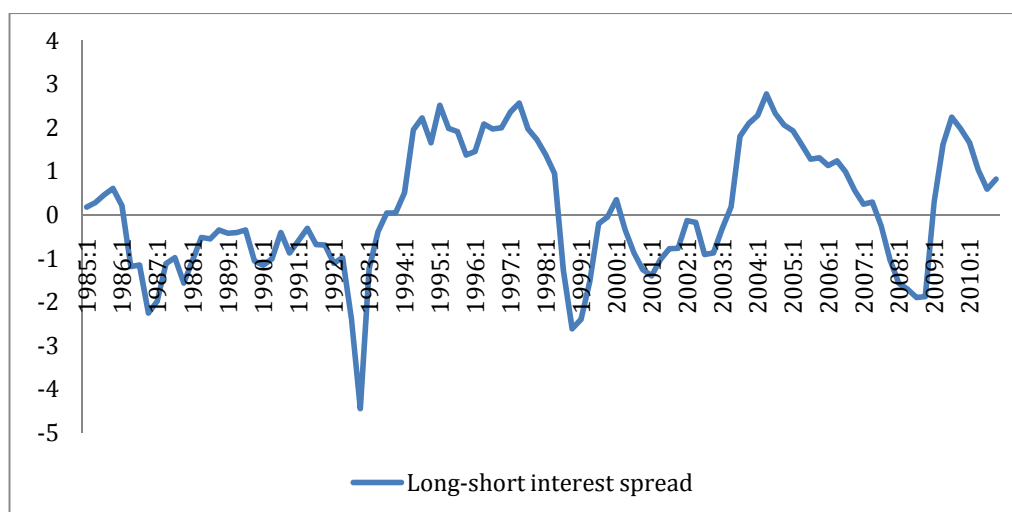
³⁵ For a thorough introduction to interest rate measures, readers are directed to Bernhardsen (2011) in Staff Memo 4/2011

short-term interest rates. Tightening the monetary policy on the other hand, will usually lead to lower inflation in the future, thus lower rates will follow. The long-term interest rates will thus not increase as much as the shorter-term interest rates, and the long-short interest spread will decrease (Estrella and Trubin, 2006).

As we can see from figure 12, the economic outlook during the late 1980s and the beginning of the 1990s was poor. The short-term rates were higher than the long-term interest rates in this period, which indicates that the individuals holding the bonds did not expect an increase in inflation. During the 1990s the economic outlook changed, and the interest rates on bonds of longer maturities increased. This is an indication of increased expected future inflation. This coincides with the discussions above regarding the economic periods in Norway.

Also the expansionary phase leading up to the financial crisis is clear. In the beginning of the 2003, the key policy rate was cut on a regular basis to help improve the Norwegian economy. When the economy started to recover and inflation started to increase, the central bank had to start adjusting by increasing the key policy rate. The central bank started to increase the key policy rate from June 2005. The sharp drop in the long-short interest spread in 2003 reflects the poor economic outlook at the time. The reduction of the key policy rate improved the outlook as this was meant to improve the economy, making the long-short interest rate spread turning positive and increasing. The spread was high during the following expansionary phase, reflecting the higher inflation expectations. The increase in the key policy rate starting in 2005 once again showed that the inflation expectations got reduced, and the spread contracted.

Figure 12: The long-short interest spread



4.7 Survey from the Central Bank of Norway

The Central Bank of Norway performs quarterly surveys on inflation expectations, expectations on wage movements and interest rate movements. The survey is performed by Perduco on behalf of the Central Bank of Norway, and is published both on the Central bank of Norway's webpages and the Perduco's webpage³⁶. The length of the series is the 2002:1-2011:1. The four groups of individuals responding to the survey are economy experts in academia and the financial industry, members in higher positions in workers' unions (both employer and employee unions), business leaders and individuals in households. The questions from the survey used in the testing of the NPC are the question about the expectations for the 12-month growth in the consumer price index (CPI). The questioning varies among the groups according to their level of economical understanding, getting answers that reflect their expectation on inflation³⁷. Extreme observations are left out of the survey.

The questions the survey participant receives are direct questions on their expectations of inflation 12 months ahead and should therefore represent the actual inflation expectations of the individuals. The participants in the survey are a representative sample of individuals in the economy and should display the broad

³⁶ For a full review of the surveys, see the Central Bank of Norway's webpages, available at URL: <http://www.norges-bank.no/no/prisstabilitet/forventningsundersokelse/>

³⁷ The survey questions are attached in the Appendix

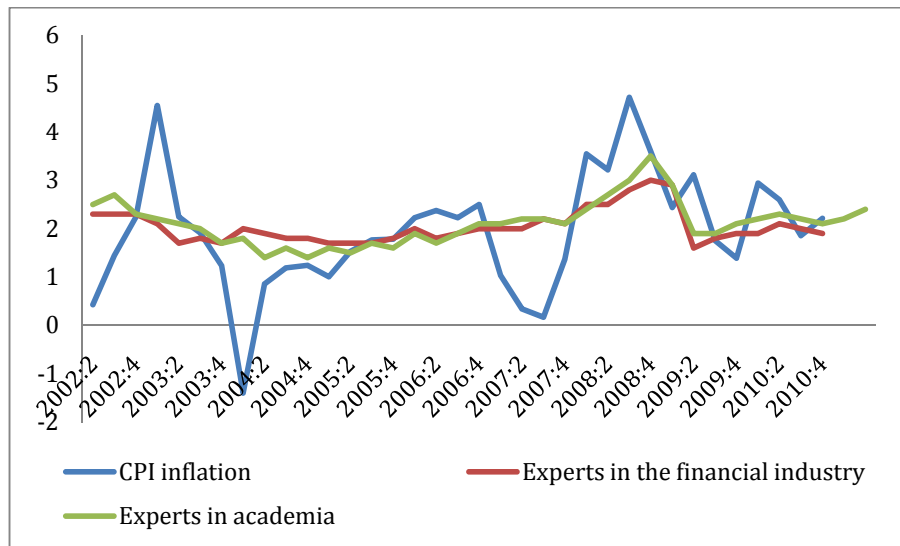
inflation expectations. The survey is divided into four groups of individuals in various sectors in the economy. The participants use all available information past and present when making their forecasts on future inflation.

4.7.1 The economy experts

The economy experts consist of economic experts in two different work fields: economic experts in academia (universities and colleges), and economic experts in the financial industry. The survey goes out to the same group of people with some minor changes in the members due to who is employed at the moment of the survey. The data was collected by Perduco through the web tool Confermit, and was sent to the respondents via e-mail. The survey present observations from the two expert sectors separately, together with a total score based on weighted averages of the two. In the thesis it is the combined score that is used as the expectations variable for the economic experts.

It is reasonable to believe that the economy experts, both in academia and in the financial industry, would make the most accurate forecasts among the sectors represented in the survey. They have knowledge about economic relations and the implications of movements in key figures, and should on the basis of their knowledge be able to make reasonably predictions on future inflation. Figure 13 shows the relation between actual inflation and the inflation expectations of economy experts in academia and the financial industry. The figure has been created by forwarding the observations of expected inflation one period ahead to make the expectations line up with actual inflation at the time. It is somewhat surprising to see that the inflation expectations of the economy experts do not follow actual inflation more closely. Up until the financial crisis hit, the inflation expectations displayed little variability even though it is clear that actual inflation were very volatile in the same period. During the financial crisis the inflation expectations fell abruptly, and leveled out at a lower point. Again it looks as the inflation expectations have found a new steady path, though on a slightly lower level than before the financial crisis.

Figure 13: Actual inflation and inflation expectations by the economy experts



4.7.2 Labor unions: Employer and employee organizations

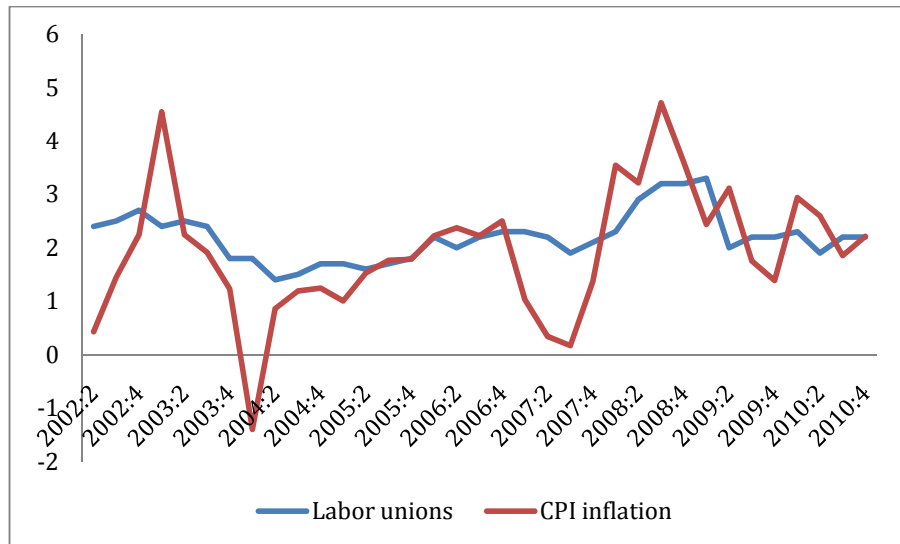
The labor unions participants consist of individuals from both the employer and the employees side, but will in the following be referred to as the labor union. In the survey, both employer and employee organizations are represented and the observations are presented separately and combined based on their weights. In this thesis, it is the combined expectations of labor unions that are used as the expectations variable for the labor unions. As for the economy experts, the data was collected by Perduco through the web tool Confirmit, and was sent to the respondents via e-mail.

The participants from the labor unions sector are, as well as economy experts, likely to have inflation expectations that are close to actual inflation given their positions in wage settlement. One of the objectives in the negotiations is to compensate workers for their purchasing power loss from inflation. Being able to predict future inflation is thus an important task for the negotiations, and the outcome of the wage settlements. The members of the labor unions must therefore look at economic key figures and make forecast based on those. Hence, it is plausible to believe that participants from the labor unions sector will have expectations that are closely linked to actual inflation.

As we saw with the economy experts, also inflation expectations of the labor union members are less volatile than actual inflation. Comparing figure 13 with figure 14

shows that labor union expectations follow the expectations of economy experts closely.

Figure 14: Actual inflation and inflation expectations from the labor unions sector



4.7.3 Business leaders

The respondents among business leaders have changed during the years the survey has been performed. From 2002 until 2009, only business leaders of Norwegian firms with 50 or more workers could participate. From 2009:1 business leaders in Norwegian firms with 20 or more workers participates in the survey. The survey displays results separately for the business leaders of 20+ and 50+ workers, and a combined score for the group as one. The combined score was used as the inflation expectations for business leaders in the testing of the NPC. The respondents in this group, the business leaders, have increased from about 300 respondents to about 500 respondents, making it a broader measure. The panel of business leaders are recruited through Perducos quarterly “business survey” (Norges næringslivsundersøkelser – NNU). The results are weighted based on region, industry and the number of employees in the firm.

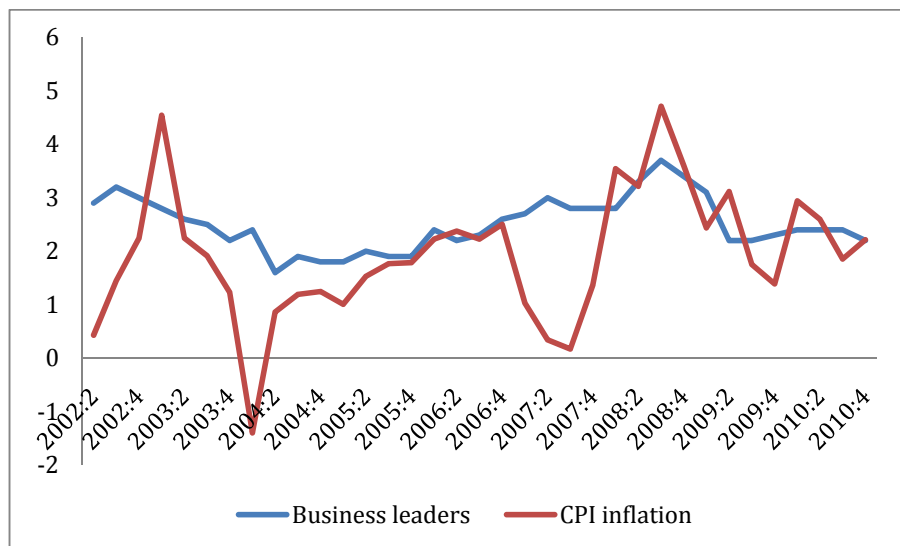
Business leaders need information about the economy and the outlook of the economy to make business decisions that maximize the firms’ profits both in the short and long run. Knowing the economic outlook and how to adapt to its surroundings is crucial to

make the business successful. One of the factors business leaders need to take into consideration when optimizing production is the inflation. The cost level increases when the prices on production input factors increase, both labor and products needed in the production. Inflation will in this regard affect the price setting decisions of the firms.

Compared to both economy experts and labor unions, the business leaders might be more influence by inflation expectations in their respective business sectors than the overall inflation. The business leaders need to consider the prices they are faced in their business, and the overall inflation might be of less considerations. In this regard, the inflation expectations might follow actual inflation less than the expectations of economy experts and labor unions.

Looking at chart 15 shows that the expectations of the business leaders follow the expectations of economy experts and labor unions, but the expectations are a slightly more volatile. The general level of inflation expectations is also generally a little higher than that of both economy experts and labor unions.

Figure 15: Actual inflation and inflation expectations by business leaders



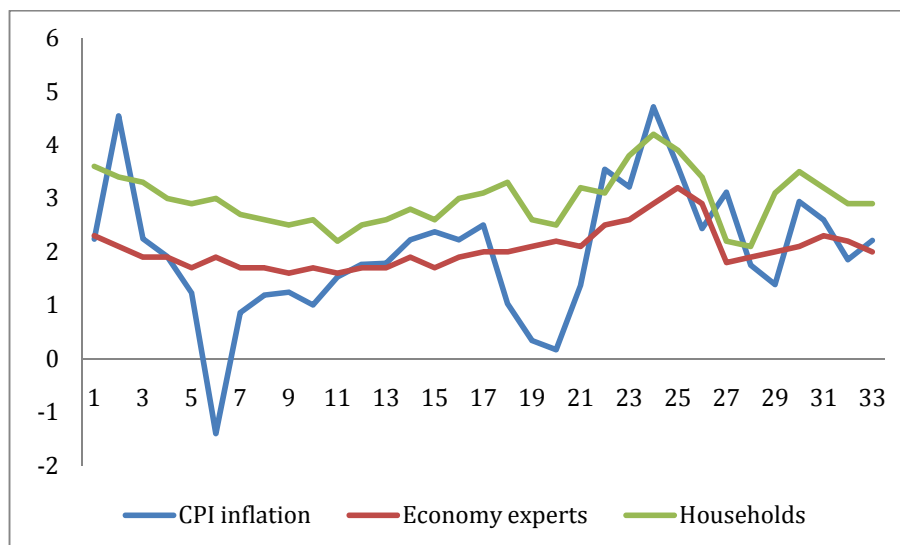
4.7.4 Households

Respondents from the household sector are a representative sample of individuals aged 15 or older. 60 % of the interviews are done by housing telephones, and 40 % is done by cell phones. A total of 1004 interviews are carried out in the household sector, and the results are weighted based on region, age and gender. The interviews are done by telephone (CATI), and are performed by Norstat Norge on behalf of Perduco.

Households are the sector in the survey-sample that is the least likely out of all the sectors in the survey to make accurate forecasts on inflation. This is not to say that they do not make inflation expectations that follow actual inflation, but given their level of expertise in economic analysis, they are the least experienced group on the field regarding economic behavior and economic key figures. On the other hand, participants from the household sector face changes in inflation on a regular basis regarding consumption and wages, and should therefore be able to predict inflation.

Looking at expected inflation from the household sector compared to the forecasts by economy experts and actual inflation in figure 16, reveals that households over-evaluates inflation by approximately 1 percentage points compared to the economy experts on average.

Figure 16: Actual inflation and inflation expectations from economy experts and households



Given table 13-16 it is clear that inflation expectations by economy experts, labor unions, business leaders and households are less volatile than actual inflation. This means that even when experiencing large fluctuations in actual inflation, individuals do not alter their expectations in the same respect. Inflation expectations do not seem to vary as much with actual inflation as we would have expected, but on the other hand, the expectations are varying with inflation, thus being correlated to the expected inflation. In this respect, expected inflation from the survey should be valid instruments for the expected inflation variable in the NPC model.

4.7.5 Shortcomings in the survey

The sample from the survey is small due to the short period of available data. The testing of the NPC using survey data is thus not robust, but will give an indication of the fit of the NPC when survey expectations are used as the instrument of expected inflation. Since the series is short, the testing should be conducted again when more data is available. The survey data are based on individuals answering the survey, and has the typical shortcomings of surveys (Gripsrud et. al. 2007).

The most likely error in this survey would be measurement errors that occur when participants do not understand the questions as intended, or participants deliberately giving untruthful answers. The problem with misconception of the questions are most likely to happen in the household sector as participants from this sector have the least knowledge of economic variables and -relations compared to the other sectors. One that is not familiar with the term inflations, CPI and 12-month growth would have trouble predicting actual inflation. Another concern pointed out by Roberts (1995) is that individuals in the survey might have little incentive to make thoughtful answers.

5 Analysis

All estimates in the analysis were significant and showed that the NPC theory fit Norwegian data. In this section I will go through the results from my estimations, and I will start by giving a brief introduction to the methods used in the analysis. The results from the use of survey instruments will be presented first before I go through the results of the use of Galí and Gertler instruments, and then compare the two. In the end of the analysis I will briefly discuss the robustness of my findings, and a discussion of whether to include a constant term or not in the regression.

5.1 The methodology

5.1.1 Instrument variables regression

The NPC equation of inflation consists of both inflation today and expected inflation. The inflation equation we wish to estimate is³⁸:

$$\pi_t = \lambda s_t + \beta E_t(\pi_{t+1})$$

Testing this relation using actual inflation as a measure of expected inflation will cause serial correlation. This is a violation of the time series assumption number 5, no serial correlation, causing the output not to be testable using standard hypothesis testing. The time series assumptions are equivalents to the Gauss-Markow assumptions for panel data, and are a set of assumptions that must hold to make inference about a tested relation when using ordinary least square (OLS) as the estimator.³⁹ If one of the five assumptions is violated, we cannot use standard testing methods as t- and F-tests to make inference. Actual inflation as a measure of expected inflation will cause serial correlation, the variable will be endogenous and the standard errors will be incorrect; hence we must use a different approach to make inference. A method well known to avoid the problems of serial correlation is to use instrument variable (IV) regression and two stage least square (2SLS) instead of OLS regression. The IV regression method use one or more variables that are instruments

³⁸ All variables are log deviations from steady state

³⁹ Read more about time series inference in Woolridge (2009), chapter 10-12

for the original variable that we wish to estimate⁴⁰. The intuition behind IV regression is that the variation in original variable comes from two separate parts; one part that is correlated with the error term, u , and another part that is not correlated with u . The part that is correlating with the error term is the problematic part that causes serial correlation, and is the part we wish to isolate and not use in the testing. The second part of the variation, the one that is not correlated with the error-term, is the one we wish to keep and use in the testing of the relation. The two conditions for a valid instrument, Z_i , for the variable we wish to estimate, X_i , is (1) instrument relevance: $corr(Z_i, X_i) \neq 0$, and (2) instrument exogeneity: $corr(Z_i, u_i) = 0$. The first condition ensures that the instrument variable is correlated with the instrumented variable meaning some of the variation in the instrument is related to the variation in the instrumented variable. The second condition ensures that the instrument variable does not correlate with the error term, thus being exogenous.

Using instrumented variables, we can estimate the inflation equation by the 2SLS estimator. The first step is to regress the original variable, actual inflation lead by 1, on all the instrument variables we have. The second step is to use the predicted values from the first step as the variable for expected inflation in the inflation equation.

5.1.2 Generalized Methods of Moments

Another approach to estimate the inflation equation, Eq. X, is to use the Generalized Methods of Moments (GMM) estimator⁴¹. Under rational expectations, individuals will use all information available to form optimal expectations. They will not make systematically wrong prognosis/forecast mistakes when predicting the future value of an economic variable since they use all information available, in other words all errors in the prognosis are random. Related to the inflation equation, the prognosis mistake for π_{t+1} will be, under the assumption of rational expectations, uncorrelated with information dated at time t or earlier. The inflation equation we wish to estimate is:

$$\pi_t = \lambda s_t + \beta E_t\{\pi_{t+1}\}$$

⁴⁰ Read more about IV regression in Stock & Watson (2006), chapter 12

⁴¹ For a short introduction to GMM, see Seppo Pynnonen (2007)

We are assuming rational expectations, hence the errors of the inflation equation is not correlated with information dated at time t and earlier. This gives rise to the orthogonal condition, and the expression used for the GMM estimation:

$$E_t\{(\pi_t - \lambda s_t - \beta \pi_{t+1})z_t\} = 0$$

, where z_t is a vector of variables dated at time t or earlier, hence uncorrelated to the prognosis mistake, the inflation surprise, in period $t+1$. If two functions are orthogonal means that they are independent of each other, and one function cannot be used to describe the other function. Thus, given all the information we have at time t , captured by the vector z_t , from time t and earlier, cannot be used to explain the prognosis mistake at time $t+1$, hence given rational expectations the expression above is a orthogonal relation and the GMM estimator can be used for testing the NPC.

5.1.3 Deviation from steady state

All variables in the estimation of the NPC are measured as log-deviations from their respective steady state value, where the steady state value is the historical average over the period. Each variable has been replaced by the value of the difference between the log of the variable value at less the log of the steady state value of the variable. Given x_t is the variable and \bar{x} is the steady state of the variable, the log-deviation of the variable from steady state is calculated by⁴²:

$$\hat{x}_t = \ln(x_t) - \ln(\bar{x})$$

For small deviations from steady state the log-deviation can be interpreted as percentage deviations from steady state, hence their associated coefficients are elasticities. The approximation above is only valid for small deviations from steady state due to its dependency on calculus as shown below:

$$\hat{x}_t = \ln(x_t) - \ln(\bar{x}) \simeq \frac{1}{x}(x_t - x) = \frac{x_t - x}{x}$$

⁴² Read more about applications of log-deviations in Zietz (2008).

For both the CPI and the long-short interest spread series, the actual deviation of the variable from its steady state value has been calculated manually and not by the log-deviation approximation because of the failure to take logs on negative values.

5.1.4 Comparing non-nested models

The models used for testing the NPC are non-nested models; hence they are not a special case of each other and are therefore not directly comparable. Looking at the R-squared alone is not the correct approach since it will always increase if more variables are added to the regression, thus not showing whether one model is to be preferred over another. An approach to compare non-nested models is to use the adjusted R-squared in the 2SLS estimation together with the R-squared⁴³. The adjusted R-squared imposes a penalty if more variables than necessary is included in the regression, and is thus indicating whether the increase in the R-squared is valid with regards to a better fit model.

Analyzing the NPC relation is done by using different measures of the instruments that make up the expected inflation term in the NPC equation. The three approaches in this study are using the survey variables from the time period 2002-2010, and the Galí and Gertler variables from the time periods 1996-2010 and 2002-2010. The NPC relation to be tested is:

$$\pi_t = \lambda s_t + \beta E_t(\pi_{t+1})$$

⁴³ Read more about comparing non-nested models in Woolridge (2009)

5.2 Results

5.2.1 Survey expectations instruments, 2002-2010

The first analysis of the NPC relation was executed by using survey expectations as instruments for the expected inflation term. The testing using survey variables was conducted by using two models of survey expectations, one with all four sectors in the survey, and another test that excluded the household expectations. The motivation for making two different instrument sets of survey expectations was to see if the results would alter depending on whose expectations that were used as instruments for expected inflation. As mentioned earlier, the household sector deviates from actual inflation on a larger scale than the other sectors in the survey. The instrument set was 4 lags of inflation expectations from the economic experts, labor unions, business leaders and households. Both 2SLS and GMM was used as estimators, but 2SLS did not provide significant results using survey data, thus only the GMM estimates are presented.

The first test using survey expectations use expectations from all four sectors as instruments for the expected inflation term.

Table 2: NPC estimates with survey expectations as instruments, 2002-2010

	(1)	(2)
VARIABLES	λ	β
	0.0762**	0.958***
	(0.0312)	(0.0256)
Observations	29	29

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The fit of the instruments are best described by the R-squared, which shows that using the survey expectation set that includes all four sectors as instruments explains 87,1 %

of the variation in the expected inflation term. This must be considered to be satisfying regarding the fit of the instruments. The estimates from the overall NPC model, shows that both marginal costs and expected inflation variables are significant on a 5 % significance level. The size and sign of the estimates is in line with existing literature, and is what we would expect⁴⁴. The goodness-of-fit regarding the overall NPC model is 51,2 %. The estimates of the NPC relation when using survey expectations from all four sectors in the survey is therefore:

$$\pi_t = 0,0762s_t + 0,958E_t(\pi_{t+1})$$

The second test of the NPC using survey expectations used only three of the sectors as instruments for the expected inflation term, namely the economy experts, labor unions and business leaders. The inflation expectations from the household sector are left out to see whether this will alter the results from table 2.

Table 3: NPC estimates with survey expectations as instruments, households excluded, 2002-2010

	(1)	(2)
VARIABLES	λ	β
	0.0972**	0.957***
	(0.0392)	(0.0312)
Observations	31	31

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Leaving out the household sector reduces the fit of the instruments regarding the expected inflation term. The R-squared is reduced to 71 %, but is still considered to be satisfying as to explaining the expected inflation term. The overall model fit is 51

⁴⁴ See for example Galí and Gertler (1999)

% according to the R-squared, which is the same as we saw for the survey model that included the household sector.

The coefficients on both variables are significant on a 5 % level, and the magnitude is within what we would expect. The estimates for the NPC using survey expectations that excludes household expectations, is thus:

$$\pi_t = 0,0972s_t + 0,957E_t(\pi_{t+1})$$

The coefficient on expected inflation is nearly identical to the estimated coefficient for the model that used everybody in the survey as instruments. The coefficient on marginal costs on the other hand, has increased from about 0,076 to 0,097. The difference could be considered minor, making the models equivalent. Taking a closer look at the overall performance of the instruments show that there is a slight preference for the model using everybody in the survey as instruments, as these instruments have more explanatory power than the model without the household sector regarding the expected inflation term. This is supported by the increase in the adjusted R-squared for the two models when all the sectors are included. For the overall NPC model on the other hand, the explanatory power is equivalent for the two models, making us indifferent between them.

5.2.2 NPC without survey instruments, 1996-2010

As we saw, using survey expectations as instruments in the NPC relation showed that the NPC model fits Norwegian data. The results were significant, and in line with what we would expect given existing literature on the NPC. It is now interesting to see whether the survey instruments make a better fit than the usual way of testing the NPC, using the actual future value of inflation and other economic key figures. In the following I will present the results from testing the NPC with the instruments used by Galí and Gertler in their study in 1999 with minor alterations. Instead of using the percentage change in the GDP deflator as a measure of inflation, I use the 12-month growth in CPI. I have also used two different measures of the commodity inflation variable, namely one with only Norwegian produced goods and one that also includes imported goods. I will get back to the difference of using these measures later, and will for now present the results using the commodity inflation variable that includes both Norwegian produced goods and imported goods. The other instruments used are the labor income share, output gap, wage inflation and long-short interest spread. All instruments are lagged by four. Neither of the 2SLS estimates in this model gave significant results and is therefore left out of the presentation.

The first estimation using the Galí and Gertler instruments consists of observations from 1996:1-2010:4.

Table 4: NPC estimates with Galí and Gertler instruments, 1996 – 2010

VARIABLES	(1) λ	(2) β
	0.0576** (0.0259)	0.917*** (0.0278)
Observations	55	55

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The Galí and Gertler instruments show an explanatory power of the expected inflation term of 88,7 %. This is only a slightly better fit than using the survey instruments. The adjusted R-squared has increased from 36,1 % to 79,2 % compared to the survey, thus the increase in the explanatory power, even though the magnitude is small, must be considered significant. What is more important is that the explanatory power of the NPC relation has increase from 51 % using survey instruments, to 78,9 % using the Galí and Gertler instruments. The adjusted R-squared has increased from 47,8 % to 78,1 %, respectively, thus making the increase in explanatory power significant. The increase in the fit of the model must therefore be considered to be both significant and of reasonable scale. The NPC estimates given the Galí and Gertler instruments are:

$$\pi_t = 0,058s_t + 0,917E_t(\pi_{t+1})$$

The estimated coefficients have changed somewhat compared to the estimates from the survey instruments. Both the estimated coefficient on marginal costs and the expected inflation have decreased by a small amount, but it is still in line with what we would expect.

The scale of the difference between the survey and the Gali and Gertler instruments must be considered large. However, there is a weakness in the comparison of the results since the survey estimates relies on fewer observations. Also, the Galí and Gertler estimation was performed from the period both before and after the monetary policy regime changed in Norway, while the survey estimation is only from the period after inflation targeting was set in effect. This could influence the results, therefore I estimated the NPC using the Galí and Gertler instruments once again, but with observations from the period 2002-2010 to match the survey estimates. Again, neither of the 2SLS estimates are significant, while all of the GMM estimates are significant.

Table 5: NPC estimates with Galí and Gertler instruments, 2002-2010

	(1)	(2)
VARIABLES	λ	β
	0.107***	0.897***
	(0.0286)	(0.0249)
Observations	31	31

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

In table 5 we see the estimates of the NPC using the Galí and Gertler instruments for the shorter time period. The fit of the instruments to the expected inflation term has now increased to 98 %, which is nearly a complete fit. Given the adjusted R-squared the improvement in fit is legitimate. The fit of the overall NPC model also seems to have increased. The adjusted R-squared is now 81 %, which is a slight increase from the same test for the longer time period, and a considerable improvement from the survey estimates. Given the corresponding increase in the adjusted R-squared shows that this is the NPC model that fit the Norwegian data the best. The NPC estimates when using the Galí and Gertler instruments for the time period 2002:1-2010:4, is:

$$\pi_t = 0,107s_t + 0897E_t(\pi_{t+1})$$

The coefficients have changed somewhat when the period is shortened. The estimate of the marginal costs has nearly doubled from the estimates of the longer time period. On the other hand, the estimate is fairly close to what we got when we used the survey instruments. The estimate of the expected inflation term is close to both the one we got from the longer time period, and from the survey.

5.3 Discussion of the results

The fit of the NPC theory to Norwegian data has through these tests shown to be valid, regardless if we use survey expectations or the Galí and Gertler variables as instruments. All tests have shown significant results on the estimated coefficients, and the sign and size of the coefficients have been in line with what we would have expected. What is more interesting is that using survey expectations as instruments show a poorer fit to the NPC model than using the Galí and Gertler instruments, which is contrary to findings by Roberts (1995). He found that survey expectations made a better fit to the NPC than the use of actual future inflation as a proxy of expected inflation⁴⁵. Comparing the standard errors of his estimates shows that in his study, the survey estimates provides a better fit. The standard errors for the survey estimates in my study however, are larger than the standard errors using the Galí and Gertler instruments, thus making the survey instruments a poorer fit even though they are significant estimates. In the following I will go through some possible explanations for my findings.

5.3.1 Variability in survey expectations

The variability in the survey expectations can be one explanation to why the survey estimates provide a poorer fit to the expected inflation term than the NPC relation. In the analysis I tested both with and without the household sector. Intuitively we would expect to see a larger difference in the estimates since household expectations deviates more from actual inflation compared to the expectations of the other sectors in the survey. The results however proved to be similar, with only a negligible preference for the model that did not include the household expectations. This is in line with the findings of Roberts (1995). He compared the NPC fit using survey expectations from both consumers and the business sector, and did not find significant differences between the two⁴⁶.

⁴⁵ Roberts (1995) use only actual future inflation as the instrument in comparison to his survey instruments, and is thus not directly comparable to my model. His findings are however relevant, and is therefore used as a reference.

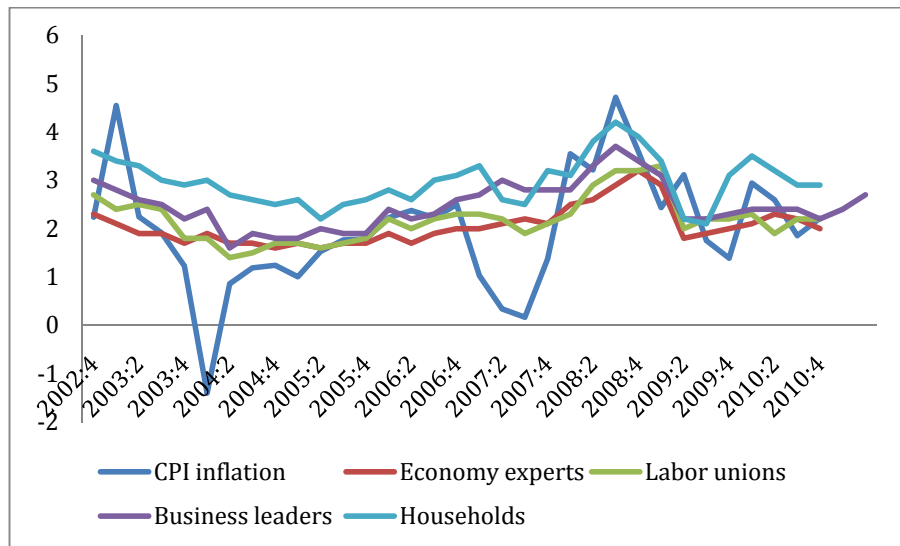
⁴⁶ Roberts (1995) used the Michigan survey and the Livingston survey in his analysis. The Michigan survey goes out to consumers, while the Livingston survey goes out to business economists.

One explanation to why using the different sectors do not alter the fit of the NPC in my thesis can be that, in general, the inflation expectations in either of the sectors are less volatile than actual inflation, as shown in figure 17. The household expectations are as we can see on a higher level than the expectations of the other sectors throughout the entire period. Nonetheless, the variation in expectations is in general low, thus making the household expectations not deviating too far from the other sectors.

The survey expectations do not follow actual inflation in the extremes, even when inflation is low (high) over several periods, expectations do not follow the low (high) level. This is especially visible for the period where Norway experienced deflation in the early second half of 2004. The inflation expectations during this deflationary period were approximately 2-3 % for the period. It should be noted that the expectations were formed in the quarter before the actual deflation occurred, but given the size and length of the decline, the participants in the survey should have had enough time to be able to alter their expectations even if the decline was a result of an economic shock that could not have been anticipated on beforehand. We see the same behavioral pattern happening in the years leading up to the financial crisis. Given the length of the period where we experience the decreasing inflation we would expect to see a decrease also in the expected inflation by the survey participants. Again, this did not happen. The participants in the survey still expected higher inflation than what was the actual level in that period, and the decline was less steep and shorter than the decline in actual inflation.

The lack of volatility in inflation expectations from the survey participants helps explain why we did not find significant differences regarding which sector we used in the testing of the NPC relation.

Figure 17 Actual inflation and inflation expectations from all the sectors in the survey

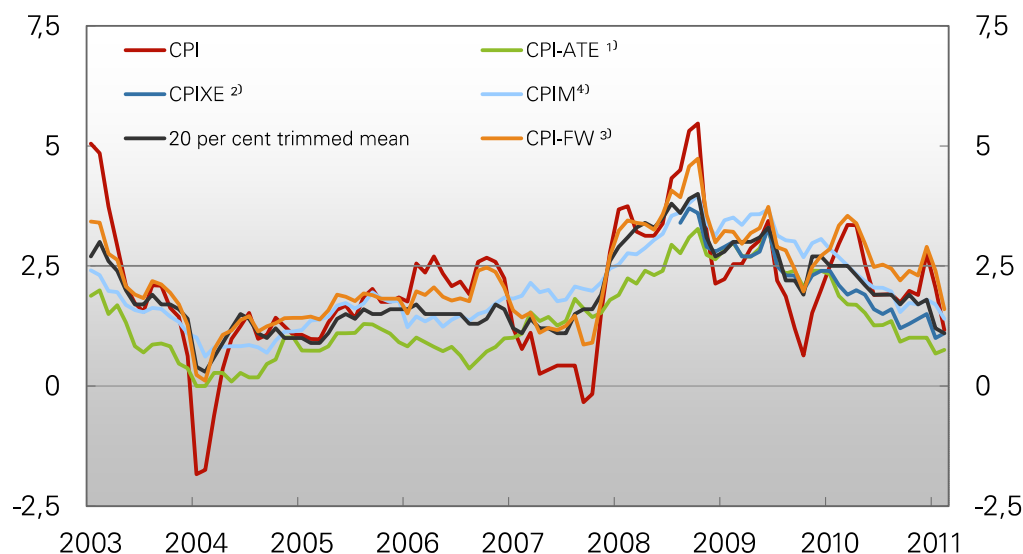


The variation in the Galí and Gertler instruments is following the inflation variability more closely, thus the instruments capture more of the variation in the expected inflation term. This might be the reason why we find a stronger connection of the Galí and Gertler instruments regarding the NPC relation.

5.3.2 The inflation measure

It is not just the variability in the survey inflation expectations that might affect the results, but also the choice of the inflation measure. A possible influencing factor in the testing of the NPC in this thesis is that the inflation measure used is the 12-month growth in the CPI. The variability in the different inflation measures is presented in figure 18, and as we can see the CPI is the most volatile inflation measure.

Figure 18: Consumer prices. 12-month change. January 2003 – February 2011



- 1) CPI adjusted for tax changes and excluding energy products
 2) CPI adjusted for tax changes and excluding temporary changes in energy prices. Real time figures. See Norges Bank *Staff Memo* 7/2008 and 3/2009
 3) CPI adjusted for frequency of price changes. See Norges Bank *Economic commentaries* 7/2009
 4) Model-based indicator of underlying inflation. See Norges Bank *Economic commentaries* 6/2010
 Sources: Statistics Norway and Norges Bank

Source: The Central Bank of Norway⁴⁷

Given that the inflation expectations from the survey were not very volatile (cf. figure 17), using the CPI as the inflation measure might influence the results. As shown in figure 18 the CPI is more volatile than the other inflation measures, much to the reason that energy prices and changes in taxes and interest rates are a part of the CPI measure. The inflation measure used by the central bank when deciding on the key policy rate is different measures of the underlying inflation, i.e. inflation measures that are adjusted for tax changes, interest rate changes and various degrees of adjustments considering energy products and prices⁴⁸. Two measures of underlying inflation are the CPI-ATE and CPIXE. As we can see from figure 18, these measures are less volatile than the CPI, and would have given an inflation measure that would have better reflected the underlying inflation.

⁴⁷ Monetary Policy Report 1/11, chart 1.7

⁴⁸ Read more about the implementation of monetary policy in the Monetary Policy Report 1/11, or at The Central Bank of Norway's webpages: www.norges-bank.no

In general, the participants in the survey expect inflation that is near the inflation target set by the Central Bank of Norway. The poorer fit of the survey expectations can be explained by considering that individuals in the economy might not alter their expectations much even though inflation deviates in the short run. They still expect inflation to be approximately 2,2-3 %, which is within the same range as the inflation target set by the central bank. The target of the central bank is inflation of 2,5 % in the medium term, thus it looks as if the survey participants are not deviating too much from this target.

Given the above, we must consider the possibility that the expectations of the survey participants might not deviate as much from the underlying inflation as it deviates from the CPI inflation measure. Figure 18 compared to the survey expectations in figure 17 indicates that the survey expectations are more closely linked to CPI-ATE and CPIXE than CPI, but since this is not tested we cannot draw any conclusions about this relation. It is thus just an indication that the chosen inflation measure in this thesis might have influenced the fit of the survey expectations in the NPC relation.

5.3.3 Some remarks about the analysis

Both the 2SLS estimations and the GMM estimations display similar results regarding the size of the estimated coefficients. The GMM estimates however, is the only method that provided significant results, and is therefore the chosen estimation method. 2SLS is a simpler estimation method, and we can be experiencing errors in the estimation. The estimation method 2SLS might experience problems with induced moving average residuals (Bårdsen et. al. 2002). This has not been corrected for in this thesis, and might be the reason why the 2SLS results are not significant.

To test the robustness of my results, I included different measures of some of the variables. The commodity inflation variable was measured using both Norwegian produced goods only, and Norwegian produced goods and imported goods. The result from using the two different measures showed that excluding imported goods from the variable made the NPC relation not significant when the testing period was 1996:1-2010:4. In the shorter period, the NPC relation showed to be significant. When including the imported goods in the commodity inflation variable, the NPC proved to be significant on a 5 % level regardless of the length of the time period. Given that the NPC failed when altering just one of the instrument variables indicates that the NPC relation is not very robust. For the survey I tested the NPC using different compositions of the sectors in the survey. The compositions that would most likely make different results was using expectations from the household sector and compare it to the economy experts. My results showed that the composition of the survey participants had little or negligible effect on the overall NPC relation.

I also conducted tests of the NPC using different amounts of lags on the instrument variables, both for the survey and the Galí and Gertler replica. Neither of these tests proved to be significant on a 5 % level, thus indicating that my findings are sensitive, and that the results of the NPC relation is dependent on which instruments that are included and how many lags that are included.

Some studies of the NPC relation include a constant term when estimating the NPC. The reason behind including a constant term in the equation is to capture non-zero sample average inflation (McAdam and Willman 2003). Although it is not theoretically founded, it can be argued for that including a constant term is reasonable as it might account for changes in the

steady state inflation (i.e. steady state inflation is not constant). This in turn relies on the monetary policy regime. Given that Norway has changed its monetary policy regime during the period of my testing of the Galí and Gertler replica, it was interesting to also include estimations of the NPC that included a constant term.

All the estimates were done with and without a constant term in the regression. Models that excluded the constant term performed better than its corresponding model without a constant term. The R-squared and the corresponding adjusted R-squared, showed that the regressions without the constant term made a better fit to the NPC relation than without the constant term. The difference in the estimates when including or excluding a constant term was non trivial; the estimated of the expected inflation term nearly halved in size and the estimates of the marginal costs nearly doubled in size when including a constant term. This can be an indication of the fact that the constant term is actually capturing changes in the monetary policy regime, and hence the steady state inflation. However, the estimates that did not include a constant term were found to have the overall better fit, and were therefore the chosen approach for all the models.

6 The Conclusion

The purpose of this thesis has been to estimate the New Keynesian Phillips curve (NPC) relation using Norwegian data, and more precisely using survey expectations as instruments for the expected inflation term in the NPC. As a comparison to the survey results I have used a replication of the Galí and Gertler (1999) estimates, to see whether the survey or the Galí and Gertler instruments would provide differing results.

The first estimation used survey expectations as instruments for the expected inflation term in the NPC. The results proved to be significant, and the size and signs of the estimates were in line with theory. Estimates on the Galí and Gertler (1999) replica also proved to be significant, much as we would expect. More interestingly, the Galí and Gertler replica proved to be the preferred model over the survey when deciding on which one had the better fit regarding the NPC. The survey expectations estimates, although significant, had a poorer model fit than the Galí and Gertler estimates. This is somewhat surprising given that it is contrary to the findings of Roberts (1995).

The Galí and Gertler estimates were based on more observations than the estimates using survey expectations. To make sure this was not influencing the results I redid the Galí and Gertler estimates using only the observations from the same period as the survey estimates were based on. Once again, the conclusion was that the Galí and Gertler estimates were superior to the survey estimates regarding model fit.

Some caution must be taken regarding the estimations. The survey estimates are based on few observations, thus we cannot draw strong conclusions. The chosen inflation measure might also have influenced the results, as it does not reflect underlying inflation in the same respect as for example CPI-ATE or CPIXE. Using a different measure of inflation as the CPI-ATE or CPIXE in the NPC could be an interesting subject for further study.

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Appendix A: Survey questions used in the thesis

For a full review of the survey, see the Central Bank of Norway's webpages, available at URL: <http://www.norges-bank.no/no/prisstabilitet/forventningsundersokelse/>

The particular questions for the different sectors are as follow:

Economy experts

Question 1:

Hva tror du den generelle prisstigningen på varer og tjenester er om 12 måneder, målt ved 12-månedersveksten i KPI (konsumprisindeksen)?

Labor unions:

Question 8:

Hva tror du den generelle prisstigningen på varer og tjenester er om 12 måneder, målt ved 12-månedersveksten i KPI (konsumprisindeksen)?

Business leaders

Question 14:

Hva tror du den generelle prisstigningen på varer og tjenester, målt ved konsumprisindeksen, er om 12 måneder?

Households:

Question 25b:

Sammenliknet med dagens prisnivå, hvor mange prosent tror du prisene kommer til å stige de nærmeste 12 månedene?