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The Effect of Oil Prices on Norwegian Petroleum Wages

An Empirical Analysis from 1973 to 2015

Master's thesis in Economics
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Preface

This master thesis is the end product of five years at the Department of Economics at NTNU. First of all I would like to thank: my advisor, Kåre Johansen, whose guidance has been tremendously helpful. Furthermore, I would like to thank my Mom and Dad, who have helped and supported me through my years in Trondheim and London. I would also like to thank all the proofreaders, especially thanks to Graeme Cox for using his spare time to help edit this project. Last, but definitely not least, I would like to thank my fantastic girlfriend, Synne, for her great patience and support in the last couple of months.

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Abstract

From the exploration of the first profitable oil field, Ekofisk, the Norwegian economy has been highly reliant on the petroleum sector. In 2017, the oil and gas industry accounted for 52.8% of total exports. With the economy depending on such a volatile commodity, it is intriguing to examine how it impacts sectoral wage formation. Therefore, this thesis focuses on how the development of the oil price has affected the petroleum wage development. Specifically, we focus on analysing short and long-run effects of the oil price. In the literature, the Norwegian wage formation is regarded as highly centralised. Theoretically, this implies that there is little scope for product prices to affect sectoral wages. However, when we apply an Error Correction Model to data stretching from the beginning of the oil adventure to present day, we do in fact find product price effects. We discover that the oil price accounts for around 14% of the long-run petroleum sector wage formation. The remaining share of the long-run wage formation was found to be determined by the manufacturing wage. Effects of the oil price in the short-run are absent, whilst we do find short-run effects of the manufacturing wage. The results are consistent and holds during several robustness checks. However, using a Granger-causality test, we detect some simultaneous effects between the petroleum wage growth and the manufacturing wage growth. This could lead to an overestimation of the results. The findings of this thesis are interesting because it challenges the view of a fully coordinated wage formation in Norway, and it suggests that the oil price is a driver in the petroleum wage formation.

Sammendrag

Helt siden oppdagelsen av det første profitable oljefeltet, Ekofisk, har den norske økonomien vært avhengig av petroleumssektoren. I 2017 utgjorde denne sektoren omlag 52,8% av den totale norske eksporten. Når økonomien er så avhengig av en slik volatil råvare, er det interessant å undersøke på hvilken måte den påvirker den sektorielle lønnsdannelsen. Med dette som utgangspunkt, vil denne masteroppgaven fokusere på hvordan utviklingen i oljeprisen har påvirket utviklingen i petroleumslønnsdannelsen. Fokuset vil ligge på kort- og langsiktige effekter av oljeprisen. I litteraturen, blir den norske lønnsdannelsen sett på som svært sentralisert. Teoretisk sett innebærer dette at produktprisen i liten grad påvirker sektorielle lønninger. I strid med denne teorien finner vi, ved å bruke en feiljusteringsmodell, signifikante effekter av produktprisen. Funnene våre tilsier at oljeprisen utgjør omtrent 14% av den langsiktige petroleumslønnsdannelsen, mens industrilønningene står for den resterende andelen. På kort sikt er det fraværende effekter av oljeprisen, mens vi finner signifikante kortsiktige effekter av industrilønnen. Resultatene er konsistente og holder for flere robusthetssjekker. Dog, ved bruk av en Granger-kausalitetstest finner vi kortsiktige simultane effekter mellom olje lønnsveksten og industri lønnsveksten. Dette kan føre til overestimerte resultater. Funnene i denne analysen er interessante, fordi det utfordrer synet om en fullt sentralisert lønnsdannelse i Norge, og fordi det gir uttrykk for at oljeprisen er en viktig driver for petroleumssektorlønninger.

Contents

1. Introduction

The main objective of this analysis is to investigate how the development in the oil price has affected the development of the Norwegian petroleum sector wage cost. Specifically, we analyse possible short and long-run effects of the oil price, from 1973 to 2015. The question we would like to answer is whether the petroleum wage development is affected by the oil price in a Norwegian context. Furthermore, we want to examine to what degree, if any, the oil price affects the petroleum sector wage formation.

The petroleum sector is of great importance to the Norwegian economy. In 2017, the oil and gas sector accounted for around 52.8% of the country's total exports.[1] It is of significant interest to understand how the economy reacts to changes in the price of such a volatile commodity. Historically, the Norwegian petroleum sector has had a higher wage level than the manufacturing sector. In the beginning of the oil adventure in the mid 1970s, a petroleum worker could expect 35- 40% higher wages than in manufacturing. Dyrstad (2016) explains the initial gap as a result of compensating differentials, where some work required special skills, whilst other work was generally less appealing. The relative wage gap increased in the years after the first oil field discoveries. However, a stricter wage settlement policy, introduced in 1981, led to a diverging trend in the relative wage, lasting for 20 years. Since then, the relative wage gap has escalated together with the increasing oil price of the early 2000s (Dyrstad, 2016).

Norway is a highly unionised country, with 1.8 million workers affiliated with a union.[1] Holmlund & Zetterberg (1991) argue that a high degree of unionisation is associated with highly centralised wage bargaining. In accordance with this hypothesis, we can infer that the Norwegian wage bargaining system is highly centralised (Johansen, 1996). However, both Johansen (1996, p. 89) and Wulfsberg (1997, p. 421) point out that 50% of the wage inflation is due to wage drift.[2] This implies that local wage bargaining leaves some scope for firm and sector specific rent sharing, in the Norwegian economy. Thus, insider effects, such as the oil price, may have considerable effects on sector specific wage determination. This hypothesis is confirmed by the results in Johansen (1996, 1999), who uses data for Norwegian industries, and Wulfsberg (1997), who uses data for Norwegian manufacturing

[1] Numbers from Statistics Norway, StatBank Norway

[2] Wage drift is the residual difference between actual hourly wage growth and the wage increase formed by central negotiations (Holden, 1989).

firms.

The empirical literature covering the oil price effect on macroeconomic and financial variables is vast, where Hamilton (1983, 1996), Mork (1989), Mork et al. (1994), Hooker (1996), Jiménez-Rodríguez & Sánchez (2005) and Cologni & Manera (2008) are all relevant. However, empirical evidence on the sectoral impact of the oil price is limited. A couple of earlier studies cover the effect of oil price shocks on real wages. Keane & Prasad (1996) use sectoral panel data for the USA, to analyse real wage effects of the oil price. Their main results suggest that oil price shocks has substantial adverse effects on real wages for all workers, across all sectors. Jiménez-Rodríguez & Sánchez (2005) generally analyse macroeconomic variables. However, they also cover real wages to some extent. Using a vector auto regression model (VAR), they analyse the effect of oil price shocks across net oil importers and exporters. They find evidence of positive real wage responses to an oil price increase in Norway. On the other hand, net importers of oil experience detrimental real wage effects of an oil price shock. The Norwegian central bank does also find positive Norwegian real wage effects, as a result of increasing oil prices (Solheim, 2008).

Encouraged by the limited research covering the sectoral effects of the oil price, this thesis will focus on the Norwegian petroleum sector. Dyrstad (2016) examines how a governmental intervention in 1981 affected the Norwegian petroleum wage formation. The intervention tried to prevent Dutch disease effects in the Norwegian economy, which is a problem that occurs when abundance of a natural resource has adverse effects on a country's manufacturing firms (Bjørnland, 1998). By using an Error Correction Model (ECM), he discovered that the governmental intervention did indeed help to prevent increasingly high wage inflation. The wage settlement became more centralised, which also caused diverging relative wages in the Norwegian petroleum sector.

The theoretical foundation of this thesis is a wage formation model used by Raaum & Wulfsberg (1998) and Hoel & Nymoen (1988), among others. Theoretically, the wage bargaining takes place between firms and centralised unions. It predicts that an increase in both the product price and the alternative wage, should raise the bargained wage. Furthermore, we follow Dyrstad's econometric approach and use an Error Correction Model. When applying an ECM to the data it is found that the oil price constitutes about 13-14% of the long-run wage formation in the petroleum sector, whilst the remaining 85-87% is accounted for by the manufacturing sector. The results is found to be consistent with previous research on the Norwegian manufacturing sector (Johansen, 1996, 1999; Wulfsberg, 1997). On the other, Dyrstad (2016) finds no long-run effects of the oil price, contradicting the results presented in this thesis. Possible reasons for why this is the case, will be elaborated on in subsequent chapters.

The thesis is structured as follows: The next section introduces some background information about the Norwegian petroleum sector and the Norwegian wage formation. Chapter 3 presents the theoretical model, followed by a presentation of the data and the empirical framework in Chapters 4 and 5. Chapter 6 displays the empirical results and presents estimates for long and short-run effects of the oil price and the manufacturing sector, on the petroleum wage. A summary, and concluding remarks, are presented in Chapter 7.

2. Background

2.1 Oil in Norway

The exploration of oil and gas on the Norwegian continental shelf began in 1966. However, the first profitable field, Ekofisk, was not discovered until late 1969, followed by new discoveries in subsequent years (Dyrstad, 2016). The federal government played an active role in developing a petroleum industry in Norway (Mohn & Osmundsen, 2008), and in 2007 the returns from petroleum products accounted for 16% of the GDP, making the petroleum sector a large contributor to the Norwegian economy (Eika & Olsen, 2008). The government secured the income from the Norwegian continental shelf through three different strategies. First, through ownership in different oil fields.[3] Secondly, through high taxation on petroleum products. Thirdly, through dividends from the oil company, Statoil, where the government is a major shareholder (Eika & Olsen, 2008). Furthermore, the Petroleum Fund was established in 1990, which later evolved into the Government Pension Fund-Global (Caner & Grennes, 2010). The main objective of the fund is to save and invest the income from the petroleum sector and thus assure the well-being of the nation in difficult times (Eika & Olsen, 2008). For example, in the aftermath of the recent oil price shocks, the Norwegian government had a lot of scope for counter-cyclical economic policies to lessen the effects of the oil price fluctuations. The central wage settlement was also moderate in this period, which helped stimulate the economy (NOU 2016:15, 2016, p. 29).

Employment in the petroleum industry has surged since the beginning of the 1970s. Whilst employment was only about $6,600$ workers in 1973, it increased to over $78,000$ in 1993 (Dyrstad, 2016). The increase can be observed by the solid line in Figure 1. It represents the number of working hours in the Norwegian petroleum industry, in millions of hours. Petroleum sector employees worked about 400 thousand hours in 1973, compared to about 105 million hours in 2015. The dashed line in Figure 1 displays the logarithm of the oil price index from 1973 to 2015. When observing the two graphs depicted in Figure 1, we see that the number of working hours have an upward sloping trend throughout the sample. The growth rate slows down in oil price slumps, and escalates during oil price booms. For example, total number of working hours are unchanged during the late 1980s oil price fall, but starts to increase when the oil price stabilises. However, after the

[3] Known as SDØE, The States Direct Economical Engagement in the Oil Industry (My translation)

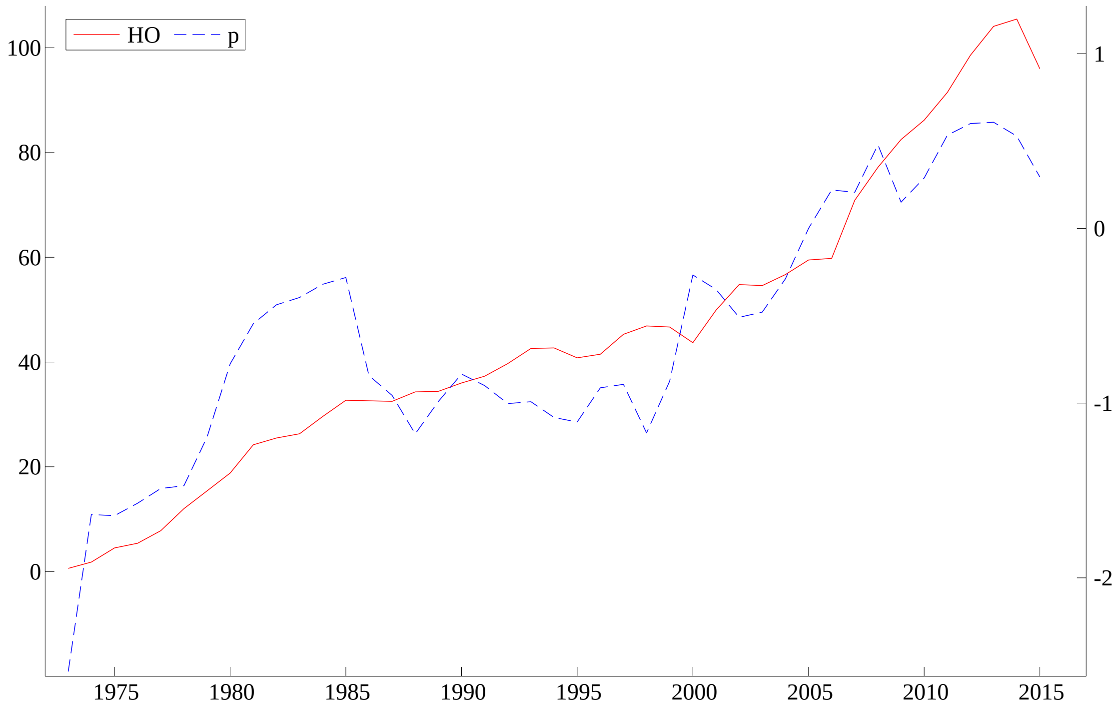

Figure 1: Solid red line: Hours worked in the Norwegian oil sector from 1973 to 2015 in millions of hours (Left axis). Dashed blue line: Log of the oil price (Right axis).

most recent oil price shock many workers affiliated with the petroleum sector were laid off (NOU 2016:15, 2016, p. 23). This trend can be observed in Figure 1 as the total number of working hours decreases around 2014.[4]

Figure 2 displays that the petroleum sector wage have been persistently higher relative to the manufacturing wage. The figure presents the log of hourly wage costs in the petroleum sector minus log of hourly wage costs in the manufacturing sector. The relative wage has fluctuated throughout time, which seems inconsistent with coordinated wage theory (Dyrstad, 2016). The wage surged just before the policy change of 1981, but plummeted some years after the oil price shock of 1987. This drop in the relative wage may imply that the oil price shock had a larger impact on the petroleum sector wage, compared with the wage in the manufacturing sector. This should not be the case if there are no insider forces in the sector.

[4]Unfortunately, there are not enough data to trace the trend after 2015, nor is the employment effect of the oil price in the scope of this thesis. However, it is an interesting topic for further analysis

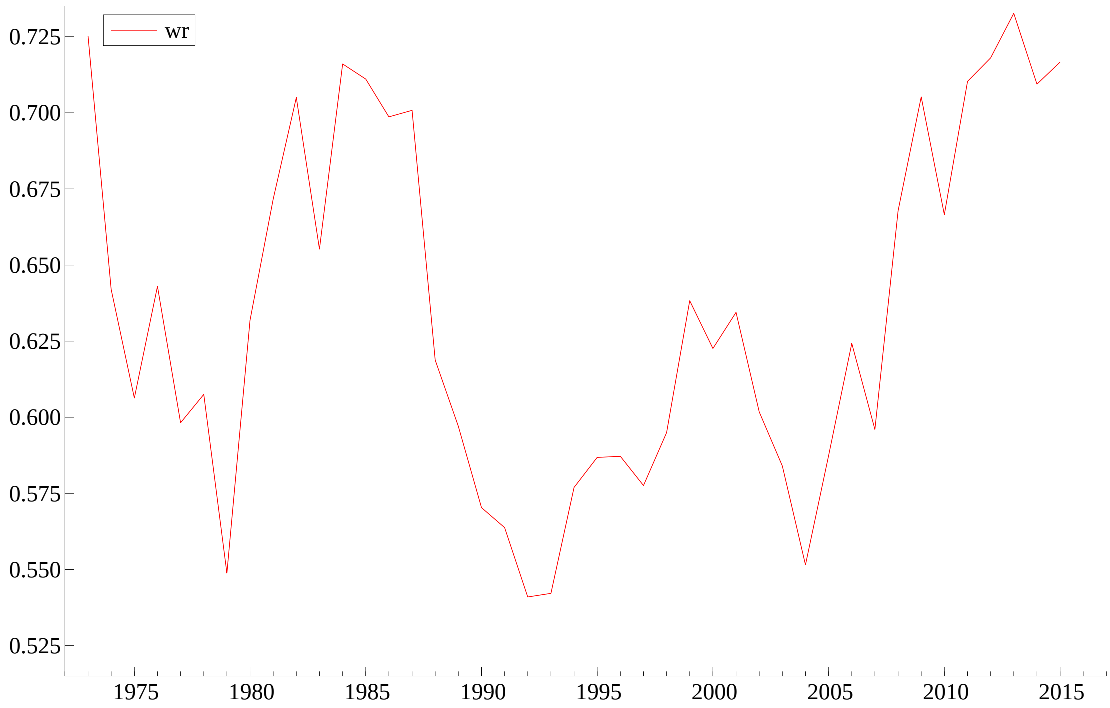

Figure 2: Log of the wage in petroleum sector minus log of wage in the manufacturing sector (log of relative wage).

2.2 Norwegian Wage Formation

The Scandinavian wage theory,[5] is the foundation of wage negotiations in Norway, and it can be seen as an implementation of the model of Aukrust (1977).[6] Following this theory, the bargained wage should be determined such that the firms can remain profitable when competing internationally. If wage inflation is too high, firms exporting to the world market will gradually erode over time (Holden, 2016). Negotiations start with internationally competing firms, such as shipping, oil and gas and manufacturing enterprises. The initial bargaining are known as «the main negotiations» , and the outcome of these negotiations works as a benchmark for the remaining industries' settlements (Holden, 2016).

The main negotiations are biannual and conducted between The Norwegian United Federation of Trade Unions, the second largest LO member,[7] and The Federation of Norwegian Industries, the

[5]Known as «Frontfagsmodellen»

[6]Known as «Hovedkursteorien»

[7]*LO*, The Norwegian Confederation of Trade Unions, is the main federation for unions organising blue-collar workers in Norway (Dyrstad, 2016)

largest NHO member.[8] Hence, the outcome of these negotiations should keep wage inflation at a manageable level for firms to remain internationally competitive (NOU 2016:15, 2016, p. 17). Annual negotiations take place at the local level, adjusting for local conditions. These settlements may result in wage drift, which works against the theory of fully centralised Norwegian wage formation (Raaum & Wulfsberg, 1998).

As Figure 2 portrays, the relative wages have been persistently higher in the petroleum sector than in the manufacturing industry. One theoretical explanation could be the competitive market theory, which predicts higher wages due to the workers skills, or as a result of higher compensating differentials (Holmlund & Zetterberg, 1991). Another theoretical explanation is the insider-outsider theory, of Lindbeck & Snower (1988). The theory has been used by many to explain wage determination in different sectors (Dyrstad, 2016; Johansen, 1996; Johansen, 1999, Holmlund & Zetterberg, 1991; Nickell & Wadhwani, 1990). It predicts that a gain in labour productivity does not increase the employment rate, but rather, increases the insiders' wages (Nickell & Wadhwani, 1990). Lindbeck & Snower (2001) explain the persistence of insider wages due to labour turnover costs, through cost of hiring and providing firm specific training. This is known as the adjustment cost theory and is discussed in Borjas (2013).

To what extent the Norwegian wages are affected by insider forces, is inconsistent in the literature. Holmlund & Zetterberg (1991) found rather small and inconsistent effects of productivity and product prices on industry wages. Wulfsberg (1997, p. 431) argue that the model of Holmlund & Zetterberg (1991): *«Exhibits significant autocorrelation and is therefore likely to be dynamically misspecified»*. Johansen (1996, 1999) found highly persistent long-run insider effects across Norwegian industries. Furthermore, Wulfsberg (1997) also found significant long-run insider effects in the Norwegian manufacturing industries, but to a smaller extent. Both Johansen (1999) and Wulfsberg (1997) point out that the large gap in insider weights between the two studies, may be due to the fact that the studies are conducted at different aggregation levels. The weight will be higher when the variables are aggregated to the industry level. Nevertheless, the two latter studies find significant evidence against full centralisation in the Norwegian wage settlement.

Turning to outsider variables, Wulfsberg (1997) found no effect of unemployment on the manufacturing wage. Furthermore, he found evidence of strong cointegration between the bargained

[8] *NHO*, The Confederation of Norwegian Enterprises, is the main organisation for private sector firms (Dyrstad, 2016)

wage and alternative wages. Holmlund & Zetterberg (1991) found evidence that the negotiated wage is always increasing in the outsider wage, but found perverse wage responses to higher Norwegian unemployment. Johansen (1996) found a negative long-run relationship between industry wages and unemployment. The next chapter presents a theoretical model that works well in the Norwegian institutional framework. This model will serve as the theoretical foundation for the empirical analysis.

3. Theory - The Right to Manage Model

We will now cover the «Right to Manage» model, and lay a theoretical foundation for further empirical analysis. The model has been used by Wulfsberg (1997) and Hoel & Nymoen (1988), who both use data for Norwegian manufacturing firms, and by Nickell & Andrews (1983) who use similar data for Britain. Wulfsberg (1997, p. 421) argues that this model is a good fit for the Norwegian wage formation due to the fixed intervals between negotiations. Furthermore, it is fitting due to the fact that firms and unions do not bargain over employment, but over wages. The approach used in this thesis is identical to the one in Johansen (2000), which is similar in many ways to the model of Hoel & Nymoen (1988). It includes both insider variables, such as productivity and product prices, and outsider variables such as the unemployment level, unemployment benefit and alternative wage. The effects of the different insider and outsider variables are analysed by the end of this chapter.

3.1 The Union's Preferences

We begin by assuming M members in the union, whereby N_0 of these members are employed when the wage negotiations begin. Thus, there are $(M - N_0)$ unemployed members before bargaining. After negotiations, N out of the M union members are employed, whilst $(M - N)$ are unemployed. The nominal bargained wage after negotiations is w, whilst the gross wage rate is $\widetilde{w}$. t_P is the payroll tax, making the wage $w = (1 + t_P)\widetilde{w}$. Furthermore, the income tax rate is given by t_I, which makes the nominal disposable income of a worker equal to $\widetilde{w}(1 - t_I)$. The real disposable income of the worker can thus be written as $w_K = \frac{w(1-t_I)}{P_c(1+t_P)} = \theta w$ where P_c is the consumer price and $\theta = \frac{(1-t_I)}{P_c(1+t_P)}$ is a wedge between the wage cost per worker and the consumer real wage. We further assume that workers prefer to be insiders, working in the primary sector, and that there are two possible outcomes for a outside worker not employed in the primary sector. Either, the worker receives a wage from an alternative workplace, or the worker remain unemployed.[9] Assuming identical taxes in both sectors, the alternative consumer wage, w_{AK}, can be expressed as $w_{AK} = \frac{w_A(1-t_I)}{P_c(1+t_P)} = \theta w_A$.

An unemployed worker will receive unemployment benefits, B, which is a fraction of the alternative wage $B = b\frac{w_A}{(1+t_P}$, $0 < b < 1$, where b is often referred to as the replacement ratio. Hoel & Nymoen (1988) points out that this form of income is taxable in Norway, so the disposable unemployment

[9]A third alternative, which is not included in this analysis, is to become a part of a labour market programme. Johansen (2000) specifies a model for this, and the effects of these programmes has been analysed in Raaum & Wulfsberg (1998)

benefit becomes $\frac{B(1-t_I)}{P_c} = bw_A \frac{(1-t_I)}{P_c(1+t_P)} = b\theta w_A$. The utility of the workers depend on their disposable real income. An employed worker gains a utility $v(\theta w)$, whilst a worker who receives an alternative wage has a utility $v(\theta w_A)$ and a fully unemployed worker receives a utility $v(b\theta w_A)$. It is defined that $v(\theta w) > v(\theta w_A) > v(b\theta w_A)$.[10]

We assume that the union has utilitarian preferences. This means that the firm considers every member as identical and that the union's utility is the sum of all individuals. The utility after the wage negotiations becomes

$$V = \begin{cases} Mv(\theta w) & \text{for } N = M \\ Nv(\theta w) + (M-N)v^0 & \text{for } N < M \end{cases} \tag{3.1}$$

where v^0 is the expected outside utility of a laid-off union member. The first equation in (3.1) is the union's utility if all the members are insiders. The first part of the second equation in (3.1) represents the total utility of the workers employed in the primary sector, whilst the second part represents the remaining $(M - N)$ members' expected outside utility. Since it is unlikely that all union members are employed, we will assume that $N < M$. Furthermore, we can expand v^0 by letting it depend on the unemployment rate, u

$$v^0 = \rho(u)v(b\theta w_A) + [1-\rho(u)]\,v(\theta w_A), \tag{3.2}$$
$$0 < \rho(u) < 1, \quad \rho_u > 0$$

where $\rho(u)$ is the expected time spent unemployed, which is positively related to the average unemployment rate, u. When $\rho(u)$ is high, it is less likely that a laid-off worker can find an alternative source of income, and that the worker is more likely to receive unemployment benefits.

The actions each part can undertake if negotiations break down, is an important part of this model. For instance, the union can strike, whilst the firms can impose a «lock-out». We assume that the N_0 employed union members will, during a strike, receive a utility $\bar{v}$, and that the remaining $(M - N_0)$ union members receives the expected outside utility, v^0. The utility of the union during a strike, $\overline{V}$, becomes

$$\overline{V} = N_0\bar{v} + (M - N_0)v^0 \tag{3.3}$$

[10] $\frac{dv}{d(\theta w)} > 0$, $\frac{d^2v}{d(\theta w)^2} < 0$, $\frac{dv}{d(\theta w_A)} > 0$, $\frac{d^2v}{d(\theta w_A)^2} < 0$, $\frac{dv}{d(b\theta w_A)} > 0$, $\frac{d^2v}{d(b\theta w_A)^2} < 0$

The union will not accept a situation where the bargained wage yields a lower utility than the utility during a conflict. Hence, the condition $V > \overline{V}$, must be satisfied. During a strike, the members will receive a strike income which is assumed to be proportional to the alternative wage, and taxable. This gives a utility $\bar{v} = v(s\theta w_A)$, where $0 < s < 1$. We obtain the net utility of the union by subtracting (3.3) from (3.1)

$$\begin{aligned} V - \overline{V} &= Nv(\theta w) + (M - N)v^0 - [N_0\bar{v} + (M - N_0)v^0] \\ &= N(v(\theta w) - v^0) + N_0(v^0 - \bar{v}) \end{aligned} \tag{3.4}$$

3.2 The Firm's Objective Function

We now turn our focus towards the firms, which is assumed to maximise their profits using the following profit function

$$\pi = R(N) - wN, \quad R_N > 0, \quad R_{NN} < 0 \tag{3.5}$$

where $R(N)$ is total revenue, given by

$$R(N) = PY = PAF(N), \quad F_N > 0, \quad F_{NN} < 0 \tag{3.6}$$

where P is the product price, Y is output, $AF(N)$ is the production function. A is an exogenous productivity factor and F follows the conditions $F_N > 0$, $F_{NN} < 0$. Since this thesis focuses on oil as the product, we assume the price to be exogenous. Furthermore, it is assumed that the firm is risk neutral, i.e. the firm's utility is equal to its profits (Hoel & Nymoen, 1988). For a profit maximising firm, which are a price taker in the market, the employment will be defined as

$$PAF_N(N) = w \tag{3.7}$$

$$N = N\left(\frac{w}{AP}\right), \quad N' < 0 \tag{3.8}$$

where

$$\frac{dN}{dw} = \frac{1}{AP}N' \tag{3.9}$$

Equation (3.7) shows that the marginal product of labour has to be equal to the bargained nominal wage. Equation (3.8) merely shows that labour is dependent on bargained wages, the level of productivity and product prices. Using (3.8) we can rewrite the profit function

$$\pi = R\left[N\left(\frac{w}{AP}\right)\right] - wN\left(\frac{w}{AP}\right) = \pi(w, AP) \tag{3.10}$$

where

$$\frac{d\pi}{dw} = -N \tag{3.11}$$

Equation (3.11) is often referred to as Shepard's lemma (Varian, 1992), and it tells us that if the wage increases by one, the firm's employment is reduced by N. In the case of a breakdown in negotiations, the firm's action is lock out. If a lock out (or strike) occurs, the firm will stop production i.e. $\bar{\pi} = 0$, assuming no fixed costs. The profit needs to satisfy $\pi > \bar{\pi} = 0$

3.3 The Nash Bargaining Solution

During negotiations, there are several offers and counter offers. The outcome of negotiations will depend on three elements. First, the firm's and the union's objective function, V and π. Second, the firm's and the union's threat points, $\overline{V}$ and $\bar{\pi}$. Third, the relative bargaining power of the union, β, and the firm, $(1 - \beta)$. We assume that the outcome of the negotiations is given by the solution to a Nash bargaining problem. The Nash objective becomes

$$O = (V - \overline{V})^{\beta}(\pi - \bar{\pi})^{1-\beta} \tag{3.12}$$

It is technically easier to log-transform (3.12), and then obtain the first order condition for ln O.

$$\Omega \equiv \ln O = \beta \ln(V - \overline{V}) + (1 - \beta)\ln(\pi - \bar{\pi}) \tag{3.13}$$

We can rewrite (3.13) by substituting in for $(V - \overline{V})$ from (3.1), and use the fact that $N = N\left(\frac{w}{AP}\right)$ and $\pi = \pi(w, AP)$ from (3.8) and (3.10), respectively. If we also set $\bar{\pi} = 0$, the objective function becomes

$$\Omega = \beta \ln\left[N\left(\frac{w}{AP}\right)(v(\theta w) - v^0) + N_0(v^0 - \bar{v})\right] + (1 - \beta)\ln \pi(w, AP) \tag{3.14}$$

Since the two negotiating parts are bargaining over wages, the first order condition that maximises (3.14), becomes

$$\Omega_w(w,Z)=\beta\frac{\frac{1}{AP}\frac{dN}{d(w/AP)}\cdot(v(\theta w)-v^0)+\theta v_w N}{N\left[v(\theta w)-v^0\right]+N_0(v^0-\bar{v})}-(1-\beta)\frac{N}{\pi}=0 \tag{3.15}$$

The second order condition is $\Omega_{ww}<0$. Equation (3.15) tells us that a relative increase in the union's utility from increasing wages must be equal to the firm's relative loss from increasing the wage. The nominal wage depends on the exogenous variables, which are included in the vector Z.

3.4 Effects of Product Prices and Productivity

The oil price is the main variable of concern in this analysis. Therefore, the main focus will be on how product prices and productivity affect the wage formation. The effect of outsider variables is presented at a later point.

We begin by altering the first order condition, (3.15), making it better suited for analysing price and productivity effects. For simplicity, we assume that payroll and income taxes are equal and set to zero, $t_p=t_I=0$, making the wedge only dependent on consumer prices, $\theta=\frac{1}{P_c}$. This yields

$$\beta\frac{\frac{1}{AP}\frac{dN}{d(w/AP)}\cdot\left(v\left(\frac{w}{P_c}\right)-v^0\right)+\frac{1}{P_c}v_w\left(\frac{w}{P_c}\right)\cdot N}{N\left[v\left(\frac{w}{P_c}\right)-v^0\right]+N_0\left(v^0-\bar{v}\right)}-(1-\beta)\frac{N}{\pi}=0 \tag{3.16}$$

Furthermore, by multiplying through with w, and divide the numerator and the denominator by N we get

$$\underbrace{\beta\frac{\varepsilon_{Nw}\left[v\left(\frac{w}{P_c}\right)-v^0\right]+\frac{w}{P_c}v_w\left(\frac{w}{P_c}\right)}{\left[v\left(\frac{w}{P_c}\right)-v^0\right]+\left(N_0/N\right)\left(v^0-\bar{v}\right)}}_{\text{Union}}-\underbrace{(1-\beta)\frac{wN}{\pi}}_{\text{Firm}}=0 \tag{3.17}$$

where $\varepsilon_{Nw}\equiv\frac{dN}{d(w/AP)}\frac{(w/AP)}{N}<0$ is the elasticity of labour demand. The first term in (3.17) is the union's part of the first order condition, whilst the second term represents the firm's part. The effect of the product price, P, must be equal to the effect of technical progress, A, since it is the product of these two that occurs.

A product price or a productivity increase will affect the wage through three channels. The most obvious effect is that it will raise the firm's profits. However, we analyse profit per worker, and not the profit directly. How profits per worker reacts to a price increase is not clear, because the employment level in the firm is endogenously determined after wage negotiations. Hence, increasing product prices would give the firm incentives to produce more, and they achieve this by hiring more workers. Johansen (2000, p. 55) argues that *«It is reasonable to believe that also profits per worker, π/N, increases with AP»*. He explains this by arguing that higher product price or productivity, will increase the value added in the firm, which is split between the firm and the worker. When the «cake» increases it must increase both the firm's profits and the worker's wages after the next wage negotiation.[11] All in all, profits per worker would increase. If this is the case, $\frac{wN}{\pi}$, will decrease in value, increasing the bargained wage. However, Johansen (2000) also notes that if a firm has a Cobb-Douglas technology, the wage will remain unaffected through the profit channel.[12]

The second mechanism works through increased employment. When the firms want to produce more, they have to employ more workers. From the union's part of (3.17) we see that employment works through the term $(N_0/N)(v^0 - \bar{v})$. An increase in N, will increase the relative share employed in the primary sector, making N_0/N decrease in value. If $v^0 > \bar{v}$, the denominator will decrease, subsequently increasing the union's part, which yields higher wages.

Finally, the labour demand elasticity, ε_{Nw}, is affected by changes in product prices and productivity. An increase in these variables will make ε_{Nw} less elastic. Hence, the labour demand curve becomes steeper and the employment level will react less to higher wages. This causes the first term in (3.17) to decrease, making the bargained wage higher. However, assuming a Cobb-Douglas technology, the labour demand elasticity will remain constant (Johansen, 2000).

3.5 Outside Labour Market Effects

Unemployment, u, replacement ratio, b, and the alternative wage, w_A, are all outsider effects which enters in v^0 from (3.2). From (3.17) we see that v^0 enters in both the numerator and the denominator. Johansen (2000) argues that the outside utility will, most likely, have a positive impact on the bargained wage. Higher outside utility cuts the cost of being laid off, thus the unions can negotiate for higher wages.

[11] Neither the firms nor the workers has monopolistic power over wages in this model.

[12] See the Appendix in Johansen (2000) for a more comprehensive example using a Cobb-Douglas technology with this model.

The more interesting problem is how the outside utility reacts to changes in the outside labour market variables. We begin by assuming that there are no taxes and that the consumer price equals one, making the wedge $\theta = 1$. We can then rewrite (3.2)

$$v^0 = \rho(u, Z_u)v(bw_A) + [1 - \rho(u, Z_u)]\, v(w_A), \tag{3.18}$$
$$0 < \rho(u, Z_u) < 1, \quad \rho_u > 0$$

The partial effect of unemployment on the bargained wage will be negative. The pool of worker at a firm's disposal will be greater, hence, the firm is able to find workers willing to work for a lower wage. Formally

$$\frac{\partial v^0}{\partial u} = \rho_u[v(bw_A) - v(w_A)] < 0 \tag{3.19}$$

The effect of higher unemployment will be negative, but the magnitude of higher unemployment depends on two effects. First, if it is hard to find alternative work, i.e. ρ_u is high, the outside utility becomes marginally lower, because the probability of staying unemployed for a long period is higher. Secondly, if the replacement ratio, b, is high, the gap between the utility of an unemployed worker and the utility of a worker earning an alternative wage, will be lower. Thus, higher unemployment benefits will marginally dampen the unemployment effect and the outside utility will decrease by less.

$$\frac{\partial^2 v^0}{\partial u \partial b} = \rho_u w_A \frac{dv}{d(bw_A)} > 0 \tag{3.20}$$

The last effect is through the alternative wage. Assuming that b is constant, a higher alternative wage will have a positive level effect on the outside utility. From (3.21), we see that a higher alternative wage will increase the utility for both groups of outside workers

$$\frac{\partial v^0}{\partial w_A} = \rho b \frac{dv}{d(bw_A)} + (1 - \rho)\frac{dv}{dw_A} > 0 \tag{3.21}$$

To recap, the effect of the outside utility on the bargained wage is ambiguous. However, it is reasonable to believe that a higher outside utility will give a higher bargained wage (Johansen, 2000). How the expected outside utility reacts to changes in the outside factors depends on the variable in question. Higher unemployment will reduce the outside utility, subsequently reducing the bargained wage. An increase in the two remaining variables, the replacement ratio and the alternative wage, will have a positive effect on the outside utility. Subsequently, yielding a higher bargained wage. The theory is consistent with empirical evidence for alternative wages (Holmlund & Zetterberg, 1991; Wulfsberg, 1997). On the other hand, empirical evidence on the unemployment effect is ambiguous (Johansen, 1996; Wulfsberg, 1997; Holmlund & Zetterberg, 1991).

In general, the effects of a product price or productivity increase are also ambiguous. However, as Hoel & Nymoen (1988) points out, it is reasonable to believe that the bargained wage will react positively to an increase in these variables. How the bargained wage reacts to changes in the product prices and productivity is thus an empirical question. The subsequent empirical analysis will try to answer this question in the context of oil as the product, the petroleum sector as the main sector and the manufacturing sector as the alternative sector. The following implicit wage function will be used when analysing the outcome of the wage negotiations

$$W = W(PA, w_A, Z) \tag{3.22}$$

where P, A and w_A are expected to impact the wages positively. Z, is a vector containing other variables which affects the bargained wage differently.

4. Data and Time Series Properties

This chapter begins by first defining the data used in the empirical analysis. We then proceed by explaining important time series properties for consistent and unbiased estimates. First by explaining the concept of stationary processes and how to test the variables for stationarity. Secondly, by looking at cointegration, before we conclude by explaining the concept of Error Correction Models.

4.1 Data

The data used in this analysis are annual time series data from the Norwegian petroleum and manufacturing sectors. Data is available from 1970 to 2016, but the first years do not show any real changes in oil related variables. Dyrstad (2016) points out that the oil production did not begin at full strength until 1975, whilst Solheim (2008) notes that effects of oil price shocks in the 1970s were affected by the sector still being in a developmental phase. There is no data for wage costs or working hours in the petroleum sector before 1973, underpinning these points. Therefore, the sample used in this thesis is restricted to the year 1973 and onwards. Note that due to lagged variables, the estimation will begin in 1974. Furthermore, data from 2016 are let out since it was preliminary when the analysis was conducted. All data is gathered from Statistics Norway and available online.[13] The variables used in the empirical models are the following:

- p_t = log of the oil price index.
  p is computed by dividing exports of crude oil and natural gas in current prices, by the exports of the same products at fixed 2005 prices.
- wo_t = log of hourly earnings in the petroleum sector
- wa_t = log of hourly earnings in the alternative (manufacturing) sector.
  The average hourly wage rates are computed by dividing the nominal wage cost by the total hours worked. Both variables are in millions making wo_t and wa_t average hourly wage.
- $prod_t$ = log of productivity in the oil sector.
  The productivity, is the log of the gross product in fixed prices minus the log of hours worked.
- $Stop_t$ = dummy for wage and price stops in 1979 and 1988-89.
  $Stop_t$ takes the value 1 if the year is 1979 or 1989 and 0 otherwise.

[13] ssb.no/en/statbank

- $wr_t = (wo_t - wa_t)$ = log of the relative wage between the oil and the manufacturing sector.
  The relative wage is computed by subtracting the log of the alternative wage from the log of the petroleum sector wage.
- $ws_t = (wo_t - p_t - prod_t)$ = log of the wage share in the oil sector.
  The wage share is the log of the petroleum wage minus the log of the oil price and log of the productivity. The wage share is the part of the income going to labour in a sector
- $wp_t = (wo_t - p_t)$ = log of petroleum wage minus the log of oil price.

In the literature, several methods have been used as a proxy for the oil price. Peersman & Van Robays (2012, p. 1538) use the nominal refiner acquisition cost of imported crude oil, whilst Keane & Prasad (1996, p. 391) use the producer price index for refined petroleum products deflated by the overall producer price index. The index used in this thesis works as the real export price of oil. The wage share and the relative wage are included as possible cointegrating variables. If stationary, these variables can be used as error correction terms in dynamic modelling. More on this in Sections 4.2.2 and 4.2.4

Dyrstad (2016) argues that using annual data may harm econometric analysis because large changes in one quarter will have less effect when aggregating over the entire year. If this shock has an impact on the petroleum wage, as an output variable, it may appear as an innovation in the error term, and not been controlled for. However, Dyrstad analyses the effects of a policy intervention which might have larger short-run impact compared with the variables used in this analysis. Furthermore, arguments for annual data is that the wage negotiations take place once a year.

4.2 Time Series Properties

4.2.1 Stationarity

The variables in this thesis are all time series. It is therefore crucial for the variables to have the right properties for ordinary least square estimation (OLS) to give the best unbiased linear estimates (BLUE) (Wooldridge, 2013, p. 98). Most importantly, the variables included needs to be stationary. A variable is stationary if it deviates with a constant amplitude around its (finite) mean and has a time independent covariance (Langørgen, 1993, p. 14).

As analysed in Section 4.2.3, this is not the case for all my variables. If we regress two non-stationary variables, with similar trends, we might encounter a problem of spurious regression. The estimates can thus have a high R^2 and significant t- and F-values, but without any form of economic explanation (Enders, 2015, p. 195). Furthermore, the usual assumptions for the error term being white noise will be violated. Hence, t- and F-tests, as well as the R^2, will become unreliable (Enders, 2015, p. 196). However, as elaborated on in Section 4.2.2, if two or more variables cointegrate we can perform inference tests without any problem. Formally, a weakly stationary stochastic process will have the following properties if stationary

$$E(y_t) = E(y_{t-s}) = \mu \tag{4.1}$$

$$E(y_t - \mu)^2 = E(y_{t-s} - \mu)^2 = \sigma^2 \tag{4.2}$$

$$E[(y_t - \mu)(y_{t-s} - \mu)] = E[(y_{t-j} - \mu)(y_{t-j-s} - \mu)] = \gamma_s \tag{4.3}$$

Equations (4.1)-(4.3) states that a weakly stationary process, y_t, has a constant expected mean, constant variance and a constant autocovariance, respectively. If we consider the following first order autoregressive process AR(1). Formally, this is a linear combination of the last period's previous value of the dependent variable (Brooks, 2008, p. 215)

$$y_t = \alpha_0 + \rho y_{t-1} + \varepsilon_t \tag{4.4}$$

where ε_t has white noise properties following the Gauss-Markov assumptions, i.e. $E(\varepsilon_t) = 0$, $VAR(\varepsilon_t) = \sigma^2$, $cov(\varepsilon_t, \varepsilon_{t-k}) = 0 \; \forall \; t$ and $k \neq 0$ (Wooldridge, 2013). If we substitute in for y_{t-1}, y_{t-2} and so on, we can rewrite (4.4) as a Moving Average (MA) process. A moving average process is a linear combination of the white noise residuals (Brooks, 2008, p. 211). y_0 is assumed to be the initial value

$$y_t = \alpha_0 \sum_{i=0}^{t-1} \rho^i + \rho^t y_0 + \sum_{i=0}^{t-1} \rho^i \varepsilon_{t-i} \tag{4.5}$$

If $t \to \infty$, (4.5) can be rewritten as

$$\lim_{t \to \infty} y_t = \frac{\alpha_0}{1 - \rho} + \sum_{i=0}^{\infty} \rho^i \varepsilon_{t-i} + \rho^t y_0 \tag{4.6}$$

Therefore, if t is sufficiently large and $|\rho|< 1$, the last part of (4.6) will disappear.[14] This yields the following expected mean

$$E(y_t) = \frac{\alpha_0}{1-\rho}$$

which is constant and time independent if $|\rho|< 1$. The variance of the y_t process becomes

$$\begin{aligned} Var(y_t) &= E[(\varepsilon_t + \rho\varepsilon_{t-1} + \rho^2\varepsilon_{t-2} + \ldots)^2] = \sigma^2[1 + \rho^2 + \rho^4 + \ldots] \\ &= \frac{\sigma^2}{1-\rho^2} \end{aligned}$$

The process has a constant variance if $|\rho|< 1$. Turning to the autocovariance of y_t

$$\begin{aligned} Cov(y_t, y_{t-s}) = \gamma_s &= E[(\varepsilon_t + \rho\varepsilon_{t-1} + \rho^2\varepsilon_{t-2} + \ldots)(\varepsilon_{t-s} + \rho\varepsilon_{t-s-1} + \rho^2\varepsilon_{t-s-2} + \ldots)] \\ &= \sigma^2\rho^s[1 + \rho^2 + \rho^4 + \ldots] \\ &= \frac{\sigma^2\rho^s}{1-\rho^2} \end{aligned}$$

which is also constant and time independent if $|\rho|< 1$.

From the above results, it is clear that $|\rho|< 1$ is a vital condition for a process to be stationary. If this condition is satisfied, the mean, variance and covariance will be constant and independent throughout time. Langørgen (1993) explains a stationary process as having a short memory. This means that after shocks and innovations there are forces pulling $\{y_t\}$ towards its mean. On the other hand, if $|\rho|> 1$, $\{y_t\}$ will explode, and innovations and other shocks will propagate throughout time. If $|\rho|= 1$, $\{y_t\}$ will be a random walk, a process which do not forget shocks. Both of the latter situations are known as non-stationary process (Langørgen, 1993).

If $|\rho|< 1$ we say that the variable, y_t, is integrated. Formally, $y_t \sim I(0)$. If we encounter a random walk, with $|\rho|= 1$, the variable will become stationary if we first differentiate the process (Enders, 2015). Assuming a random walk with drift process,[15] we find

$$y_t = \alpha_0 + y_{t-1} + \varepsilon_t \tag{4.7}$$

$$(1-L)y_t = \alpha_0 + \varepsilon \tag{4.8}$$

[14] Remember that $\sum_{i=0}^{\infty} E(\rho^i\varepsilon_{t-i}) = 0$

[15] L in (4.8) is known as the Lag-operator. L defines one lag of y_t, L^2 represents two lags, etc.

Equation (4.8) is also known as a unit root process, because the solution to the characteristic equation $[(1 - z) = 0]$ is unity. This violates the stationarity condition, that all characteristic roots, z, lies outside the unit circle (Brooks, 2008, p. 216, p. 332). The general solution to (4.8) becomes

$$y_t = y_0 + \alpha_0 t + \sum_{i=1}^{t} \varepsilon_i \tag{4.9}$$

Equation (4.8) is a random walk with drift, because its general solution, (4.9), contains two non-stationary variables. One deterministic trend, $\alpha_0 t$, and one stochastic trend, $\sum \varepsilon_i$ (Enders, 2015). If we take the first difference of (4.8) we find

$$\Delta y_t = \alpha_0 + \varepsilon_t \tag{4.10}$$

It is clear that whenever ε_t is white noise, the process in (4.10) is stationary. This can be seen by examining the mean, variance and covariance

$$\begin{aligned}
&E(\Delta y_t) = E(\alpha_0 + \varepsilon_0) = \alpha_0 \\
&Var(\Delta y_t) \equiv E[(\Delta y_t - \alpha_0)^2] = E(\varepsilon_t)^2 = \sigma^2 \\
&Cov(\Delta y_t, \Delta y_{t-s}) \equiv E[(\Delta y_t - \alpha_0)(\Delta y_{t-s} - \alpha_0)] = E[\varepsilon_t \varepsilon_{t-s}] = 0
\end{aligned}$$

A random walk process y_t, as (4.8), is said to be integrated by order one. Also denoted $y_t \sim I(1)$. As previously discussed, this process will be stationary by first differences, i.e. $\Delta y_t \sim I(0)$. Generally, if y_t is stationary after the dth difference, it is said to be dth order integrated, or $y_t \sim I(d)$. We can write this as $\Delta^d y_t \sim I(0)$. Normally, economic time series are either $I(0)$ or $I(1)$ (Langørgen, 1993).

To analyse whether a variable is stationary or not, we use a test developed by Dickey & Fuller (1979), known as the Dickey-Fuller (DF) test. We start by assuming the following random walk with drift model

$$y_t = \alpha_0 + \rho y_{t-1} + \varepsilon_t \tag{4.11}$$

We want to test whether y_t is a unit root. The null hypothesis is $\rho = 1$, against the alternative hypothesis $\rho < 1$. By subtracting y_{t-1} from both sides of the equation, we can rewrite (4.11) as

$$\Delta y_t = \alpha_0 + (\rho - 1)y_{t-1} + \varepsilon_t \tag{4.12}$$

$$= \alpha_0 + \psi y_{t-1} + \varepsilon_t, \quad \psi = (\rho - 1) \tag{4.13}$$

We can now test $\psi = 0$ (which makes $\rho = 1$), against the alternative $\psi < 0$ (making $\rho < 1$). The test statistic is obtained with a straightforward t-test

$$\text{test statistic} = \frac{\hat{\psi}}{\widehat{SE(\hat{\psi})}}$$

Where $\hat{\psi}$ is the estimated value of ψ, and $\widehat{SE(\hat{\psi})}$ is the estimated standard error of $\hat{\psi}$. The hypothesis becomes

$$H_0 : \psi = 0 \Rightarrow y_t \sim I(1)$$

$$H_A : \psi < 0 \Rightarrow y_t \sim I(0)$$

The null hypothesis is thus rejected if the t-values, in absolute terms, are greater than the critical value, in absolute terms. However, the test statistic does not follow a usual t-distribution, invalidating the conventional critical values for t-tests (Brooks, 2008). A set of other critical values derived from simultaneous experiments are used in the DF test. These are usually larger than normal critical values, in absolute terms, and will vary with model specification (Brooks, 2008, p. 328).[16]

The DF test is only valid if the error term, ε_t, is white noise. We have previously seen that the error term, ε_t, cannot be serially correlated for it to be white noise. If the dependent variable, Δy_t, is autocorrelated, the error term will be autocorrelated as well. Hence, invalidating the test (Brooks, 2008). The solution to this problem is to extend (4.13) with p lags of the dependent variable, Δy_t

$$\Delta y_t = \alpha_0 + \psi y_{t-1} + \sum_{i=1}^{p} \kappa_i \Delta y_{t-i} + \varepsilon_t \tag{4.14}$$

Equation (4.14) is known as the augmented Dickey-Fuller (ADF) test. The lags of Δy_t will control for possible serial correlation (Brooks, 2008). How many lags to include is an empirical question and can

[16] E.g. if the model we are testing contains a constant and a trend, the critical value will be larger, in absolute terms, compared to a model with only a constant.

be answered with the use of information criteria (IC). A problem with ICs is to find the appropriate lag length for the dependent variabel. If too many lags are included it will reduce the degrees of freedom. This loss will, *ceteris paribus*, reduce the test statistic. On the other hand, too few lags will not remove all of the serial correlation and bias the results (Brooks, 2008). The Akaike information criteria (AIC) is used to find the correct number of lags for this test.[17] The AIC is given with the following equation

$$\text{AIC} = \ln\left(\frac{1}{T}\sum_{t=1}^{T}\hat{\varepsilon_t}^2\right) + \frac{2k}{T} \tag{4.15}$$

Where T is the number of observations and $k = p + q + 1$ is the number of lags and variables. The first part of (4.15) considers the goodness of fit in terms of the sum of squared residuals. The second term penalises extra variables, q, and extra lags, p, by adding $\frac{2k}{T}$. Enders (2015) notes that the AIC can work better than competing ICs in smaller samples. We select the model with the lowest AIC.

4.2.2 Cointegration

Early wisdom in time series econometrics were to first differentiate all non-stationary variables in a regression (Enders, 2015). Problematic with such an approach is that a long-run solution will not be feasible to find. In the long-run $y_t = y_{t-1}$, thus $\Delta y_t = 0$ (Brooks, 2008). A theory introduced by Engle & Granger (1987), asserts that if there exist a stationary linear combination of two or more non-stationary variables, with the same order of integration, the variables are said to cointegrate. Hence, we can use this stationary combination in an OLS regression, with consistent results. Following the theory of Engle & Granger, we have the following simple equation

$$z_t = y_t - \alpha_0 - \beta_1 x_t \tag{4.16}$$

both y_t and x_t are assumed to be $I(d)$, α_0 is a constant and β_1 is a scaling parameter. In general, a linear combination of these variables will give $z_t \sim I(d)$. However, if a linear combination of y_t and x_t is stationary, z_t becomes $I(d-b),\ b > 0$. For example if $d = b = 1$, where both x_t and y_t are $I(1)$, the z_t-term becomes $I(0)$. In this situation β is known as the cointegration factor.

We can interpret z_t as an error term with white noise properties. It will temporarily deviate from its

[17] The AIC is the metric OxMetrics reports for this test. Other ICs are presented in Enders (2015). The different tests penalises the number of variables differently.

zero mean, and frequently fluctuate through the zero line (Engle & Granger, 1987). Thus, z_t equals zero in the long-run. Consequently, the long-run solution for (4.16) becomes

$$y_t = \alpha + \beta x_t \tag{4.17}$$

This static long-run solution will be useful in the subsequent empirical analysis, since the variables in question are non-stationary. Further interpretation of the error term can be done by assuming that z_t is an AR(1) process:

$$z_t = \varphi z_{t-1} + \nu_t \Rightarrow \Delta z_t = (\varphi - 1) z_{t-1} + \nu_t \tag{4.18}$$

If $\varphi < 1$, a positive deviation from equilibrium, will result in a negative impact in the next period growth rate, and vice versa. In other words, there is an underlying mechanism working towards a long-run equilibrium.

4.2.3 Test for Unit Root

Tests for possible unit roots in the included variables are presented in Table 1. The test is conducted by using the augmented Dickey-Fuller test, as considered in (4.14). The first column displays the variables in levels and in first differences (denoted by Δ). t-statistics from the ADF are presented in the second column, with corresponding lags, used in the test, presented in the last column. Considering the number of lags chosen by the AIC, we can conclude that the data are not prone to much autocorrelation.

Only one of the level variables presented in Table 1 is significant at the 5% level, namely, wo_t. However, if we plot the series, as in Figure 3, we find that it is highly unlikely that wo_t is stationary. Such a problem may occur if the true coefficient, ρ, in (4.14) is close to unity (Brooks, 2008). In the situation of a small sample size, the test can have problems separating between ρ being 0.97 or 1. The estimated coefficient is 0.97, with a very small standard error of 0.033. Therefore, the ADF concludes that $\rho = 0.97$ due to the small sample size. Since Figure 3 shows a clear trend in wo_t, it is possible that we wrongly reject the null hypothesis that wo_t is a unit root. This is known as a type 1 error (Thomas, 2005). All other level variables presented in Table 1 are unit-roots. Hence, performing OLS on these variables is not preferred. Plots of all the variables are presented in the Appendix.

Table 1: Unit root tests

Variable	ADF test value	Number of lags
wo_t	-3.514^{*}	0
wa_t	-2.465	1
p_t	-1.387	0
$prod_t$	-0.5735	0
Δwo_t	-3.575^{*}	1
Δwa_t	-3.711^{**}	0
Δp	-4.952^{**}	0
$\Delta prod_t$	-5.792^{**}	0
wr_t	-1.437	1
ws_t	-2.061	0
wp_t	-1.583	0
Δwr_t	-7.202^{**}	0
Δws_t	-6.055^{**}	1
Δwp_t	-5.169^{**}	0

Notes: The table presents t-values from a ADF-test with a constant. Sample from 1976. The DF critical values are 5%=-2.94 and 1%=-3.61. The numbers of observation is T=39 for variables in levels, and T=38 for variables in first differences denoted Δ. The number of lags is found using Akaike information criteria. * and ** shows the significance level of 5% and 1%, respectively

When the variables are first differentiated, they go from being random walks to being stationary processes. First difference of wo_t and wa_t are plotted in Figure 4. This is an expected result subject to the econometric theory presented in Section 4.2.1. Including the first differenced variables in the empirical analysis will deliver consistent results. In addition, if some of these variables cointegrate we can use them in a long-run dynamic model. An example of such a model is presented in Section 4.2.4.

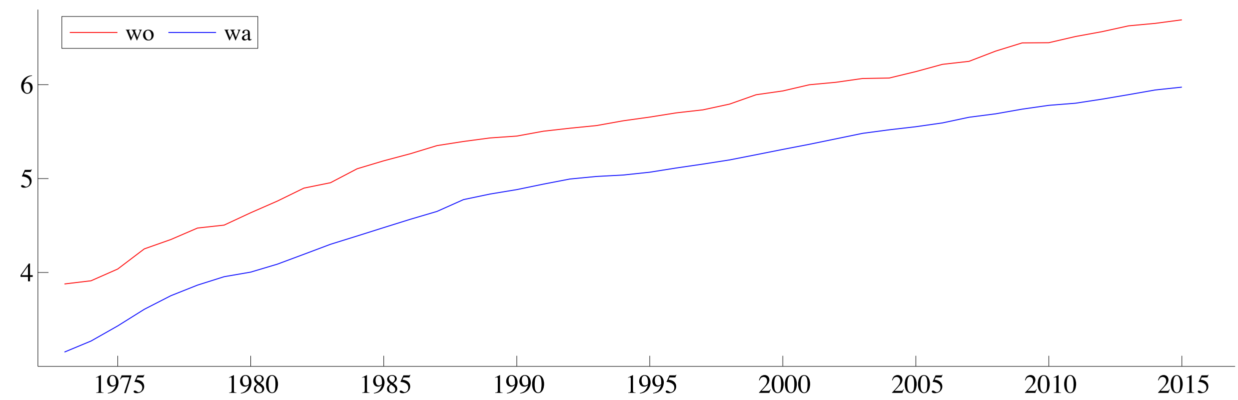

Figure 3: Log of hourly wage in the petroleum and manufacturing sector from 1973 to 2015.

Table 1 reveals that the relative wage, wr_t, does not have stationary properties. By analysing the relative wage, plotted as the solid line in Figure 5, we see that the relative wage curve has long periods deviating from its mean of 0.63. If the ADF had resulted in statistically significant t-values, it would indicate a cointegrating relationship between wo_t and wa_t, and thus we could use this link in a long-run dynamic model.

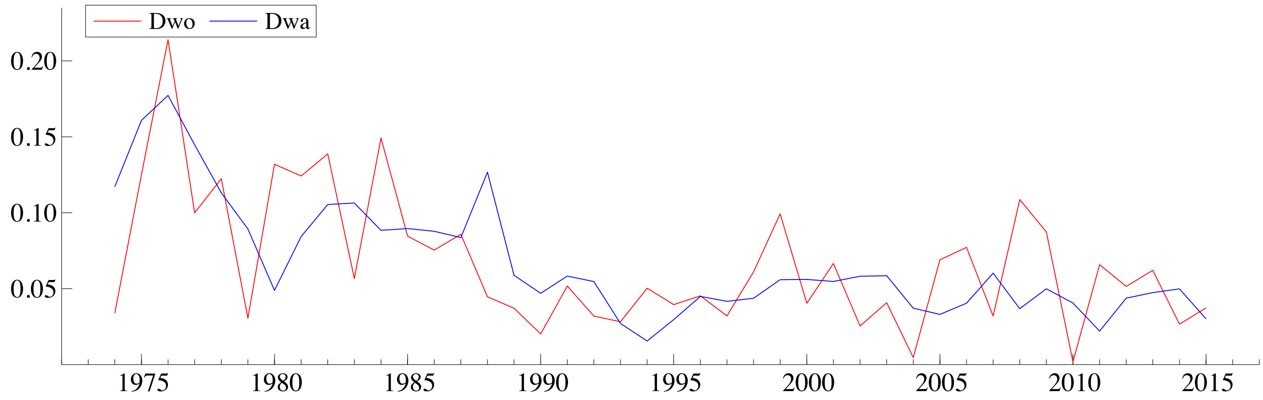

Figure 4: Petroleum and manufacturing sector growth in log of hourly wages from 1974 to 2015.

Surprisingly, the wage share, ws_t, was non-stationary. In an article on Norwegian wages curves, Johansen (1995) finds evidence of a highly significant relationship between the variables forming the wage share in the Norwegian industry sector. A result also found by Nymoen & Rødseth (2003). It would be reasonable to believe that the wage share had similar properties in the oil sector as in the manufacturing sector. However, Dyrstad (2016) points out that the petroleum sector productivity uses the best available technology at the world market, so the difference between the manufacturing and petroleum sector may be explained by the higher fluctuation in the petroleum sector productivity.[18] Hence, we cannot use the wage share as an error correction term in dynamic modelling.

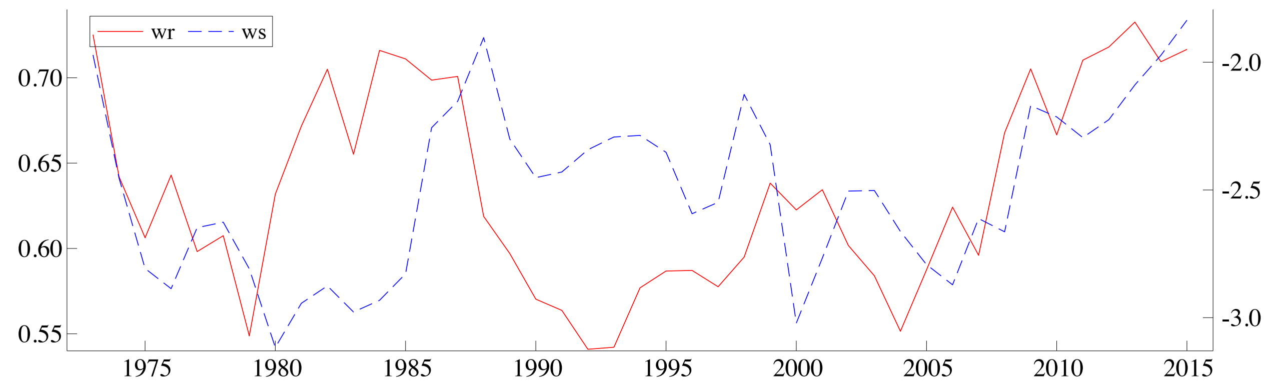

Figure 5: Solid line: Log of relative wage, the same as in Figure 2 (Left axis). Dashed line: Log of the wage share in oil sector from 1973 to 2015 (Right axis).

[18]See Figure A.6 in the Appendix for a plot of the two productivity variables

4.2.4 Error Correction Model

An Error Correction Model (ECM) is useful for the empirical analysis because of its tight link to economic theory (De Boef & Keele, 2008). The name of the model comes from its correcting nature towards a long-term equilibrium. It is also useful if series are highly autocorrelated, or close to integrated (De Boef & Keele, 2008).

From Section 4.2.3 we find all the important variables to be integrated, thus making ECM appropriate for this analysis. We begin by assuming the following autoregressive distributed lag model (ADL)

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \beta_0 x_t + \beta_1 x_{t-1} + \varepsilon \tag{4.19}$$

We use a Bårdsen transformation to reparameterise the equation by subtracting y_{t-1} from both sides, as well as adding and subtracting $\beta_0 x_{t-1}$ on the RHS. De Boef & Keele (2008, p. 189) argues that: *«The Bårdsen transformation (...) is perhaps the most useful form of the ECM»*

$$\begin{aligned}
\Delta y_t &= \alpha_0 + (\alpha_1 - 1) y_{t-1} + \beta_0 x_t + c_1 x_{t-1} + \varepsilon_t \\
&= \alpha_0 + (\alpha_1 - 1) y_{t-1} + (\beta_0 + \beta_1) x_{t-1} + \beta_0 \Delta x_t + \varepsilon_t \\
&= \alpha_0 + \alpha_1^* y_{t-1} + \beta_1^* x_{t-1} + \beta_0^* \Delta x_t + \varepsilon_t
\end{aligned} \tag{4.20}$$

where $\alpha_1^* = (\alpha_1 - 1)$, $\beta_0^* = \beta_0$ and $\beta_1^* = (\beta_0 + \beta_1)$. The coefficient β_0^* represents the short-run elasticity of y w.r.t. x, whilst α_1^* is the error correcting term, also referred to as the speed of adjustment (Brooks, 2008). The coefficient β_1^* will be used in the long-run analysis. Equation (4.20) is a simple ECM with only one explanatory variable. However, x_t, can easily be expanded to a vector of two or more explanatory variables, $\boldsymbol{x_t}$. Such an expanded model will be used in the subsequent empirical analysis. The model can also be expanded with lagged first-differences to account for any inertia in the short-run shocks.

Equation (4.21) is a more commonly used notation of the ECM. It presents a dynamic adjustment model, first presented by Engle & Granger (1987), and uses a cointegration term, z_{t-1}, instead of two separate variables as in (4.20). We know from before that $z_t \sim I(0)$ if y_t and x_t cointegrates.

$$\Delta y_t = -\alpha_{EG} z_{t-1} + \gamma_1 \Delta x_t + \gamma_0 + \nu_t \tag{4.21}$$

Compared with (4.20), $z_{t-1} = (y_{t-1} + \frac{\beta_1^*}{\alpha_1^*}x_{t-1})$, and α_{EG} is the speed of adjustment towards equilibrium. If $\frac{\beta_1^*}{\alpha_1^*} = 1$, it implies that x_{t-1} is homogeneous of the first degree. This will be a useful result for the empirical analysis, because it represents one of the assumptions in the theoretical model. Equations (4.20) and (4.21) are equal, and will produce the same results if y_t and x_t are cointegrated, and thus, Δy_t, will be $I(0)$, in both equations.

A simple method to test for cointegration was introduced by Kremers et al. (1992), known as the error-correction-based test. The test states that if y_t and x_t cointegrates the estimate $\hat{\alpha}_1^*$, will necessarily be significantly negative. This is consistent with the *Granger representation theorem* which states that if the variables are cointegrated, there exists an ECM, and vice versa (Enders, 2015). Following this theorem, there must exist cointegration between variables if there exists an ECM, i.e. when $\alpha_1^* < 0$. If several lagged level variables are included in the vector $\boldsymbol{x_t}$, we cannot state which variables are cointegrating. However, if all variables are significant it is reasonable to believe that all of the variables cointegrate. In such a situation, Δy_t, becomes $I(0)$.[19]

Kremers et al. (1992, p. 325) argues that the ECM test is better suited than the Dickey-Fuller unit root test because: *«It uses available information more efficiently than the Dickey-Fuller test»*. They argue that a DF-test can marginally reject the null hypothesis of no cointegration. However, analysing the corresponding variables in an ECM framework, may give highly significant results. The test applies a standards t-test. It tests the null hypothesis of no cointegration, $\alpha_1^* = 0$, against the alternative hypothesis of significant cointegration, $\alpha_1^* < 0$. The test uses critical values located between conventional critical t-values and DF critical values. Where the critical values calculated by Kremers et al. (1992, p. 338) are: 5% $t_{ECM} = -2.02$ and 1% $t_{ECM} = -2.80$.

If the estimated regression gives a coefficient, $\hat{\alpha}_1^*$, which has a t-value less than t_{ECM} it will exist a long-run equilibrium model. Thus, the series in (4.20) converges toward its unconditional means, such that $E(y_t) = y$ and $E(x_t) = x$ (De Boef & Keele, 2008). All growth rates and the error term, ε_t, will be zero in the long-run. Equation (4.20) thus becomes

$$y = \frac{\alpha_0}{-\alpha_1^*} + \frac{\beta_1^*}{-\alpha_1^*}x \tag{4.22}$$

Equation (4.22) is a static long-run model, where the long-run effect of x on y is given by the

[19] Another test is the "two-step" Engle-Granger method, which uses Dickey-Fuller critical values to test the null hypothesis of no cointegration. The test will not be derived in detail. See Brooks (2008, p. 341) for more.

coefficient $\beta_1^*/(-\alpha_1^*)$.

We have found in this chapter that many of the included variables are non-stationary. Thus, a dynamic model, based on an ECM, is appropriate in the empirical analysis due to the nature of the variables. The next chapter presents the empirical framework used to analyse petroleum wages, where the ECM is applied and discussed in detail.

5. Empirical Framework

This chapter presents an empirical wage equation which builds on the wage formation theory presented in Chapter 3. We begin with a general unrestricted model (GUM), where we have included variables which, in theory, are presumed to have an effect on the petroleum wage. The Error Correction Model presented in (5.1) is based on models previously used in empirical research on Norwegian wage formation (Johansen, 1995; Nymoen & Rødseth, 2003; Dyrstad, 2016)

$$\begin{aligned}\Delta wo_t = \beta_0 &+ \beta_1 wo_{t-1} + \beta_2 wa_{t-1} + \beta_3 p_{t-1} + \beta_4 prod_{t-1} + \beta_5 \Delta wa_t \\ &+ \beta_6 \Delta wa_{t-1} + \beta_7 \Delta p_t + \beta_8 \Delta p_{t-1} + \beta_9 \Delta prod_t \\ &+ \beta_{10} \Delta prod_{t-1} + \beta_{11} STOP_t + \varepsilon_t\end{aligned} \tag{5.1}$$

where wo is the petroleum wage, wa is the alternative manufacturing wage, p is the oil price and $prod$ is the productivity in the petroleum sector. All variables are expressed as natural logarithms. This means that the coefficients can directly be interpreted as elasticities. All β's are unknown and will be estimated using OLS. On the basis of earlier literature, and the fact that we use annual data, only one lag of the growth variables are included.[20]

We will treat the oil price as strictly exogenous. Productivity will also be treated as exogenous since the petroleum sector utilises the best available technology (Dyrstad, 2016). Furthermore, the GUM consists of current and lagged growth rates of industry wage, oil price and productivity. $STOP$ is a dummy variable included to capture effects of the price and wage freeze in 1979 and the wage law in 1988-89. ε_t is the error term, and is assumed to be independently normally distributed with an expected mean of zero and a constant variance.

In Chapter 3 we discussed a theoretical static long-run model. This model predicted that all variables included in the GUM will have a positive impact on the wage. The dummy variable was not discussed in the theoretical framework. However, earlier empirical research has proved it to be negative (Johansen, 1995; Nymoen & Rødseth, 2003; Dyrstad, 2016). It is therefore reasonable to believe it to impact the petroleum wage growth negatively as well. Whether or not the effects are equal in the short-run, as opposed to the theoretically long-run framework, is an empirical question, which we will analyse further in Chapter 6.

[20] Longer lags were tested, but with insignificant results for lags longer than one year

The error correcting part of the model is made up of the petroleum wage, industry wage, oil price and productivity, all in levels, and lagged one year. As discussed in Section 4.2.4, if β_1 is negative and significantly different from zero, Kremers et al. (1992) argues that the included variables cointegrate, and there exists a long-run solution. Thus, β_1 can be interpreted as the speed of adjustment parameter towards a long-run equilibrium. The greater the value of β_1, in absolute terms, the quicker is the response from any disequilibrium (Enders, 2015). The short-run effects on the petroleum wage are represented by the growth variables. We find the long-run solution by assuming that all variables are constant in the long-run

$$wo_t = wo_{t-1} = wo, \quad wa_t = wa_{t-1} = wa, \quad p_t = p_{t-1} = p, \quad prod_t = prod_{t-1} = prod$$

All short-run effects disappear, and we are left with the following static long-run solution

$$wo = \frac{\beta_0}{-\beta_1} + \frac{\beta_2}{-\beta_1}wa + \frac{\beta_3}{-\beta_1}p + \frac{\beta_4}{-\beta_1}prod + \frac{\beta_{11}}{-\beta_1}STOP \tag{5.2}$$

As the petroleum wage is presumed to mainly be affected by the industry wage, the oil price and the productivity, the Scandinavian wage theory predicts that their coinciding coefficients are homogeneous of degree one (i.e. $\frac{\beta_2}{-\beta_1} + \frac{\beta_3}{-\beta_1} + \frac{\beta_4}{-\beta_1} = 1$). This implies that there are no other variables affecting the petroleum wage in the long-run. We will analyse if the Scandinavian wage theory holds in Chapter 6.

5.1 Model Evaluation

Several tests are included in the analysis to test for potential misspecification in the models. It is included to make sure that there is no systematic variation in the error term, which could bias the result. All the tests are presented in correspondence with the regression models in Chapter 6.

The first test reported, *AR 1-2*, is a general test for autocorrelation. It is conducted by first predicting the error terms from a linear regression, $\hat{\varepsilon}_t$, then regress these predicted error terms on its p previous lags. The null hypothesis states that the current residual is not dependent on any of its previous values (Brooks, 2008, p. 149). We will perform a F-test under the null hypothesis that all coefficients are jointly equal to zero. If the null hypothesis is rejected under conventional critical values, there are significant autocorrelation in the model. Difficulties regarding such a test is to find the appropriate lag length. However, Brooks (2008) argues that using annual data, only one lag is regarded as sufficient. As a consequence, serial correlation would violate the Gauss-Markov assumptions. It follows that the OLS estimates are no longer BLUE. Hence, inference tests are no longer valid, and the coefficients becomes inconsistent (Brooks, 2008).

The second test reported, *ARCH 1-2*, is a test of autoregressive volatility in the residual, i.e. if the current residual volatility is dependent on previous periods volatility. Significant ARCH effects will violate the constant variance condition, and invalidate OLS. The test is conducted in similar fashion as the autocorrelation test. It begins by running a linear regression and predict the squared residuals, $\hat{\varepsilon}_t^2$. We then proceed by regressing previous values of the squared residuals, on the current squared residual. The null hypothesis states that non of the coefficients are statistically significant. We test this by applying a F-test. Failing to reject the null hypothesis concludes that there are no significant ARCH effects. As with autocorrelation, ARCH violates the Gauss-Markov assumption of constant residual variance. This makes the estimated coefficients inconsistent (Brooks, 2008).

The third test applied is known as the Jarque-Bera test, denoted *Normality*, and tests whether the error terms are normally distributed or not. The test is conducted by finding the excess kurtosis and skewness of the predicted errors and compare it to a normal distribution. The test follows a χ^2-distribution, with a null hypothesis that the error term is normally distributed. Rejecting the null hypothesis will not impact the estimated coefficients, however, conclusions regarding inference tests will be wrong, and the coefficients becomes inconsistent (Brooks, 2008, p. 163).

The fourth test, *Hetero*, is a «White test» for heteroscedasticity (White, 1980). It tests if the variance of the error term is constant and not affected by different values of the independent variables. Heteroscedasticity violates the constant residual variance condition. Hence, OLS will not be BLUE, making the coefficients inconsistent. The test is conducted by regressing $\hat{\varepsilon}_t^2$ on all independent variables, including corresponding squares and cross products. We then perform a F-test under the null hypothesis that all coefficients are jointly zero. A potential problem with this test is that the inclusion of many variables will reduce the degrees of freedom, which makes inference less precise (Wooldridge, 2013).

The fifth test is Ramsey's RESET test, which is a general test for model misspecification. The null hypothesis states that the model is well specified against an alternative hypothesis that there are neglected non-linearity in the model. The test expands the main regression by adding quadratic fitted values, $\widehat{wo}_t^2$, and cubed fitted values, $\widehat{wo}_t^3$. We then apply a F-test, and check whether the coefficients for the fitted values are jointly zero or not. If we fail to reject the null hypothesis we conclude that the model is wrongly specified. Problematic for the RESET test is that it does not present any guidance towards where the model is wrongly specified. Therefore, it is difficult to solve the problem of non-linearity with the information we possess (Brooks, 2008).

The last test presented, is a predictive failure Chow-test for coefficient stability (Chow, 1960). This test is chosen, as opposed to a regular Chow-test, because the break we want to analyse is at the end of the sample. The test is conducted by first regressing a sample up until the point of the possible break. We then use this model to predict the remaining periods (Brooks, 2008, p. 183). The first regression usually consists of a long sample. We then proceed by testing the null hypothesis that the prediction errors, in form of the residual sum of squares, are zero for the forecasted sample. We reject the null hypothesis if the F-statistic is greater than the critical value for a F-distribution. Following rejection, we conclude that the coefficients are significantly not equal over the period, and that there exists a structural break (Brooks, 2008). The Chow-test is used when testing for breaks in Section 6.1.3. The corresponding F-statistics are presented in the Appendix, Table A.2. The next chapter presents several models with corresponding economic interpretation.

6. Results

This chapter presents the main findings of the empirical analysis. The aim of the analysis is to uncover any long and/or short-run effects of the oil price on the petroleum wage formation. All models are estimated using OLS and all regressions include corresponding diagnostic tests. The first part of the analysis presents the results for two main models, with a stability check for both models presented in Section 6.1.3. The second part presents different sensitivity analyses to test the robustness of the results. The last section of the chapter will use a Granger-causality test to check for simultaneous effects between the petroleum wage and the industry wage.

6.1 Main Results

Table 2 presents results based on three different models. The starting point of the analysis is the general unrestricted model (GUM) from (5.1). We observe that the error correcting term of the GUM, wo_{t-1}, is negative and significant at the 5% level. Following the econometric theory presented in Section 4.2.4, this is the correct signature for the adjustment term, and it suggests that there are long-run effects supported by the data. The long-run effect of the manufacturing wage is large and significant, whilst the effect of the oil price is smaller, but also significant. Both estimates are positive, coinciding with theoretical expectations. The only long-run variable which does not have the appropriate sign is the productivity, which we observe as negative. Following the theory presented in Chapter 3, a productivity increase was said to have a positive effect on the bargained wage. However, the estimated effect is small and insignificant. Using (5.2) we find the long-run solution to be

$$wo = 0.882wa + 0.133p - 0.0414prod - 0.122STOP + \text{const} \tag{6.1}$$

Equation (6.1) tells us that the alternative wage is the major long-run determinant in the petroleum sector wage formation. However, the oil price does indeed have some long-run effect as well. Generally, this specification contains several statistically insignificant variables and the estimates are mostly imprecise. None of the reported short-run variables are significant, clearly telling us that the GUM is over specified. Especially interesting is the insignificant effect of the long-run productivity, $prod_{t-1}$, and the lack of significant short-run effects of the oil price, Δp_t. We proceed by applying the «general-to-specific» method, where we sequentially drop insignificant variables, before we end up with a more accurate simplified model.

Table 2: Main results. Dependent variable: Δwo_t

Variables	GUM (5.1)	Model 1 (6.2)	Model 2 (6.4)
wo_{t-1}	-0.476 (-2.79)	-0.411 (-3.96)	
wa_{t-1}	0.420 (2.38)	0.356 (3.42)	
p_{t-1}	0.0635 (2.33)	0.0590 (4.60)	
$prod_{t-1}$	-0.0197 (-0.608)		
$(wo-wa)_{t-1}$			-0.337 (-3.99)
$(wo-p)_{t-1}$			-0.0582 (-4.69)
Δwa_t	0.697 (2.11)	0.516 (2.11)	0.451 (3.30)
Δwa_{t-1}	-0.222 (-0.850)		
Δp_t	0.0436 (1.79)		
Δp_{t-1}	-0.0183 (-0.704)		
$\Delta prod_t$	0.0137 (0.262)		
$\Delta prod_{t-1}$	0.0310 (0.827)		
$STOP_t$	-0.0583 (-2.41)	-0.0500 (-2.38)	-0.0515 (-2.55)
Const	0.823 (2.97)	0.601 (5.28)	0.609 (5.79)
Statistics and diagnostics			
σ	0.029	0.028	0.028
Adj R^2	0.58	0.60	0.61
AR 1-2 test:	$F(2,32)=0.33$	$F(2,34)=0.41$	$F(2,35)=0.41$
ARCH 1-1 test:	$F(1,39)=0.023$	$F(1,40)=0.29$	$F(1,40)=0.26$
Normality test:	$\chi^2(2)=0.60$	$\chi^2(2)=1.69$	$\chi^2(2)=1.95$
Hetero test :	$F(21,19)=0.30$	$F(9,32)=0.72$	$F(7,34)=1.15$
RESET23 test:	$F(2,27)=3.64$	$F(2,34)=4.83$	$F(2,35)=4.99$

Notes: Using full sample from 1973 to 2015. Estimated t-values in parentheses. All tests under «statistics and diagnostics» are explained in section 5.1. σ is the model's standard error and Adj R^2 is the model's coefficient of determination. The models are estimated by OLS using PcGive (Doornik & Hendry, 2009).

6.1.1 Model 1

After excluding all variables with insignificant effects, we find (6.2) to be a better parsimonious model

$$\Delta wo_t = \beta_0 + \beta_1 wo_{t-1} + \beta_2 wa_{t-1} + \beta_3 p_{t-1} + \beta_4 \Delta wa_t + \beta_5 STOP_t + \varepsilon_t \tag{6.2}$$

The estimated coefficients are presented in the column (6.2) of Table 2.[21] Note the estimate stability between the important variables in the GUM and (6.2). It should also be noted that Model 1 was not favoured by the AIC using the full sample. However, it was chosen for the analysis because it was preferred by the Schwarz Bayesian information criteria, and because the alternative model included insignificant variables.[22] Furthermore, a F-test on the imposed restrictions reveals that equation (6.2) is a valid simplification of the GUM. The F-statistic is well below its critical value (p-value=0.58). All the diagnostic tests, except from the RESET-test, display appealing results. The RESET-test gives a F-statistic beyond the critical value of 3.275, which means that there are some neglected nonlinearities in the data. However, as previously discussed it is unclear what is driving the rejection of the null hypothesis, which makes it difficult to cope with the problem.

As discussed in Section 4.2.4 there has to be at least one cointegrating relationship for the ECM to give consistent results. From the test provided by Kremers et al. (1992) we know that there exists cointegration between the included variables if the estimated t-value of the error correction term, wo_{t-1}, is less than its corresponding critical values. In Model 1, we clearly reject the null hypothesis of non-stationarity at the 1%-level. Thus, we conclude that wo, wa and p cointegrate, and that there is a long-run relationship between these variables.

The petroleum wage equation, (6.2), does also include the current manufacturing wage growth. It indicates that the petroleum wage is affected by current manufacturing wage growth in the short-run. A 1% increase in the manufacturing wage rate will increase the short-run petroleum wage growth with 0.516%. Hence, a manufacturing wage increase from 2% to 2.5%, will increase the short-run petroleum wage growth with 12.9%. As previously mentioned the petroleum wage rate is not affected by short-run oil price changes in Model 1. This may be explained by the nature of the Scandinavian wage model, which is not able to fully internalise oil price changes until the next main negotiations

[21] Estimates for the step-by-step regressions used in the general to specific method are presented in the appendix, Table A.1

[22] See the appendix, Table A.1, for more.

take place. It might take more than a year before new negotiations takes place, and during this period the oil price might have changed a lot.

The error correction term takes the value $\beta_1 = -0.411$. Hence, around 41% of any deviation from the long-term solution is equalised during one year. This gives a relatively slow adjustment towards the new equilibrium. However, earlier research analysing wage formation in the Norwegian industry finds even lower rates of adjustment (Raaum & Wulfsberg, 1998; Johansen, 1995, 1996). Their findings span from -0.25 to -0.36. Thus, the petroleum sector is quicker to adjust compared to the rest of the Norwegian manufacturing sector. Model 1's long-run equilibrium becomes

$$wo = 0.866wa + 0.144p - 0.122STOP + \text{const} \tag{6.3}$$

In the long-run the petroleum wage is made up of the manufacturing wage and the oil price. A 1% increase in the alternative wage increases the petroleum wage with 0.866%, whilst a 1% rise in the oil price raises the petroleum wage with 0.144%. This result is almost identical to the results of Johansen (1996).

Summing the two long-run elasticities yields: $0.866 + 0.144 = 1.01 \approx 1$. From a F-test we find that the long-run elasticities are not significantly different from one (p-value=0.75). This is evidence that the long-run elasticities could be homogeneous of the first degree. We also remember that this was an assumption in the theoretical model. It thus follows that an increase in the alternative wage and the oil price, with an equal factor, will increase the petroleum wage with the same factor. The alternative wage accounts for around 86% of the petroleum wage formation in the long-run, whilst the oil price accounts for around 14%. When comparing Model 1 with the GUM we only find marginally different long-run effects. This provides evidence for significant insider forces in the petroleum wage formation.

6.1.2 Model 2

From Model 1 we find that elasticities of the two long-run variables were not significantly different from one. Thus, in Model 2 we impose a restriction on the long-run elasticities with respect to the manufacturing wage and the oil price to exactly equal one. By doing so we also increase the model's degrees of freedom. The new model can be written as

$$\Delta wo_t = \beta_0 + \beta_1(wo - wa)_{t-1} + \beta_2(wo - p)_{t-1} + \beta_3\Delta wa_t + \beta_4 STOP_t + \varepsilon_t \tag{6.4}$$

Results from Model 2 are reported in the third column of Table 2. The two error correcting terms $[(wo - wa)_{t-1}$ and $(wo - p)_{t-1}]$ are both highly significant and clearly reject the null hypothesis of no cointegration. The speed of adjustment of Model 2 now becomes: $\beta_1 + \beta_2 = -0.395$, which is notably similar to the one in Model 1.

The estimated short-run effects of the manufacturing wage growth are comparatively lower than in Model 1, $\beta_4 = 0.451$. However, Model 2 is more precisely estimated, with the t-value for the short-run alternative wage increasing by 150%. We now find the long-run solution for Model 2 to be

$$wo = 0.853wa + 0.147p - 0.130STOP + \text{const} \tag{6.5}$$

We observe that the long-run parameters do not change substantially when restricting the variables to satisfy the first order homogeneity condition. This provides evidence that the two major determinants in the long-run petroleum wage formation are indeed the industry wage and the oil price. Furthermore, diagnostic tests for Model 2 indicate a congruent error term. However, as for Model 1, the RESET test rejects the null hypothesis, implying that also Model 2 is subjected to misspecification.

We find similarities when comparing the results in Table 2 with the results of Dyrstad (2016). First of all, Dyrstad finds significant effects for many short-run variables before the intervention in 1981. However, after 1981 he only finds short-run effects for the alternative wage. The short-run alternative wage effect appears after the second quarter and sums to 0.5. This is similar to the short-run effects found in this thesis. On the other hand, the speed of adjustment is marginally higher, with quarterly adjustment of -0.59. The major difference between the two analyses is the long-run effects. Dyrstad indeed finds homogeneous effects in the long-run. However, the only determinant is the alternative wage. The oil price is not explicitly included in the model of Dyrstad, but works through a value added term.[23] The natural logarithm of the value added can be interpreted as the log of the oil price plus the log of the productivity. Dyrstad (2016) finds no evidence supporting a long-run value added

[23]From (Dyrstad, 2016, p. 817) *«va_t=log of value added in the Norwegian petroleum sector minus log of petroleum sector workers, no_t»*

effect. There might be different reasons for this. First, the data sample of Dyrstad (2016) includes fewer years than the data used in this thesis. It is apparent from Figure 1 that his sample includes years of a stable oil price and moderate employment inflation. We find no effects of the oil price when we apply Model 1 to the sample years used in Dyrstad (2016). Secondly, the model specification of Dyrstad (2016) is different to the one applied in this thesis. He includes a variable for changes in employment in the petroleum sector, and he also includes a trend variable. The employment variable can be endogenously determined and thus capture some oil price effects. A third possible reason for this discrepancy may be the fact that Dyrstad (2016) makes us of quarterly data. However, there should be little difference in the long-run estimates when using quarterly versus annual data.

6.1.3 Recursive Estimation

Recursive estimation is a graphical method to check parameter stability. It starts by estimating a subsample for $t - i$ periods, before regressing the subsample $t - i + 1$, followed by an estimation of $t - i + 2$, and so on, until the full sample is utilised. By this point i separate regressions have been completed. We then plot the parameters for every observation in a graph, with corresponding estimated $+/-2$ standard deviations.

Figure 6: Recursive estimation of Model 1. Dashed lines are the $+/-2$ estimated standard deviations

Note that this plot is not a statistical test for stability, but it gives us information on how stable the estimated parameters are (Brooks, 2008, p. 187). A question arising with recursive estimation, is where to begin the subsample, i.e. how large i should be. If i is too large we lose too many degrees of freedoms. If the time period is too short we might neglect structural breaks in beginning of the sample. Brooks (2008) suggests checking the parameter stability by starting at $k+1$, where k is the first year. However, the extreme volatility in the first periods will make latter period deviations less visible.

We proceed by using $i = 12$ separate samples in the recursive estimation. This means that the first subsample uses information up until 2003. From Figure 6, it is clear that there is not much evidence of any structural breaks in Model 1. The only parameter we could argue changes slightly is the oil price after 2008. However, a Chow-test with a null hypothesis of no break is clearly not rejected, with a $F-$value $= 0.57$. The forecast estimates are presented in the Appendix, Table A.2. When the stability condition is satisfied the model should give unbiased and consistent estimates.

Figure 7: Recursive estimation of Model 2. Dashed lines are the $+/-2$ estimated standard deviations

Model 2 in Figure 7, presents a slightly different picture. The estimated parameter for the relative wage and the short-run manufacturing wage, both appear to change after 2008. The parameter for the relative wage increased from a stable -0.4 in years preceding 2008, to -0.3 in 2015. The estimated short-run parameter for the alternative wage dropped from 0.7, in the years up until 2008, to 0.6 in 2015. This result indicates possible structural breaks in the data after 2008, which might bias the results. However, a Chow-test for structural break is unable to reject the null hypotheses of breaks in 2008, with a $F-$value = 0.60. A possible problem, as Dyrstad (2016) points out in a similar test, is that the result might be biased towards rejection since we have 34 observations before, but only 6 after 2008.

6.2 Sensitivity Analysis

This section conducts a set of sensitivity checks to examine whether the results from the central analysis remain consistent when adding variables with possible significant effects. If any of the additional variables have significant effect and/or the estimated coefficient from the main results change substantially, we have an omitted variable problem in the previous models. Such an issue will bias the results in the main analysis. We begin by including short and long-run total unemployment, to check for any unemployment effects. The hypothesis is that the unemployment is accounted for in the manufacturing wage and should therefore have no effect on the petroleum wage. In addition, we check for asymmetric effects of oil price changes. This is a check, which is also applied in the analysis of Mork (1989) and Jiménez-Rodríguez & Sánchez (2005). Furthermore, we will check if the oil price in average annual terms are different from the average quarterly oil price. Therefore, we substitute out the annual average with the average second quarter oil price in the regression. This is done to check the robustness of the oil price. Finally, by using a Granger-causality test in a simple VAR framework, we check for possible simultaneous effects between the petroleum sector wages and the manufacturing sector wage. Results from the sensitivity analysis are presented in Table 3. Since Model 2 proved to be the best fit in Section 6.1, we use it as the foundation for the sensitivity analysis.

6.2.1 Model 3

Model 3 checks for any effects of the total unemployment in the economy. t_u is the log of the total unemployment, which is defined as the average annual unemployment rate.[24] Following the Scandinavian wage model, the total unemployment should be reflected in the manufacturing wage.

[24]The unemployment variable is found to be non-stationary in levels from a Dickey-Fuller test. It is stationary in first differences

Table 3: Results from robustness checks. Dependent variable Δwo_t

	Est. period: 1974-2015		Est. period 1979-2015	
Variables	Model 3	Model 4	Model 2*	Model 5
$(wo - wa)_{t-1}$	-0.362 (-4.29)	-0.348 (-3.92)	-0.266 (-2.88)	-0.267 (-2.86)
$(wo - p)_{t-1}$	-0.0562 (-4.63)	-0.0623 (-4.82)	-0.0586 (-4.49)	
$(wo - pQ2)_{t-1}$				-0.0568 (-4.40)
Δwa_t	0.429 (3.08)	0.611 (3.77)	0.222 (0.999)	0.264 (1.20)
Δp_t		-0.00359 (-0.0860)		
tu_{t-1}	-0.0228 (-1.73)			
Δtu_t	-0.0245 (-1.27)			
$p_t^+ * \Delta p_t$		0.0349 (0.618)		
$STOP_t$	-0.0523 (-2.63)	-0.054 (-2.66)	-0.0461 (-2.32)	-0.0478 (-2.38)
Const	0.540 (4.76)	0.630 (5.73)	0.579 (4.91)	0.584 (4.82)
Statistics and diagnostics				
σ	0.027	0.028	0.028	0.027
Adj R^2	0.63	0.60	0.46	0.45
AR 1-2 test:	$F(2,33) = 1.07$	$F(2,33) = 0.46$	$F(2,30) = 0.18$	$F(2,30) = 0.059$
ARCH 1-1 test:	$F(1,40) = 0.66$	$F(1,40) = 0.66$	$F(1,35) = 0.088$	$F(1,35) = 0.10$
Normality test:	$\chi^2(2) = 2.94$	$\chi^2(2) = 2.24$	$\chi^2(2) = 3.05$	$\chi^2(2) = 1.86$
Hetero test :	$F(11,30) = 1.73$	$F(11,30) = 0.75$	$F(7,29) = 1.26$	$F(7,29) = 0.87$
RESET23 test:	$F(2,33) = 3.41$	$F(2,33) = 5.89$	$F(2,30) = 3.10$	$F(2,30) = 3.57$

Notes: The models are estimated using PcGive (Doornik & Hendry, 2009). Estimated t-values in parentheses. Sample periods are given in the first row.

Thus, the effect of the total unemployment variables is expected to be zero. Model 3 can be written as

$$\begin{aligned} \Delta wo_t = \beta_0 + \beta_1(wo - wa)_{t-1} + \beta_2(wo - p)_{t-1} + \beta_3\Delta wa_t + \beta_4 tu_t \\ + \beta_5\Delta tu_{t-1} + \beta_6 STOP_t + \varepsilon_t \end{aligned} \tag{6.6}$$

From Table 3 we indeed find that the unemployment effects are small and insignificant in the short and long-run. Compared with Model 2, there are only marginal differences in this specification. The speed of adjustment coefficient ($\beta_1 + \beta_2 = -0.418$) is slightly higher compared with Model 2 (-0.395). The short-term effect of the alternative wage is a bit higher, and still significant in Model

3. The long-run model can be written as

$$wo = 0.866wa + 0.134p - 0,0545tu - 0.125STOP + \text{const} \tag{6.7}$$

From the long-run equation, (6.7), we observe a marginally higher effect of the alternative wage, and a slightly lower effect of the oil price. To sum up, we find no significant effects of the total unemployment variable, neither in the long nor the short-run. Thus, yielding robust estimated coefficients in Model 2, for this specification. Hence, we conclude that the manufacturing sector wage incorporates the unemployment effects well.

6.2.2 Model 4

In model 4 we include a dummy for asymmetric short-run effects of the oil price. The dummy p_t^+ takes the value 1, if the growth in the oil price, Δp_t, was positive last period, and 0 otherwise. Borjas (2013) presents a theory on why changes in the output price can produce asymmetric wage effects. The theory predicts that a firm will encounter asymmetric costs of firing and hiring workers. For instance, when firing a worker, the firm might need to provide severance pay, making firing workers costly. It will therefore be cheaper for a firm to hire workers in an oil price booms, which would up the cost of wages. This increase in the wage would thus be larger, in absolute value, compared with a wage decrease during a bust. Model 4 in Table 3, can be written as

$$\begin{aligned} \Delta wo_t = \beta_0 + \beta_1(wo - wa)_{t-1} + \beta_2(wo - p)_{t-1} + \beta_3\Delta wa_t + \beta_4\Delta p_t + \\ + \beta_5\, p_t^+ \cdot \Delta p_t + \beta_6 STOP_t + \varepsilon_t \end{aligned} \tag{6.8}$$

The parameter, β_4, gives the short-run effect of a negative oil price shock. On the other hand, $\beta_4 + \beta_5$, gives the effect of a positive oil price shock. A significant β_5, implies asymmetric effects. However, the results in Table 3 shows that the estimates for β_4 and β_5 are both small, and insignificant, which indicates that neither positive nor negative oil price shock matter in the short-run.[25] Other regressions where the dummy interact with the other short-run variables were tested. However, all the interaction terms in these regressions were insignificant. Compared with Model 2, we find only minor differences

[25] Following Mork (1989) we tested another specification for asymmetric responses to the oil price. Instead of a dummy variable, we generate a new variable which is equal to the last period if positive, and zero otherwise. Furthermore, we include another variable which is equal the last period if negative and zero otherwise. This specification did not alter the conclusion of no asymmetric effects.

in the estimated coefficients of importance. The rate of adjustment in this specification is slightly higher, with $\beta_1 + \beta_2 = -0.410$. The short-run effect of the manufacturing sector wage is greater and more precisely estimated than in Model 2.

$$wo = 0.848wa + 0.152p - 0.132STOP + \text{const} \tag{6.9}$$

The stable long-run solution is practically unchanged from the solution in Model 2. Thus, we can conclude that there are no asymmetric effects of the oil price. Furthermore, we can conclude that Model 2 remains robust under this specifiaction.

6.2.3 Model 5

Depicted in Figure 8, are graphs of the annual average oil price and the average quarterly oil price from 1978 to 2015. When comparing the two, we observe some fluctuations in the quarterly data which are not reflected in the annual data. However, with few extreme differences. This infers that the oil price variable included in the main analysis follows the quarterly data well.

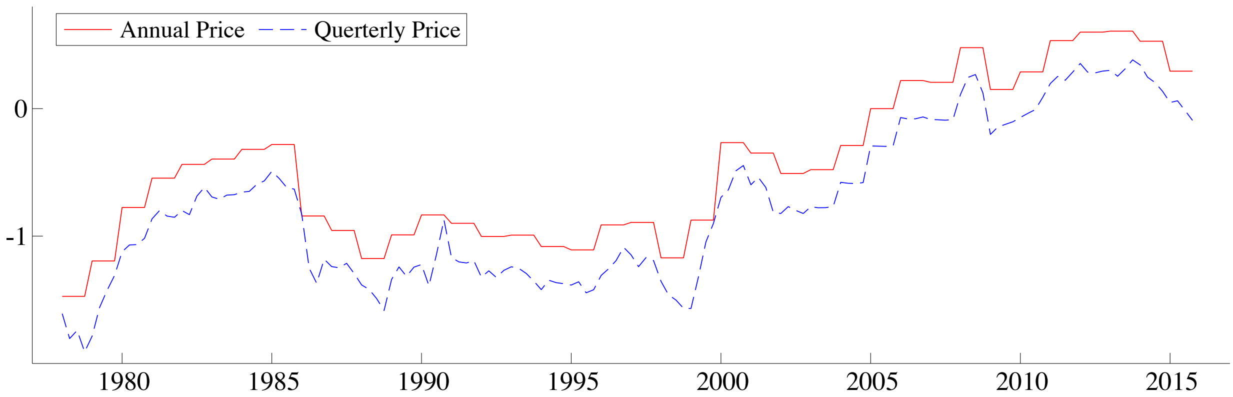

Figure 8: Solid line: The annual oil price from 1978 to 2015, calculated from dividing current export price with the export price in fixed 2015 prices. Dashed line: The quarterly average oil price from 1978 to 2015 in fixed 2005 prices

However, it is possible that the oil price at the point of negotiation deviates from the reported annual oil price. With negotiations taking place in the second quarter of the year, we can use the second quarter oil price in a regression with the petroleum wage as an extra robustness check of the oil price included in the main analysis. Note that we only have quarterly data from 1978 and onwards. This prevents us from directly comparing it with Models 1-4. However, we want to check the robustness of the oil price variable, so a direct comparison is not necessary.

Model 2*, in Table 3, is just a shorter sample version of Model 2. The estimates are less precise, with an insignificant short-run alternative wage. We still find a long-run relationship with a significant lagged petroleum wage, wo_{t-1}. The long-run relationship becomes

$$wo = 0.819wa + 0.181p - 0.142STOP + \text{const} \tag{6.10}$$

The long-run effect of the oil price is a bit higher with the shorter sample, whilst the manufacturing wage is equivalently lower. For Model 5, in Table 3, we substitute the average annual oil price, p, with the average second quarter oil price, $pQ2$. We immediately see that the difference in the estimates are almost non-existent when compared with Model 2*.

$$wo = 0.825wa + 0.175pQ2 - 0.148STOP + \text{const} \tag{6.11}$$

The long-run effects of the second quarter oil price, $pQ2$, are a bit lower, indicating that the second quarter oil price determines less of the petroleum wage. Hence, some fluctuations, which are not accounted for in the average annual price, are apparent. However, the long-run differences are small, and we can therefore conclude that the annual oil price variable used in the above analysis is robust.

6.2.4 Granger Causality Test

In this section, we will use a Granger causality test (Granger, 1969), to check for possible simultaneous effects between the petroleum wage and the alternative wage. The test is conducted by first estimating a general VAR system, given in (6.12) and (6.13). Because it is important that the variables in a VAR system are stationary, we first differentiate all the variables. We know from Chapter 4 that inference testing becomes invalid if the included variables are non-stationary. It should be noted that we have no information of a long-run relationship when inducing stationarity (Brooks, 2008). However, we proceed by using the VAR system as a check of the robustness for the previous results, and not as a tool to find a long-run solution. We can write the system as

$$\Delta wo_t = \gamma_1 + \sum_{i=1}^{m} \alpha_{1i} \Delta wo_{t-i} + \sum_{j=1}^{m} \beta_{1j} \Delta wa_{t-j} + \sum_{k=1}^{m} \lambda_{1k} \Delta p_{t-k} + \rho_1 STOP + \varepsilon_{1,t} \tag{6.12}$$

$$\Delta wa_t = \gamma_2 + \sum_{j=1}^{m} \beta_{2j} \Delta wa_{t-j} + \sum_{i=1}^{m} \alpha_{2i} \Delta wo_{t-i} + \sum_{k=1}^{m} \lambda_{2k} \Delta p_{t-k} + \rho_2 STOP + \varepsilon_{2,t} \tag{6.13}$$

where m is the chosen lag length. The optimal lag length of a VAR model is not given in economic theory, i.e. we do not know how long it will take for shocks to work through the system (Brooks, 2008). To find the appropriate lag length we can use information criteria in a multivariate framework. It works as in the univariate case, but slightly modified to fit a system of equations Brooks (2008, p. 294). Beginning with four lags we found, by sequentially removing one lag at the time, that the information criteria chose a restricted model with only one lag. The majority of the estimated coefficients are significant with this specification.

To test for any feedback effects using a Granger-causality test, we have the following null hypotheses

$$(i) \quad H_0^i : \sum_{j=1}^{m} \beta_{1j} = 0, \quad \text{and} \quad (ii) \quad H_0^{ii} : \sum_{i=1}^{m} \alpha_{2i} = 0$$

Hypothesis (i) tests whether changes in Δwa generates a change in Δwo, whilst (ii) tests if Δwo causes a change in Δwa. If we cannot reject (i), but we reject (ii), we say that the petroleum wage growth Granger-causes the industry wage growth. If the opposite is true; we reject (i), but fail to reject (ii), the industry wage growth Granger-causes the petroleum wage growth. If we reject both hypotheses we have feedback effects in both directions (Brooks, 2008). We anticipate that (i) will be rejected since we found that wa has both a long and short-run effect on wo. Therefore, the interesting test is (ii). If we fail to reject this hypothesis, the univariate estimates for the industry wage are precise. In contrast, a rejection of the hypothesis means that the petroleum wage growth and the industry wage growth are simultaneously determined.

The estimates from the regression of (6.12) and (6.13), with one lag, are presented in Table 4. Equation (6.12), Δwo_t, shows highly significant effects for the lagged industry wage growth, Δwa_{t-1}. As expected, (i) is rejected. From the column representing (6.13), we find significant effects of the lagged petroleum wage growth on Δwa_t. Hence, (ii) is also rejected, and we face a simultaneous bias. The effects of the alternative wage are likely to be overestimated in the main models. As the petroleum sector is a big driver in the Norwegian economy, contributing with 52.8% of total exports, it is not surprising that the oil wage development affects the manufacturing sector wage development. However, the coefficient of lagged industry wage growth is greater than the estimated effect of the lagged petroleum wage growth. It is therefore likely that the feedback effect is relatively small.

Table 4: Results from VAR estimation

Variables	(6.12) Δwo_t	(6.13) Δwa_t
Δwo_{t-1}	0.0216 (0.142)	0.213 (2.63)
Δwa_{t-1}	0.636 (3.55)	0.689 (7.24)
Δp_{t-1}	0.0497 (2.19)	0.0299 (2.48)
$STOP_t$	−0.0582 (−2.26)	−0.0142 (−1.04)
Const	0.0221 (1.83)	0.00307 (0.479)
Statistics and diagnostics		
σ	0.035	0.019
Adj R^2	0.43	0.77
AR 1-2 test:	$F(2,34) = 2.62$	$F(2,34) = 1.83$
ARCH 1-1 test:	$F(1,39) = 0.0012$	$F(1,39) = 11.08$
Normality test:	$\chi^2(2) = 2.60$	$\chi^2(2) = 4.78$
Hetero test :	$F(7,33) = 2.44$	$F(7,33) = 3.07$
RESET23 test:	$F(2,34) = 1.08$	$F(2,34) = 1.61$

Notes: The models are estimated using PcGive (Doornik & Hendry, 2009). Dependent variables given in first row. Using full sample from 1975 to 2015. Estimated t-values in parentheses.

We have in this chapter presented, and analysed, the results from an ECM. The findings in the main models proved to be consistent under several specifications. The estimated long-run effects of the alternative wage and the oil price, was found to range between $84.8 - 86.6\%$ and $13.3 - 14.4\%$, respectively. The robustness checks suggested that the findings from the main models were robust, with the estimated effects not changing much. When it comes to the short-run, we only found significant elasticities with respect to the alternative manufacturing wage, ranging from $0.451 - 0.516$. We did detect some concurrent effects, suggesting that the estimated coefficients might be overestimated. However, these effects appear to be relatively small.

7. Summary and Conclusion

This thesis has examined how the development in oil prices has affected the petroleum sector wage in the past four decades. The purpose was to analyse possible oil price effects on the petroleum sector wage development. The findings suggests that there are indeed significant long-run effects of the oil price on the petroleum sector wage cost. We also found the estimated effects to be robust for several specifications. Furthermore, we checked for possible simultaneous effects between the petroleum sector wage growth and the manufacturing sector wage growth. We did detect some simultaneous effects, which could overestimate the results.

The analysis was built on the theoretical «Right to Manage» model. This model was chosen because of its good fit to the Norwegian wage formation. The model predicted that an increase in an insider variable, such as the oil price, would yield a higher bargained wage in the long-run. It also predicted that higher outsider wage, as the manufacturing wage, would increase the bargained wage as well. From this theoretical framework, we found an implicit wage equation which worked as the foundation for the empirical analysis.

The analysis used an error correction model for two reasons: First, because the variables included in the analysis were non-stationary. Second, because it is closely linked to economic theory. Two main models were analysed in this framework. The first model, did not restrict the long-run variables to be homogeneous of the first degree. It proved to be a good fit to the data with significant short and long-run effects. However, the only significant short-run variable was the manufacturing wage growth. The absence of a short-run oil price effect was discussed, where one argument was that the wage negotiations takes place annually, so short-term fluctuation in the oil price should have little effect on the petroleum wage growth. In the long-run, both the manufacturing wage and the oil price were drivers determining the petroleum wage. Mostly through the manufacturing sector wage, but also through the oil price. Following the Scandinavian wage theory, the second model restricted the variables to be homogeneous of the first degree. This resulted in a more precisely estimated model. The short-run manufacturing wage growth remained highly significant, with an elasticity of 0.45. In the long-run, we found outsider effects of around 85% and insider effects of around 15%. Both estimates were stable throughout the sample and consistent with the theoretical model. Furthermore, the estimates from the main models show that the variables return to equilibrium at a speed of $41 - 48\%$, annually. Resulting in a quicker speed of adjustment than previously found in the

Norwegian manufacturing sector.

Interestingly, the petroleum sector productivity did not have any effect on the petroleum wage growth neither in the short nor the long-run, for any of the specifications. The theory of a positive productivity effect was proven wrong, when specifically analysing the petroleum sector. Why this is the case is not clear, since earlier literature indeed found significant productivity effects. One explanation might be that the productivity of the petroleum sector uses the best available technology, and thus fluctuate more than the manufacturing sector productivity.

Several sensitivity checks were conducted, and suggested the main analyses were robust. The total unemployment rate did not affect the petroleum wage, suggesting that it is incorporated in the alternative wage. No evidence of asymmetric effects were supported by the data neither for positive nor negative oil price shocks. The oil price index remains credible when substituting the average annual price with the quarterly price. When doing so, we found no support of any differences in the data. This result implies that the oil price index used in the main models is robust.

In contradiction to the article of Dyrstad (2016), we found significant long-run effects of the oil price. Possible explanations for this were posed, but the most plausible one is that he used data for a period with a generally stable oil price, and moderate employment growth. We did not discover any effects when using our model for the period applied in Dyrstad (2016). Therefore, extending the sample to include more years resulted in significant oil price effects. Some simultaneous effects were discovered when using a Granger-Causality test. The feedback effect from the petroleum wage growth was relatively small, but highly significant. A result which could lead us to overestimate the effects in the main models.

From the robust evidence supported by the data we can concluded that the development in the oil price does affect the long-run development in the petroleum wage. These results are compelling for two reasons: First, we discovered a significant relationship between the oil price and the petroleum wage growth. This is, to my knowledge, not found previously in the literature. Secondly, the findings adds to the literature opposing the theory of full centralisation in Norway. Earlier research has found such insider effects in the manufacturing sector. However, this analysis suggests that there are such effects in the petroleum sector as well.

Since the results may be overestimated due to simultaneous effects between the petroleum and the manufacturing wage growth, further analysis in the field is needed. One method could be to apply a vector error correction model, for a more precise multivariate model. Furthermore, it would be interesting to analyse the wage and employment effects of the most recent oil price shock, in more depth when sufficient data is available.

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A. Appendix

A.1 Additional Figures and Tables

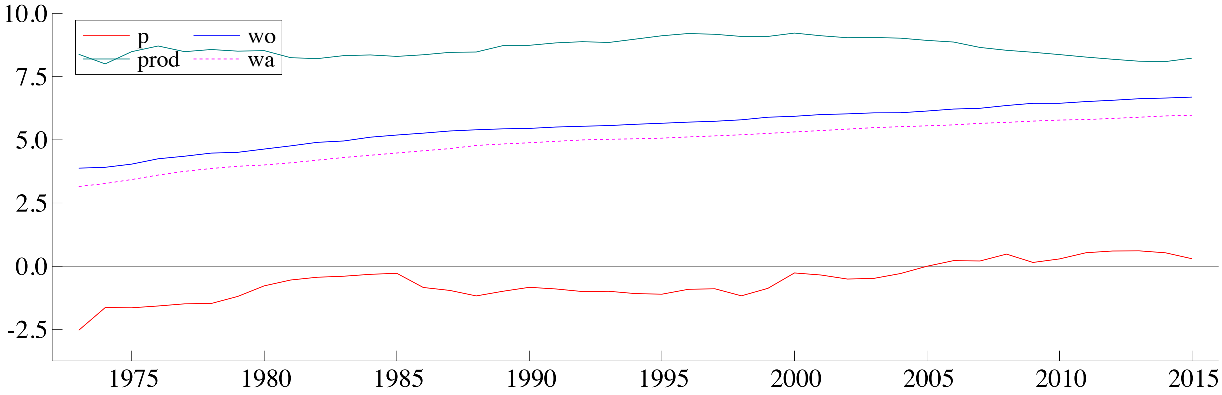

Figure A.1: Log of Oil wage, log industry wage, log of oil price and log of productivity in levels

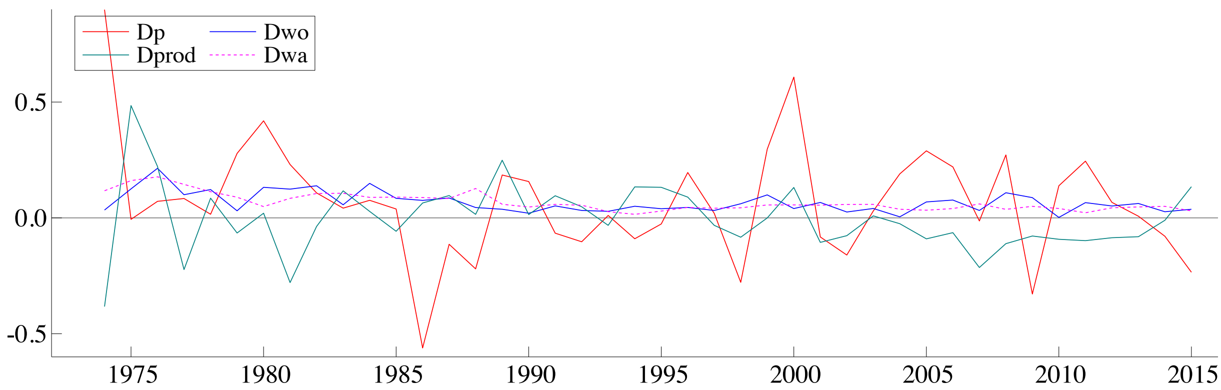

Figure A.2: Growth rates of log of oil wage, log of industry wage, log of oil price and log of productivity

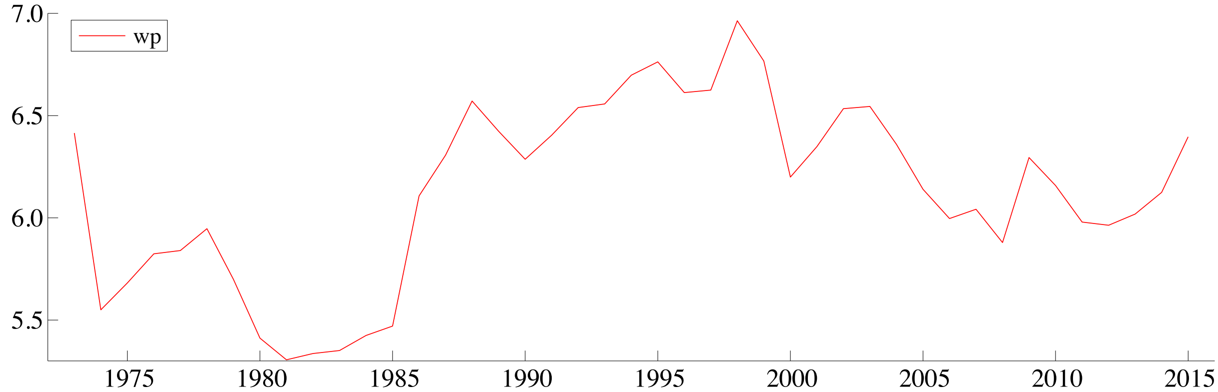

Figure A.3: Petroleum wage relative to oil price.

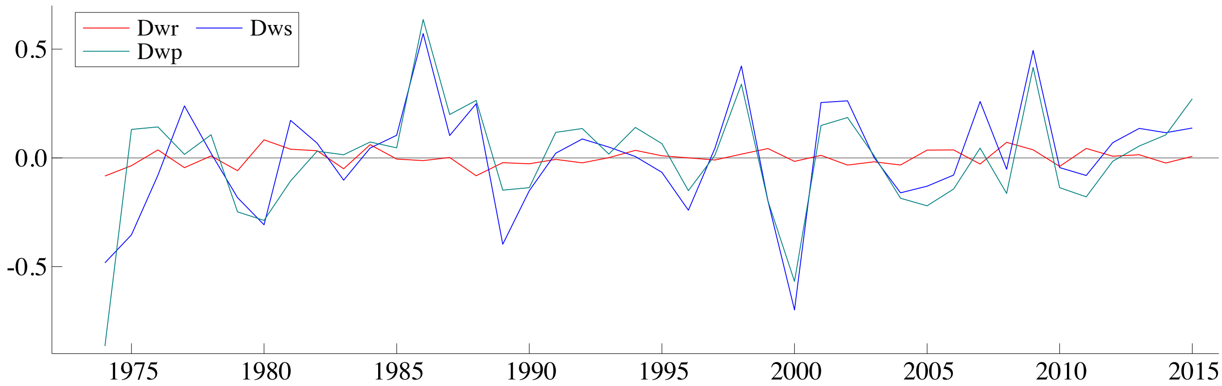

Figure A.4: Growth rates for the wage share, relative wage and the Petroleum wage relative to the oil price

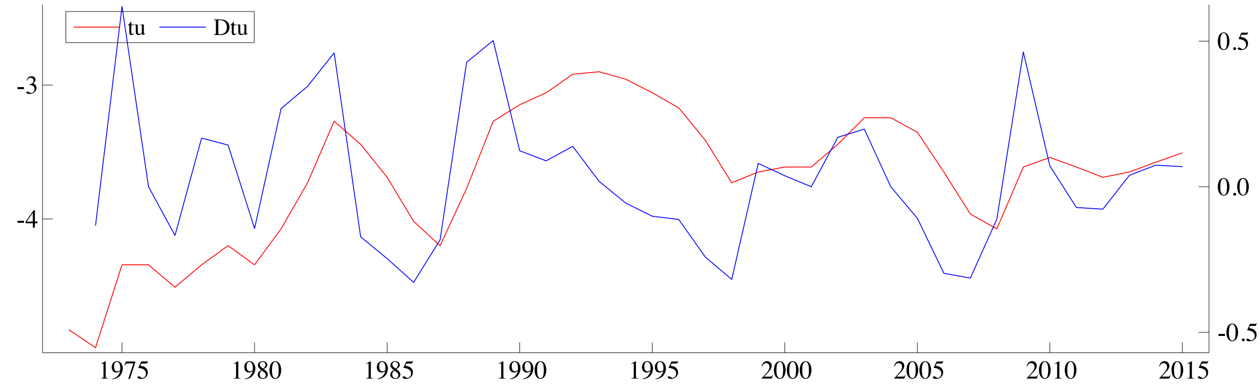

Figure A.5: Total unemployment in levels,tu (Left axis) and Unemployment growth rate, Dtu (Right axis)

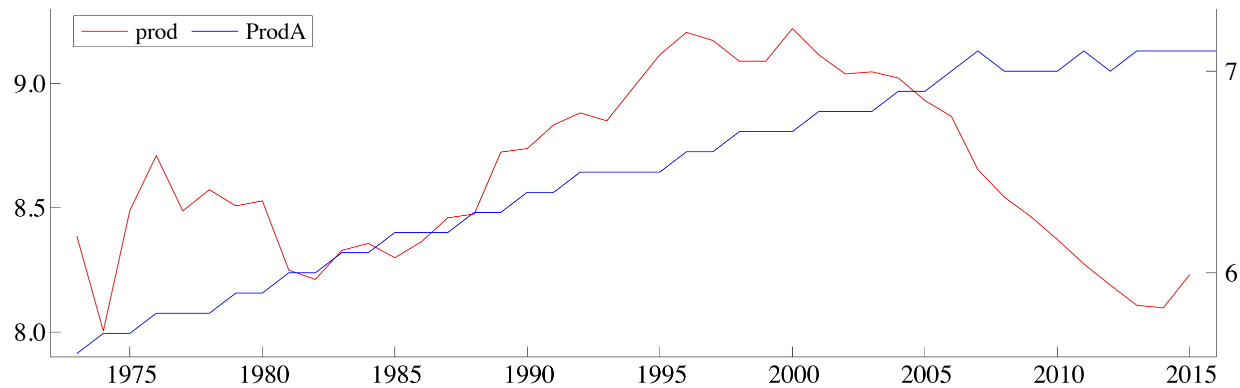

Figure A.6: Petroleum sector productivity (prod) and the industry sector productivity (ProdA)

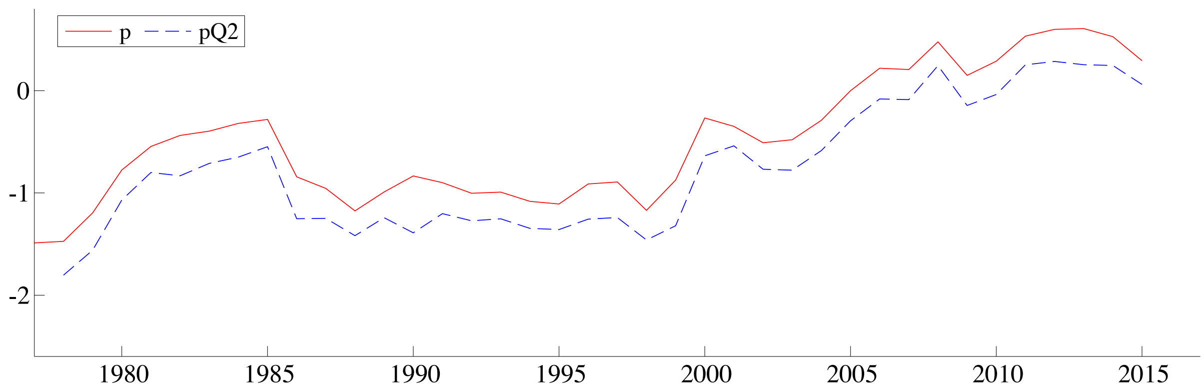

Figure A.7: Solid line: Annual oil price. Dashed line: Oil price from 2nd quarter from 1978-2015, computed by dividing current export prices on the export price in fixed 2015 prices

Table A.1: Results from general to specific. Dependant variable Δwo_t

Variables	Eq1 OLS	Eq2 OLS	Eq3 OLS	Eq4 OLS	Eq5 OLS	Eq6 OLS	Eq7 OLS
wo_{t-1}	-0.476 (-2.79)	-0.436 (-2.80)	-0.425 (-4.01)	-0.438 (-4.19)	-0.411 (-3.96)		
wa_{t-1}	0.420 (2.38)	0.369 (2.40)	0.370 (3.46)	0.384 (3.65)	0.356 (3.42)		
p_{t-1}	0.0635 (2.33)	0.0744 (3.66)	0.0660 (4.90)	0.0642 (4.83)	0.059 (4.60)		
$prod_{t-1}$	-0.0197 (-0.608)						
$(wo-wa)_{t-1}$						-0.317 (-3.05)	-0.337 (-3.99)
$)wo-p)_{t-1}$						-0.0694 (-4.09)	-0.0582 (-4.69)
Δwa_t	0.697 (2.11)	0.661 (2.06)	0.571 (2.26)	0.601 (2.41)	0.516 (2.11)	0.573 (2.24)	0.451 (3.30)
Δwa_{t-1}	-0.222 (-0.850)	-0.207 (-0.802)				-0.226 (-0.901)	
Δp_t	0.0436 (1.79)	0.0456 (1.91)	0.0326 (1.55)	0.0262 (1.33)		0.0443 (1.90)	
Δp_{t-1}	-0.0183 (-0.704)	-0.0230 (-0.935)				-0.0212 (-0.883)	
$\Delta prod_t$	0.0137 (0.262)	0.0336 (0.830)	0.0230 (0.900)			0.0273 (0.726)	0.0367 (2.12)
$\Delta prod_{t-1}$	0.0310 (0.827)	0.0259 (0.716)				0.0250 (0.703)	
$STOP_t$	-0.0583 (-2.41)	-0.0545 (-2.36)	-0.050 (-2.41)	-0.0508 (-2.45)	-0.0500 (-2.38)	-0.0575 (-2.63)	-0.0515 (-2.55)
Const	0.823 (2.97)	0.685 (4.34)	0.607 (5.36)	0.607 (5.38)	0.601 (5.28)	0.673 (4.39)	0.609 (5.79)
Statistics and diagnostics							
σ	0.029	0.029	0.027	0.028	0.028	0.028	0.028
Adj R^2	0.58	0.59	0.60	0.61	0.60	0.60	0.61
AR 1-2:	$F(2,32)=0.33$	$F(2,28)=0.38$	$F(2,29)=0.54$	$F(2,33)=0.32$	$F(2,34)=0.41$	$F(2,29)=0.57$	$F(2,35)=0.41$
ARCH 1-1:	$F(1,39)=0.023$	$F(1,39)=0.0048$	$F(1,40)=0.088$	$F(1,40)=0.42$	$F(1,40)=0.29$	$F(1,39)=0.0023$	$F(1,40)=0.26$
Normality:	$\chi^2(2)=0.60$	$\chi^2(2)=1.09$	$\chi^2(2)=1.86$	$\chi^2(2)=1.64$	$\chi^2(2)=1.69$	$\chi^2(2)=0.84$	$\chi^2(2)=1.95$
Hetero:	$F(21,19)=0.30$	$F(19,21)=0.32$	$F(13,28)=0.50$	$F(11,30)=0.60$	$F(9,32)=0.72$	$F(17,23)=0.42$	$F(7,34)=1.15$
RESET23:	$F(2,27)=3.64$	$F(2,28)=4.00$	$F(2,32)=3.14$	$F(2,33)=4.89$	$F(2,34)=4.83$	$F(2,29)=3.85$	$F(2,35)=4.99$
AIC:	-4.0165	-4.0526	-4.1629	-4.1869	-4.1854	-4.0943	-4.2051
SBC:	-3.5149	-3.5929	-3.8319	-3.8973	-3.9371	-3.6764	-3.9962

Notes: [a]The models are estimated by OLS using PcGive (Doornik & Hendry, 2009) Full sample estimates with t-values in parentheses. Even though the AIC chooses Eq4 using the first ECM , the preferred specifications are Eq5, which is chosen by SBC.If we expand to the full sample, Eq5 is clearly superior. For the second specification Eq7 is preferable. F-tests are conducted to test the validity of the restrictions imposed. σ is the model's standard error and Adj R^2 is the model's coefficient of determination

Table A.2: Main results with forecast. Dependent variable: Δwo_t

Variables	Full sample 1975-2015 GUM (5.1)	Est.: 1975-2008 For: 2009-2015[a] GUM	Full sample 1974-2015 Model 1 (6.2)	Est.: 1974-2008 For: 2009-2015[a] Model 1	Full sample 1974-2015 Model 2 (6.4)	Est.: 1974-2008 For: 2009-2015[a] Model 2
wo_{t-1}	-0.476 (-2.79)	-0.467 (-2.60)	-0.411 (-3.96)	-0.473 (-3.65)		
wa_{t-1}	0.420 (2.38)	0.378 (2.07)	0.356 (3.42)	0.418 (3.25)		
p_{t-1}	0.0635 (2.33)	0.0818 (2.50)	0.0590 (4.60)	0.0532 (3.86)		
$prod_{t-1}$	-0.0197 (-0.608)	0.0312 (0.620)				
$(wo-wa)_{t-1}$					-0.337 (-3.99)	-0.425 (-3.49)
$(wo-p)_{t-1}$					-0.0582 (-4.69)	-0.0539 (-4.11)
Δwa_t	0.697 (2.11)	0.747 (2.16)	0.516 (2.11)	0.566 (2.17)	0.451 (3.30)	0.601 (3.41)
Δwa_{t-1}	-0.222 (-0.850)	-0.307 (-1.12)				
Δp_t	0.0436 (1.79)	0.0589 (2.20)				
Δp_{t-1}	-0.0183 (-0.704)	-0.0503 (-1.61)				
$\Delta prod_t$	0.0137 (0.262)	0.0466 (0.770)				
$\Delta prod_{t-1}$	0.0310 (0.827)	0.00804 (0.195)				
$STOP_t$	-0.0583 (-2.41)	-0.0527 (-2.07)	-0.0500 (-2.38)	-0.0515 (-2.34)	-0.0515 (-2.55)	-0.0505 (-2.41)
Const	0.823 (2.97)	0.546 (1.63)	0.601 (5.28)	0.631 (4.85)	0.609 (5.79)	0.624 (5.11)
Statistics and diagnostics						
σ	0.029	0.029	0.028	0.029	0.028	0.29
Adj R^2	0.58	0.60	0.60	0.60	0.61	0.61
AR 1-2 test:	$F(2,32)=0.33$	$F(2,20)=0.48$	$F(2,34)=0.41$	$F(2,27)=0.34$	$F(2,35)=0.41$	$F(2,28)=0.36$
ARCH 1-1 test:	$F(1,39)=0.023$	$F(1,32)=0.013$	$F(1,40)=0.29$	$F(1,33)=0.025$	$F(1,40)=0.26$	$F(1,33)=0.036$
Normality test:	$\chi^2(2)=0.60$	$\chi^2(2)=0.12$	$\chi^2(2)=1.69$	$\chi^2(2)=1.45$	$\chi^2(2)=1.95$	$\chi^2(2)=1.24$
Hetero test :	$F(21,19)=0.30$	$F(21,12)=0.29$	$F(9,32)=0.72$	$F(9,25)=0.41$	$F(7,34)=1.15$	$F(7,27)=0.74$
RESET23 test:	$F(2,27)=3.64$	$F(2,20)=3.92$	$F(2,34)=4.83$	$F(2,27)=4.60$	$F(2,35)=4.99$	$F(2,28)=4.74$
Chow test:	-	$F(6,23)=0.86$	-	$F(6,29)=0.57$	-	$F(6,30)=0.60$

Notes: [a] Forecast period. Using full sample from 1973 to 2015. Estimated t-values in parentheses. All tests under «statistics and diagnostics» are explained in section 5.1. σ is the model's standard error and Adj R^2 is the model's coefficient of determination. The models are estimated by OLS using PcGive (Doornik & Hendry, 2009).

A.2 Graphical Residual Analysis of Main Models

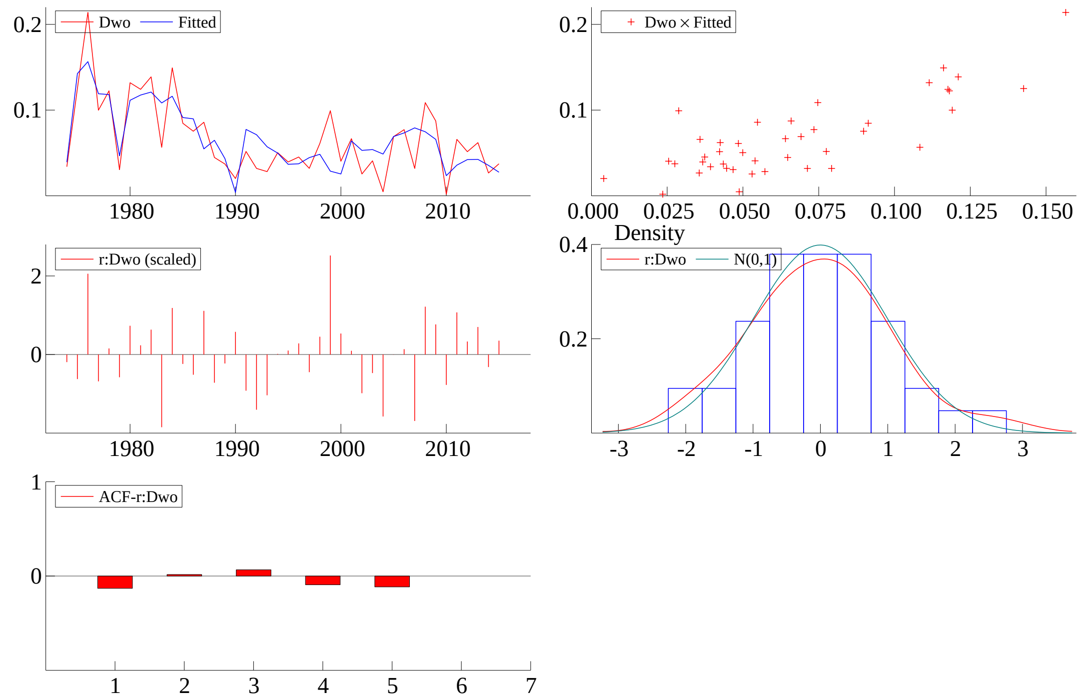

Figure A.8: Graphical analysis of the residuals of model 1, equation (6.2)

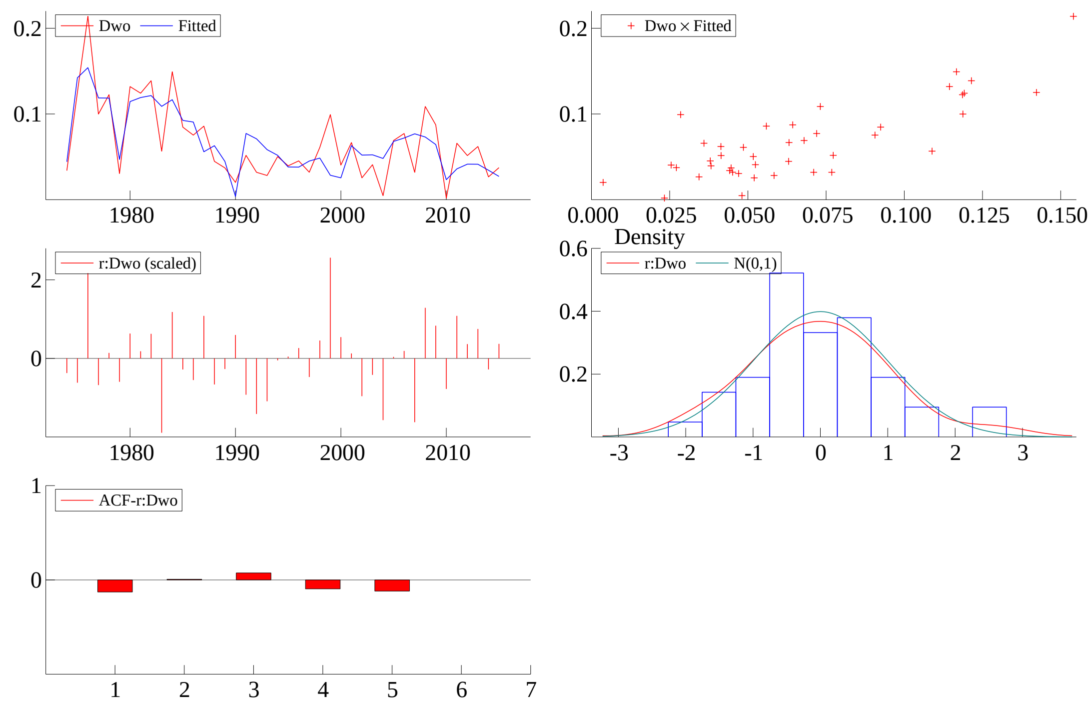

Figure A.9: Graphical analysis of the residuals of model 2, equation (6.4)

A.3 Recursive Estimation of the Remaining Models

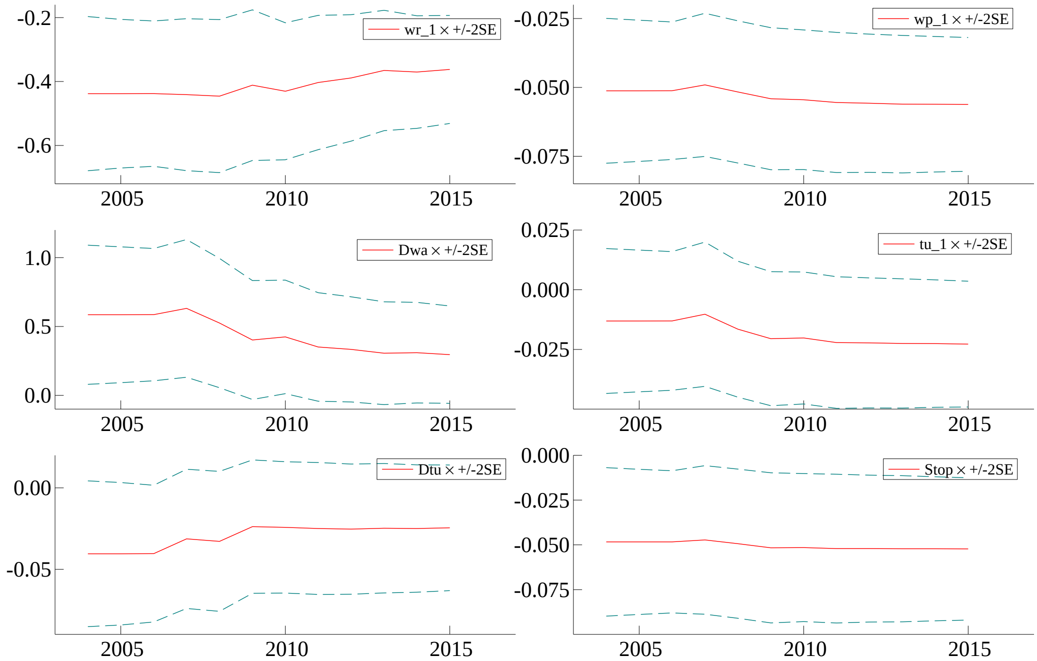

Figure A.10: Recursive estimation of Model 3. Dashed lines are the $+/-$ 2 estimated standard deviations

Figure A.11: Recursive estimation of Model 4. Dashed lines are the $+/-$ 2 estimated standard deviations

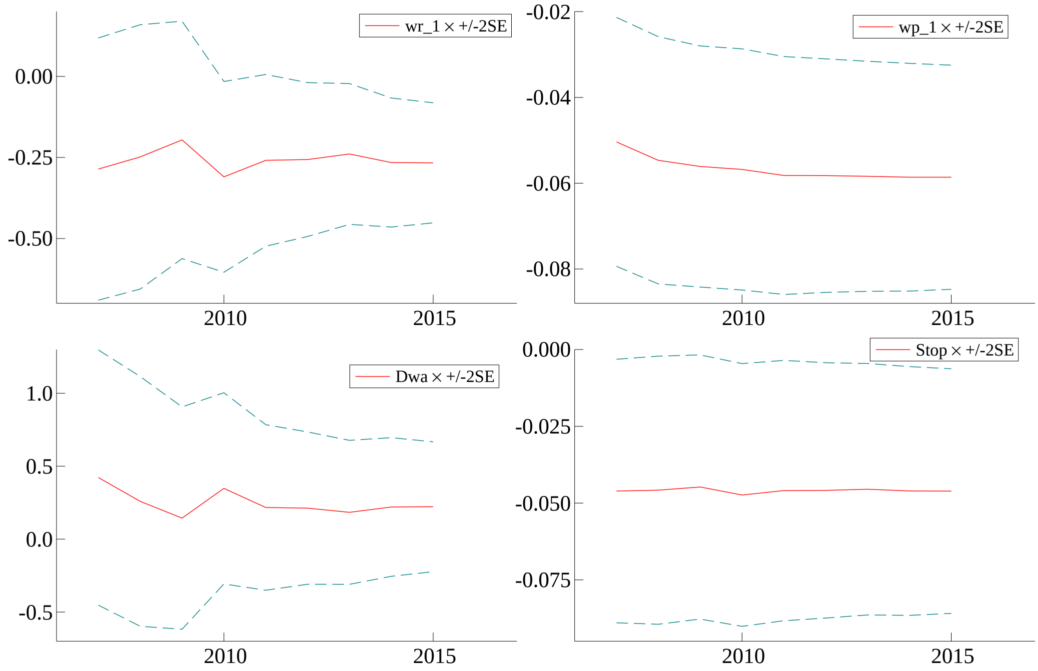

Figure A.12: Recursive estimation of Model 2*. Dashed lines are the $+/-$ 2 estimated standard deviations

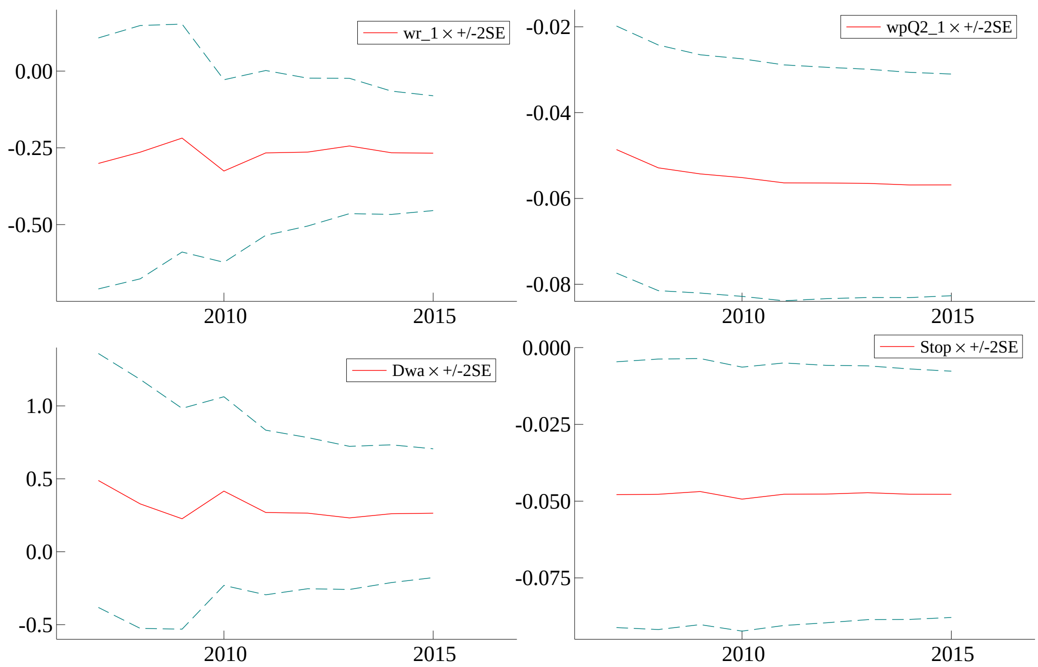

Figure A.13: Recursive estimation of Model 5. Dashed lines are the $+/-$ 2 estimated standard deviations