



A New Pricing Model for the Real Estate Market in Rogaland

Based on the pricing model by Jacobsen and Naug

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Abstract

The main hypothesis of this paper is that the well-known and widely adopted pricing model by Jacobsen and Naug (2004) can be improved for Rogaland's real estate market. The new pricing model presented is also used on the real estate market in Hordaland for comparisons, in order to verify that the model works on more than one region. The hypothesis is grounded on the fact that when we re-estimate the original model from Jacobsen and Naug on regional data, the adjusted explanatory power is significantly lower for both Rogaland and Hordaland compared to the authors' national model. Rogaland has an especially low adjusted explanatory power of 44.4%, whereas the adjusted explanatory power for Hordaland is 50.5%. The hypothesis is further based on the fact that contemporary national real estate models do not embed differences across regions in Norway. Inspired by the research from Terrones and Otrok (2004) we argue that the incorporation of a region-specific variable enable us to better explain the real estate prices in Rogaland. As such, we include oil investments in our new pricing model, since the majority of activity in the petroleum industry is located in this county. We also argue that short-term supply of real estate, measured by listed volumes, should be included. Furthermore, we question Jacobsen and Naug's model specification, which violates the requirements for error correction models (ECM). Consequently, we ensure that the new pricing model presented is specified theoretically correct. We find that an increase of one billion NOK in oil investments has a positive effect on the real estate prices in Rogaland of 0.512% for a given period. For Hordaland, we find that the same increase in oil investments reduce the real estate prices by 0.758%. Furthermore, a one percentage change in listed volume will increase the real estate prices in Rogaland and Hordaland by 0.011% and 0.009%, respectively. Our main contribution is that the new pricing model outperforms the original model by Jacobsen and Naug, both in terms of predicting actual real estate prices and in terms of a higher adjusted explanatory power of 70.1% for Rogaland and 61.6% for Hordaland.

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1 Introduction

The Norwegian real estate market is a much-discussed topic both in the literature and in the media. Apart from the real estate crisis in the late 1980's and in the wake of the financial crisis in 2008, the prices of real estate have experienced an almost uninterrupted growth. The recent oil price crisis in 2014 has, however, set a damper on the price development in petroleum dependent regions. This situation forms the backdrop for this paper.

We first introduce the real estate pricing model by Jacobsen and Naug (2004) presented in the article "What drives real estate prices?" in *Money and Credit* 4/04. In this model, the authors use an error correction model (ECM) to identify key drivers behind the short-term and long-term dynamics of the Norwegian real estate market. The authors find that the housing stock, unemployment rate, interest rate after tax, the income level, and the expectations to own and the overall economy, contribute to explain the price development observed in the market.

We re-estimate the model by Jacobsen and Naug on regional data for Rogaland and Hordaland. Based on our findings, we derive a new and improved pricing model for Rogaland, in particular, with the use of a one-step approach of ECM. To verify the validity of our new model, we use Hordaland for comparisons. The motivation for deriving an improved real estate model for Rogaland is grounded on the fact that contemporary national real estate models do not embed differences across regions in Norway. Inspired by the research of Terrones and Otrok (2004) we argue that the incorporation of a region-specific variable enable us to better explain the real estate prices in Rogaland. As such, we include oil investments in our new pricing model.

We conduct our analysis based on the following research question:

Can we improve the original pricing model for real estate by Jacobsen and Naug for Rogaland in particular?

To our knowledge, this paper is one of few, which derive a regional pricing model correctly according to theory on ECMs. Furthermore, this paper is to our knowledge the only to successfully incorporate a petroleum specific variable explaining the price development in the real estate market in Rogaland and Hordaland. In addition, while previous research often assume that the short-term supply of real estate is constant, we also improve the pricing model by including the volume of listed real estate, which proxy the short-term fluctuation on the supply side of the real estate market.

Applying monthly data from 2003 to 2016 we find that the original model of Jacobsen and Naug poorly explain the price development in the real estate market of Rogaland and Hordaland with adjusted explanatory power of 44.4% and 50.5%, respectively. The new pricing model we present, improve the adjusted explanatory power to 70.1% for Rogaland and 61.6% for Hordaland. We find that an increase of one billion NOK in oil investments increase the real estate prices in Rogaland with 0.512% for a given month. This finding is in line with our hypothesis of Rogaland being the most oil-dependent county in Norway. For Hordaland, we find that the same change in oil investments causes the real estate prices to decrease by 0.758%. This finding is unexpected, however reasonable, as Rogaland was hit harder by the oil price crisis in 2014 than Hordaland, which experienced a positive development in real estate prices. We find that a percentage change in listed volumes infer an increase of 0.011% in real estate prices in Rogaland, whereas the same change increase the real estate prices in Hordaland by 0.009%. We argue that these results are prone to reversed causality, as booming real estate prices increase the activity in the real estate market. Finally, our new real estate model clearly outperforms Jacobsen and Naug's model in predicting the actual real estate prices.

The paper is structured with the following chapters: In chapter 1, we present background information on the Norwegian real estate market and the petroleum industry. In the second chapter, regional differences is presented through descriptive analysis comparing Rogaland with Hordaland, where we justify the choices made to improve the original model by Jacobsen and Naug. Chapter 3 presents the original model of Jacobsen and Naug on regional level for Rogaland and Hordaland, before we introduce our new re-specified model, which incorporates the new variables. In chapter 4, we describe the data used in the models. Chapter 5 features the empirical results and the analysis of our findings. Lastly, we conclude our research in chapter 6.

2 Background Information

2.1 The real estate market

In this chapter, we explain the Norwegian real estate market in general, in addition to the main mechanisms behind the demand and supply for real estate. In order to discuss these mechanisms, it is necessary to separate the short-term from the long-term effects.

Real estate among Norwegian households

Real estate can both be seen as a consumer good and as a capital- or investment object. This means that when a household purchase a real estate for living purposes, the household also invests in the capital object that real estate is. In 2016, almost 77% of the Norwegian households owned the real estate they lived in, while the remaining 23% constituted the real estate rental market (SSB, 2017a). The decision to purchase real estate often represents the largest single investment done during a household's lifetime, and consequently, real estate will often represent the largest share of a household's total wealth.

While almost eight out of ten Norwegian households own their own real estate for living purposes, there are 16% of these households which also have purchased a secondary real estate, not including real estate for leisure (Eiendomsmegler 1, 2017). Most of these secondary real estate objects are either rented out, used as commuter apartments or are uninhabited.

The supply side of the real estate market

In general, the supply can be thought of as the existing housing stock. Changes in supply comes from the construction of new buildings and the reduction in the existing housing stock. According to Jacobsen and Naug (2004), there are many factors which will affect the construction of new buildings. Two important ones are plot- and construction costs as they affect the constructor's willingness to invest in a new real estate project. Reductions in the existing housing stock, can be caused by natural disasters, demolition, reconstruction, and change of use.

Historically, new building make up a small proportion relative to the total housing stock. According to NoU (2002:2), one therefore often assumes that the aggregate supply of real estate is given, independent of the price. In the short-term, NoU states that the the supply is mainly given by the current housing stock, as it takes time to build and complete new real estate projects. Therefore, the short-term real estate prices are assumed to only fluctuate by changes in the demand for real estate. However, one can argue that the supply may also vary in the short-term, since new real estate projects are not included in the housing stock before they are completed, although usually listed and potentially sold in the market before the start of construction. Consequently, we argue that listed real estate may embed short term changes which will not be accounted for in the housing stock.

Jacobsen and Naug (2004) argues that the supply is quite stable in the short-term, but not in the long-term. In the long-term, the supply of housing is expected to adapt to the demand. The economic rationale behind this is that when real estate prices are high, constructors tend to start new real estate projects, given that the cost of construction is lower than the current market prices of real estate. When the supply increases as these projects are completed, the price will adapt to a new equilibrium reflecting the increased supply in the market. In other words, supply is lagged as new projects are initiated in a booming market, and when new projects are completed, market mechanism will stabilize the price development due to a stronger supply.

The demand side of the real estate market

The demand for real estate can be separated into two components; demand for real estate for living purposes and demand for real estate as an investment object. According to Jacobsen and Naug (2004), these two types of demand are both driven by the same main factors in the long-term; household's income, interest rate, unemployment rate and housing stock.

It can be argued that the aggregate demand for real estate also depends on the size of the population and their preferences for where they want to live. According to NoU (2002:2), increased urbanization and changes in demographic patterns can in the long-term result in more pressure on the real estate market in and nearby the largest cities, while rural real estate markets might suffocate from lower demand. Another driver for real estate demand is labour immigration, where Norway in the recent decade has experienced a growth in labour immigrants from the

Baltics, Sweden and other countries (SSB, 2017b).

When it comes to the short-term demand, NoU (2002:2) states that the main drivers are immigration shocks and changes in the household's willingness or ability to pay. The household's ability to pay could change in the short term by job loss and changes in interest rate or income level. If the household's willingness to pay were to change, this could be caused by for instance a change in the assessment of real estate as an investment object. Another driver behind changes in short-term demand is the expectation about one's future financial situation as well as the expectations to the overall economy. If expectations about future growth in income and improved payment capabilities are high, households will potentially increase their demand for real estate resulting in a pressure on aggregate demand and higher market prices. Economic instability and uncertainty about one's future financial situation might on the other hand slow down the demand.

Beside the drivers mentioned above, the real estate market is prone to financial policies and regulations aiming to stimulate the demand on the short-term. Jacobsen and Naug (2004) argue that governmental financial policies regarding bank restrictions may be an important driver for the real estate demand, although it was not statistically significant in their own paper. Such policies could affect the real estate market either by a directly imposed regulation whose objective is to dampen the demand, or indirectly by policies which aim to lower the availability of credit or impose unfavourable taxation of real estate.

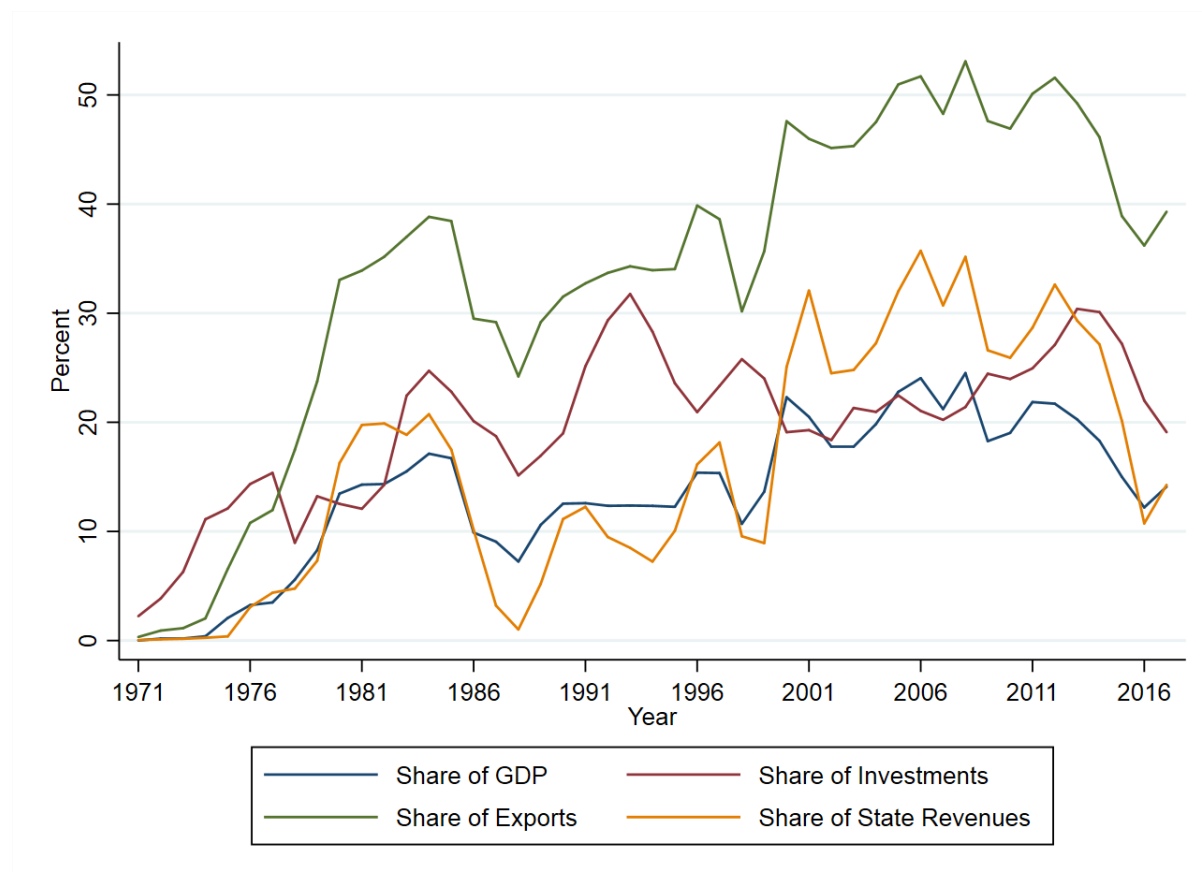
2.2 The petroleum industry

During the last decades, Norway has experienced an overwhelming growth in wealth. High revenues from the petroleum industry has contributed to an extraordinary growth in the Norwegian economy relative to other comparable economies. At the same time, the petroleum industry has increased with a stronger pace than the rest of the Norwegian economy, making it two-folded. In this chapter, we want to elaborate on the development in the petroleum industry and the effect it has had on the Norwegian economy. By looking at the implications of a two-folded economy, we want to highlight the vulnerability of being an oil-dependent country. Further on, we explain the consequences in the wake of an oil-price shock, such as the one in 2014.

An Oil-dependent Economy

Since the first exploration of oil at Ekofisk on the continental shelf the day before Christmas in 1969, Norway has experienced an adventure involving greater welfare due to petroleum related revenues. Before the oil price shock in 2014, the petroleum industry accounted for almost 30 percent of the state revenue in Norway and approximately 20% of the Norwegian GDP (Ministry of Finance, 2017). The petroleum investments have furthermore had an incredible growth in the years before the oil price drop in 2014, reaching a share of 30% of total investments for the first time since 1993. Being a small and open economy, Norway exports large parts of the petroleum production to foreign trade partners, where the petroleum industry accounted for nearly 50% of the total Norwegian export before the oil price drop in 2014. Consequently, there are no doubts that the petroleum industry has been and will be important for Norway. This is also confirmed by figure 2.1, which shows the development in the petroleum industry's share of GDP, share of investments, share of exports, and share of state revenues.

Figure 2.1: Macroeconomic Indicators for the Petroleum Industry. The figure shows the petroleum industry's percentage share of Norwegian GDP, Total Investments, Total Export and State Revenues from 1971 to 2017



Source: Ministry of Finance (2017)

Due to the revenue stream from the petroleum industry, the Norwegian Government has been able to conduct high spending in the public sector. Additionally, the petroleum industry employs thousands of Norwegian citizens, both directly in petroleum companies and indirectly through companies selling goods and services to these companies (Hungnes, 2017). This makes both citizens and the society itself vulnerable to shocks affecting the petroleum industry.

The oil crisis in 2014

From June 2014 to January 2016, the oil price fell from 115 dollars per barrel to 27 dollars per barrel, a drop of 75 percent in magnitude. There are several reasons behind the oil price drop in 2014. In short, during the period of 2000-2010, China and other emerging economies such as Russia, Brazil and India experienced a strong economic growth. Due to increased demand

for oil in these economies, as well as the Organization of the Petroleum Exporting Countries' (OPEC) strict production policy, the oil price increased to almost 140 dollars per barrel up until 2008. Due to the global recession after 2008, the oil price collapsed reaching a bottom of 40 dollars per barrel before it quickly recovered. However, the economic growth in the emerging economies had subsided, accompanied by US and Canada's decision to increase domestic production in shale formation and oil sand.

Figure 2.2: Historical Price of Crude Oil Brent (January 2000 - November 2017). USD per barrel labeled on the y-axis.



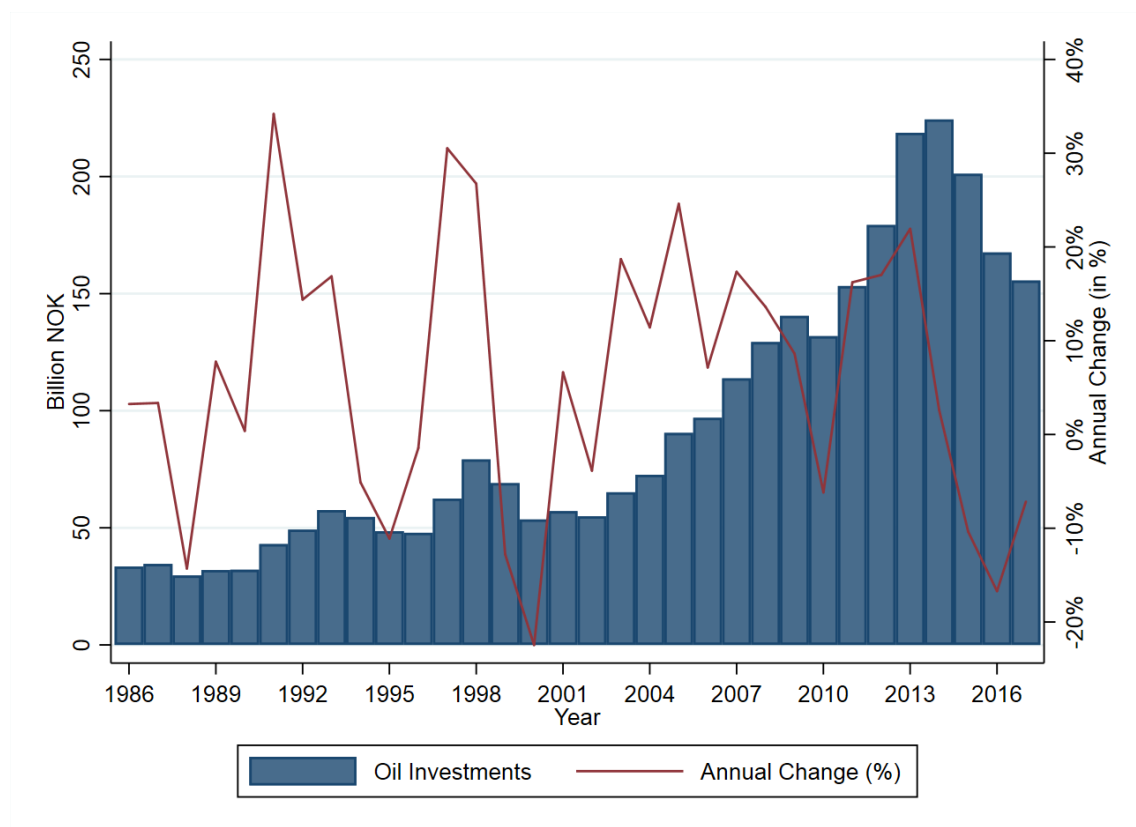
Source: Thompson Reuters (retrieved from Sparebank 1 SR-bank)

Between 2011 and the summer of 2014, the oil price fluctuated between 100 and 125 dollars per barrel, before the price suddenly dropped. During this period, the US and Canada increased their production, flooding the world market with larger volumes of oil. The world's largest oil producer, Saudi Arabia, had to decide whether to let the price drop below break-even price for US production or to acknowledge lost market shares by ceding production. By keeping its production stable at high levels relative to the increased world supply, Saudi Arabia sent the oil price downwards.

Oil-dependent Norway and the oil crisis of 2014

Even though the Norwegian oil production is low compared to other oil producing countries, we have seen that the Norwegian economy is very dependent on the petroleum industry. During the years up until 2014, the cost level in companies operating at the Norwegian continental shelf increased in line with the oil price. When the oil price suddenly collapsed, many of the operating oil fields at the continental shelf became unprofitable (Cappelen et. al, 2014). This forced many of the companies in the petroleum industry to downsize their workforce, which affected the regions on the West coast of Norway in particular, since most of the employees in the petroleum industry are situated here. As a result, the unemployment rate increased and the income level decreased. Besides unprofitable oil fields, the level of investments in existing and new projects on the continental shelf were postponed, which eventually hit companies in the subsea- and supply industry too. Oil investments declined by -10.3% from 2014 to 2015 and by -16.7% from 2015 to 2016. This was the largest decline since the year of 2000.

Figure 2.3: Historical Development in Oil Investments (1986-2017). Annual percentage change labeled on the right y-axis, with the billion NOK amount on the left y-axis.



Source: Statistics Norway (Accrued oil investments, table: 09602)

2.3 Regional differences between Rogaland and Hordaland

In this section, we will perform a descriptive analysis of regional differences between Rogaland and Hordaland around the time of the oil crisis, which occurred in June 2014. Both Rogaland and Hordaland are situated on the West coast of Norway and have relatively petroleum dependent economies compared to other Norwegian counties. As we discuss later in this section, Rogaland has a higher share of employees in the petroleum industry than Hordaland. Consequently, we argue that this might affect the real estate market in Rogaland to a larger extent than Hordaland.

First, we provide an overview of the price development in the real estate market. Furthermore, we argue that these differences were prone to a supply shock in Rogaland prior to the oil crisis of 2014. Finally, we analyse differences between Rogaland and Hordaland for each of the key economic drivers for real estate that Jacobsen and Naug (2004) found relevant (except for the interest rate, which is a national measure and thus do not vary across regions). This is done in an attempt to explain the observed differences between the two real estate markets. The analysis is also done in order to justify our choice of including a petroleum specific variable when deriving our new pricing model for Rogaland in particular, and in order to justify our choice of using Hordaland for comparisons.

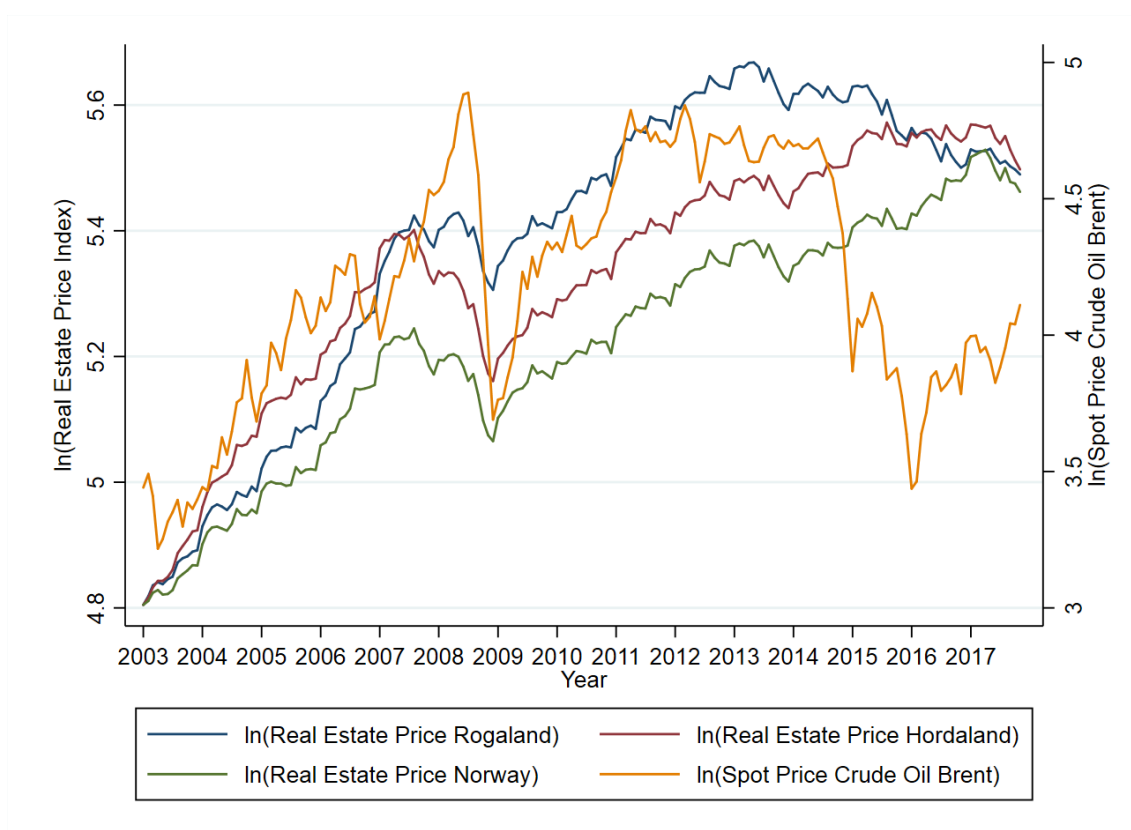
Regional differences in the real estate markets

During the last two decades and prior to the oil crisis in 2014, the Norwegian economy experienced an extensive positive development. With increased real income, low and stable inflation, low interest rates and unemployment rates, the real estate market in Norway was booming. The growth was especially strong for the most petroleum dependent counties on the West coast, such as Rogaland and Hordaland. According to Eiendom Norge (2017)¹, the overall real estate

¹ The price statistic is based on a cooperation of Eiendom Norge, Eiendomsverdi and Finn.no. The statistic includes all real estate sold through Finn.no, which accounts for about 70%. To avoid seasonality issues, the index is constructed using a x12 ARIMA. Base year: 2003

prices in Norway has increased by 150% ² from January 2003 to November 2017. The real estate prices in Rogaland and Hordaland have had an even higher increase, 157% and 159% respectively, during this same period.

Figure 2.4: Real Estate Price Index vs. Spot Price Crude Oil Brent (January 2003 to November 2017). The graph shows the growth rate of the index for Rogaland, Hordaland and Norway labeled on the left y-axis. The spot price of crude oil brent is also in growth rate and labeled on the right side y-axis.



Source: Eiendom Norge/Finn.no/Eiendomsverdi AS, Thomson Reuters (retrieved from Sparebank 1 SR-bank)

The real estate markets in Rogaland and Hordaland have reacted differently to the oil price drop in June 2014. While Rogaland experienced a 5% ³ decline from June 2014 to November 2017, Hordaland had an increase of 9%. The real estate market in Norway overall increased by 20%, where the booming real estate market in Oslo contributed to the strong domestic growth.

² Inflation-adjusted index: Norway: 93%, Rogaland: 98%, Hordaland: 100%

³ Inflation adjusted index: Norway: 10%, Rogaland: -12%, Hordaland: 0%

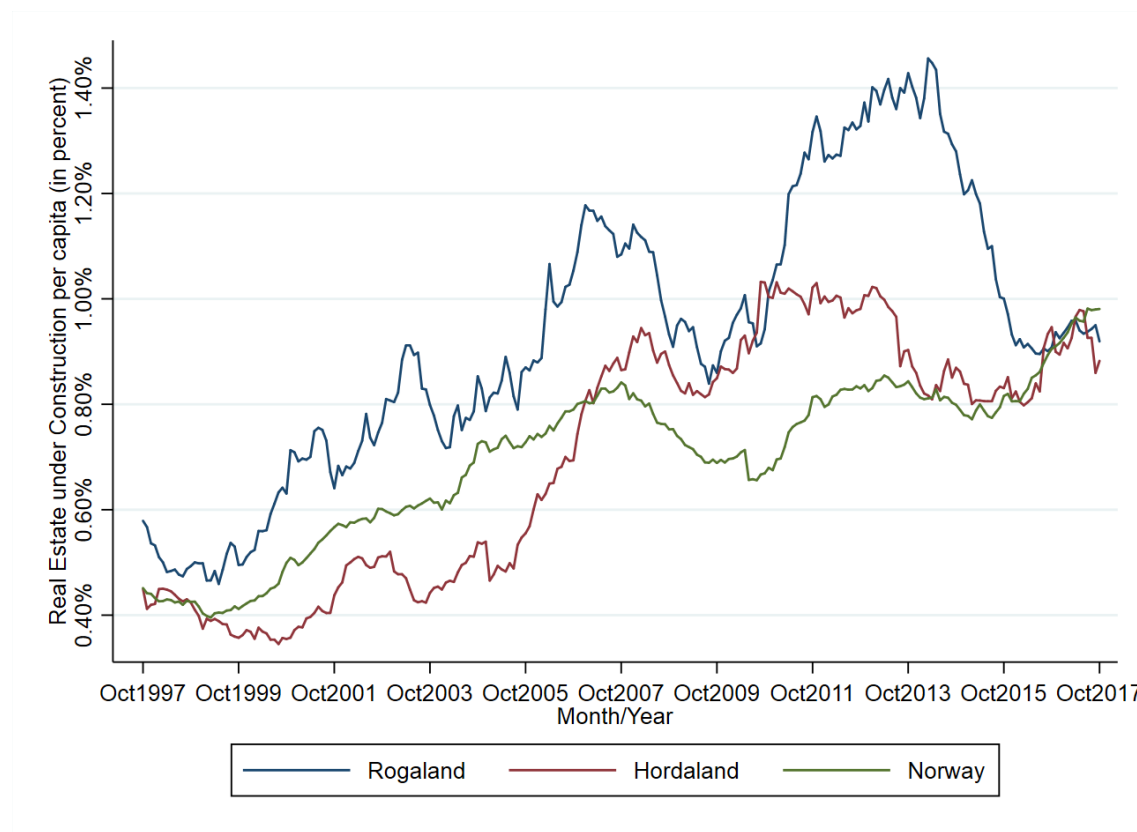
There are some important implications to notice from figure 2.4 above. First, we observe that the oil price drop found its way into the real estate market of Rogaland some time after the shock in 2014, which implies that there are some lag in the real estate market. Secondly, we observe that while the real estate prices in Rogaland dropped after the oil price shock in 2014, the market prices in Hordaland (and Norway in general) continued to grow before stabilizing in 2017. When the real estate market in Hordaland exceeded the index of Rogaland in April 2016, it was the first time since December 2006. During this almost ten years period, Rogaland had experienced a higher increase in the real estate prices than all other Norwegian counties.

If we take a closer look at the period before the oil price collapse, we find that Rogaland experienced an increase of 170%⁴ from January 2003 up until June 2014, while Hordaland only experienced an increase of 137% in the same period. Both these counties experienced a stronger growth than the overall Norwegian real estate prices which rose by 109%. The strong growth in the real estate prices of Rogaland underpins the hypothesis of being an oil-dependent region, where the booming oil-economy experienced in the same period has found its way into the region's real estate market.

As we have discussed above, the price growth in Rogaland has been steeper than for Hordaland prior to the oil price collapse. In addition, we observed that the real estate prices declined in Rogaland after the oil price collapse, while it continued to increase in Hordaland. If we look at the number of real estate objects under construction per capita in the two counties, we might be able to address this different development.

⁴ Inflation adjusted index: Norway: 76%, Rogaland: 127%, Hordaland: 99%

Figure 2.5: Real Estate under Construction per Capita (Oct 1997-Oct 2017). The rate is measured by the volume of real estate under construction in Rogaland, Hordaland and Norway divided on the respective number of capita.



Source: Statistics Norway (Real estate under construction, table: 03723 and Population, table: 01222)

Figure 2.5 illustrates the strong growth in number of real estate under construction per capita in Rogaland from the fall in 2009 until the summer of 2014. When the oil price collapsed in the summer of 2014, the market balance of real estate were subject to a decline in demand, while the supply of real estate were too high for the market to absorb. There is therefore reason to argue that there were a supply shock of real estate in Rogaland in the years before the oil price collapse, which first came to sight when the oil price plummeted in 2014.

During the same period, Hordaland experienced a stable rate in real estate under construction per capita, which started to diminish in early 2013. Furthermore, the increase in general, were much lower in Hordaland than in Rogaland. Consequently, Hordaland did not suffer from such a strong decline in the real estate prices as the number of real estate under construction per capita were much lower, and the demand did not drop at the same rate as in Rogaland.

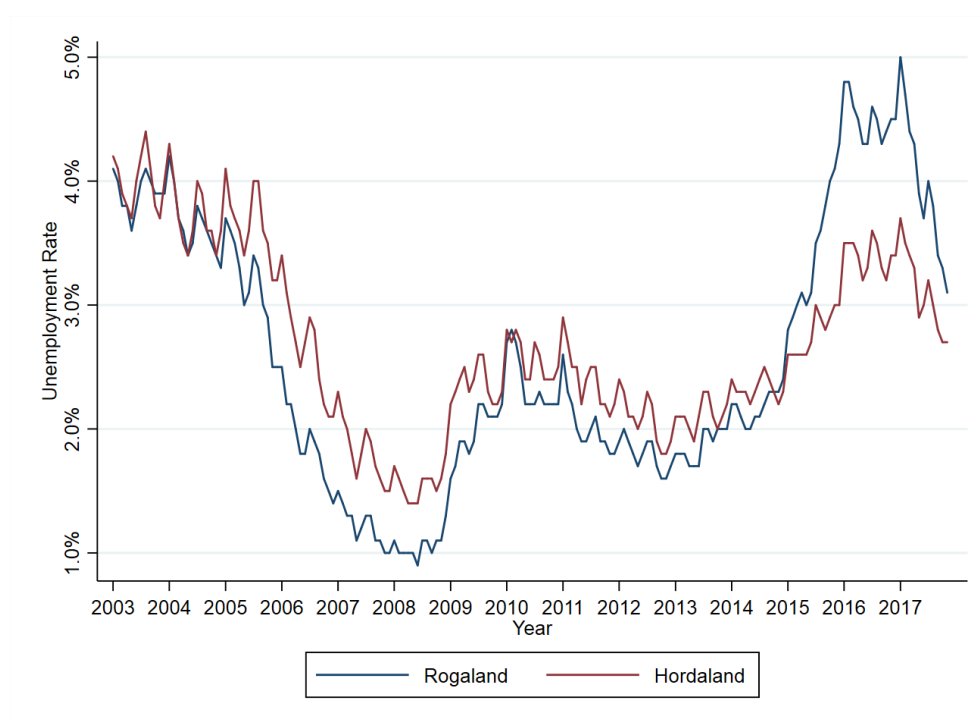
This will be discussed in more detail in the next section, when we look at differences in key economic drivers for the real estate price for the two counties.

Regional differences in key economic drivers for the real estate price

Unemployment

Unemployment measured as share of total workforce increased in both Rogaland and Hordaland in the following years after the oil price fall in June 2014, see figure 2.6 below. From June 2014 to January 2016, the unemployment rate increased from 2.1% to 4.8% in Rogaland. The unemployment rate was close to 5% throughout 2016 before it started a sharp decline in the spring of 2017. Meanwhile, Hordaland had a much more modest increase in the unemployment rate from 2.3% in June 2014 to 3.5% in January 2016. As with the unemployment rate in Rogaland, the unemployment rate in Hordaland was stable throughout 2016, before starting to decline in early 2017.

Figure 2.6: Historical Unemployment Rates in Rogaland and Hordaland (Jan 2003 - Oct 2017). The figure illustrates reported registered full-time unemployed as percentage of the total workforce in each county.



Source: Norwegian Labour and Welfare Administration (NAV) (2017)

The number of employees which have lost their jobs in the wake of the oil price drop in 2014 are uncertain. The Research Institute of Stavanger reported in 2015 that 40% of the total workforce in Rogaland were employed in petroleum related industries, higher than all other counties in Norway (Blomgren, 2015). Among these 99 110 employees, about 58% were directly employed in the onshore petroleum industry. For the second largest oil-dependent county, Hordaland, there were 56 640 people employed in petroleum related industries, where almost 55% were directly employed in the onshore petroleum industry. Rogaland has the highest share of employees working in the subsea- and supply industry which provides services to the domestic petroleum production at the continental shelf. On the other hand, Hordaland has a larger fraction of employees in the subsea- and supply industry which exports its services to foreign petroleum companies. Consequently, the petroleum related industry in Hordaland is less exposed to oil price shocks compared to Rogaland. This is due to both a lower cost level abroad and benefits gained in export when trading with a weaker Norwegian Krone. This can therefore partly explain why Rogaland seemed to struggle more than Hordaland throughout the oil crisis in 2014.

Another reason why Hordaland did not suffer from the same increase in the unemployment rate as Rogaland is that the workforce of Hordaland is more diversified. The weak Norwegian currency in the wake of the oil price collapse also contributed to favourable terms of trade for export industries not related to the petroleum industry, such as the aquaculture industry and the tourism industry - industries with stronger presence in Hordaland than Rogaland. Additionally, Hordaland has a large and stable public sector, which employs approximately 17 percent of the county's workforce⁵.

Housing stock

During the last 15 years, the growth in the housing stock has been approximately one percent each year in both Rogaland and Hordaland. Meanwhile, after the oil price collapse in 2014, the growth in the housing stock in Rogaland went down from 1.21% in 2015 to 0.95% in 2016. In Hordaland, the growth were more stable, being 0.85% in 2015 and 0.95% in 2016. From figure

⁵ SSB, table: 06424 (Employees in municipal sectors)

2.7 below, we observe that the growth rate in the housing stock has declined in Rogaland for the last five years, while the growth rate in Hordaland has been quite stable in the same period. These numbers illustrate how real estate investors in Rogaland reduced the rate of investments in new projects as the profitability of these projects were reduced due to lower demand and real estate prices following the oil price collapse in mid 2014.

Figure 2.7: Annual Growth in Housing Stock (2002-2017). The figure shows the percentage growth for each year in the housing stock for Rogaland and Hordaland.



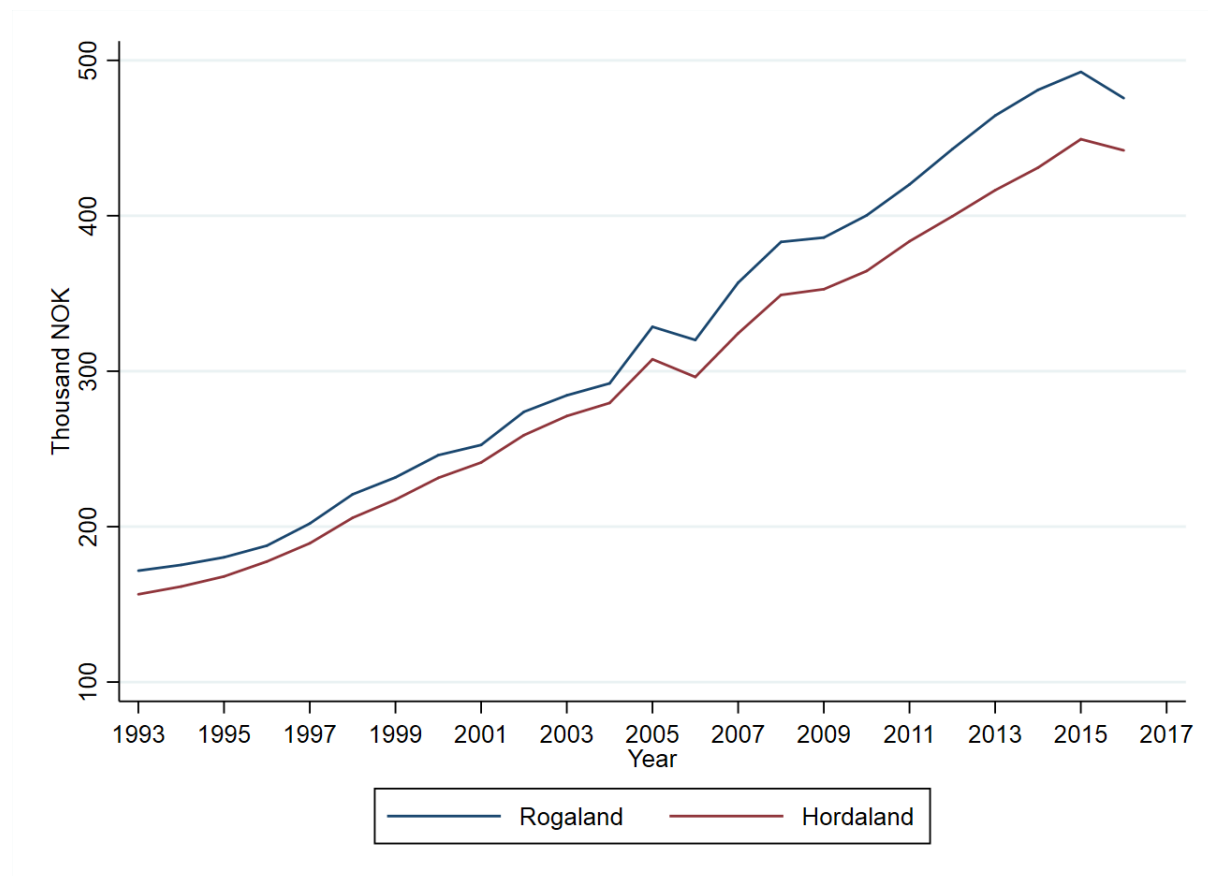
Source: Statistics Norway (Housing stock, table: 03175)

Income

The average gross income per capita shows a decline in both Rogaland and Hordaland after the oil collapse in 2014. After the drastic oil price fall, the oil investments declined and the downsizing among the oil companies increased dramatically. From 2014 to 2015 the growth in average gross income in Rogaland started to diminish from previous years, and from 2015 to 2016 the average gross income declined by 3.4%. On the other hand, Hordaland experienced a growth in average gross income from 2014 to 2015 in line with years, before the income level

declined by 1.6% from 2015 to 2016. We also notice from figure 2.6 how the difference in average gross income between the two counties increased during the time before the oil price collapse in 2014.

Figure 2.8: Average Annual Gross Income (1993-2016). The numbers are measured in thousand NOK and include salaried employees 17 years of age and older in Rogaland and Hordaland.



Source: Statistics Norway (Tax statistics for personal tax payers, table: 03068)

Expectations

Each quarter, TNS Gallup presents an expectation barometer in cooperation with Finance Norway (Kantar TNS and Finance Norway, 2017). Based on the sample of respondents, a trend indicator is constructed where the expectations to own and the overall domestic economy is questioned.

Figure 2.9: Expectation Barometer for Norway and the Southwest Region of Norway. The Southwest region includes both Rogaland and Hordaland. Positive values in the index labeled on the y-axis represent the degree of positive expectations and negative values represents the degree of negative expectations.



Source: Kantar TNS and Finance Norway (2017)

As expected, expectations to the economy fell drastically following the oil price collapse in 2014. In the Southwest region of Norway, including Rogaland and Hordaland, the barometer fell from 20.8 in June 2014 to -3.0 in June 2015. This trend continued into 2016, where the barometer fell with an additional 17.3 points, having a value of -20.3 points in mid 2016. The

expectations about the economy were now negative for the first time since the financial crisis in 2008. After a continuing decline throughout 2016, the barometer turned upwards again in an upward-going trend from the beginning of 2017, indicating positive expectations about both their own and the overall domestic economy.

2.4 Conclusion background information

In this chapter, we have presented background information about the real estate market and the petroleum industry in Norway, in addition to regional differences between Rogaland and Hordaland. The latter is done in order to justify our choice of including a petroleum specific variable when deriving our new pricing model for Rogaland in particular with Hordaland as comparison. In our descriptive analysis, we have seen that the real estate markets in Rogaland and Hordaland have reacted differently to the negative oil price shock in June 2014. While Rogaland experienced a 5% decline in real estate prices from June 2014 to November 2017, Hordaland has had an increase of 9%. One reason may be that Rogaland experienced a supply shock prior to the oil price drop in 2014, and that the market balance was strongly affected by high supply and lower demand. For Hordaland, the growth in supply of real estate was lower prior to 2014, and the demand were less affected by the downturn in the petroleum industry. Based on the descriptive analysis of key economic drivers, these differences seems to be due to the fact that Rogaland is more oil-dependent than Hordaland. The favourable terms for trade up until 2014 have especially increased the growth in petroleum-dependent regions, such as Rogaland. Besides having the largest share of companies from the petroleum industry located in its region, Rogaland also has the largest employment rates directly and indirectly related to the petroleum industry. We have therefore decided to improve Jacobsen and Naug's pricing model for real estate, where our new pricing model is specified for the real estate market in Rogaland in particular. By using Hordaland for comparisons, we are further able to verify that the model also works on other regions too, which are less petroleum-dependent and which have had a different development in their real estate market compared to Rogaland.

3 The Pricing Models

In this chapter, we present the two pricing models, Model I and Model II. In Model I we have re-estimated the pricing model for real estate that Jacobsen and Naug (2004) used in the article "What drives real estate prices?" in *Money and Credit* 4/04. Instead of re-estimating this model on a national level, we perform the model on Rogaland and Hordaland. In Model II, we present a new and improved pricing model for the real estate market in Rogaland, in particular, with Hordaland as comparison.

We use a one-step error correction model (ECM) approach when deriving the two models, as Engle and Granger's two-step approach possess several weaknesses. Engle and Granger estimate the long-term equilibrium separately, which prevents us from receiving full information about the long-term dynamics (Engle and Granger, 1987). Banerjee et al. (1993, pp. 230-252) further argue that the one-step approach also is statistically superior to the two-step approach.

In order to use a one-step ECM model, the variables need to be $I(0)$ or $I(1)$ -processes and the real estate price has to be co-integrated with the explanatory variables (Banerjee et al., 1993, pp.6-7). We test whether these requirements are met in chapter 5: *Empirical Results*. Traditionally, weak exogeneity has also been a necessary prerequisite for estimating a one-step ECM. Dolado (1992, pp. 139-143) argues that the assumption of weak exogeneity often turns out to be too strict in simple co-integrated models, and that so-called long-term weak exogeneity is sufficient. Furthermore, Geweke (1984, pp. 1121-1122) argues that weak exogeneity is not testable, as tests for exogeneity do not generate hypotheses that can be rejected. It is rather a subjective matter, based on the variables the economist views as parameters of interest along with the purpose of the model. We argue that our model satisfies the requirement of long-term weak exogeneity, since the processes that generate our explanatory variables do not directly affect the other explanatory variables in the model. For a full review of long-term weak exogeneity, see Dolado (1992). When it comes to the specification of a one-step ECM, the short-term variables can be specified quite freely, but it is important to include all the co-integrating variables in the

specification of the long-term dynamics of the model. The long-term variables must also be lagged so that they are one period behind the short-term variables.

3.1 Model I: Jacobsen and Naug's pricing model

Model I is a re-estimation of the national pricing model for real estate that Jacobsen and Naug (2004) used in the article "What drives real estate prices?" in *Money and Credit* 4/04. In their model, the authors include income, interest rate after tax, unemployment rate, housing stock and expectation to explain changes in the real estate prices.

We have re-estimated the model with the exact same specifications using a one-step ECM. However, while Jacobsen and Naug (2004) uses data on a national level, we have used data on a regional level for all variables except for the interest rate. This is done in order to test the model's validity on specific regions. We concentrate on Rogaland and Hordaland, two regions highly exposed to the petroleum industry. Furthermore, we use monthly data from January 2003 to December 2016, while Jacobsen and Naug use quarterly data from 1990 to 2004, see chapter 4: *Data*. Because of different estimation periods and the fact that we use regional data in the model, we will not compare this paper's empirical results to theirs. The regional model by Jacobsen and Naug is specified as follows:

$$\begin{aligned} \Delta \ln(\text{Realestateprice})_{i,t} = & a_0 + b_1 \Delta \ln(\text{income})_{i,t} + b_2 \Delta \text{interestrate}_t + b_3 \Delta \text{interestrate}_{t-1} \\ & + b_4 \text{Expectation}_{i,t} + c_1 \ln(\text{Realestateprice})_{i,t-1} + d_1 \text{interestrate}_{t-1} \\ & + d_2 \ln(\text{Unemployment})_{i,t} + d_3 \ln(\text{income} - \text{housingstock})_{i,t-1} \\ & + y_1 \text{Season1} + y_2 \text{Season2} + y_3 \text{Season3} + u_{i,t}, \end{aligned} \quad (3.1)$$

where Δ = first difference, \ln = *logarithm* and $u_{i,t}$ = *error term*

3.2 Model II: Our new pricing model for Rogaland

Model II is our new pricing model for the real estate market in Rogaland, in particular. We have used a one-step ECM approach for this model too. The motivation for deriving a new pricing model for the real estate market in Rogaland is twofold. First, we question the specification of

Jacobsen and Naug's model. Second, we find that Model I has very low adjusted explanatory power for both Rogaland and Hordaland, see chapter 5: *Empirical Results*. The adjusted explanatory power is especially low for Rogaland.

We have made several re-specifications in our new model compared to Jacobsen and Naug's original model. Firstly, we do not transform the unemployment variable into logarithmic form. This is because the unemployment rate does not usually grow exponentially, see chapter 4: *Data* for more details. Secondly, we ensure that all variables included in the long-term dynamic is lagged, since this is a requirement for the ECM (Engle and Granger, 1987, 251-276). Thus, the unemployment rate is re-specified. Additionally, we do not see any economic reason for including the lagged interest rate in the short-term dynamics and will consequently not include this in our new model. Finally, we include two additional explanatory variables; oil investments and listed volumes of real estate. The first one is included to control for the short-term effects petroleum related investments will have on the real estate prices, beyond what existing variables explain. The second is included to control for changes in the short-term supply of real estate.

We also run our model on Hordaland for both comparisons and to verify that our model works for more than one region. We believe that Hordaland is a good region for this purpose, as already explained in section 2.2: *The petroleum industry* and section 2.3: *Regional differences between Rogaland and Hordaland*. Here, we explain that Hordaland is dependent on the petroleum industry, but to a less extent than Rogaland. We also explained how the real estate market in Hordaland reacted differently to the oil crisis compared to Rogaland, based on the development in key economic parameters. By running Model II on Hordaland, we can therefore verify that the model works on other regions too, which are less petroleum-dependent and which has had a different development in their real estate market.

Our new pricing model, Model II is specified as follows:

$$\begin{aligned}
 \Delta \ln(\text{Realestateprice})_{i,t} = & a_0 + b_1 \Delta \text{Interestrates}_t + b_2 \Delta \ln(\text{Income})_{i,t} + b_3 \text{Expectation}_{i,t} \\
 & + b_4 \text{Oilinvestment}_{i,t} + b_5 \Delta \ln(\text{Listed})_{i,t} \\
 & + c_1 \ln(\text{Realestateprice})_{i,t-1} + d_1 \text{Interestrates}_{t-1} \\
 & + d_2 \ln(\text{Income} - \text{Housingstock})_{i,t-1} + d_3 \text{Unemployment}_{i,t-1} \\
 & + y_1 \text{Season1} + y_2 \text{Season2} + y_3 \text{Season3} + u_{i,t},
 \end{aligned} \tag{3.2}$$

where $\Delta = \text{first difference}$, $\ln = \text{logarithm}$ and $u_{i,t} = \text{error term}$

Here are the coefficient estimates b_i the short-term relationship, c_i the error-correction parameter and d_i the coefficients for the long-term relationship. The coefficient estimates y_i belongs to the dummy variables included in the model. The three dummy variables are included to control for seasonal variations. We do not need to difference expectation and oil investments, since they already are on differenced form, see chapter 4: *Data*.

4 Data

In this chapter, we present the data used in Model I and Model II. We use monthly data from 2003-2016 on both models, except for the data on oil investments and listed volumes of real estate, which are only included in Model II. The real estate prices, the interest rate, the income and the oil investments are furthermore adjusted with Consumer Price Index (CPI) to derive values in real terms.

Real estate price

The real estate prices used in Model I and Model II are based on the index of sold real estate by each region as reported by Eiendom Norge (2017). This accounts for approximately 70% of the total objects sold throughout the year. The index is distributed through Eiendom Norge in collaboration with Eiendomsverdi and Finn.no. We use the index instead of average square meters, as the latter varies largely with the type of real estate sold. By doing so, we eliminate potential issues with different real estate compositions between Rogaland and Hordaland. We use the logarithm of the real estate price index in both Model I and Model II, just as Jacobsen and Naug (2004) did. This provides us with elasticities when interpreting the coefficients.

Income

According to Jacobsen and Naug (2004), income is one of the economic factors explaining the real estate prices. We use regional data from Statistics Norway (SSB) of average gross income for individuals over the age of 17¹. The statistics only provide annual data, and to get monthly data, we divide the annual income by the number of months. We argue that this is reasonable, since income seldom increases a lot between months. It would have been preferably to use the household's total income, but as these numbers are difficult to achieve by region, we use the

¹ SSB, (Tax statistics for personal tax payers, table: 03068)

data explained above. Consequently, we might suffocate from less explanatory power in our models. We further transform the income into logarithm like Jacobsen and Naug did.

Interest rate

The interest rate is another explanatory variable in Jacobsen and Naug's real estate model. We use a domestic average of interest rates for mortgage loans from a basket of Norwegian banks² in our models. We argue that a national interest rate is a good proxy for the interest rates in both Rogaland and Hordaland, since high competition among banks ensure similar interest rates across Norway. We further adjust the interest rate for tax. The marginal tax rate on capital income- and expenses were 28% until the end of 2013, whereas it has gradually declined towards 25% as of 2016. We have used the appropriate tax rate for each year when adjusting the interest rates. Since Model I is a re-estimation of the original model, we keep the same specification for the interest rate as Jacobsen and Naug did. However, we exclude the lagged interest rate in the short-term dynamics in our new Model II as we do not see any economical reason for including the lagged interest rate in the short-term dynamics. We keep the differenced interest rate in the short-term and the lagged interest rate in the long-term dynamics.

Unemployment

Jacobsen and Naug (2004) also includes unemployment rate as an explanatory factor for the real estate prices. Both Statistics Norway (SSB) and the Norwegian Labour and Welfare Administration (NAV) publish data on unemployment, but with different calculations. While NAV counts the number of unemployed based on people who have registered themselves as full-time unemployed, the numbers from SSB are based on interviews³. One can argue that the numbers from SSB are the most representative, as they also include people who are searching for jobs, but not registered as unemployed at NAV (SSB, 2017c). However, SSB's unemployment data is not a very precise measure for regional analysis, as it consists of interviews done on a random sample from the total population of Norway. We have therefore chosen to use the unemployment rates presented by NAV for Rogaland and Hordaland in specific. NAV reports the data in

² SSB (Interest rates in banks and mortgage companies, table: 08175)

³ The Labour Force Survey (Arbeidskraftundersøkelsen, AKU)

percentage and by month, and we have kept them in this format in the models. In the original model by Jacobsen and Naug, the unemployment rate is not lagged in the long-term dynamics. As discussed in chapter 3: *Pricing Models*, this violates the requirement for ECM. From an economical argument, it neither gives sense that changes in the unemployment rate will affect the real estate prices in the same period. Consequently, we will use lagged unemployment rate in our Model II, while we use the same specification as Jacobsen and Naug in Model I. Furthermore, we will not use the logarithm of the unemployment rate in our Model II. According to Krauth (2017) time series are often transformed into natural logarithm if they are expected to grow exponentially, such as GDP per capita, population and consumption. Variables that are expected to fluctuate around a fixed level do not need to be transformed. Examples given are savings rates, interest rates and unemployment rates. We therefore argue that the unemployment rate does not need to be transformed.

Housing Stock

Along with the variables mentioned above, Jacobsen and Naug (2004) also include the housing stock as an economic factor explaining the real estate prices, especially in the long-term. We have used data on existing housing stock measured by volume in both models⁴. Housing stock not for residential purposes have been excluded from the data set. We argue that the volume of housing stock is a better measure than the number of square meters, as the size of real estate objects (in terms of square meters) varies a lot. Another reason for using the volume of the housing stock is that there are different price developments within business cycles regarding different types of real estate. In a booming economy, for instance, the demand for real estate as investment object increases, and thus the demand for apartments, since these objects are more attractive than houses in the rental market.

Economic Expectations

Jacobsen and Naug (2004) uses TNS Gallup's national expectation barometer as proxy for the household's expectations about their own and the domestic economy. We use data from the

⁴ SSB (Existing building stocks, table 03175)

Southwest region of Norway only, since we are explaining the real estate price of Rogaland and Hordaland in both models. The data is obtained from TNS Gallup, consisting of approximately a thousand telephone interviews among households in each observation period (Kantar TNS and Finance Norway).

Jacobsen and Naug (2004) further argues that the expectation barometer is highly correlated with the interest rate and unemployment rate, two variables that are already included as explanatory variables in the model. They therefore run a regression of the expectation barometer with interest- and unemployment rates as explanatory variables. Then, they use the difference between predicted and actual value as an estimate of changes in expectations that are not caused by the interest rate and the unemployment rate. This difference is used as the explanatory variable in their final preferred model in order to avoid issues with multicollinearity. We use the same procedure when we create the expectation variable for both models. The model for the expectation variable is described in equation 4.1 below, see appendix A for the output. Jacobsen and Naug further use a mathematical formula on the residuals from this model to catch non-linear relationships (concavity/convexity)⁵. We do the same for the residuals used in Model I and Model II.

$$\begin{aligned} \Delta Expectation_{i,t} = & a_0 + b_1 \Delta Interestrate_t + b_2 \Delta Unemployment_{i,t} \\ & + c_1 Expectation_{i,t-1} + d_1 Interestrate_{t-1} + d_2 Unemployment_{i,t-1} \quad (4.1) \\ & + y_1 season1 + y_2 season2 + y_3 season3 + u_{i,t} \end{aligned}$$

The applied restriction related to income and housing stock

Jacobsen and Naug (2004) argue that income and housing stock have the same long-term effect, but with opposite sign. This is because they find a high correlation between income and housing stock. As such, they use a lagged variable of real income less housing stock in the model's long-term dynamics. We do the same in both Model I and Model II as we also find strong correlation in the regional data.

⁵ $Expectation = (Residual\ estimate - Actual\ value) + 100(Residual\ estimate - Actual\ value)^3$

Oil investments (only included in Model II)

As discussed in chapter 2: *Background Information*, Rogaland is much more dependent on the petroleum industry than Hordaland. Besides having the largest share of petroleum industry companies located in the region, Rogaland also has the largest employment rates directly and indirectly related to the petroleum industry. We therefore include oil investments in Model II. The research by Terrones and Otrok (2004) also suggest that specific geographical factors could explain the real estate prices in a region, as we consider oil investments might do for the real estate market in Rogaland. The data used for oil investments constitutes direct investments in the petroleum industry including exploration ⁶. We believe oil investments is a good explanatory variable for the real estate price - especially in Rogaland. However, this variables correlate strongly with income according to a Pearson's correlation coefficient test. Therefore, we regress oil investments on income and use the residuals in Model II (see appendix B for output):

$$\begin{aligned} \Delta Oilinvestments_{i,t} = & a_0 + b_1 \Delta \ln(Income)_{i,t} + d_1 Oilinvestments_{i,t-1} + d_2 \ln(Income)_{i,t-1} \\ & + y_1 Season1 + y_2 Season2 + y_3 Season3 + u_{i,t}, \end{aligned} \quad (4.2)$$

where Δ = first difference, \ln = logarithm and $u_{i,t}$ = error term

The residuals are included to control for the effects changes in oil investments have on the real estate price, beyond what is explained by the income level. Such effects would first and foremost be immaterial effects not captured by the other explanatory variables in our model.

Listed volumes of real estate (only included in Model II)

In Norway, most of the potential buyers of real estate use Finn.no to obtain information about market prices and sales prospectus. This information is provided by real estate brokers who list the real estate object on behalf of the selling party in the transaction. As over 70% of all real estates are listed through this platform, it gives both the sellers and buyers of real estate good

⁶ SSB (Accrued oil investments, table: 09602)

information about the supply as well as the current price level in the market.

Based on economic intuition, increased (decreased) supply will reduce (increase) the market prices given that the demand is not changing. As discussed in Chapter 2, Jacobsen and Naug (2004) argue that the supply of real estate is quite constant in the short-term, and that price fluctuations are determined by changes in the demand for real estate. In the long-term, supply will adapt to the market demand, affecting the rate at which constructors invest in new projects to meet the changing demand as it often takes time from new projects are initiated until they are finished. Consequently, the new objects will not be included in the housing stock before they are completed, often years after these objects are potentially sold.

We disagree with Jacobsen and Naug and argue that the short-term supply of real estate may also be an important explanatory variable for the real estate prices. Including the volume of listed real estate will therefore, based on economic intuition, contribute to explain price fluctuations in the real estate market. New real estate projects are most often listed and sold before the construction even start, and we therefore argue that the listed volume of real estate is a good proxy for changes in real estate supply in the short-term. As there are no issues with multicollinearity between the listed volume of real estate and any of the other included explanatory variables, we only transform the variable into logarithm.

5 Empirical Results

5.1 Empirical Results from Model I

In this section we present and interpret the empirical results from Jacobsen and Naug's pricing model for real estate, Model I, run on monthly data for Rogaland and Hordaland from 2003 to 2016. Before we do this, we present the results from the unit root test.

Empirical results from the unit root test

One of the requirements for using a one-step ECM is that the data variables used in the model are either stationary or first difference-stationary (Banerjee et al., 1993, pp. 6-7). We use the Augmented Dickey-Fuller test to investigate which interaction order our variables have, or whether they are stationary. To find the correct number of lags to use in the Augmented Dickey-Fuller test, we perform Akaike's Information Criteria, as this test is the most correct one to use on monthly data (Liew, 2004, pp.1-9). The output from the test is presented in table 5.1 on the next page.

Table 5.1: Test Results for the Augmented Dickey-Fuller Test for Stationarity by Counties. The number of lag is determined with Akaike's Information Criteria. We label drift or no drift for each of the variables based on a graphical analysis. The null hypothesis is that the variable is non-stationary, i.e. unit root is present.

Variable	Rogaland	Hordaland
ln(Real estate price)	0.073	-0.867
Number of lags	2	2
Drift/ no drift	Drift	Drift
ln(Income)	-1.785	-2.507
Number of lags	1	2
Drift/ no drift	Drift	Drift
Interest rate	-2.909***	-2.909***
Number of lags	2	2
Drift/ no drift	No drift	No drift
Expectation	-12.846***	-12.866***
Number of lags	4	4
Drift/ no drift	No drift	No drift
ln(Unemployment)	0.744	-0.503
Number of lags	2	4
Drift/ no drift	No drift	No drift
ln(Income-Housingstock)	-6.548***	-4.343***
Number of lags	1	2
Drift/ no drift	No drift	No drift

* Significant at the 0.10 probability level ** Significant at the 0.05 probability level *** Significant at the 0.01 probability level

Based on the test results in table 5.1, we see that *Interest rate*, *Expectation* and $\ln(\text{Income} - \text{Housingstock})$ are stationary at 1% significance level for both counties. We also find $\ln(\text{Realestateprice})$, $\ln(\text{Income})$ and $\ln(\text{Unemployment})$ to be stationary after differencing, which indicates that these variables are of the first integration order, $I(1)$.

Empirical results from the one-step ECM

Table 5.2: Empirical Results from Model I. In the left column we have the short-term dynamics, the error-correction parameter, the long-term dynamics and dummy variables, with the corresponding variable names. The two columns to the right show the coefficient estimates and the standard error in paranthesis for Rogaland and Hordaland, respectively.

	Variables	Rogaland	Hordaland
Short-term dynamics	$\Delta \ln(\text{income})_t$	0.227**** (0.0619)	0.279**** (0.0951)
	$\Delta \text{Interestrate}_t$	0.103 (0.220)	-0.019 (0.241)
	$\Delta \text{Interestrate}_{t-1}$	0.014 (0.181)	0.045 (0.164)
	Expectation_t	1.80e-09*** (8.88e-10)	1.80e-08**** (5.27e-09)
Error correction parameter	$\ln(\text{Realestateprice})_{t-1}$	-0.013*** (0.00547)	-0.013** (0.00659)
Long-term dynamics	$\text{Interestrate}_{t-1}$	-0.061 (0.186)	-0.258* (0.165)
	$\ln(\text{Unemployment})_t$	-0.001 (0.00361)	0.010*** (0.00452)
	$\ln(\text{Income} - \text{Housingstock})_{t-1}$	0.001 (0.00249)	0.004** (0.00215)
Dummy variables	Season 1	0.019**** (0.00265)	0.014**** (0.00235)
	Season 2	0.007**** (0.00247)	0.004*** (0.00183)
	Season 3	0.008**** (0.00257)	0.005*** (0.00243)
	Constant	0.057*** (0.0274)	0.094**** (0.0281)
	N	166	166
	R2	0.481	0.538
	Adjusted R2	0.444	0.505

*Significant at the 0.15 probability level ** Significant at the 0.10 probability level *** Significant at the 0.05 probability level

**** Significant at the 0.01 probability level

Explanatory power and validity of the model

Another requirement for using an ECM, is that the real estate price is co-integrated with the explanatory variables. Co-integration means that two or more variables of the same integrated order have a common long-term development (Wooldridge, 2012, p. 632). In a one-step ECM, we have co-integration if the coefficient of the error correction parameter, the lagged real estate price, is negative and significant when conducting a regular t-test (Banerjee et al., 1993, p. 155). This is the case as long as the variables are $I(0)$ or $I(1)$ processes. We see from table 5.2 above, that there is co-integration between the real estate price and the explanatory variables in Model I.

We furthermore find that income and expectation are significant in the short-term dynamics. For Hordaland, we have that the lagged interest rate, the unemployment rate and lagged income less housing stock is significant as well. The adjusted explanatory power is only 44.4% for Rogaland and only 50.5% for Hordaland, while it is 87.73% for Norway with Jacobsen and Naug's (2004) data set. This is perhaps not such a big surprise, since Jacobsen and Naug aimed at deriving a pricing model for the real estate market in Norway, and not for specific regions. Moreover, we only include monthly data from 2003 to 2016 in our data set, while Jacobsen and Naug uses quarterly data from 1990 to 2004. Nevertheless, the empirical results suggest that there are room for improvements when explaining the real estate prices at regional level. Since the model has an especially low adjusted explanatory power for Rogaland, we have chosen to derive a new pricing model for this county in particular with Hordaland as comparison, see chapter 5.2: *Empirical Results* from Model II.

We suspect the reason for the much lower adjusted explanatory power for Rogaland may be that the real estate market in Rogaland is very dependent on the petroleum industry, while Jacobsen and Naug's model does not exhibit any petroleum related explanatory variables. Their model neither control for short-term supply of real estate. We furthermore question their model specification, which do not follow the formal requirements for an ECM from a theoretical standpoint. They violate the requirements of the model by not lagging the unemployment variable in the long-term dynamic. We also disagree with Jacobsen and Naug's transformation of the unemployment rate into logarithm, since unemployment does not usually grow exponentially.

The diagnostic plots and formal tests indicate quite robust and valid results for Jacobsen and Naug's model for Rogaland and Hordaland, but it struggles with non-normally distributed residuals and autocorrelation. Non-normally distributed residuals gives biased estimates, while autocorrelation gives both biased and inefficient estimates. This means that we have to interpret the empirical results from the ECM above with care. We solve the problem with autocorrelation, however, by using robust error terms (Wooldridge, 2012, pp. 412-448). Jacobsen and Naug did not find any problems with autocorrelation in their analysis, but this may be due to the fact that they used a Durbin-Watson test, which gives biased estimates when stochastic variables are present (Nerlove and Wallis, 1966, p.236). We use the Breusch-Godfrey test instead, as this test is much more applicable for ECMs (Dimitrios and Hall, 2011 p.159). See appendix C for the output from the diagnostic tests.

Interpretation of coefficient estimates

Short-term dynamics

The significant coefficient estimates in the short-term dynamic have a direct economic interpretation. As such, a log-log relationship is interpreted as the price elasticity of real estate, while a log-level relationship is interpreted by multiplying the coefficient with one hundred to get the percentage change in the real estate price by one unit change in the explanatory variable.

We find that the income is a significant explanatory variable for the real estate price in Jacobsen and Naug's model, both in their original paper and in Model I with regional data. The intuition is that growth in real income will increase the households payment capabilities and their access to mortgage loans issued by the bank. We find that the real estate price will increase by 0.23% in Rogaland if the real income increase by 1% in month t . The short-term effect from changes in real income is slightly stronger for Hordaland, with an increase in the real estate prices of 0.28% for a 1% increase in the real income. The variables are significant at 1% significance level for both counties.

We also find that the expectation about the household's own and the overall economy is statistically significant in Model I. For both Rogaland and Hordaland, we find that the constructed expectation variable is positive and significant at 5% and 1% significance level, respectively. The effects on the real estate prices for monthly changes in the constructed expectation variable

is minimal, but positive as expected.

Long-term dynamics

We find that the coefficient estimate of the $Realestateprice_{t-1}$, i.e. the error correction parameter, is statistically significant and negative at 5% for Rogaland and 10% for Hordaland. The coefficient estimate of -0.013 tells that the real estate price increases (declines) by 0.013% in month t if the real estate price lies 1% under (over) the estimated long-term dynamic in month $t - 1$, ceteris paribus.

The other coefficient estimates in the long-term equilibrium relationship cannot be interpreted as direct economic effects. As such, we must calculate how the long-term effect is allocated on future periods. This is done with regard to the error correction speed measured by the coefficient estimate of the error correction parameter, $Realestateprice_{t-1}$. As such, we have that:

$$\text{Long-term economic effect} = \frac{-d_i}{c_i},$$

where d_i is the coefficient estimate from the long-term dynamic and c_i is the coefficient estimate for the error correction parameter, $Realestateprice_{t-1}$. We add a negative sign in the formula, since c_i will be negative as long as there is co-integration.

The unemployment rate is significant and positive at 5% significance level for Hordaland, but has low impact on the real estate prices in Model I. This result is somewhat unexpected. If the unemployment rate was to increase permanently by one percentage point, for instance from 4% to 5% (i.e. by 25%), this would impose a 0.26% increase in the real estate prices in Hordaland over time. A positive relationship between the unemployment rate and the real estate price is the opposite of what economic intuition would suggest. One explanation for this might be that our estimation period includes the oil price collapse in Rogaland, where most of the jobs in the petroleum industry are located. As the petroleum companies downsized in Rogaland, employees in the petroleum industry from Hordaland situated in Rogaland moved back to Hordaland to find new jobs. Consequently, oil employees from Hordaland who moved back to their home county imposed an additional pressure on demand for real estate as well as to increase the unemployment rate reported in Hordaland. In addition, we are critical to the use of an unlagged

variable of unemployment in the long-term dynamic of the model, since this violates the requirements of ECM. We also argue that the specification of the unemployment variable does not make sense from an economic perspective either, since a change in the unemployment rate in one period usually do not affect the real estate price instantly, but rather in future periods. This seems to be the case for our data set as well, as can be seen from the descriptive analysis in section 2.3: *Regional differences between Rogaland and Hordaland*. For Rogaland, the coefficient estimate is not significant.

The coefficient estimate for the applied restriction on income and housing stock is positive and statistically significant at 10% significance level for Hordaland. This means that a one percentage increase in the income will impose a 0.004% increase in the real estate prices, while the same change in the housing stock will decrease the real estate prices by 0.004%. These results are in line with what we should expect from economic theory. For Rogaland, the coefficient estimate is not significant.

Long-term equilibrium

We can also calculate how fast deviations in the real estate market adjust back to the equilibrium price by using the formula from Bernhardsen and Roeiseland (2000, p.191) ¹. Here, the speed of adjustment to long-term equilibrium is defined as the time it takes before half of a potential deviation is adjusted back to the equilibrium price. We find that it takes approximately 4.5 years, i.e. 55 months or 18 quarters for both Rogaland and Hordaland. In comparison, Jacobsen and Naug (2004) find in their article that it takes approximately 5.4 years for the overall real estate market in Norway to adjust back back to equilibrium in their estimation period.

¹ *The speed of adjustment to long-term equilibrium* = $\frac{\ln(0.5)}{\ln(1-c_i)}$

5.2 Empirical Results from Model II

In this section, we present and interpret the empirical results from our new proposed pricing model, Model II, for Rogaland with Hordaland as comparison. First we present the results from the unit root test, before we discuss the empirical results from Model II.

Empirical results from the unit root test

Just as with Model I, we also test the data variables in Model II for the presence of unit roots. We test if they are $I(0)$ and $I(1)$ -processes by using an Augmented Dickey-Fuller test as this is one of the requirements for ECM. As already mentioned earlier, this test enables us to check the interaction order of our variables, or if they are stationary. We use the Akaike's Information Criteria as we did for Model I, as this test is the most correct one to use on monthly data (Liew, 2004, pp.1-9). The results are presented in table 5.3 on the next page.

Table 5.3: Test Results for the Augmented Dickey-Fuller Test for Stationarity by Counties. The number of lags is determined with Akaike's Information Criteria. We label drift or no drift for each of the variables, based on a graphical analysis. The null hypothesis is that the variable is non-stationary, i.e. there is presence of unit roots. The table shows the test statistics for the variables in Model II, which are not already presented in Table 5.1.

Variable	Rogaland	Hordaland
Unemployment	-0.617	-0.345
Number of lags	2	4
Drift/ no drift	No drift	No drift
$\ln(\text{Listed})$	-3.704***	-3.868***
Number of lags	1	2
Drift/ no drift	No drift	No drift
Oil investments	-3.397***	-3.648***
Number of lags	4	4
Drift/ no drift	No drift	No drift

* Significant at the 0.10 probability level ** Significant at the 0.05 probability level *** Significant at the 0.01 probability level

Based on the test results presented in table 5.1 and the additional variables included in table 5.3, we find that *Interest rate*, $\ln(\text{Income} - \text{Housingstock})$, *Oil investment*, *Expectation* and $\ln(\text{Listed})$ are stationary at 1% for both counties. We also find $\ln(\text{Realestateprice})$, $\ln(\text{Income})$ and *Unemployment* to be stationary after differencing, which indicates that these variables are of the first integration order, $I(1)$.

Empirical results from the ECM

Table 5.4: Empirical Results from Model II. In the left we have the short-term dynamics, the error-correction parameter, the long-term dynamics and the dummy variables, with the corresponding variable names. The two columns to the right show the coefficient estimates and the standard error in paranthesis for Rogaland and Hordaland. The number of observations, the explanatory power and the adjusted explanatory power presented at the bottom of the table.

	Variables	Rogaland	Hordaland
Short-term dynamics	$\Delta Interestrate_t$	-0.043 (0.149)	-0.095 (0.171)
	$\Delta \ln(Income)_t$	0.162**** (0.062)	0.152** (0.090)
	$\Delta \ln(Listed)_t$	0.011**** (0.001)	0.009**** (0.002)
	$Expectation_t$	2.25e-08**** (3.40e-09)	2.39e-08**** (4.56e-09)
	$Oilinvestments_t$	0.005* (0.003)	-0.008* (0.005)
Error correction parameter	$\ln(Realestateprice)_{t-1}$	-0.019**** (0.003)	-0.012*** (0.006)
Long-term dynamics	$Interestrate_{t-1}$	-0.231*** (0.101)	-0.213** (0.123)
	$Unemployment_{t-1}$	-0.319**** (0.090)	0.384*** (0.170)
	$\ln(Income - Housingstock)_{t-1}$	-0.002 (0.002)	0.0003* (0.002)
Dummy variables	Season 1	0.013**** (0.002)	0.004 (0.003)
	Season 2	-0.001 (0.002)	0.003 (0.003)
	Season 3	0.002 (0.002)	0.002 (0.002)
	Constant	0.127**** (0.021)	0.062** (0.036)
	N	167	167
	R2	0.723	0.644
	Adjusted R2	0.701	0.616

* Significant at the 0.15 probability level ** Significant at the 0.10 probability level *** Significant at the 0.05 probability level

**** Significant at the 0.01 probability level

Explanatory power and validity of the model

We have run Model II on both Rogaland and Hordaland. We do this in order to compare the results from Rogaland with a different county, and to verify that our model works on more than one region. As already explained for Model I, the real estate price has to be co-integrated with the explanatory variables in order for the ECM to be valid. We see from table 5.4 above, that this is the case for Model II for both Rogaland and Hordaland as the coefficient of the error correction parameter, $Realestateprice_{t-1}$, is negative and significant.

First of all, we get higher adjusted explanatory power for Model II than Model I for both Rogaland (70.1% against 44.4%) and Hordaland (61.6% against 50.5%). Beside the changes in the specification of the model, we also add oil investments and volume of listed real estate as explanatory variables based on our arguments in chapter 4: *Data*. The adjusted explanatory power for Rogaland becomes especially high once we account for the new variables. This is not such a big surprise as we have argued that Rogaland is more oil-dependent than Hordaland.

The plot diagnostics and formal tests further indicate quite robust and valid results for Model II, but it struggles with autocorrelation just like Model I. We control for autocorrelation by using robust errors terms (Wooldridge, 2012, pp. 412-448). See appendix D for the output from the diagnostic tests.

Interpretation of the coefficients

Short-term dynamics

As with Model I, the coefficients estimated from the short-term dynamics can be interpreted directly from the table 5.4.

The coefficient of real income is positive as expected. A one percentage point increase in the income will increase the real estate price in Rogaland by 0.162% in month t . For Hordaland, the same change will increase the real estate price by 0.152%. Such results are in line with what economic theory suggests as well as the results Jacobsen and Naug (2004) find for income in their model with domestic data. We find the short-term real income to be statistically significant at 1% level for Rogaland as in Model I, while the variable is significant at 10% for Hordaland. Increase in real income will improve the payment capabilities, and depending on

the household's allocation, increase the demand for real estate. We have that the real income has a lower effect on the real estate prices in Model II compared to Model I. In addition, the effect is stronger for Rogaland than Hordaland, which is the opposite of what we find in Model I. We argue that the higher coefficients for the real income in Model I may be due to issues with omitted variables. This argument is based on the fact that the oil investment variable is not included in Model I, but both significant in Model II and correlated with income. By cleaning the effects of income from the oil investments, and including the residuals in Model II, we are better able to get correct coefficient estimates.

As in Model I, the household's expectations to their own and the overall economy affect the real estate prices. A one unit change in expectation for a given month will increase the real estate prices with a low and positive effect. The coefficient estimates are significant at 1% level for both Rogaland and Hordaland, indicating that when households are positive to the future economic prospects it will slightly increase the real estate prices in the short-term.

As mentioned in chapter 4: *Data*, we have included the volumes of listed real estate in Model II, as we argue that this is a good proxy for changes in the short-term supply. The coefficient estimates show that a one percentage increase in listed objects will increase the real estate prices with 0.011% in Rogaland. In Hordaland, the increase is 0.009% for the same change. Both variables are statistically significant at 1% significance level. We argue that there might be reversed causality between the real estate prices and the volume of listed objects in the real estate market. When real estate prices increase, the overall activity in the real estate market increases. Especially, a booming real estate market as we have observed during our estimation period has led to many new real estate projects, where contractors list the new real estate projects before they even start construction. The growth in real estate prices will thus in the short-term result in an increase in listed objects on the market.

Oil investments is another new variable in Model II and our expectation is that growth in petroleum related investments will have a positive effect on the real estate prices, especially in Rogaland. We find such results in our model, as it is close to be significant at 10% significance level, and significant at 15% significance level, i.e. economically significant. A one unit increase in oil investments of one billion NOK increases the real estate prices in Rogaland

by 0.512%. As we have argued in chapter 2: *Background Information*, the economy in Rogaland including the real estate market are highly affected by the situation in the petroleum industry, especially the income level. The Pearson's correlation coefficient test verify this, see appendix B. The oil investment variable is therefore cleaned from effects coming from changes in income. This means that there are other effects from changes in the oil investments, which explain changes in the real estate price, besides what existing variables in our model can explain. For Hordaland, the estimates show that one unit change in oil investments will cause a decrease in the real estate prices of 0.758%. This is the opposite of what we expected. An explanation may be that Hordaland is less oil-dependent than Rogaland. As discussed in chapter 2, the downturn in the petroleum industry hit Rogaland harder as the fraction of the workforce employed directly in the petroleum industry is much higher than in Hordaland. Consequently, the growth in the unemployment rate was much higher in Rogaland after the oil price drop, as seen in figure 2.6. Hordaland, with its more diversified workforce enjoyed favourable terms of trade for its export industries, which kept the employment rate stable, the income level growing and the expectations about the future brighter relative to Rogaland. Another reason may be that in periods with high activity (high oil investments) in the petroleum industry, people in Hordaland move to Rogaland where the majority of the oil companies are situated. This would involve a lower demand for real estate in Hordaland as people migrate from Hordaland to Rogaland and consequently contribute to make the coefficient estimate of oil investments negative.

Long-term dynamics

The error correction parameter implies that the real estate prices increase (decrease) with 0.019% in month t if the real estate prices lies one percent under (over) the estimated long-term relationship in month $t - 1$, ceteris paribus. For Hordaland, the error correction parameter is 0.012%. The error correction parameter is statistically significant at 1% for Rogaland and at 5% for Hordaland.

As already pointed out in Model I, the rest of the coefficient estimates in the long-term dynamic cannot be interpreted as direct economical effects. We need to calculate to what extent this long-term effect will be allocated on future periods. This allocation is determined by the error correction speed towards long-term equilibrium measured by the coefficient of the error correction parameter. Consequently, to find the long-term effects, we divide the coefficient es-

timate from the long-term dynamics on the error correction parameter ².

The coefficient of interest rate after tax is negative in the long-term as expected, since a higher interest rate will increase the household's total housing cost and therefore reduce the payment capabilities and thus the demand for real estate. Model II implies that the real estate prices in Rogaland will decrease by 6.59% over time if the interest rate increases from 3.5 to 4.5% (an increase of 28.5%). For Hordaland, the same increase in the interest rate will result in a decrease of 6.08% over time. The variable is significant at 5% level for Rogaland and 10% for Hordaland.

During the estimation period, we have witnessed one of the largest downsizing in the history of the Norwegian petroleum industry. As discussed in chapter 2, the oil price collapse hit Rogaland hard and affected the unemployment rate more than any other region in Norway. We find that a unit increase of one percentage point in the unemployment rate from 4 to 5 % (an increase of 25%) impose a decrease of 7.96% in the real estate prices in Rogaland, being statistical significant at 1% level. This implies that higher unemployment rates will affect the real estate prices in Rogaland negatively in coming periods, which is also what we observed for Rogaland after the oil price collapse in mid 2014. The estimate for Hordaland is different from what we expected. Despite the changes we did from Model I to Model II, we still get a positive coefficient estimate in the long-term dynamics for Hordaland. Here we find that the same increase in unemployment rate will have a positive effect on the real estate prices of 9.59%, being significant at 5% level. Seeming unlikely that a higher unemployment rate will increase the real estate prices, one can argue that after the oil price collapse, employees from Hordaland who worked in petroleum companies in Rogaland, moved back to their home county. This in turn increased both the demand for real estate and the unemployment rate in Hordaland as these people now were reported as unemployed in Hordaland.

As previously explained in chapter 2, an increase in the housing stock will set a downward pressure on the real estate prices as new objects are increasing the overall supply, as long as the

² Long-term economic effect = $\frac{-d_i}{c_i}$

reduction in the housing stock is less than the number of new buildings. In our model, we do not find statistically significant effects from the housing stock affecting the real estate prices in the long-term for the two counties.

Long-term equilibrium

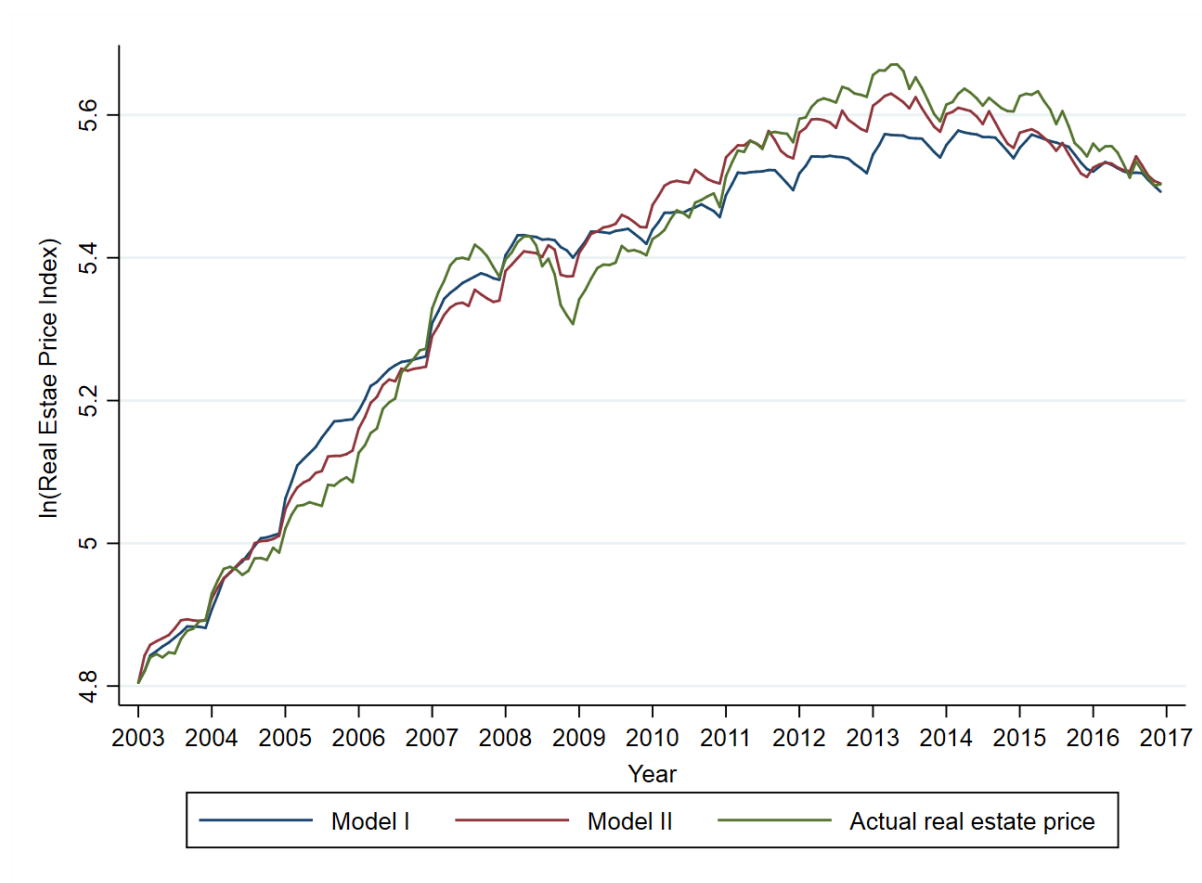
As with Model I, we calculate the time of which the half of any deviation in the real estate market is adjusted back to the equilibrium. Using the formula³ from Bernhardsen and Roeiseland (2000, p. 191) we find that this takes approximately 3 years, i.e. 36 months or 12 quarters for Rogaland. For Hordaland, the real estate market adjusts slower, with 4.8 years i.e. 57 months or 19 quarters before half of a deviation is adjusted towards the equilibrium.

5.3 Predicted real estate prices vs. actual real estate prices for Model I and Model II

The empirical results discussed in section 5.2 show that our new pricing model, Model II, is better at explaining the real estate prices than Jacobsen and Naug's model, Model I. We can also analyze the explanatory power graphically with a prediction of the two models against the actual real estate prices. These plots are shown in figure 5.1 and figure 5.2 below.

³ *The speed of adjustment to long-run equilibrium* = $\frac{\ln(0.5)}{\ln(1-c_i)}$

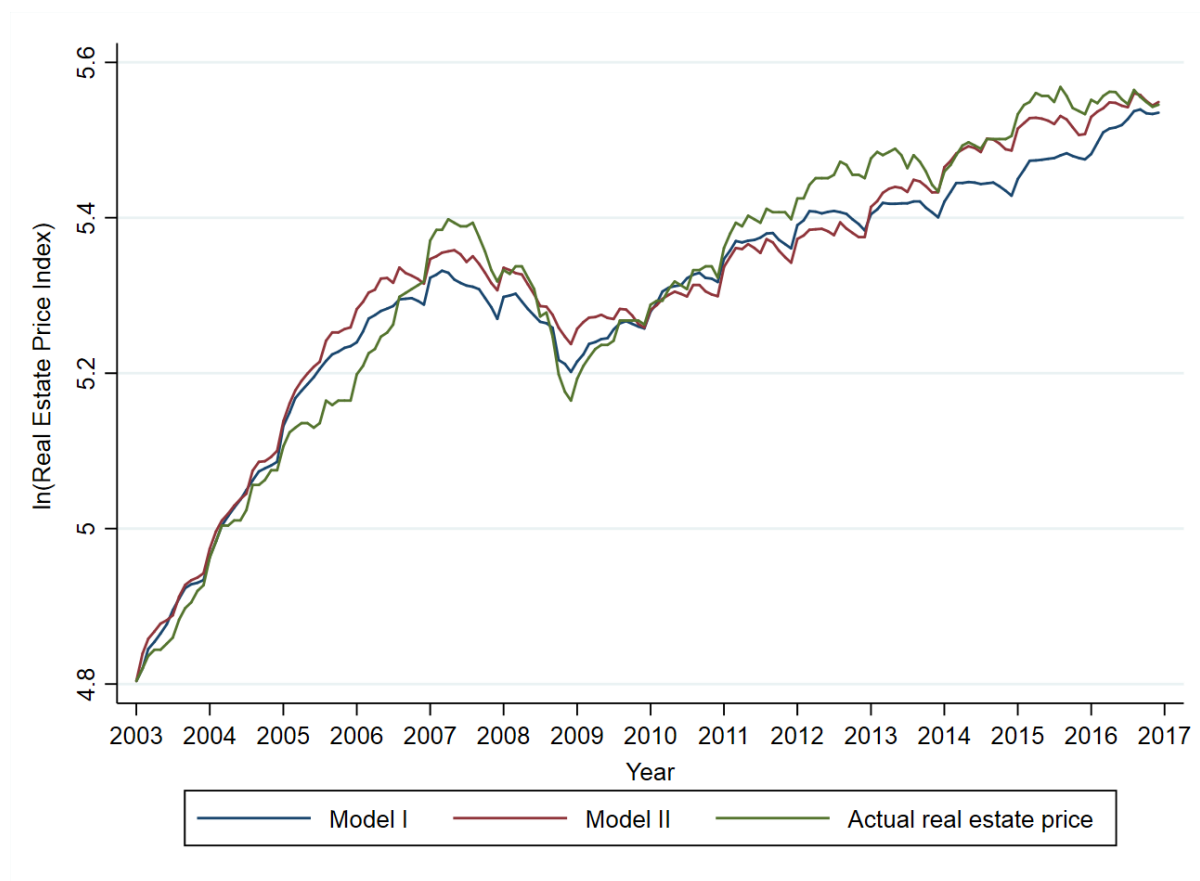
Figure 5.1: Predicted Prices for the Real Estate Market in Rogaland. The figure presents the predicted real estate price index for Model I and Model II against the actual observed real estate price index. The real estate index is measured in real terms and transformed to logarithm, and labeled on the y-axis.



Source: Own estimates, Eiendom Norge (2017)

In this paper, we have included oil investments as an explanatory variable to better explain the price development in the real estate market of Rogaland. From figure 5.1, we observe that our Model II clearly outperforms the original model of Jacobsen and Naug (Model I) in the periods of 2004-2007 and 2011-2015. As seen in figure 2.3, the oil investments increased a lot in the period before the financial crisis of 2008 and in the period prior the oil price collapse of 2014. In these periods, the predicted real estate prices of Model II is much closer to the actual real estate prices, which underpins our hypothesis in which the oil investments contribute to explain the real estate prices in Rogaland.

Figure 5.2: Predicted Prices for the Real Estate Market in Hordaland. The figure presents the predicted real estate price index for Model I and Model II against the actual observed real estate price index. The real estate index is measured in real terms and transformed to logarithm, and labeled on the y-axis.



Source: Own estimates, Eiendom Norge (2017)

We have also argued in this paper that Hordaland is less dependent on the petroleum industry compared to Rogaland. However, we find that the predicted real estate prices of Hordaland in some periods are close to the actual real estate prices and outperforms the model of Jacobsen and Naug (2004) on average. Especially, in the period of 2014-2016 the new pricing model explains the real estate prices in Hordaland well. Compared to Rogaland, the high oil investments in 2011-2015 do not seem to have had the same effect on Hordaland, which underpins our arguments of Hordaland being less dependent on the petroleum industry.

6 Conclusion

In this paper, we have shown that Rogaland is a more oil-dependent county than Hordaland. Moreover, the workforce in Rogaland is highly dependent on the activity in the petroleum industry, while the workforce in Hordaland is more diversified towards export related industries which have enjoyed favorable terms for trade after the oil price crisis. We also suggest that there was a supply shock in Rogaland in the years before 2014, which reinforced the fall in the real estate market when the oil price collapsed. Consequently, the downturn in the petroleum industry hit Rogaland hard with a fall in real estate prices of 5% from June 2014 to November 2017, whereas the real estate market in Hordaland increased by 9% during the same period.

We have presented a new and improved real estate pricing model for Rogaland. The motivation for deriving a new pricing model for the real estate market is twofold. Firstly, we argue that the specification of Jacobsen and Naug's model violates the formal error correction model requirements. Secondly, we find that the model has low adjusted explanatory power when we perform this model on regional data for Rogaland and Hordaland (Model I). The adjusted explanatory power is especially low for Rogaland with 44.4% (50.5% for Hordaland).

The new pricing model includes oil investments and the volume of listed real estate in order to better explain the real estate prices in Rogaland. We find that oil investments has a significant effect on the real estate prices in Rogaland, where a unit increase of one billion NOK in the oil investments impose a 0.512% increase in the real estate prices in the short-term. For Hordaland, the same change will impose a decrease in the real estate prices of 0.758%. This finding was somewhat unexpected, however reasonable based on the findings of Hordaland being less dependent on the petroleum industry. Compared to Rogaland, Hordaland is to a larger extent diversified with export related industries, which have experienced positive development in the wake of the oil crisis, such as the aquaculture industry.

The volume of listed real estate is included as a proxy for the short-term changes in supply of real estate. Here we find that a percentage increase in listed volume of real estate impose a modest increase of 0.011% on the real estate prices in Rogaland (0.009% for Hordaland). We argue that these results are prone to reversed causality, where booming real estate prices increase the market activity where contractors invest in new real estate projects, which are listed before the construction has started.

We have also criticized the model specification of the original model by Jacobsen and Naug (2004), where the unlagged unemployment rate in the long-term dynamics and the inclusion of lagged interest rate in the short-term dynamics violates the requirements for an ECM. Our new pricing model, Model II, has an adjusted explanatory power of 70.1% for Rogaland and 61.6% for Hordaland

Finally, we find that our new pricing model clearly outperforms the original model of Jacobsen and Naug in predicting the actual real estate prices although Jacobsen and Naug (2004) did not find this to be statistically significant. The predicted prices in Model II are especially close to the actual real estate prices in Rogaland in the years where oil investments were high, which underpins the choice of including oil investments as an explanatory variable in our new pricing model.

For further research, it would be interesting to incorporate credit data into our pricing model as well. We suspect credit to be a relevant explanatory variable for the real estate prices, although Jacobsen and Naug (2004) did not find this to be statistically significant in their model. It would also be of interest to analyse any possible endogenous effects, for instance, derive a long-term instrumental variable for the housing stock. We would also like to investigate further the unexpected, negative relationship between oil investments and the real estate price in Hordaland. We suspect that the immigration pattern between Rogaland and Hordaland in periods of changing activity in the petroleum industry might be an explanation.

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A Appendix

Table A.1: The Expectation Model Used in Model I and Model II. In the left column we have the variables included in the expectation model, in addition to the number of observations, explanatory power and adjusted explanatory power. The two columns to the right shows the coefficient estimates for Rogaland and Hordaland.

Variables	Rogaland	Hordaland
$\Delta interestrate_t$	-48.972	-34.023
$\Delta \ln(Unemployment)_t$	-1.301	14.841*
$Expectation_{t-1}$	-0.057*	-0.040*
$Interestrate_{t-1}$	-4.785*	4.9351*
$\ln(Unemployment)_{t-1}$	0.677*	2.462*
<i>Season1</i>	3.158**	2.669**
<i>Season2</i>	1.426	1.485
<i>Season3</i>	3.394**	3.134**
<i>Constant</i>	1.638	7.684
<i>N</i>	167	167
<i>R2</i>	0.103	0.142
<i>AdjustedR2</i>	0.057	0.099

* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

B Appendix

Table B.1: The Oil Investment Model Used in Model II for Rogaland and Hordaland. In the left column we have the variables included in the oil investments model, in addition to the number of observations, explanatory power and adjusted explanatory power. The two columns to the right shows the coefficient estimates.

Variables	Rogaland coefficients	Hordaland coefficients
$\Delta \ln(\text{income})_t$	-2592.33	-4811.56
$\Delta \ln(\text{Oil investments})_{t-1}$	-0.1379***	-0.1019***
$\ln(\text{Income})_{t-1}$	4299.689***	3491.433***
Season1	-619.250***	-548.377***
Season2	249.368*	283.792**
Season3	-65.316	-55.570*
Constant	-43182.24***	-34894.6***
N	167	167
R2	0.305	0.286
Adjusted R2	0.278	0.259

* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Table B.2: Pearson's Correlation Coefficient Test. In the left column we have the variables being tested and in the two columns to the right the correlation coefficients for Rogaland and Hordaland. As can be seen from the table, there is high correlation between oil investments and real income in both counties.

Variables	Rogaland	Hordaland
Oil investments against real income	0.913	0.894

C Appendix

Diagnostic tests for Model I

Table C.1: Variance Inflation Factor (VIF) Test for Multicollinearity for Model I. In the left we have the variables for Model I. The two columns to the right shows the VIF-values for Rogaland and Hordaland. The mean VIF-value is presented at the bottom. As can be seen from the table, there is no issues with multicollinearity.

Variables	VIF Rogaland	VIF Hordaland
$\ln(\text{Unemployment})_t$	3.08	3.86
$\ln(\text{Realestateprice})_{t-1}$	2.42	3.96
Season1	1.69	1.75
$\text{Interestrate}_{t-1}$	2.99	4.11
Expectation_t	2.08	1.64
Season3	1.64	1.74
$\Delta \ln(\text{income})_t$	1.45	1.42
Season2	1.51	1.67
$\Delta \text{interestrate}_{t-1}$	1.18	1.27
$\Delta \text{interestrate}_t$	1.54	1.61
$\ln(\text{income} - \text{housingstock})_{t-1}$	1.32	1.32
Mean VIF	1.90	2.21

VIF value below 4 indicates no problem with multicollinearity. VIF values up to 10 is often accepted.

Figure C.1: Sequence Plot for Rogaland to Detect Possible Heteroscedasticity. The estimated residuals from Model I on the y-axis and fitted values on the x-axis. The plot illustrates that there is no problems with heteroscedasticity.

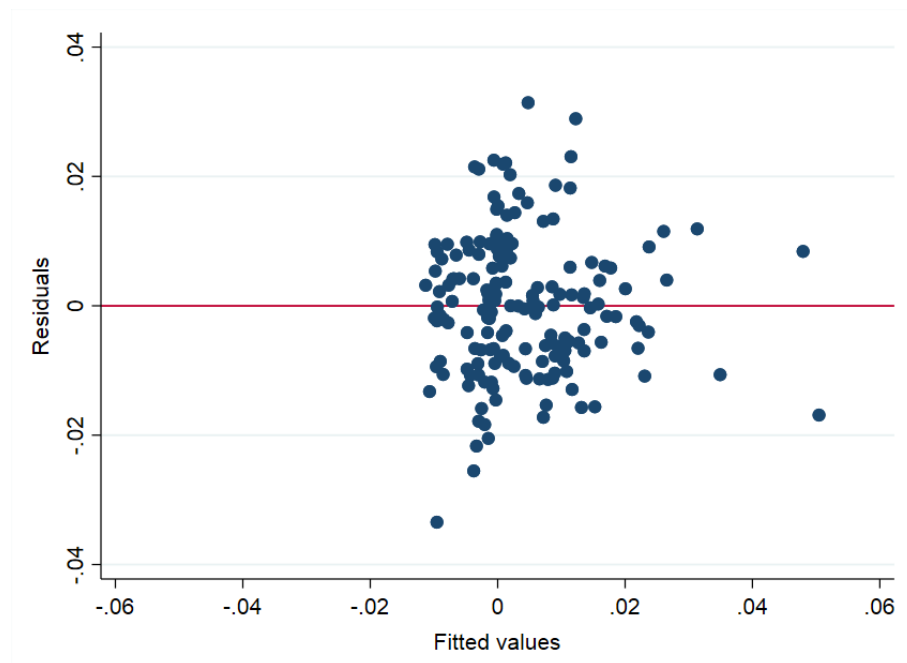


Figure C.2: Plot of Fitted Values vs. Time for Rogaland to Detect Possible Heteroscedasticity. The Fitted values on the y-axis and time on the x-axis. The plot illustrates that there is no problems with heteroscedasticity.

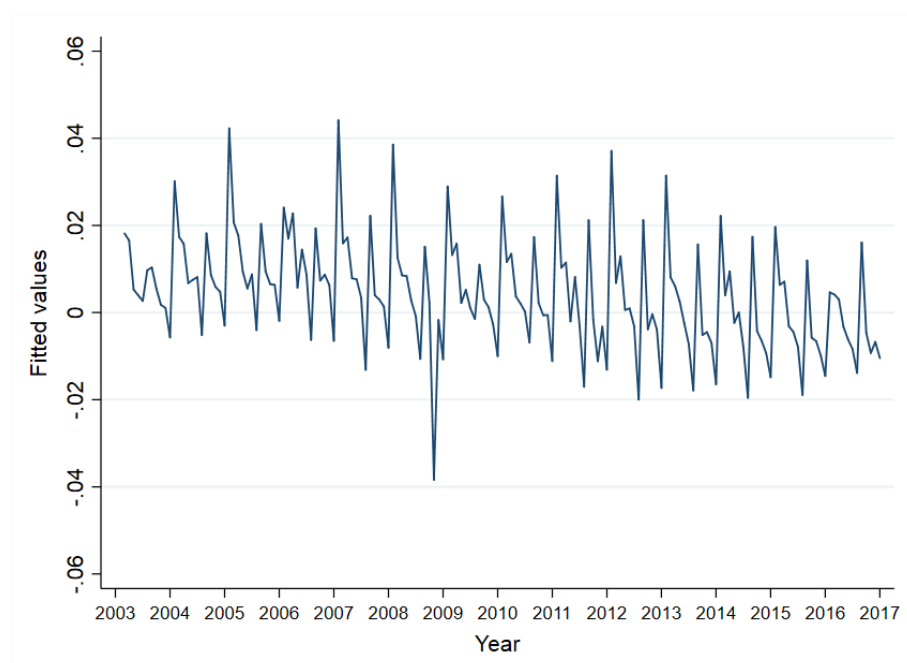


Figure C.3: Sequence Plot for Hordaland to Detect Possible Heteroscedasticity. The estimated residuals from Model I on the y-axis and fitted values on the x-axis. The plot illustrates that there is no problems with heteroscedasticity.

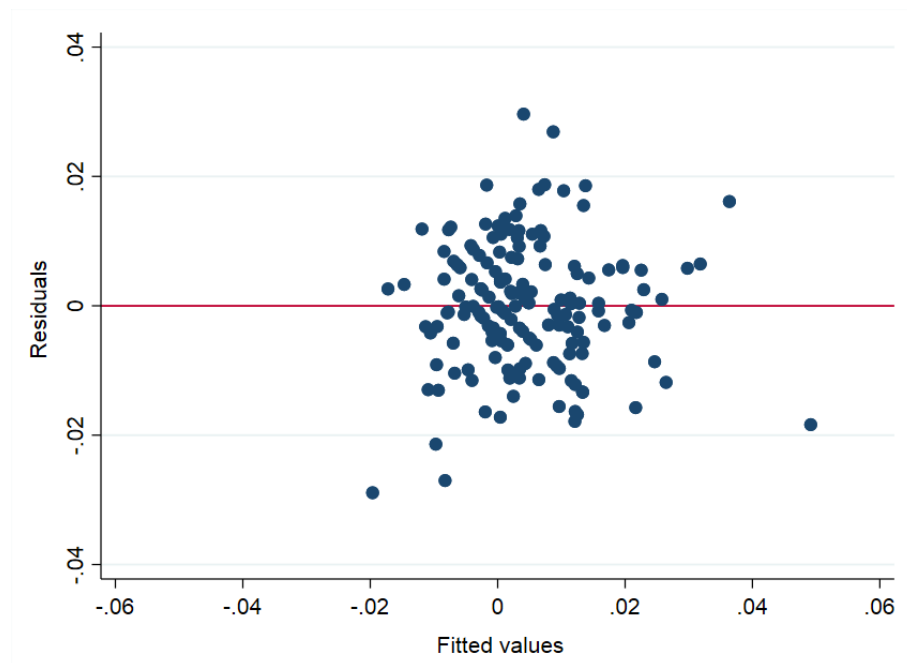


Figure C.4: Plot of Fitted Values vs. Time for Hordaland to Detect Possible Heteroscedasticity. The Fitted values on the y-axis and time on the x-axis. The plot illustrates that there is no problems with heteroscedasticity.

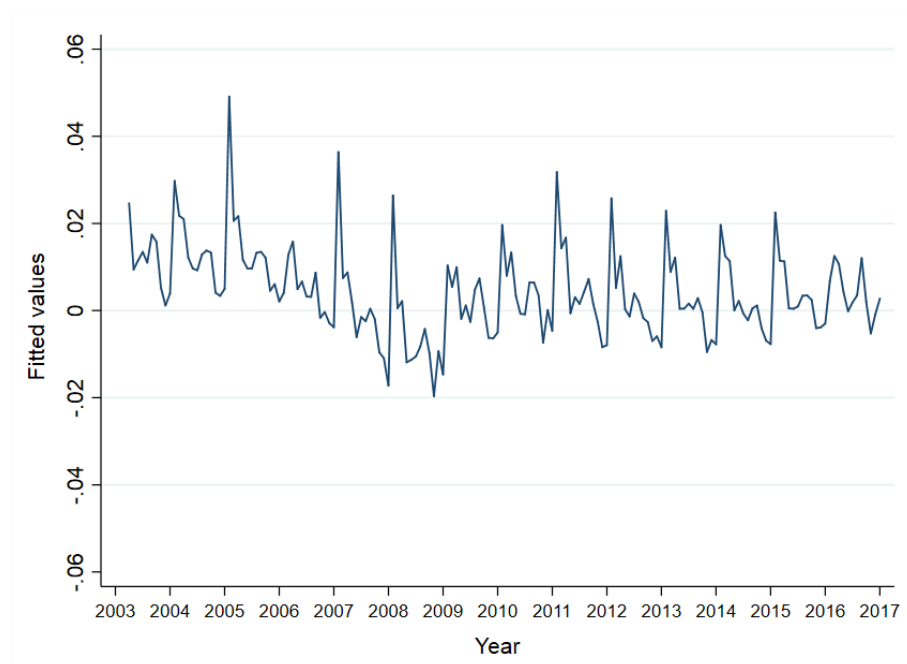


Table C.2: Breush-Pagan to Detect Possible Heteroscedasticity for Model I. The two columns to the right shows the test statistic and the p-value for Rogaland and Hordaland. We cannot reject the null hypothesis of constant variance.

	Rogaland	Hordaland
$Chi2(1)$	0.35	0.04
$Prob > chi2$	0.5535	0.8436

Null hypothesis: Constant variance

Figure C.5: Lag Plot for the Residuals Estimated in Model I for Rogaland to Detect Possible Autocorrelation. The residual estimates on the y-axis and fitted values on the x-axis. From the plot, we see that there is indications of autocorrelation present.

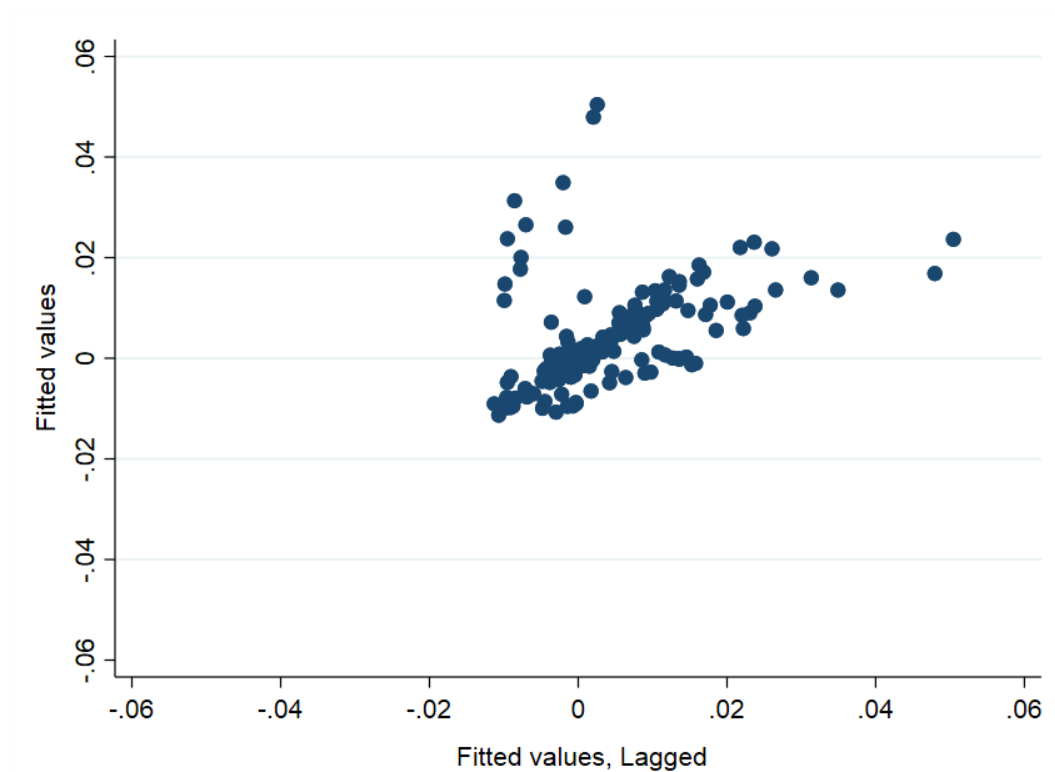


Figure C.6: Lag Plot for the Residuals Estimated in Model I for Hordaland to Detect Possible Autocorrelation. The residual estimates on the y-axis and fitted values on the x-axis. From the plot, we see that there is indications of autocorrelation present.

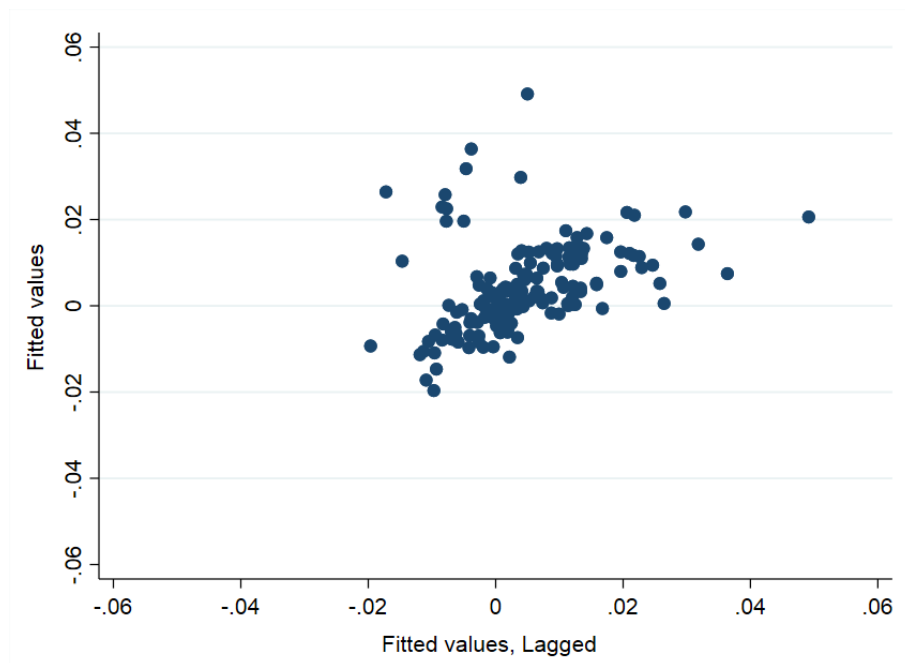


Figure C.7: Normal Probability Plot of Residuals in Model I for Rogaland to Detect Non-normality. The plot indicates problems with normally distributed residuals.

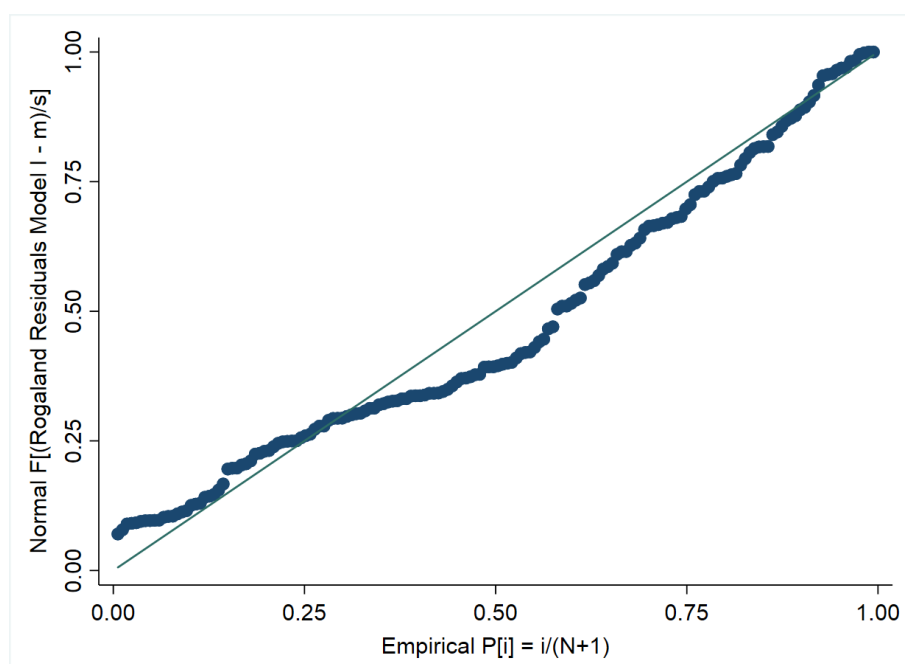
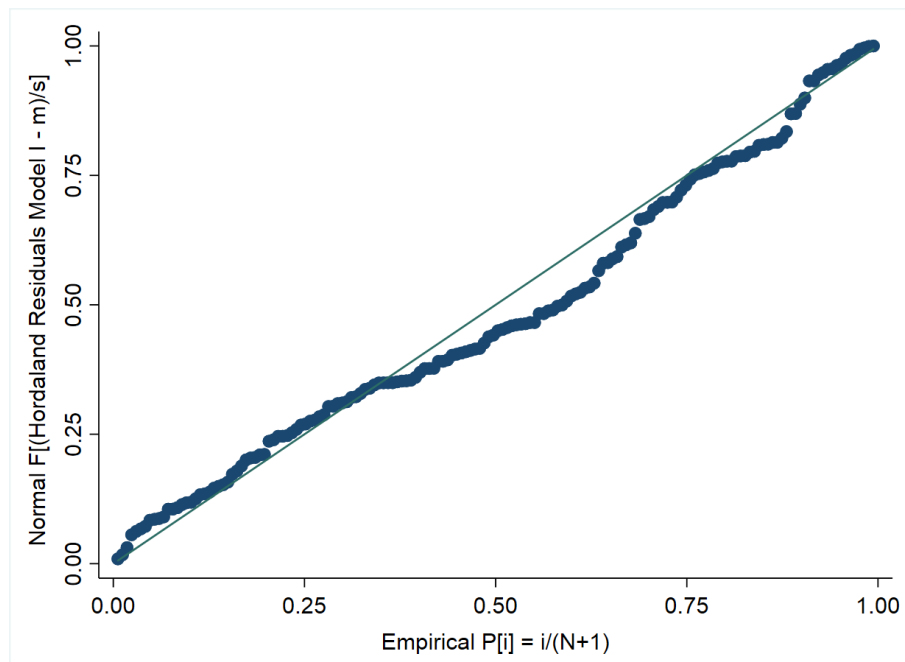


Figure C.8: Normal Probability Plot of Residuals in Model I for Hordaland to Detect Non-normality. The plot indicates problems with normally distributed residuals.



D Appendix

Diagnostic tests for Model II

Table D.1: Variance Inflation Factor (VIF) Test for Multicollinearity in Model II. In the left we have the variables for Model II. The two columns to the right shows the VIF-values for Rogaland and Hordaland. The mean VIF-value is presented at the bottom. As can be seen from the table, there is no issues with multicollinearity.

Variables	VIF Rogaland	VIF Hordaland
$Unemployment_{t-1}$	1.98	3.27
$\ln(Realestateprice)_{t-1}$	1.68	2.92
Season1	2.65	3.36
$Interestrates_{t-1}$	1.35	2.56
$Expectation_t$	1.15	1.09
Season3	1.81	1.82
$oilinvestments_t$	4.01	6.75
$\Delta \ln(income)_t$	1.69	2.14
$\ln(listed)_t$	1.32	1.58
Season2	2.48	1.44
$\Delta interestrate_t$	1.75	1.44
$\ln(income - housingstock)_{t-1}$	1.38	1.33
Mean VIF	1.94	2.65

VIF value below 4 indicates no problem with multicollinearity. VIF values up to 10 is often accepted.

Figure D.1: Sequence Plot for Rogaland to Detect Possible Heteroscedasticity. The estimated residuals from Model II on the y-axis and fitted values on the x-axis. The plot illustrates that there is no problems with heteroscedasticity.

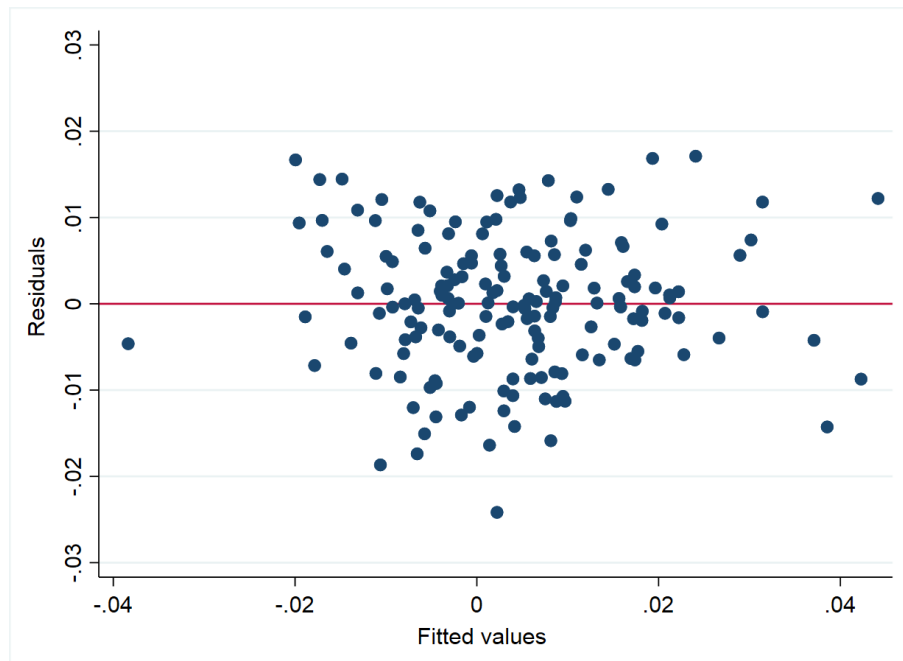


Figure D.2: Plot of fitted values vs. time for Rogaland to detect possible heteroscedasticity. The Fitted values on the y-axis and time on the x-axis. The plot illustrates that there is no problems with heteroscedasticity.

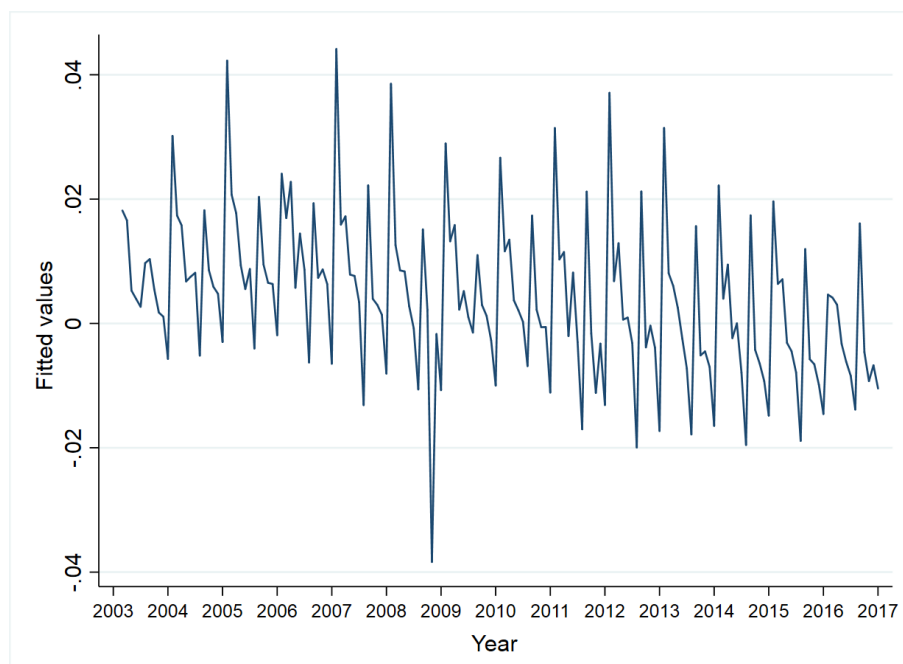


Figure D.3: Sequence Plot for Hordaland to Detect Possible Heteroscedasticity. The estimated residuals from Model II on the y-axis and fitted values on the x-axis. The plot illustrates that there is no problems with heteroscedasticity.

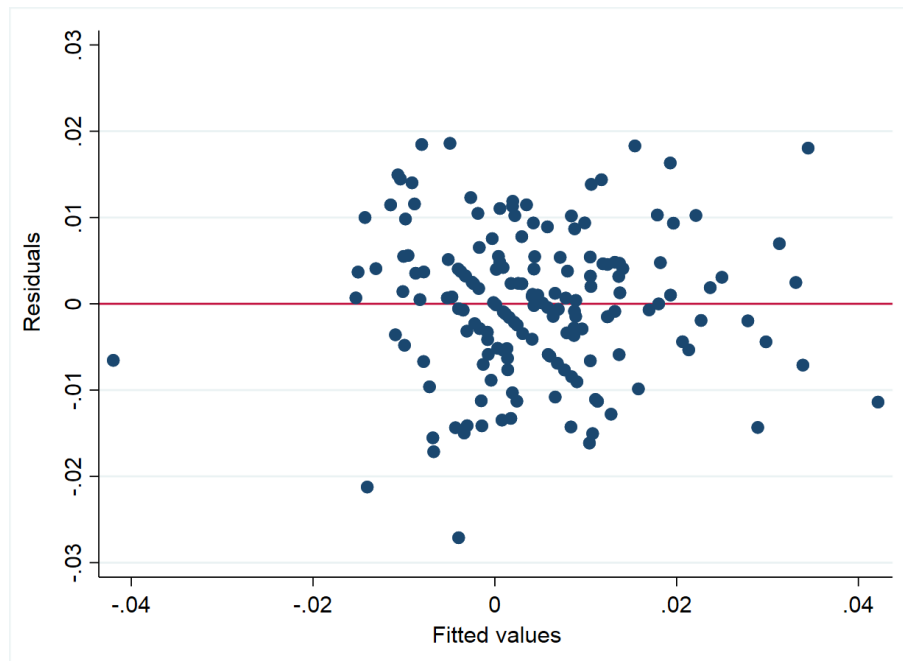


Figure D.4: Plot of Fitted Values vs. Time for Hordaland to Detect Possible Heteroscedasticity. The Fitted values on the y-axis and time on the x-axis. The plot illustrates that there is no problems with heteroscedasticity.

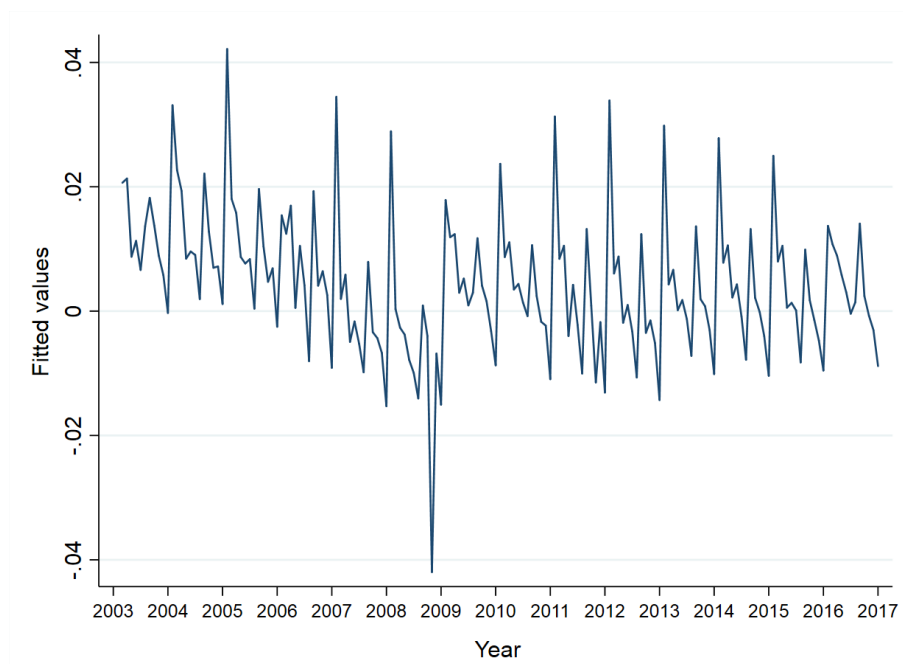


Table D.2: Breush-Pagan to Detect Possible Heteroscedasticity for Model I. The two columns to the right shows the tes statistic and the p-value for Rogaland and Hordaland. We cannot reject the null hypothesis of constant variance.

	Rogaland	Hordaland
$Chi2(1)$	0.45	0.85
$Prob > chi2$	0.5011	0.3565

Null hypothesis: constant variance

Figure D.5: Lag Plot for the Residuals Estimated in Model II for Rogaland to Detect Possible Autocorrelation. The residual estimates on the y-axis and fitted values on the x-axis. From the plot, we see that there is indications of autocorrelation present.

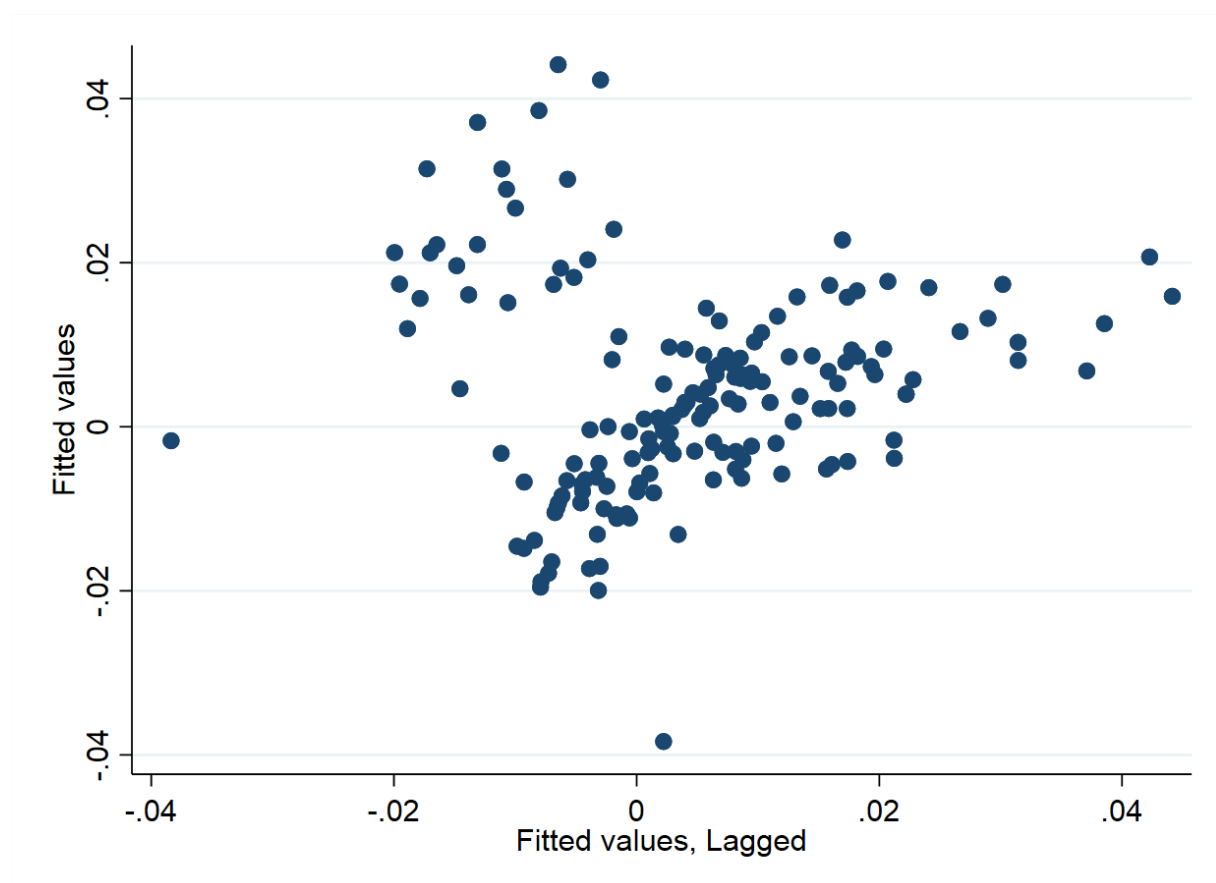


Figure D.6: Lag Plot for the Residuals Estimated in Model II for Hordaland to Detect Possible Autocorrelation. The residual estimates on the y-axis and fitted values on the x-axis. From the plot, we see that there is indications of autocorrelation present.

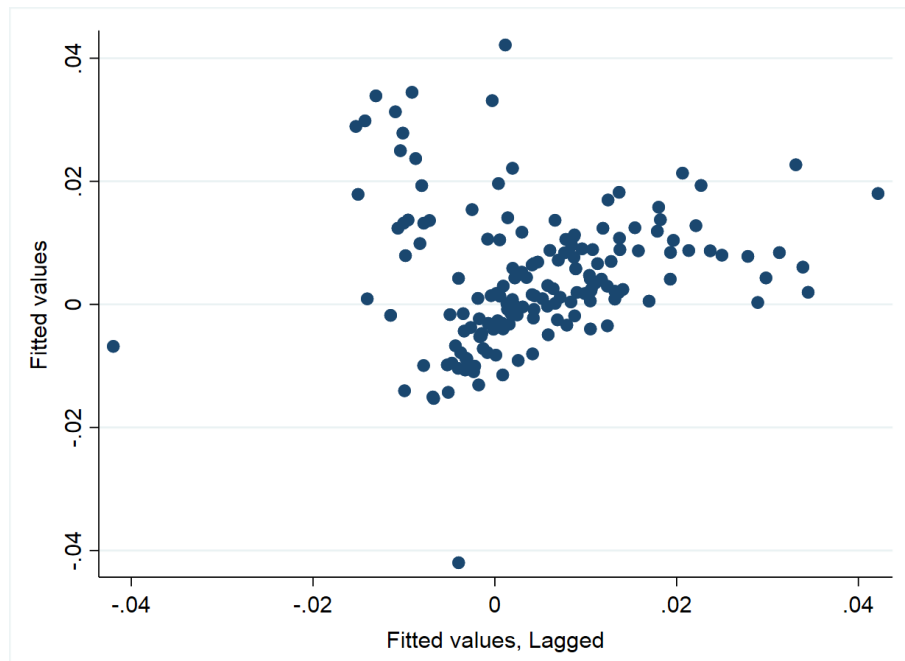


Figure D.7: Normal Probability Plot of Residuals in Model II for Rogaland to Detect Non-normality. The plot illustrates that the residuals are normally distributed.

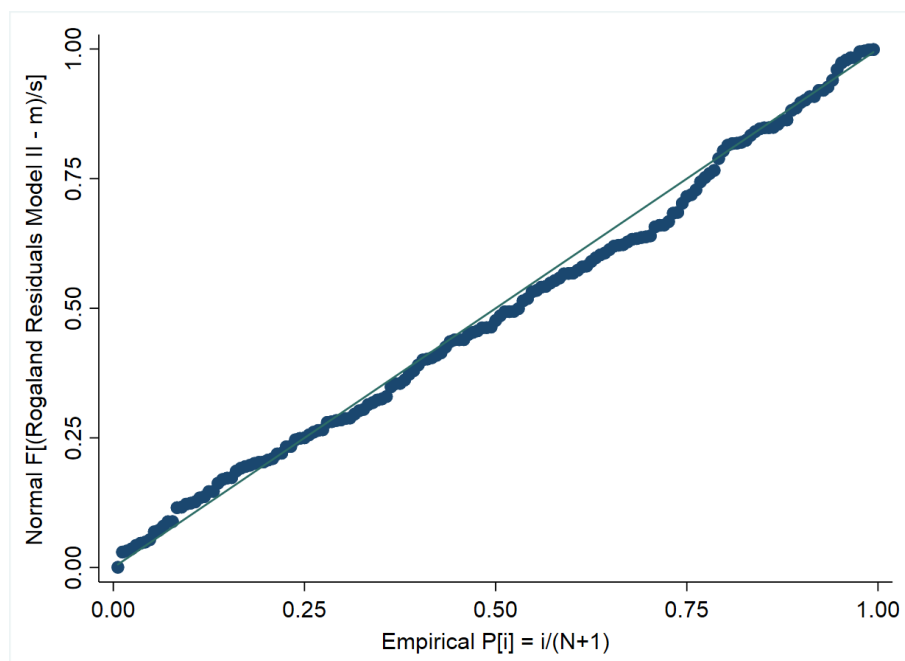


Figure D.8: Normal Probability Plot of Residuals in Model II for Hordaland to Detect Non-normality. The plot illustrates that the residuals are quite normally distributed.

