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An Empirical Analysis of the Northwestern European Housing Market

A Panel Vector Error Correction Model Approach

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Abstract

We examine the international relevance of the house price model by Jacobsen and Naug (2004). First, we evaluate if the model is relevant to describe the housing market in Norway when extending the sample. In contrast to previous studies (Anundsen & Jansen, 2011; Boug & Dyvi, 2008; Lebesby, 2010), we include the financial crisis in to account for the altered relationship between interest rates and house prices. The adjusted model shows a better fit and we find that the financial crisis had a negative effect on house prices. We apply the adjusted model to seven additional countries in the Northwestern European area and find evidence against the hypothesis of an international relevance for the model. The model does not capture short-run fluctuations and shows limited support for long-run dynamics. Hence, we conclude that the model is not able to explain dynamics in the housing market outside Norway. Next, we evaluate whether some of the variables explain dynamics in the overall Northwestern European housing market by changing the model specifications. We build a Panel Vector Error Correction Model and find that both lending rates and unemployment rate are determinants of house prices in the short-run, and that the trend in the lending rate, the unemployment rate, and the disposable income influence long-run house prices. Further, the size of several long-run variables is coherent with the size of the variables found by Jacobsen and Naug in the original paper from 2004, indicating that prices in the Norwegian market move proportionally with the estimated trend for the broader market, in the event of changes to the independent variables. In total, we provide evidence for the relevance of the variables in explaining dynamics in the Northwestern European housing market.

Preface

This thesis is written as a part of our Master of Science in Financial Economics at the Norwegian School of Economics and marks the end of our time at NHH. Initially, we had several economical topics that we wanted to investigate. After discussing topics throughout the summer, we concluded that we both shared a strong interest in the housing market due to its significant impact on individuals and the economy in general. From there, we did not look back and we started to evaluate how we were to attack this comprehensive topic. Writing this thesis has been highly educational, but also challenging at times.

First of all, we would like to thank our supervisor, Nataliya Gerasimova, for constructive feedback and support throughout this process. Your guidance has truly been helpful. We would also like to thank the European Mortgage Federation for interesting discussions and data. In addition, we would like to express our gratitude to European national statistical bureaux for valuable contributions in the process of gathering data. Lastly, we would like to thank lecturers and fellow students for all the good memories and for making the years at NHH unforgettable. We will miss you!

Didrik Hauglund Berge

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1. Introduction

Our analysis is divided into two parts. The first part addresses the international relevance of Norges Bank's preferred house price model for the Norwegian market, identified by Jacobsen and Naug (2004). We test the hypothesis: *The model proposed by Jacobsen and Naug is relevant in an international context and can be used to understand the effects of fundamental factors in multiple national housing markets in Northwestern Europe*. To the best of our knowledge, this is the first paper covering the broader applicability of Norges Bank's house price model, and we contribute to the literature by evaluating the model's potential for generalisation to national housing markets in the Northwestern European region.

Norges Bank concluded (2008) that the original model did not capture the effects of the financial crisis on the house prices. Hence, we further contribute to the literature on Norwegian house price models by accounting for the altered relationship between short-run interest rates and house prices during the financial crisis, as previous studies do not include it (Anundsen & Jansen, 2011; Boug & Dyvi, 2008; Lebesby, 2010). We find that the financial crisis impacted house prices negatively and caused a positive relationship between banks' lending rates and house prices, driven by cuts in the policy rate coupled with a drop in house prices. Hence, we conclude that the model must account for the financial crisis in 2008 to find comparable effects to the original model.

For the analysis of the Northwestern European market, we construct country-specific datasets by evaluating time series from national statistical agencies, international databases, and central banks, for each variable. In consensus with national statisticians and multiple experts on the European housing market, we identify comparable time series to ensure consistency. The estimated models yield similar results across the Northwestern European countries, with no support for short-run effects and significant long-run effects for multiple countries. We conclude that the model specification is unable to estimate the short-run fluctuations outside the Norwegian market, while the model shows signs of capturing long-run effects from the unemployment rate and the lending rates. Nonetheless, the model seems to over-estimate the effects due to low error correction terms, so we conclude that the model is unable to explain long-run dynamics outside the Norwegian market.

We use a unique dataset constructed by the European Mortgage Federation (EMF) on an annual frequency to evaluate our conclusions. We annualise the model and verify it by comparing the annualised Norwegian model with the quarterly Norwegian model. The annualised Norwegian model yields similar long-run effects to the quarterly models and validates the use of annualised models. Moreover, the results provide additional support for the relevance of the model in describing the Norwegian market. The findings from the annualised models for the remaining countries are consistent with the original conclusion and support the notion that the model has limited application outside the Norwegian market.

We conclude that the model is still relevant in describing the Norwegian housing market but that it cannot be generalised to the broader Northwestern European market with valid results.

For the second part of the analysis, we test the hypothesis; *The long-run dynamics in the Northwestern European housing market can be explained by recognised fundamental factors.* Based on our findings from the first analysis, and the presence of cointegrated relationships between the variables, we construct a panel vector error correction model (PVECM) that captures both short-run and long-run effects from changes to the unemployment rate, lending rate, disposable income, and number of completed dwellings, in the housing market. The analysis contributes to the existing literature by constructing a dynamic model suited to the analysis of the implications from multiple economic trends in the Northwestern European economy on house prices.

We analyse the effects and conclude that both the lending rate and the unemployment rate are determinants of house prices in the short run. Nonetheless, our hypothesis focuses on the long-run relationships between the trend in economic variables and house prices, and we identify significant relationships from the trend in the lending rate, the unemployment rate, and the disposable income to long-run house prices. The findings are in line with previous studies covering the European housing market and our expectations of the variables based on the country-specific analyses. By comparing the estimated long-run relationships for the lending rate and the unemployment rate to the results from the original paper by Jacobsen and Naug, we provide additional insights about the Norwegian house market. We find the effects of both variables to be similar to the estimated long-run effects for the Norwegian market, despite different, unrelated datasets and inherently different model specifications for the two analyses. A permanent one percent increase in unemployment rates and a one percentage point increase in lending rates are associated with a decrease of 0.5 percent and 5.6 percent in long-run house prices, respectively. The consistent results support the effects from the estimated PVECM, and if we assume both models to be relevant in explaining the housing market, the result implies that a permanent change to any of the explanatory variables in Northwestern Europe is expected to cause Norwegian house prices to move proportionally with the estimated trend for the broader market.

We contribute to the literature on the European housing market by constructing a long-run model for the effect from trends in the Northwestern European economy on house prices. Further, we evaluate the connection between the Norwegian housing market and the broader Northwestern European market and find similar effects from established fundamental factors. In conclusion, we accept the hypothesis that long-run dynamics in the Northwestern European housing market can be explained by several of the variables from the Norwegian model specification.

The remainder of this thesis is organised as follows. Chapter 2 describes the importance of the housing market, not just to the activity level of the economy, but also to households' and individuals' economy. Chapter 3 present a selection of the wide range of literature devoted to explaining effects in the housing market. The housing market is a popular field of study, and the chapter focuses on research for Northwestern Europe covering the variables included in the constructed models. Chapter 4 describes a theoretical framework that serves as a foundation to understand the dynamics of the housing market and the relevance of multiple factors. Chapter 5 outlines the methodology used to evaluate the hypotheses of the thesis and describes the properties of the relevant dynamic regression models in detail. Also, the chapter presents the underlying assumptions that must be fulfilled for the results to be valid. Chapter 6 presents the original model by Jacobsen and Naug from 2004 by summarising the results and explains how to interpret the effects correctly. Chapter 7 introduces the variables that constitute the dataset and describes how some variables are transformed to be on a comparable format across countries, while Chapter 8 evaluates whether the same variables must be differenced to avoid potential spurious relationships resulting from non-stationarity. Chapter 9 presents the re-estimated models and evaluates the relevance of the model specification for eight national housing markets in the Northwestern part of Europe over an extended period. Chapter 10 outlines the process of deriving the alternative house price model for the Northwestern European countries. In addition, the chapter interprets the final results and evaluates the effects to determine if the long-run dynamics of the overall market can be explained by trends in the economy. Finally, Chapter 11 concludes with the hypotheses and findings of the thesis.

2. The Northwestern European Housing Market

The housing market has important economic implications for the well-being of a nation. Housing investments reflect the country's economic development and are an integrated part of the economy, making up about six percent of the total GDP per year in European countries (Kohlscheen, Mehrotra, & Mihaljek, 2018). The housing market affects the economy primarily through investment in housing from construction companies and by altering the consumption and private investments of individuals.

Firstly, investments in the housing market stimulate economic activity, mostly due to spillover effects to occupations involved in purchases, sales, and construction of dwellings, but also from investments in improving the quality of the residence. The construction of new dwellings directly contributes to growth in the economy, with construction companies buying land and building materials, and employing workers. In addition, establishing new communities stimulates additional economic activity as new infrastructure and services are needed. The second-hand market for dwellings also contributes to economic growth by generating demand for real estate agents, lawyers, moving companies, and new interiors, coupled with taxes and transaction fees.

Secondly, a house purchase represents the biggest investment during an average person's life (Folger, 2019). Consumers usually invest heavily in their dwelling, and the development of the housing market has substantial consequences for the wealth of households. The implications for household wealth have spillover effects on consumer spending with increased consumption in the case of a price appreciation, as homeowners become wealthier and more confident (Bank of England, 2019). Further, households evaluate their savings relative to their outstanding debt, where mortgage tend to constitute the largest share. A fall in house prices will reduce the asset value relative to the mortgage, which likely will reduce spending and personal investments to avoid default.

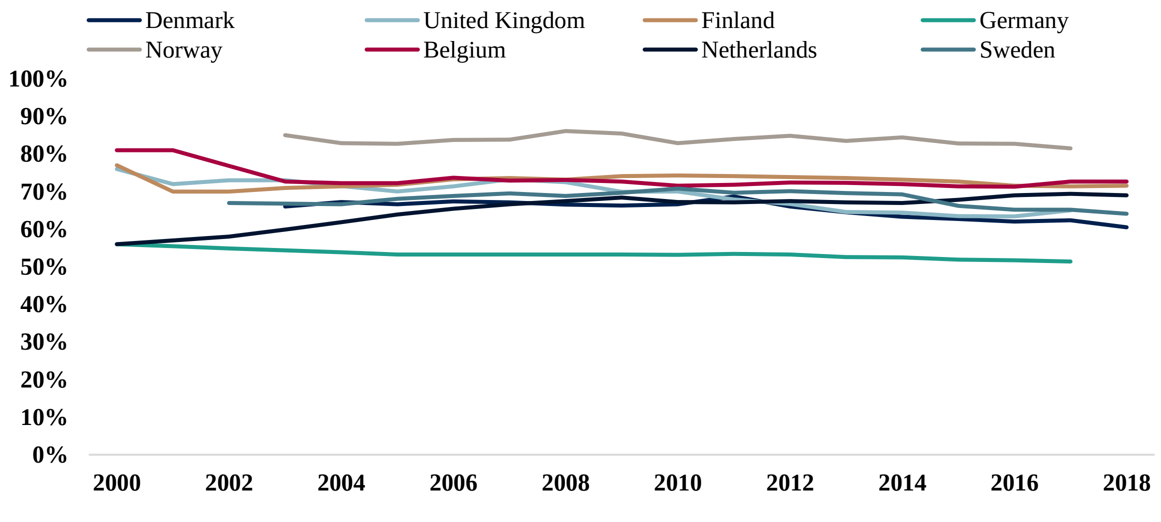
From its impact on investments and consumption activity, it is evident that the housing market is of great importance to the business cycles and economic activity of a country. The importance of the housing market has prevailed for centuries, supported by financial incentives and cultural norms. The next sections outline the financial benefits and risks of house ownership and how recent demographic trends have influenced the Northwestern European housing market.

2.1 Financial Benefits of Owner-Occupied Dwellings

The benefits of house ownership are widely recognised across nations, as displayed by the stable share of owner-occupied dwellings relative to rental in **Figure 1**. The purchase of a dwelling is perceived to be a sound investment, and politicians in the western world have emphasised the importance of house ownership for financial security and wealth-building opportunities, primarily referring to the financial benefits of ownership compared to renting. The financial benefits have contributed to high owner-occupation rates in Europe, which can be assigned to five aspects of financing primarily related to the use of mortgages (Herbert & Belsky, 2006).

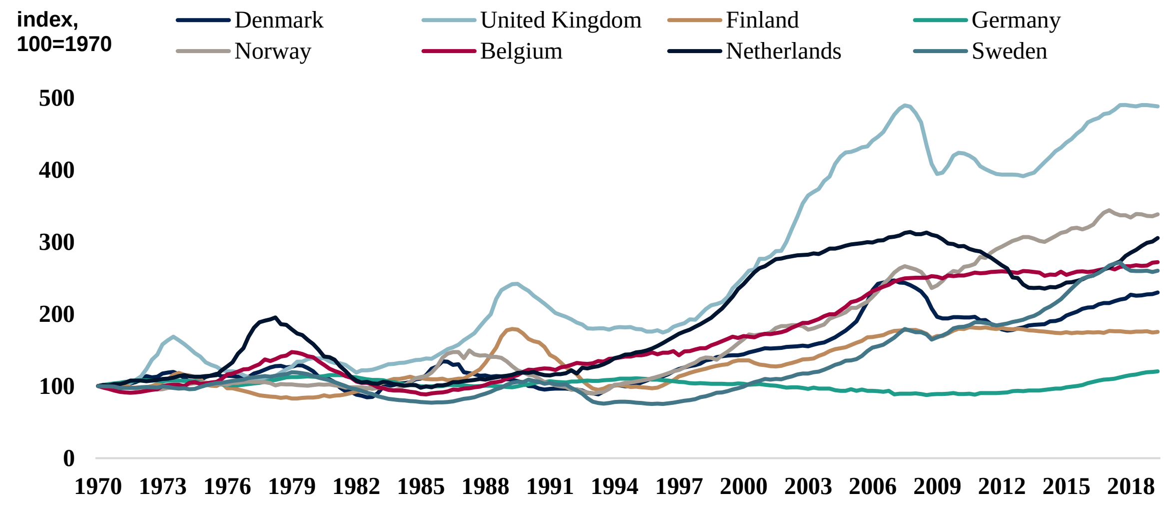
Historically, most dwellings have increased in value over time. **Figure 2** shows the development in real house prices, and the growth in nominal house prices has, on average, outperformed inflation for most countries. The yearly difference between house prices and inflation may appear modest but accumulates to a remarkable effect on household wealth over a lifetime.

Figure 1: Owner-Occupied Dwellings as Percentage of Total Dwellings



Source: European Mortgage Federation (EMF)

Figure 2: Quarterly Development in Real Housing Prices Between 1970-2018



Source: The Organization for Economic Co-operation and Development (OECD)

Further, the effect of real price appreciation on household wealth improves if the purchase is debt-financed. Mortgages are widespread across most countries, as most families are unable to buy a house purely with equity. The gearing effect from mortgage increases the return from the house purchase but is not without risks. Most banks limit the gearing of households by imposing a minimum equity share when lending to new customers, reducing the probability of a default. Nevertheless, gearing has a significant effect on household wealth over time, and as long as the real house prices increase and one does not default, a high Loan-to-Value (LTV) ratio yields higher returns.

Mortgage interest tax deduction further enhances the financial benefits from the use of debt for house purchases. Governments allow taxpayers who own their own home to adjust their taxable income by the amount of interest paid. However, the deduction of mortgage interests is not allowed in all European countries, and the amount deductible varies with national tax policies. In the countries that allow for deductions, the tax deduction functions as an indirect subsidy of house purchase, fueling housing demand.

Mortgages also function as a form of forced saving for households. The part of the monthly mortgage payment that goes towards principal reduction reduces the total amount of debt and increases the net worth of the household. The size of the principal effect is dependent on the type of mortgage, with the most common being serial loans and amortisation loans. A serial loan has constant principal payments and varying interest payments. Hence, the savings are constant across the mortgage period. Amortisation loans are more prevalent in Europe with a fixed monthly payment, where the principal payments account for an increasing part of the monthly payment as the mortgage decreases. Thus, the savings effect from amortisation loans increases over time, with a larger portion of the total mortgage payment going toward principal reduction.

The final financial benefit from homeownership comes from the stability and predictability of future payments[1] relative to rental payments. If a household is unable or unwilling to buy a dwelling, the relevant alternative is the rental market. The variation in rental prices is less predictable than mortgage payments and high volatility in the rental market causes more households to buy their dwelling (Sinai & Souleles, 2005). Also, rental payments do not contribute towards the household wealth and tend to follow the development in housing prices. While housing costs from mortgages decline in real terms over time, the housing costs from rental tend to increase over time (OECD, 2019).

2.2 Risks Associated with Owner-Occupied Dwellings

The benefits presented in section 2.1 are not without risks, a fact that has been proven repeatedly through history, and most recently during the financial crisis in 2008. The bust in house prices was widespread in Europe, with, for example, UK property prices dropping 20 percent in 16 months (Morrison, 2018). Logically, this wiped out values accumulated by house owners over several years.

Declining house prices are the exception rather than the rule, and rising prices over time have led households to take on more debt when buying a dwelling. The increase in debt levels is supported by historically low interest rates in the European market, containing the interest burden of borrowers (Klovland, 2019). Consequently, households have faced few difficulties with managing their mortgages, but high gearing levels put households in severe risk of default in the event of rising interest rates, potentially leaving families in financial distress.

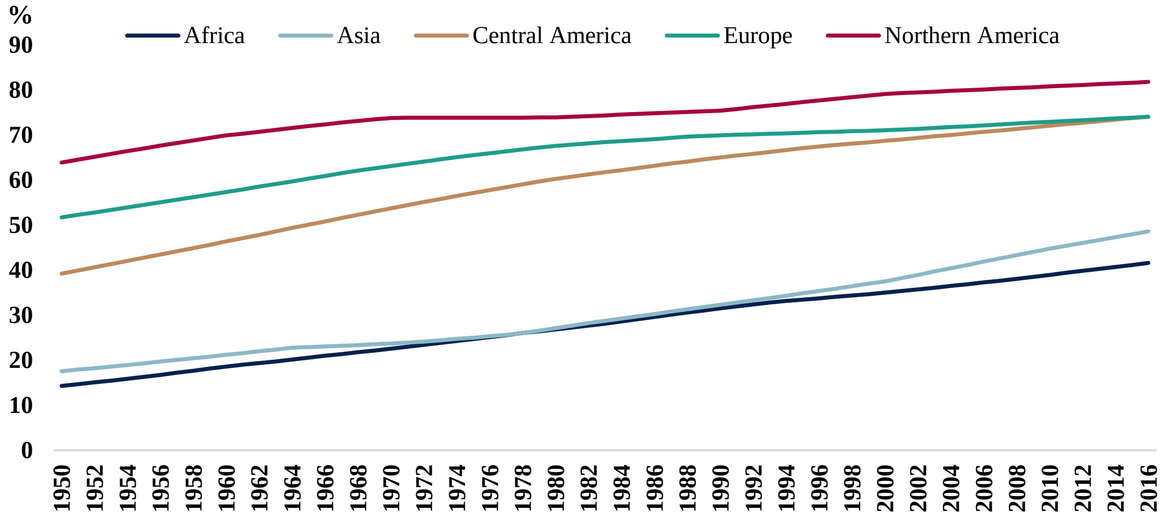
[1] The level of predictability of mortgages is dependent on the choice of interest rate, as floating interest rates loans fluctuate with market dynamics.

House purchases cause households to be heavily invested in a specific geographical location with limited opportunities for wealth diversification. The dwelling is subject to local variations, and the owner is unable to diversify the risk of these fluctuations across different housing markets. Further, the gearing effect from mortgages increases the impact of local fluctuations on household wealth, where small price changes have a significant impact on the equity share. Households have limited geographical mobility if they are to retain the value appreciation due to high transaction costs. A considerable part of the house value is lost when moving, due to transaction fees and taxes, which reduce the incentives to move between regions during turbulent times.

2.3 Recent European Demographic Trends

The industrialisation over the last century has affected the way of living. One apparent trend is how communities have grown in size all over the world, and today, cities are the centrepiece on all continents. The term for this trend is urbanisation and it reflects migration from rural to urban areas within a specific country (Cambridge Dictionary, 2019). The urban population increases rapidly on a global scale, illustrated in **Figure 3**, and the United Nations (2018) estimate the urban proportion to increase from about half of the world's population today to more than two-thirds by 2050. Urbanisation has led to an increase in the number of megacities around the world, reflecting the emergence of the modern economy with more opportunities in big cities relative to the rural areas. The shift from agricultural employment to more service-based industries results in a broader range of employment opportunities and access to social and cultural activities. Further, improved infrastructure, a safe neighbourhood, and access to medical care provide a stable environment for the families living in urban areas.

Figure 3: Development in Urbanization

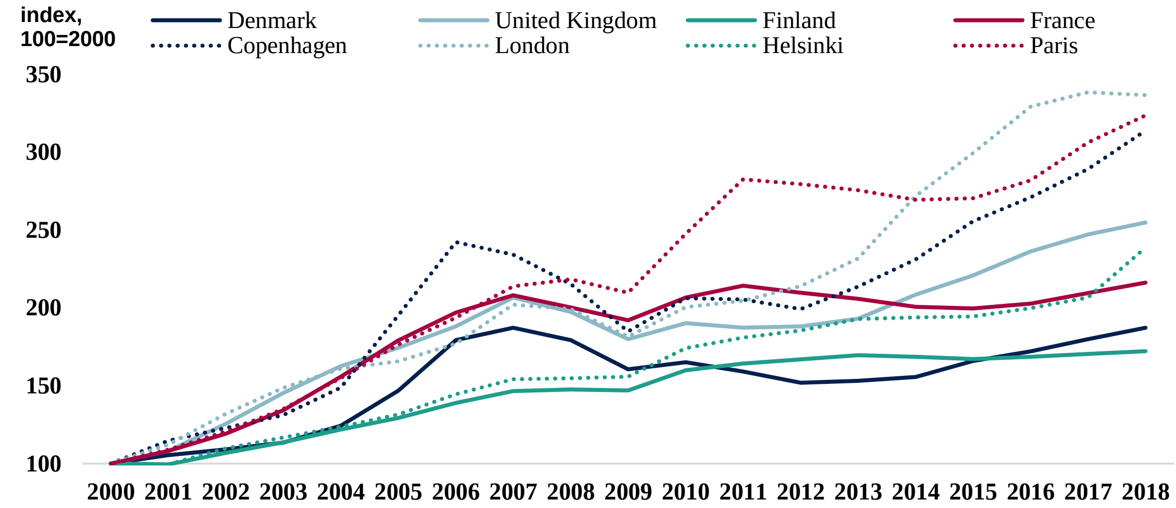


Source: United Nations (UN) and Our World in Data

The changing demographics lead to an imbalance between the rural and urban areas, with people leaving their homes in the countryside to live in more geographically limited areas. The shift in housing demand imposed a local price pressure in urbanised areas, typical for several European cities over the last decades. To cope with the increased demand in geographically limited areas, construction companies built upwards as land was limited and expensive. The transition from living in houses to apartments led to a segregated national housing market, displayed in **Figure 4** for some European countries, with house prices in cities outpacing the rest of the country.

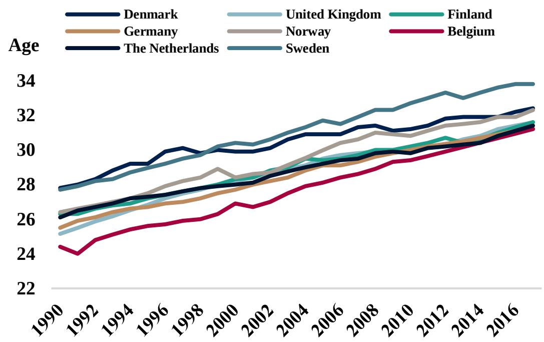
The European family pattern has also changed with the trend in urbanisation, altering the way of living. Historically, the need for a dwelling usually came with marriage or the first child, but getting married and starting a family is less pressing for young adults in modern society. The age at first marriage and first childbirth for women in several European countries is illustrated in **Figure 5** and **Figure 6**, and indicate that the establishment phase of young couples is introduced later in life. The establishment phase usually implies the need for a dwelling, and with less haste to establish a family, young adults in Europe are slower to enter the housing market. This trend is also reflected in the statistics about young adults that choose to live with their parents, a growing concern in several European countries, with experts warning about the consequences (Mohdin, 2019). Nonetheless, young adults today appear to be less concerned with homeownership, changing the characteristics of the European housing market.

Figure 4: Development in Nominal House Prices for Selected Countries and Capitals



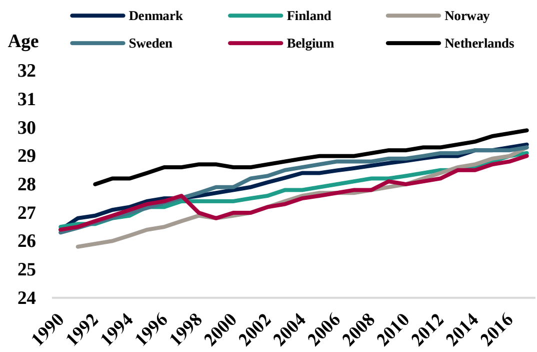
Source: European Mortgage Federation (EMF)

Figure 5: Women's Age at First Marriage



Source: OECD

Figure 6: Women's Age at First Child



Source: OECD

2.4 The Importance of Understanding the Housing Market

The development in house prices is important to several participants in a country´s economy. As explained in preceding sections, it is important for households. The dwelling represents an important source of wealth to homeowners, and the future development in house prices affects the wealth accumulation. Some homeowners want to benefit from the wealth accumulation by increasing consumption through mortgage-backed loans, and predictable house prices help households to utilise their mortgage as a source of capital and to plan their finances.

The banks are also exposed to house prices and closely monitor the development to estimate potential loan losses in the future, being the issuer of the mortgage-backed loans. Banks would incur significant losses should the collateral value of a dwelling fall below the remaining mortgage value coupled with households defaulting on their debt payments. Consequently, expectations of future house prices are an essential variable for banks when deciding on their mortgage policy for households.

Next, expectations of future house prices are important to the activity level in the economy and are of interest to investors. A construction company chooses to initiate a project if the expected sales price is attractive relative to the building cost, commonly expressed using Tobin’s Q (Corder & Roberts, 2008). A Tobin’s Q greater than one stimulates housing investments and the construction of new dwellings. Hence, future house prices and the certainty of the estimates is an important determinant of investment activity.

Finally, the drivers of house prices are important to the authorities to gauge the health of the economy. The state of the housing market is closely monitored by governments, given the importance of the housing market both to the general economy and to individuals. Financial and monetary policies take the health of the housing market into account to avoid house price bubbles, as they tend to have severe consequences for the national economy. Special care is taken due to the characteristics of the sector, with high leverage ratios and a large number of private participants opposed to professional investors (Brunnermeier & Oehmke, 2012). The problem is that the state of the housing market is unobservable by nature and requires an indirect assessment using other perspectives. A common approach is to evaluate the development of house prices with the fundamental factors expected to determine prices.

A price bubble is forming if the house price development is detached from the development in the fundamental factors, and Stiglitz (1990) describes the issue of housing bubbles based on speculation, stating that "*if the reason that the price is high today is only because investors believe that the selling price will be high tomorrow – when 'fundamental' factors do not seem to justify such a price – then a bubble exists*".

To evaluate the health of the housing market, fundamental factors ought to be identified. Jacobsen and Naug addressed the issue for the Norwegian housing market in 2004, and similar research has been conducted for housing markets all over the world. In the following section, we gauge the empirical support for the fundamental factors identified by Jacobsen and Naug (2004) and elaborate on how this thesis contributes to the field by modelling the broader Northwestern European housing market.

3. Literature Review

The housing market is a popular field of research, and several studies over the past decades identify determinant factors. The models estimated in this thesis are based on the fundamental factors identified by Jacobsen and Naug in 2004. Consequently, the literature review focuses on the empirical support for the relevance of interest rate, disposable income, unemployment rate, construction activity, and household expectations, especially emphasising Norwegian studies and European studies. We include country-specific research on housing markets outside Norway, and focus on the Northwestern European region, as these housing markets are relevant for our thesis. Finally, we elaborate on how we contribute to the existing literature by analysing the housing markets in the Northwestern European region.

Interest rate

Most studies find interest rates to be negatively correlated with the development in house price because they represent the cost of financing. The relationship is documented in multiple studies across European countries. In Norway, Jacobsen and Naug (2004) find a negative relationship between nominal interest rate and house prices in their original model, and between real interest rate and house prices in an alternative model. This is supported by Anundsen and Jansen (2011), who find a negative long-run relationship between the real interest rate and house prices. Further, Boug and Dyvi (2008) with Statistics Norway find a negative relationship between the real interest rate and the price of existing dwellings.

Outside Norway, country-specific studies find similar effects from interest rates on house prices. Meen (2002), Wagner (2005), Oikarinen (2005), and Verbruggen, Kranendonk, & Toet (2005) all find a negative elasticity of real house prices relative to real interest rate for the UK, Denmark, Finland and the Netherlands, respectively. The estimated elasticities are comparable to the estimated elasticity of -3.2[2] for real interest rate, found by Jacobsen and Naug (2004). These findings are further supported by Barot and Yang (2002) who identify a negative relationship between real interest rate and real house prices in a study of housing markets in the UK and Sweden.

[2] The results range between -2.2 and -7.7.

The results from the country-specific studies are supported by studies of the broader European market. Adams & Füss (2010) find the relationship between long-run interest rates and demand for house prices to be present in 15 European countries, while Égert & Mihaljek (2007) find a similar effect for most countries in Europe. However, they find the effect to be much more severe in Eastern and Central Europe, compared to all OECD countries. The relevance of interest rates for house markets in the OECD countries is supported by Andrews (2010) who finds the negative effect of long-run real interest rates to be present in several countries. Moreover, Hilbers, Hoffmaister, Banerji, & Shi (2008) argue that a dual role of interest rate exists in the European market, with mortgage rates being an indicator of financing costs and the risk-free rate determining the opportunity cost.

Income

The disposable income is expected to be positively correlated with house prices because higher income leads to higher demand for dwellings. Jacobsen and Naug (2004) find a positive correlation for the Norwegian housing market, further supported by the research of Boug and Dyvi (2008). The results are similar across Scandinavia, as Clausen (2013), Wagner (2005) and Oikarinen (2005) find a positive correlation between disposable income and house prices for Sweden, Denmark and Finland. Moreover, Hunt and Badia (2005) find a similar effect from real income to real house prices in the UK, and Hofman (2005) reaches the same conclusion for the Dutch housing market. The results for Sweden and the UK are further supported by specific studies evaluating the Swedish and the UK markets, conducted by Holly and Jones (1997) and later by Barot and Yang (2002).

In the Euro area, Annett (2005) finds the expected positive correlation with house prices, which is supported by Égert and Mihaljek (2007) who use GDP per capita as a proxy for changes in income and find the expected positive correlation with house prices. Further, Égert and Mihaljek argue that the effect from income on house prices is more important in countries with high growth in per capita GDP. Terrones and Otrok (2004) evaluate a panel of 18 countries and find the positive effect from income across the countries.

Unemployment Rate

The unemployment rate mirrors the uncertainty in the economy through expectations of wage income and increased uncertainty regarding the ability to carry debt. Therefore, rising unemployment rates are mainly found to affect house prices negatively. In Norway, Jacobsen and Naug (2004) find the negative correlation between the unemployment rate and house prices. They argue that a rising unemployment rate will affect future wage growth negatively, again influencing house prices through added uncertainty. The results are similar to research into the housing market in Sweden and the UK by Barot and Yang (2002). In Sweden, they find a negative effect from unemployment rate in the short-run, and in the UK, they find negative short-run and long-run effects from unemployment rate on house prices. Several European studies find a similar effect on the housing market. Égert and Mihaljek (2007), Adams and Füss (2010), and Andrews (2010) all find a negative correlation between unemployment rate and house prices in the broader European market.

Construction

Theory on housing supply assumes that the housing stock is mostly fixed in the short run but will affect house prices in the long run (Corder & Roberts, 2008). Tobin's Q (1969) is often used to model the changes to the housing stock using the cost of construction and house prices. Previous research varies in how changes to the housing stock is included, but common approaches include changes to the total housing stock, the number of dwellings completed in the period, the number of dwellings started in the period, or the cost of construction. The cost of construction is expected to be positively correlated with house prices, while the remaining approaches are expected to have a negative correlation. Higher building costs for new dwellings will limit the number of new dwellings and, hence, reduce the supply, while an increase in the number of new dwellings started or completed will increase the total supply of dwellings.

Jacobsen & Naug (2004) estimate changes in supply for the Norwegian market using a combined variable of disposable income and housing stock and find the housing stock to be negatively correlated with house prices. Country-specific models for European countries support the results, where Verbruggen, Kranendonk, & Toet (2005) , Meen (2002), and Wagner (2005), find a negative elasticity of real house prices relative to housing stock supply to be present in the Netherlands, the UK, and Denmark. Adams and Füss (2010) evaluate the relevance of construction costs by analysing the effect of changes in prices of materials and labour for the broader European market and find the expected positive correlation.

Expectations

The expectation variable is relevant for our section covering Jacobsen and Naug's model. They argue that expectations can be based on fundamental factors, not just on future price increases, and Anundsen and Jansen (2013) support the argument and test a similar variable for expectations. Outside Norway, the impact from expectations on house prices is mostly analysed in research regarding house price bubbles. House price bubbles tend to form when demand for dwellings increases today because individuals expect house prices to rise in the future. An example of a study that focuses on expectations is Case & Shiller (1988), which found that buyers in booming housing markets expect greater price appreciation than buyers in a controlled market for the US.

Our Contribution

Our contribution to the existing literature is twofold. First, we evaluate the broader applicability of the model created by Jacobsen and Naug (2004) for the Norwegian market and test a hypothesis regarding the relevance:

Hypothesis 1: *The model proposed by Jacobsen and Naug is relevant in an international context and can be used to understand the effects of fundamental factors in multiple national housing markets in Northwestern Europe.*

To the best of our knowledge, this is the first report that evaluates the model in an international context, and we contribute to the literature by analysing its relevance in describing the housing market in seven countries in Northwestern Europe, in addition to the Norwegian market. Moreover, we add to the literature on Norwegian house price models by accounting for the implications of the financial crisis in 2008. The crisis led to an altered relationship between lending rates and house prices, and Norges Bank (2008) concluded that the model does not estimate house prices accurately during the period. Hence, we expand the original model by including variables that are specific to the financial crisis.

Second, we construct a house price model for Northwestern Europe that is suitable for analysis of the effect of multiple economic trends on house prices. We separate short-run and long-run effects in the housing market by creating a Panel Vector Error Correction Model (PVECM) and use the variables from the first analysis as a base to test a hypothesis of long-run dynamics in the region:

Hypothesis 2: *The long-run dynamics in the Northwestern European housing market can be explained by recognised fundamental factors.*

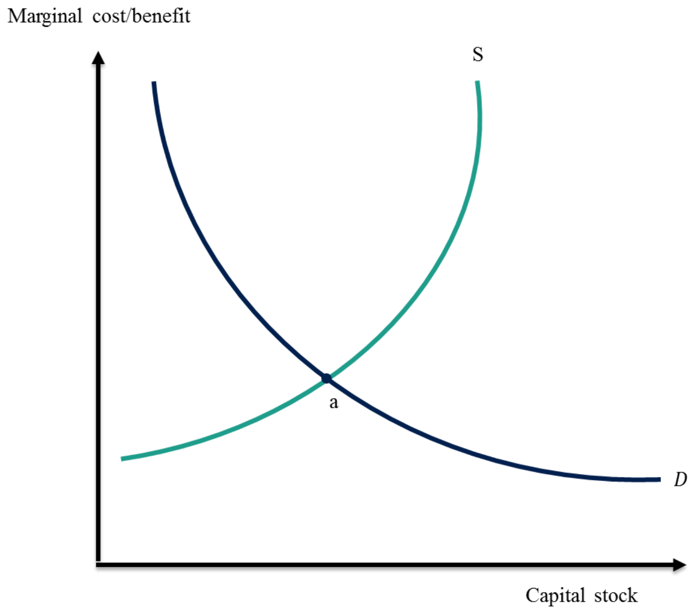
We contribute to the existing literature by constructing a dynamic model suited for the analysis of the implications from multiple economic trends in the Northwestern European economy on house prices. We evaluate multiple model specifications to derive a model that precisely captures both short-run effects and long-run effects on house prices in Northwestern European countries.

4. Supply and Demand in the Housing Market

The housing market is complex, with government regulations and the potential for asymmetric information between buyer and seller. In addition, multiple characteristics such as location and size split the dwelling stock into heterogeneous products (Kurlat & Stroebel, 2014). Further, there are substantial transaction costs associated with dwelling transactions for both buyers and sellers, such as real estate commission, fees, and local taxes. Modelling the housing market perfectly involves great complexity, and is likely to be impossible. Therefore, simplifying assumptions are implemented in order to understand more easily the dynamics of the housing market.

A supply and demand framework with homogeneous products and no transaction costs or regulations serves as the foundation to describe the market. **Figure 7** provides a simple illustration of the market, and the equilibrium price in the housing market is determined from the intercept between sellers and buyers. Either an increase in supply or a decrease in demand leads to reduced house prices, while reduced supply or increased demand result in increased prices. We explain the characteristics of supply and demand in the housing market in detail in the following sections.

Figure 7: Supply and Demand Framework



4.1 Supply

The supply curve in the housing market illustrates the quantity of dwellings available for different prices, and we use Boug & Dyvi (2008) as our theoretical foundation to explain the supply-side mechanisms. The supply of housing consists of both new and existing dwellings, and it is assumed that the supply is driven by the house price and the cost of investing in new dwellings. The cost of new dwellings is primarily driven by building costs and cost/price of land. The following can be generalised as:

$$J_{starts} = J(P_K, P_I, P_S), f_K > 0, f_I < 0, f_S < 0 \quad (1)$$

$P_K = House\ Price$

$P_I = Building\ Costs$

$P_S = Cost/Price\ of\ Land$

$f_j = the\ derivative\ of\ P_j\ with\ respect\ to\ j$

$j = K, I, S$

The relationship above states that an increase in house prices, given fixed investment costs, will lead to increased investment in new dwellings. Conversely, an increase in investment costs, given that house prices are fixed, leads to a decrease in new dwelling investments.

Modelling the supply of dwellings is difficult in practice (Quigley, 1979). Firstly, there are different methods of measuring the housing supply. For example, the number of started dwellings and completed dwellings are metrics to measure changes in supply. However, the housing stock is also affected by decisions made by owners regarding the conversion of the existing housing stock (Kim, Phang, & Wachter, 2012). The conversion can typically be demolition, abandonment, repair, or renovation, or that the dwelling is used for something other than living accommodation. Also, the supply is determined by both the cost of land and cost of construction, for which it is difficult to obtain valid data (Kim, Phang, & Wachter, 2012). Difficulty with finding reliable data for modelling limits the possibilities, and hence we assume that the supply of housing is exogenously given in the models.

The supply of dwellings has different characteristics in the short run relative to the long run. Dwelling investment is a bureaucratic procedure with government regulations, technical requirements, and limited construction capacity, which reduces the responsiveness of the supply side in the short-run. Hence, the supply of dwellings is assumed to be limited to existing dwellings in the short run. The supply of dwellings adjusts to changes in the market over time, for example by completing more dwellings in the event of increased demand. Hence, in the long run, the supply is comprised of existing dwellings and new dwellings.

4.2 Demand

The demand curve illustrates the demanded quantity for a given price. The housing market is a special market as everyone needs a place to live, and in general, people can cover this necessity by either renting or owning a dwelling. Further, Jacobsen and Naug (2004) state that the demand is separated into two components: demand for owner-occupied dwellings and demand for dwellings as an investment object. They assume that the first component is much larger than the latter and, as such, the theory focuses on the demand for owner-occupied dwellings. The following function explains the demand for dwellings:

$$H^d = f\left(\frac{V}{P}, \frac{V}{HL}, Y, X\right), f_{\frac{V}{P}} < 0, f_{\frac{V}{HL}} < 0, f_Y > 0, \tag{2}$$

$H^D = housing\ demand$

$V = total\ housing\ cost\ for\ a\ typical\ owner$

$P = an\ index\ of\ prices\ of\ other\ goods\ and\ services$

$HL = total\ housing\ costs\ for\ a\ typical\ tenant$

$Y = households'\ disposable\ income$

$X = a\ vector\ of\ other\ fundamental\ factors\ that\ affect\ housing\ demand$

$f_i = the\ derivative\ of\ f_i\ with\ respect\ to\ i$

$i = \frac{V}{P}, \frac{V}{HL}, Y$

Equation (2) states that if the cost of owning a dwelling increases relative to the cost of rent or other goods and services, the demand for dwellings will decrease. Further, an increase in real disposable income leads to an increase in demand for dwellings. The X vector captures other observable factors that may have an impact on demand. Examples of such factors are demographic variables, the banks’ lending policies, and the population’s expectations of future income and housing costs.

The cost of ownership measures the value of goods that the owner relinquishes by owning and occupying the dwelling in a period. The relationship is expressed in the following equation:

$$\frac{V}{P} \equiv \frac{\mathrm{PH}}{\mathrm{P}} BK = \frac{PH}{P} [i(1-\tau) - E\pi - (E\pi^{PH} - E\pi)] \qquad (3)$$

$BK = housing\ cost\ per\ real\ unit\ of\ currency\ invested\ in\ housing$
$PH = price\ of\ an\ average\ dwelling\ (measured\ in\ kroner)$
$i = nominal\ interest\ rate\ (measured\ as\ a\ rate)$
$\tau = marginal\ tax\ rate\ of\ capital\ income\ and\ expenses$
$E\pi = expected\ inflation\ (expected\ growth\ in\ P\ and\ HL\ measured\ as\ a\ rate)$
$E\pi^{PH} = expected\ growth\ in\ PH\ (measured\ as\ a\ rate)$

The $i(1-\tau) - E\pi$ represents the real after-tax interest rate and measures both the cost of interest payments from a housing loan and the real interests that the borrower forgoes by having equity placed in housing. $E\pi^{PH} - E\pi$ is the expected real price growth of the average dwelling, indicating that the cost of owning a dwelling is reduced if the expected real growth of housing increases. This leads to an increase in demand for housing.

Finally, the effects mentioned above are assumed similar to the demand for dwellings as an investment object. The demand increases with increased income and if rents increase relative to house prices. Similarly, lower interest rates and higher expected prices in the housing market make it more attractive to invest in dwellings compared to depositing money, increasing demand for housing as an investment object. Therefore, equations (2) and (3), which describe the demand for owner-occupied dwellings, are representative of the overall demand in the housing market.

4.3 Equilibrium in the Short Run and the Long Run

We find the supply and demand equilibrium by using the demand functions and the exogenous supply, with the latter equal to the actual housing stock for each period. The equilibrium condition requires the demand for housing to equal the supply, where the house price clears the market. More formally, by setting equation (3) into equation (2), and then setting this merged equation equal to supply and solve for house price, the following function describes the fundamental equilibrium of the housing market on a semi-logarithmic form:

$$lnPH_t = \beta_1 lnP_t + \beta_2 lnHL_t + \beta_3 lnYN_t + \beta_4 BK_t + \beta_5 lnH_t + \beta_6 g(X_t) + \varepsilon_t \quad (4)$$

The subscript t captures the time-period and ε_t captures the unobserved effects varying across time. Further, YN represents the nominal disposable income, which accounts for the effect of higher house prices on the purchasing power in the housing market. The variable is derived from the following relationship:

$$YN = Y \cdot (P^{\alpha_1} \cdot HL^{\alpha_2} \cdot PH^{\alpha_3}) \quad (5)$$

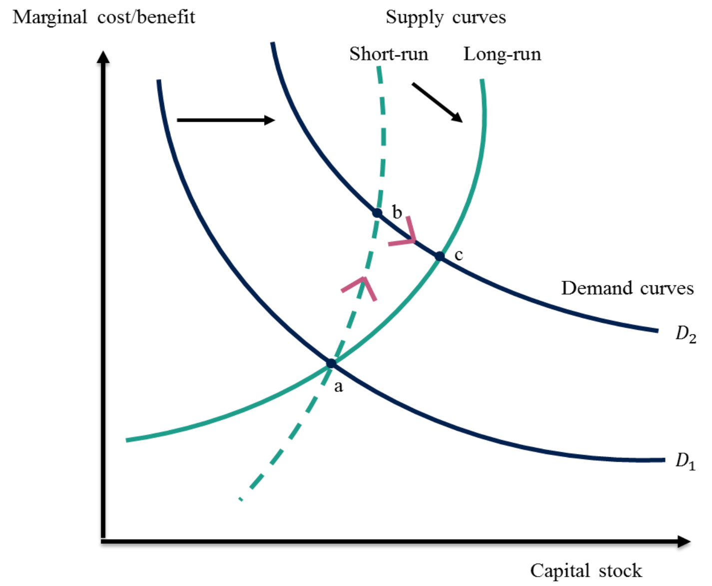
Where

$$\alpha_1 + \alpha_2 + \alpha_3 = 1$$
$$\alpha_1 < \beta_1, \alpha_2 < \beta_2$$

The equilibrium in the housing market is the intercept between supply and demand, but the slow responsiveness in the supply for dwellings implies that a temporary equilibrium exists for the housing market in the short run. The short run supply of housing is inelastic due to adjustment costs associated with changing the housing stock (Corder & Roberts, 2008). It takes several months to construct a dwelling, and, as such, there are risks involved, especially as most investment projects are irreversible. Hence, the short-run supply curve is steeper than the long-run supply curve, leading to a temporary equilibrium when shifts in the demand curve occur. This causes a natural split between the short-run and long-run market for housing, illustrated in **Figure 8**.

Figure 8 demonstrates a situation with a positive shock in demand for dwellings. The limited response from the supply-side leads to a temporary equilibrium in point (b). The short-run equilibrium motivates housing investments and causes the capital stock to adjust as more projects are finalised over time to profit from the price increase. Hence, the market eventually returns to a long-run equilibrium in point (c).

Figure 8: Extended Supply and Demand Framework



5. Empirical Method

This thesis includes country-specific house price models and a dynamic model for the Northwestern European market. We use time series techniques and panel data techniques with different properties to find the effect of the independent variables on house prices. This chapter describes these properties and how they are tested.

5.1 Time Series models

The first part of the thesis evaluates the house price model for individual countries using the Ordinary Least Squared (OLS) method. A simple OLS model for time series data is presented in the following equation:

$$y_t = \beta_o + \beta_1 x_t + \varepsilon_t \tag{6}$$

Where y_t is the dependent variable and x_t is the relevant independent variable used to describe the development. β_1 is the coefficient that describes how much the average value of y_t changes with one unit change in x_t, while β_o is the constant term. The ε_t is the error term, covering all unobserved factors expected to have an impact on y_t.

To estimate the causal effect of a change in the independent variable on the response variable, we address the assumptions behind the estimation techniques. A valid model is both consistent and unbiased, which is ensured by complying with the following four OLS assumptions presented by Greene (2008) and Kennedy (2008):

1. **Linearity** in parameters says that the dependent variable is formulated as a linear function of a set of independent variable and the error term
2. **Random sample** of observations
3. **Full rank** assumption says that there is no exact linear relationship among independent variables (no multicollinearity)
4. **Exogeneity** says that the expected value of disturbances is zero or disturbances are not correlated with any regressors

Moreover, for an estimator to be the Best Linear Unbiased Estimator (BLUE), we require the following assumptions to be included:

5. Disturbances have the same variance (**homoscedasticity**) and are not related to one another (**no autocorrelation**).
6. The observations on the independent variable are **not stochastic** but fixed in repeated samples without measurement errors.

5.2 Panel Data models

In the second part of the analysis, we use a panel data structure to create a PVECM for house prices in Northwestern Europe. The dataset is two-dimensional and represents an unbalanced panel, often called longitudinal data, characterised by observations of the same cross-sectional units i at time t. For the estimates to represent the causal effect of the independent variables on the dependent variable, the model must comply with the OLS assumptions described in section 5.1. A generalised panel data model is presented in equation (7) (Wooldridge, 2016).

$$y_{it} = \beta_0 + \beta X_{it} + \varepsilon_{it} \tag{7}$$
$$i = 1, \dots, N$$
$$t = 1, \dots, T$$

Where y_{it} is the dependent variable and X_{it} is a vector containing the relevant independent variables used to explain the dependent variable. The ε_{it} is the error term, covering all unobserved factors expected to impact the y_{it}. The two-dimensional structure of the data indicates that the error term consists of both an unobserved time-invariant heterogeneity, a_i, and a time variant idiosyncratic error, u_{it}. Consequently, the error term can be broken down into:

$$\varepsilon_{it} = a_i + u_{it} \tag{8}$$

With

$$\varepsilon_{it} \sim i.i.d(0, \sigma_\varepsilon^2)$$

5.3 Homoscedasticity

Assumption 5 in section 325.1 requires the errors to have constant variance conditional on the independent variables for the model to be BLUE, and a violation of homoscedasticity causes the standard errors to be biased (Wooldridge, 2016). The coefficient estimates are not affected by the violation, but they become less precise. In addition, biased error terms may result in overestimation of the goodness of fit from the model, as it calculates the t-tests and

F-tests using an underestimated level of variance, potentially leading to wrong conclusions about the significance of coefficients (Wooldridge, 2016). The presence of heteroscedasticity can be identified graphically or by using formal tests.

5.3.1 Graphical Assessment of Homoscedasticity

Heteroscedasticity can be evaluated by plotting the error terms against the fitted values and look for patterns. The error terms are homoscedastic if the plots display random and uniform error terms, without any patterns. On the other hand, a pattern in the error terms indicates heteroscedasticity. This can be difficult to assess if the sample size is small; consequently, this chapter also presents more formal tests.

5.3.2 Formal Tests of Homoscedasticity

The general null hypothesis of homoscedasticity in time series is:

$$H_o: Var(u_t | x_{t1} \ldots x_{tk}) = \sigma^2 \qquad (9)$$

Multiple tests are available, but they use different methods to evaluate the null hypothesis against the alternative hypothesis of non-constant variance in the error terms. The following section presents the procedure for the commonly used Breusch-Pagan test.

The Breusch-Pagan test

The Breusch-Pagan test starts by regressing the squared error terms from an estimated model on the independent variables and can be expressed as follows (Wooldridge, 2016):

$$\hat{u}^2 = \delta_0 + \delta_1 x_1 + \cdots + \delta_k x_k + \varepsilon \qquad (10)$$

Next, the test statistic for the Breusch-Pagan test is calculated using either the Lagrange multiplier (LM):

$$LM = nR^2_{\hat{u}^2} \qquad (11)$$

or the F statistic:

$$F = \frac{R^2_{\hat{u}^2}/k}{((1 - R^2_{\hat{u}^2})/(n - k - 1))} \qquad (12)$$

The chi-squared distribution is used in the former case and F-distribution in the latter case. A small p-value from the Breusch-Pagan test leads to rejection of the original null hypothesis and indicates that heteroscedasticity is present.

5.4 Normality

The error term must follow a normal distribution, conditional on the independent variables for the inference of the parameters to be valid as inference tests assume the error terms to be normally distributed (Wooldridge, 2016). It can be difficult to draw a conclusion based on graphical assessments, so to test for normality, we use the Shapiro-Wilk test and the Kolmogorov-Smirnov test for time series. For more details, see Razali and Yap (2011). Further, a powerful test for assessing multivariate normality in PVECMs is the improved Jarque-Bera test by Urzúa (1996). The hypotheses using the Urzúa specification are:

$$H_0: The\ error\ terms\ are\ multivariate\ normal$$
$$H_1: The\ error\ terms\ are\ not\ multivariate\ normal$$

5.5 Serial Correlation

In addition to homoscedasticity, assumption 5 in section 5.1 requires the error terms to be uncorrelated. Correlation between the error terms in different periods is referred to as serial correlation or autocorrelation (Wooldridge, 2016). The assumption of no serial correlation is expressed in equation (13):

$$Corr(u_t, u_s|X) = 0, for\ all\ t \neq s \tag{13}$$

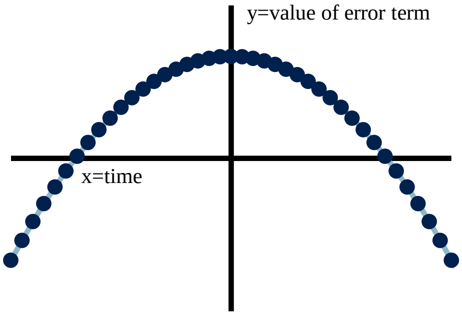
A systematic correlation between error terms across periods implies that the model is no longer BLUE and that the standard errors and, consequently, the test statistics are no longer valid. The coefficients are still unbiased, but the standard errors are biased, which may lead to wrong conclusions regarding the significance of the variables. Serial correlation often results from misspecifications of the model, and typically, the correlation leads to an underestimation of the uncertainty in the estimates. In turn, this leads the model to conclude that the variables are more significant than what is true. The issue of serial correlation can be addressed from graphical assessment or by using more formal tests.

5.5.1 Graphical Assessment of Serial Correlation

Serial correlation can be assessed by plotting the error terms across time and looking for patterns. There are three possible outcomes: positive serial correlation, negative serial correlation, or no serial correlation. Positive serial correlation occurs when an error term of a given sign tends to be followed by an error term of the same sign (Pedace, 2019). Conversely, negative serial correlation occurs when an error term tends to be followed by an error term of the opposite sign. Both patterns lead to issues with the model. Lastly, when the pattern of error terms appears to be random, the error term exhibits no serial correlation and satisfies the assumption.

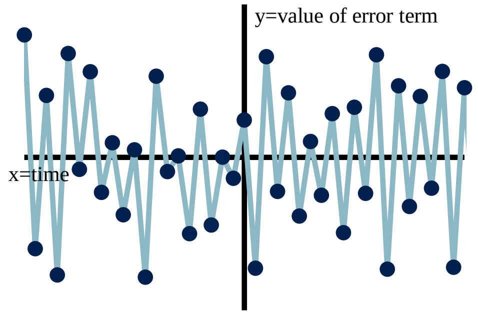
Figure 9 and **Figure 10** are visual examples of positive and negative serial correlation. The examples illustrate clear cases of serial correlation, which make it easy to draw a conclusion. In more realistic cases, it is often more challenging to determine if the error terms exhibit some form of serial correlation. Hence, more formal tests can be helpful.

Figure 9: Positive Serial Correlation



Source: Self-made and illustrative only

Figure 10: Negative Serial Correlation



Source: Self-made and illustrative only

5.5.2 Statistical Tests for Serial Correlation

Multiple tests can be used to identify the presence of serial correlation in the error terms. Two common tests for time series presented by Wooldridge (2016) are the Durbin-Watson test and the Breusch-Godfrey test. The Durbin-Watson tests for serial correlation in the naïve model, while the Breusch-Godfrey considers the lagged model. Further, the Lagrange Multiplicator test is suited for VECMs.

Durbin-Watson

The Durbin-Watson test is based on the OLS error terms and the null hypothesis and alternative hypothesis are stated as:

$$H_0: No\ first - order\ serial\ correlation\ exist$$

$$H_1: First - order\ serical\ correlation\ exist$$

With the corresponding test statistic:

$$d = \frac{\sum_{t=2}^{n}(\hat{u}_t - \hat{u}_{t-1})^2}{\sum_{t=1}^{n}\hat{u}_t^2} \tag{14}$$

The test includes the contemporaneous error term and consecutive error term and requires the classic linear model assumptions[3] to be fulfilled. The test statistic returns a value [0, 4], which is compared to the d-distribution. Values of d well below 2 imply that successive error terms are positively correlated, while values well above 2 indicate a negative correlation. The d value is compared to an upper and lower limit, dependent on the required significance level. The bounds are summarised in **Table 1**.

Table 1 - Durbin-Watson Limits

	Positive serial correlation	Negative serial correlation
Upper limit	$d < d_{L,\alpha}$	$(d-4) < d_{L,\alpha}$
Lower limit	$d > d_{U,\alpha}$	$(d-4) > d_{U,\alpha}$
Inconclusive	$d_{L,\alpha} < d < d_{U,\alpha}$	$d_{L,\alpha} < (d-4) < d_{U,\alpha}$

Breusch-Godfrey

A drawback with the original Durbin-Watson test is the requirement of strictly exogenous independent variables. The Breusch-Godfrey test for serial correlation does not require exogenous variables and provides an alternative test if the independent variables should exhibit correlation with the error term of the preceding period. Also, the Breusch-Godfrey test tests for higher orders of serial correlation, which are not identified by the Durbin-Watson test. The general hypothesis to order p can be formulated as:

$$H_0: No\ serial\ correlation\ of\ any\ order\ up\ to\ p\ exists$$

$$H_1: The\ error\ term\ follows\ an\ AR(p)\ or\ MA(p)\ process$$

With the corresponding test statistic:

$$LM = (n-p)R_{\hat{u}}^2 \tag{15}$$

Where n is the number of observations and $R_{\hat{u}}^2$ is derived from the regression of

[3] The assumptions include linearity in parameters, no perfect collinearity, zero conditional mean, homoscedasticity, no serial correlation, and normality of the error terms. See section 5.1 for further information

$$\hat{u}_t \; on \; x_{t1}, \dots, x_{tk}, \hat{u}_{t-1}, \dots, \hat{u}_{t-p} \tag{16}$$

For all

$$t = (p + 1), \dots, n$$

The test follows a chi-squared distribution, and the null hypothesis of no serial correlation is rejected if the test statistic exceeds the critical value from the chi-squared table. The decision on the number of lags to include is not always apparent, and a potential solution is to run the test for multiple values of p to ensure that no serial correlation is present in the error terms, regardless of the periods included.

The Lagrange Multiplicator Test

The Lagrange Multiplicator (LM) test is commonly used to evaluate VECMs. In general, the LM test indicates the number of lags needed to avoid the problem of serial correlation in an unrestricted VAR model (Hossain, 2019). Next, the optimal lag specification of the VECM is derived by subtracting one lag from the indicated lag structure in the LM test (Hossain, 2019). The following null hypothesis against the alternative hypothesis is tested:

$$H_0: No\ serial\ correlation\ at\ lag\ h$$

$$H_1: Serial\ correlation\ at\ lag\ h$$

5.6 Stationarity

In time series analysis, stationarity is an underlying assumption that must be satisfied to avoid spurious relationships.[4] In theory, strict stationarity is required, and Wooldridge (2016) states that "*a stationary time series process is one whose probability distributions are stable over time in the following sense: If we take any collection of random variables in the sequence and then shift that sequence ahead h time periods, the joint probability distribution must remain unchanged.*" The requirement of strict stationarity is overly restrictive in most time series analyses, and a weaker form is often assumed to be sufficient. The weaker form only requires constant mean and variance across time.

[4] When a regression analysis indicates a relationship between two or more unrelated time series, due to a similar trend or random walk (Wooldridge, 2016).

Time series can exhibit many forms of non-stationary behaviour, including trends, cycles, or random walk. The presence of non-stationary variables invalidates the mean, variance, and other metrics (Nau, 2019). Typical examples of non-stationary variables are macroeconomic variables like Gross Domestic Product (GDP) or capital stock, which exhibit growth over time. Due to the long-term growth rate in the variable, the mean and variance increase with the sample size, which leads to an underestimation of future mean and variance. Hence, non-stationary variables do not give valid results if included in their original form and may lead to spurious regressions. To overcome the problem, the trend must be analysed.

In general, most trends are either deterministic or stochastic and can be separated by the nature of the shocks to the series. A deterministic trend always reverts to the long-term trend as the effect of the shock is eventually eliminated. The reverting towards the long-term trend indicates that the variable can be forecasted, and hence, that the trend can be estimated. Consequently, a non-stationary variable with a deterministic trend is stationary if the long-term trend is removed (Hamilton, 1994). Such variables are said to be trend-stationary and can be included in the regression analysis if an appropriate time trend is included (Wooldridge, 2016).

Conversely, a time series with a stochastic trend does not become stationary by detrending the variable, as the effect of shocks to the series is permanent. The persistence in shocks to the series makes it difficult to predict future values as the series does not revert to the long-term trend. Highly persistent time series, unit root processes, become stationary following a series of successive differences. The number of differences is denoted by $I(d)$ where d represents the order of integration (Wooldridge, 2016). Most stochastic variables are said to be integrated of order one, as it is unusual to encounter variables of higher order.
Several tests exist to test the order of integration for time series. The Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test are common unit root tests. They are based on the model of the first-order autoregressive process:

$$y_t = \phi_1 y_{t-1} + \varepsilon_t \tag{17}$$

Where ϕ_1 is the autoregression parameter and the basis for the test. The tests evaluate the value of ϕ_1 and the null hypothesis states that the time series contains a unit root, meaning that it is non-stationary. This is more formally expressed as:

$$H_0: \phi_1 = 1$$
$$H_1: |\phi_1| < 1$$

The ADF test and PP test differ in how they are implemented. The ADF test uses lags to evaluate the presence of unit root, and a problem may arise when choosing the correct number of lags. A general rule to determine the maximum number of lags was proposed by Schwert (1989) using the formula:

$$Lags = 12\left(\frac{T}{100}\right)^{\frac{1}{4}} \tag{18}$$

Too few lags leave the test subject to serial correlation, while too many lags reduce the power of the test (Arltová & Fedorová, 2016). The problem of determining the correct number of lags can be complicated in time series, and the PP test provides an alternative solution. The test addresses the potential problem of serial correlation by making a non-parametric correction of the final test statistic (Phillips & Perron, 1988). Hence, the test is robust towards serial correlation without requiring a number of lags to be specified.

Several studies have identified the problem of low power in unit root tests[5] in finite samples, and the problem can be especially severe in small samples. The results from unit root tests are primarily affected by the length of the time series and the value of the autoregression parameter, ϕ_1. Arltová and Fedorová (2016) have performed a simulation study with almost 300 000 generated time series that investigates the statistical power of multiple unit root tests for positive values of ϕ_1, where $\phi_1 = 1$ is a non-stationary, I(1) time series. The simulation is performed on four different lengths: T=25, T=50, T=100, and T=500.

The main findings relevant to our thesis are that the ADF and PP tests perform poorly in the case of T=25, and are, in fact, more likely *not* to reject non-stationarity in the case of stationary variables with $\phi_1 > 0.3$ for the ADF test and $\phi_1 > 0.4$ for the PP test, despite the time series being stationary (Arltová & Fedorová, 2016). The results improve drastically for time series with T=50 and T=100, but as ϕ_1 approaches 1, the power of the tests drastically decline. The results from the simulation study imply that the tests have limited applicability

[5] See Blough (1988), Lo and MacKinlay (1989), and Schwert (1987)

for small samples and that the results should be evaluated in the light of economic reasoning.[6]

Arltová and Fedorová (2016) suggest including the results from the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test when evaluating the stationarity of time-series with T=25. The test has a null hypothesis of stationarity against the alternative of non-stationarity. It performs better in the simulation studies and finds that for $\phi \leq 0.8$, the test is expected not to reject a true null hypothesis, which is a far better result for small sample sizes compared to the ADF and PP tests. Hence, it serves as a superior alternative when we evaluate stationarity of time series with small sample sizes.

5.7 Cointegration

The problem of non-stationarity can be solved by differencing, as a variable integrated of order d become stationary after d differences. This approach safely deals with any problems following non-stationary variables, but potentially limits the analysis (Wooldridge, 2016). By first differencing series that contain a unit root and performing a regression on the differences, information about the long-run effect is removed.

In some cases, an alternative to creating stationary variables can be to cointegrate variables of the same order, making the long-term trend predictable. Hence, cointegrated variables allow for a more detailed analysis than first difference estimation. In the cointegrated process, each of the variables contains a unit root, but when combined with another unit root process, the cointegrated variables revert toward each other in the long run (Sheppard, 2019). Although the variables temporarily deviate, they eventually revert to the long-term stochastic trend. Consequently, if two variables integrated of the same order are cointegrated, the trend is predictable, and differencing is no longer the best solution (Sims, 2013).

Cointegration deals with the potential problem of spurious regression while capturing both the short-run and long-run effects of the non-stationary variables. Most unit root processes are integrated of order one, which also applies to the economic variables that are relevant to this thesis. A cointegrated relationship can be exemplified using three variables y_t, x_t, z_t all

[6] See «Selection of Unit Root Test on the Basis of Length of the Time Series and Value of AR(1) Parameter» by Markéta Arltová and Darina Fedorová (2016) for further details on the results.

$I(1)$. If there exists a linear combination of $ay_t + bx_t + cz_t$ that is stationary, the variables are said to be cointegrated (Buck, 1999). The linear combination has constant mean, constant variance, and serial correlation that only depend on the time distance between the variables (Wooldridge, 2016).

5.7.1 Statistical Tests for Cointegration

The Engle-Granger two-step method and Johansen test are common methods to test for cointegration. The Engle-Granger two-step method requires either (1) two variables, (2) a system with exactly one cointegrated relationship or (3) the cointegration vector to be known, while the Johansen test is less restrictive and allows for multiple variables and cointegrated relationships (Sheppard, 2019). For this paper, only the Johansen test is included. The test is performed in steps with the general hypotheses:

$$H_0\colon number\ of\ cointegrating\ vectors\ \leq r$$

$$H_1\colon Number\ of\ cointegrating\ vectors\ > r$$

The test starts with $r = 0$, which tests for no cointegrated vectors against the alternative of cointegrated vectors, and ends when a null hypothesis cannot be rejected. To illustrate, if the null hypothesis is rejected for $r = 0$, the test continues to the next rank and tests for maximum one cointegrated relationship against the alternative of more than one cointegrated relationship. This process continues until the maximum number of cointegrated relationships are determined.

5.8 Error Correction Model

Error correction models (ECM) assume a long-run stochastic trend in the included independent variables (Guo, 2017). Engle & Granger (1987) first showed that if there are cointegrated relationships, there would always be a corresponding ECM. The ECM is a dynamic model, which allows for analysis of the short-term effects while at the same time estimating a long-run equilibrium (Wooldridge, 2016). A dynamic model reduces the potential problem arising from serial correlation, but the OLS-estimation will no longer be BLUE when including lagged variables.[7]

[7] Lagged variables break the assumption of not-stochastic independent variables, see the last BLUE assumptions in section 5.1.

The ECM can be exemplified with a dependent variable, y_t, and an independent variable, x_t, both integrated of first order. If the two variables are not cointegrated, the first differences estimator can be used, but the estimator limits the model to estimate short-run effects. To derive the ECM, we begin with a first difference estimator expressed as:

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta y_{t-1} + \gamma_0 \Delta x_t + \gamma_1 \Delta x_{t-1} + u_t \tag{19}$$

If y_t and x_t are cointegrated with the parameter β, a stationary variable can be included in the model following the discussion from section 5.7. The new equation is expressed as:

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta y_{t-1} + \gamma_0 \Delta x_t + \gamma_1 \Delta x_{t-1} + \delta(y_{t-1} - \beta x_{t-1}) + u_t \;, \tag{20}$$

Where $\delta(y_{t-1} - \beta x_{t-1})$ is the error correction term and equation (20) represents the ECM.

The error term captures the deviation from the long-run equilibrium in the last period and adjusts the dependent variable towards the equilibrium. Hence, the error term coefficient, δ, estimates the model's adjustment speed. For the ECM to revert towards the long-run equilibrium, $\delta < 0$ is required. $(y_{t-1} - \beta x_{t-1})$ describes the deviation between the equilibrium and dependent variable from the preceding period, and $y_{t-1} \neq \beta x_{t-1}$ indicates that the model deviated from the long-run equilibrium in the preceding period (Wooldridge, 2016). The differenced independent variables are included to analyse the short-run effects and are less important in terms of significance, as the model does not require short-term relationships (Thomas, 1993).

5.9 Vector Error Correction Model

Vector Error Correction Models (VECM) can be used when modelling multivariate time series and is a generalisation of the univariate ECM (Suharsono, Aziza, & Pramesti, 2017). Where the ECM is a single equation model, the VECM is a multiple equation model based on a Vector Autoregression (VAR) model used in the presence of cointegrated relationships. The VECM adds the error correction term to the VAR model and, hence, it allows for interpretation of short-term effects. The model assumes all variables to be endogenous, which simplifies the implementation of the model, as exogeneous and endogenous variables do not need to be separated (Andrei & Andrei, 2014). A general VECM[8] follows in equation (21):

[8] The relationship is described in more detail by Anderson, Qian, & Rasche (2006)

$$\Delta y_t = \Pi y_{t-1} + \sum_{h=1}^{l} \Gamma_h \Delta y_{t-h} + \Phi d_t + \varepsilon_t \,, \tag{21}$$

Where a $n \cdot n$ matrix is the $\Pi = \alpha\beta'$ and α and β are $n \cdot r$ full rank matrices. Hence, the Πy_{t-1} represent the error-correction term of the model (Hauser & Michael, 2019). The d_t represent deterministic terms, the r from the Johansen's test determine the number of cointegrated relationships among the variables, and ε_t is a normal mean zero error with a positive covariance matrix (Koop, Roberto, & Strachan, 2007).

An important aspect of the VECM is to select the appropriate lag length, and the selection criteria Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) can be helpful to determine the appropriate lag length. Bewley & Yang (1998) find that the performance of the VECM suffers in the case of both underfitting and overfitting of the lag length. In general, underfitting leads to limited insight from the model due to oversimplified assumptions, while overfitting may lead to a too good fit with the variables and have limited potential for generalisation of the results. Further, Ho & Sorensen (1996) find that over-specification of the lag length may lead the Johansen's test to overestimate the cointegration rank in a particular system, and argue in favour of the BIC criteria when conducting cointegration analysis. In the event of deviating results, the BIC is, in general, more restrictive when suggesting the appropriate number of lags compared to the AIC.

5.10 Panel Vector Error Correction Model

The theory in this thesis covering PVECM is limited to the case of constant cointegration rank for the cross-sectional units. This is preferred as it takes the panel data dimension into account and assumes homogeneous long-run coefficients and adjustment parameters (Groen & Kleibergen, 2003).

The VECM from section 5.9 can be generalised to account for the panel data dimension by including the unit-specific term, represented by i. Hence, the PVECM is expressed as:

$$\Delta y_{i,t} = \Pi_{\mathrm{i}} y_{i,t-1} + \sum_{h=1}^{l_i} \Gamma_{i,h} \Delta y_{i,t-h} + \Phi_{\mathrm{i}} d_{i,t} + \varepsilon_{i,t} \,, \tag{22}$$

The interpretation is similar to the general VECM, with for example the $\Pi_i y_{i,t-1}$ representing the error correction term for the panel model. The use of a PVECM allows for analysis exploiting the benefits from a dataset covering multiple units across time.

5.11 Granger Causality

The regression models mentioned above establish a correlation between variables. To address the issue of separating correlation from causality, the Granger causality test can be used. The Granger test identifies whether past values of the independent variables aid in the prediction of the dependent variable, after accounting for the effect on the dependent variable from past values of the dependent variable. If the test finds such a relationship, then the independent variable is said to Granger cause the dependent variable (Granger, 1969). Hence, for a variable to Granger cause the dependent variable, some of the lagged values must have non-zero effects. The null hypothesis of the Granger test for a pair of one independent variable and one dependent variable can be written as:

$$H_0: \beta_{x,y,1} = \beta_{x,y,2} = \cdots = \beta_{x,y,n} = 0$$

$$H_0: \beta_{y,x,1} = \beta_{y,x,2} = \cdots = \beta_{y,x,n} = 0$$

The two tests can yield four potential conclusions summarised in **Table 2**.

Table 2 - Granger Causality Table

Granger causality	Fail to reject: $H_0: \beta_{y,x,1} = \beta_{y,x,2} = \cdots = \beta_{y,x,n} = 0$	Reject: $H_0: \beta_{y,x,1} = \beta_{y,x,2} = \cdots = \beta_{y,x,n} = 0$
Fail to reject: $H_0: \beta_{x,y,1} = \beta_{x,y,2} = \cdots = \beta_{x,y,n} = 0$	$y \nRightarrow x$ $x \nRightarrow y$ $(no\ Granger\ causality)$	$y \nRightarrow x$ $x \Rightarrow y$ $(x\ Granger\ causes\ y)$
Reject: $H_0: \beta_{x,y,1} = \beta_{x,y,2} = \cdots = \beta_{x,y,n} = 0$	$y \Rightarrow x$ $x \nRightarrow y$ $(y\ Granger\ causes\ x)$	$y \Rightarrow x$ $x \Rightarrow y$ $(bi-directional\ Granger\ causality, or\ feedback)$

The test can be extended to include multiple independent variables, and pairs of all variables are tested to identify Granger causal relationships. A causal relationship found in one test can change by including more variables, as what may appear to be a causal relationship can be affected by an omitted variable. Hence, it is important to include all variables in the model to avoid the wrong conclusion of causality.

The Granger test requires two assumptions for the relationship to be valid (Parker, 2012): the causal relationship must persist for several periods, and the future values cannot cause the present. The first assumption is valid in most cases but can be violated if expectations of future values affect present decisions. The second assumption requires the causal effect to persist for several periods as the Granger test is based on lagged effects. Hence, the test would not recognise an effect that only lasts one period (Parker, 2012).

6. Jacobsen & Naug's Error Correction Model

Jacobsen and Naug (2004) analyse the Norwegian housing market following a threefold increase in prices between 1992 and 2004 and identify fundamental factors. They estimate a model to see how house prices respond to changes in these factors. Moreover, they analyse whether house prices were above the level indicated by the fundamental factors, which could suggest that the Norwegian housing market experienced a housing bubble. Lastly, the model explains how the house prices would be affected if the Norwegian economy developed in line with the analysis in the Central Bank's inflation report. To answer these questions, they estimate an error correction model on the logarithm of house prices. Below follows a discussion of the features of the model and variables included or excluded from the final model.

6.1 Included Variables

The Norwegian Association of Real Estate Agents (NEF) and the Association of Real Estate Agency firms publish the price index used in the model at a monthly frequency, and it measures the average housing price per square metre adjusted for the size of the dwelling, type of dwelling, and location of the dwelling. The original model uses quarterly figures between Q2-1990 and Q1-2004. From January 1997, the authors had monthly data available, and the numbers are converted to quarterly figures by averaging the monthly observations.

Jacobsen and Naug estimate the effect of several variables:

- households' total (nominal) wage income
- indices for house rent paid and total house rent in the consumer price index (CPI)
- other parts of the CPI adjusted for tax changes and excluding energy products (CPI-ATE)
- various measures of the real after-tax interest rate
- the housing stock (as measured in the national accounts)
- the unemployment rate (registered unemployment)
- backdated rise in house prices
- household debt
- the total population
- the shares of the population aged 20-24 and 25-39

- various measures of relocation/centralisation
- TNS Gallup's indicator of households' expectations concerning their own financial situation and the Norwegian economy (the consumer confidence indicator).

They include both lagged and current variables to account for delays in household behaviour. The result of having relatively few observations and many explanatory variables gave meaningless coefficients, and for this reason, the authors estimate several models where only some of the variables are included.

Jacobsen and Naug's preferred model suggests a nominal relationship between house prices and the independent variables. Firstly, the model indicated a better fit when including nominal interest rate compared to real interest rate. Secondly, the inflation rate was insignificant in models that included both interest rate and inflation rate. Lastly, the inflation rate mainly had the wrong sign relative to expectations in the estimated models. Jacobsen and Naug also estimate a real version of the preferred model.

Housing rents and consumer prices generally yielded coefficients and t-values close to zero in the estimated models and, hence, Jacobsen and Naug do not conclude that these affect house prices. The authors argue that the insignificance of the housing rents can be explained by rents in housing cooperatives being an important part of the house rent indices in the CPI. In addition, rent prices have been subject to heavy regulations historically, which indicates that the relationship between the house rents in the CPI and house prices should be estimated with caution.

The effects of several market rates, such as three-month, twelve-month, three-year, and five-year rates, were tested together with banks' lending rates. Jacobsen and Naug find that the banks' lending rates are highly significant in all models, while market rates are insignificant in models that include the banks' lending rates. A potential explanation can be that both house prices and the difference between market rates and banks' lending rates are dependent on the economic outlook. Thus, the market rates can capture effects from changing economic views, which in turn likely lead to an underestimated effect of interest rate expectations in the model. Lastly, the interest rate was used to stabilise the exchange rate in the 1990s. The authors suggest that households then may have used the observed interest rate as an approximation of future interests, underlining the difficulties associated with identifying the effects of interest rate expectations on house prices.

Jacobsen and Naug estimate the effects of population movements and other demographic factors on house prices. They do not find any significant effects, which can be explained by these factors slowly changing over time, coupled with a relatively short estimation period. However, the authors highlight that the final model, to some extent, is affected by demographics as it affects wage income, which in turn is included in the final model.

Further, Jacobsen and Naug include TNS Gallup's indicator of households' expectations of the Norwegian economy and their financial situation to capture expectation effects. The expectations index and house prices are highly correlated. However, the expectations index is also highly correlated with the interest rate and the unemployment rate, both of which are included as independent variables in the final model. For example, an interest rate reduction generally leads to expectations that real house prices are going to increase, which may lead to people trying to expedite house purchases. Alternatively, increased unemployment rate may lead to expectations of lower income growth and lower ability to repay debt going forward. To avoid the potential problem arising from the correlation, Jacobsen and Naug estimate a model that explains the consumer confidence index with the interest rate and unemployment rate as independent variables.

The difference between the actual value and fitted value is used as a measure of shift in expectations not related to changes in unemployment or interest rate. Jacobsen and Naug use the error terms to calculate an expectation variable given by:

$$EXPEC = (E - F) + 100 \cdot (E - F)^3 \tag{23}$$

$$where\ (E - F)\ is\ the\ residual, \varepsilon$$

The last part of the equation is included to improve fit and to account for disproportional effects of large changes in the expectations index[9].

[9] Not mentioned in the article, but explained by Bjørn Naug over mail.

6.2 The Fundamental Factors to Include in the Model

To capture both short-run and long-run effects of the fundamental factors, Jacobsen and Naug propose a one-step error correction model. The model explains the logarithm of house prices using the wage income, the housing stock, the unemployment rate, banks' after-tax lending rate, and the adjusted consumer confidence index. The variables in the model with small letters are on logarithmic form, while the Δ is a difference operator subtracting X_{t-1} from X_t.

Jacobsen and Naug find the effect of the wage income and housing stock to be imprecisely estimated due to a high level of correlation. Therefore, they impose a condition that the housing stock and wage income must have the same long-run effect with opposite signs in the model, even though they cannot reject a null hypothesis that the two variables have different signs. Hence, they construct a variable with the difference between the wage income and the housing stock to find the long-run effect.

6.3 The Interpretation of the Effects Captured by the Model

The short-run effects explain how changes to the fundamental factors for the current and preceding period affect the changes to the house prices of the current period (Klovland, 2019). The model finds three short-term effects: (1) a positive effect from positive changes to the nominal wage income in the same period, (2) a negative effect from an increase in after-tax interest rate in both the current and preceding period, and (3) a positive effect from an increase in the modified expectations index.

Further, the error correction mechanism of the model reverts the house prices towards the long-run equilibrium if the actual price deviated from the predicted price in the preceding period (Klovland, 2019). If house prices in period were lower than predicted by the long-term fundamentals, the error correction mechanism included indicate that house prices should increase in the following period. Hence, the error correction term, c, is negative in Jacobsen and Naug's (2004) final model, illustrated in equation (24).

$$price_t = \beta_1 \Delta income - \beta_2 \Delta INTEREST(1-\tau)_t - \beta_3 \Delta INTEREST(1-\tau)_{t-1} + \beta_4 EXPEC_t - c[houseprice_{t-1} + \beta_5 INTEREST(1-\tau)_{t-1} + \beta_6 unemployment_t + \beta_7 (income - housingstock)_{t-1}] + \beta_0 + \delta_1 S1 + \delta_2 S2 + \delta_3 S3 \quad (24)$$

The long-run solution is found by eliminating all difference-terms from the model, leaving the model with four relevant factors in explaining long-run house prices:[10] (1) The negative effect of after-tax interest rate, (2) the negative effect of unemployment rate, (3) the positive effect of wage income, and (4) the negative effect of housing stock. The model presents a theoretical stationary level when the short-run effects are removed from the equation. Equation 25 represents the effects identified by Jacobsen and Naug.

$$price_t = 0.12\Delta income - 3.16\Delta INTEREST(1-\tau)_t - 1.47\Delta INTEREST(1-\tau)_t + 0.04 EXPEC_t - 0.12[houseprice_{t-1} + 4.47 INTEREST(1-\tau)_{t-1} + 0.45 unemployment_t \; 1.66(income - housingstock)_{t-1}] + 0.56 + 0.04S1 + 0.02S2 + 0.01S1 \quad (25)$$

[10] The direction of the effect from the independent variables on house prices is in the event of an increase in the variable.

7. Data Description

In this chapter, we describe our collected dataset for seven European countries on a quarterly frequency, an annual dataset received from the EMF, and an extended Norwegian dataset with quarterly observations received from Bjørn Naug. Differences exist in how the countries collect and report data, which potentially can invalidate the models. Hence, we place a high priority on the consistency of data to ensure comparability. This is achieved by evaluating the variables that are reported inconsistently in conjunction with national statisticians and European statistical agencies. The selection of data series is based on: (1) the availability of comparable data across all countries, (2) length and frequency of the time series, and (3) data from preceding studies.

We collect and evaluate data series for seven countries: Sweden, Denmark, Finland, the United Kingdom, Belgium, The Netherlands, and Germany. The dataset represents an unbalanced panel from 1995-Q2 to 2018-Q4. The dataset received from EMF is an unbalanced panel with annual data for 40 countries, covering the period 1983-2018. EMF and similar international federations facilitate cross-country analysis by investing resources into data gathering and evaluation of sources. As such, the dataset from the EMF enables us to cross-validate the self-collected dataset.

The collected dataset is divided into the two categories of raw data and modified data. We use the house price index and the unemployment rate without making any adjustments to the data. Conversely, the interest rate, the nominal income, the housing stock, and the consumer confidence index require some form of adjustment to ensure comparability across all countries or to be on the same form as the variables in the model proposed by Jacobsen and Naug (2004). Hereby, Jacobsen and Naug's model (2004) is referred to as the original model.

Table 3 - Expected Signs and Summary of Sources

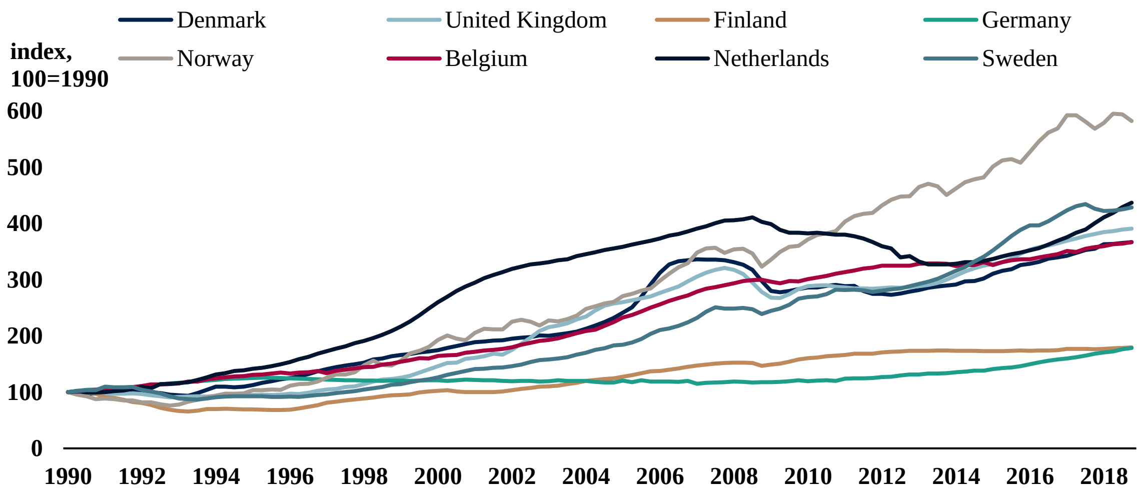
	Exp. sign	NOR	BEL	GER	NLD	UK	DNK	FIN	SWE
House price Index		NEF, EFF, finn.no and ECON	OECD Database: Housing Prices	OECD Database: Housing Prices	OECD Database: Housing Prices	OECD Database: Housing Prices	OECD Database: Housing Prices	OECD Database: Housing Prices	OECD Database: Housing Prices
After tax Interest rate	–	Not meaningful	Not meaningful	Not meaningful	Not meaningful	Not meaningful	Not meaningful	Not meaningful	Not meaningful
Interest rate	–	Norges Bank	National Bank of Belgium & ECB: RIR & MIR	The Deutsche Bundesbank & ECB: RIR & MIR	De Nederlands-che Bank & ECB: RIR & MIR	Bank of England & ECB: RIR & MIR	Danmarks Nationalbank & ECB: RIR & MIR	Bank of Finland & ECB: RIR & MIR	Sveriges Riksbank & ECB: RIR & MIR
Deduction rate	+	Gov. Budgets	Gov. Budgets	Gov. Budgets	Gov. Budgets	Gov. Budgets	Gov. Budgets	Gov. Budgets	Gov. Budgets
Unemploy-ment	–	The Directorate of Labour	ECB: Labour Force Survey	ECB: Labour Force Survey	ECB: Labour Force Survey	ECB: Labour Force Survey	ECB: Labour Force Survey	ECB: Labour Force Survey	ECB: Labour Force Survey
Disposable income	+	Statistics Norway: National Accounts	National Bank of Belgium: National Accounts	The Deutsche Bundesbank: National Accounts	De Nederlands-che Bank: National Accounts	Bank of England: National Accounts	Danmarks Nationalbank : National Accounts	Bank of Finland: National Accounts	Sveriges Riksbank: National Accounts
Housing stock	–	Statistics Norway: National Accounts	ECB: code: SHI.A.BE.D WEL.A	ECB: code: SHI.A.DE.D WEL.A	ECB: code: SHI.A.NL.D WEL.A	ECB: code: SHI.A.GB.D WEL.A	ECB: code: SHI.A.DK.D WEL.A	ECB: code: SHI.A.FI.D WEL.A	ECB: code: SHI.A.SE.D WEL.A
CCI	+	TNS Gallup	OECD Database: CCI	OECD Database: CCI	OECD Database: CCI	OECD Database: CCI	OECD Database: CCI	OECD Database: CCI	OECD Database: CCI

7.1 The Nominal House Price Index

The house price index variable represents the dependent variable of the regression. House price indices differ by (1) Type of dwellings included, (2) seasonal adjustments, and (3) real or nominal values. The indices across countries must possess the same three features to be comparable. Further, the index should reflect the characteristics of the housing market in the relevant countries. According to the Eurostat database (2019), European housing markets are changing, with an increasing proportion of the population living in apartments. Hence, to reflect the changing trend in the housing market, we find an index that includes both houses and apartments most appropriate. Next, a nominal index is preferable, as this complies with the specifications of the original model.

The nominal house price index from the OECD database (2019) is the preferred choice for the quarterly data. The index includes the price development of both houses and apartments and covers the sale of both newly built and existing dwellings while following the recommendations from Residential Property Prices Indices (RPPI). **Figure 11** displays the development in nominal housing prices for our eight selected countries in the quarterly dataset. For the annual data, EMF provides a nominal index that covers both new dwellings and existing dwellings, including both apartments and houses. The index is based on in-house statistics in addition to external statistical sources.

Figure 11: Quarterly Development in Nominal Housing Prices Between 1990-2018



Source: The Organization for Economic Co-operation and Development (OECD)

7.2 The After-Tax Interest Rate

The after-tax interest rate is included as a measure of the cost of financing. To construct the variable, we collect: (1) interest rate on loan to households for house purchase, (2) tax rate on personal income, and (3) mortgage interest tax deduction rate.

7.2.1 Interest Rate

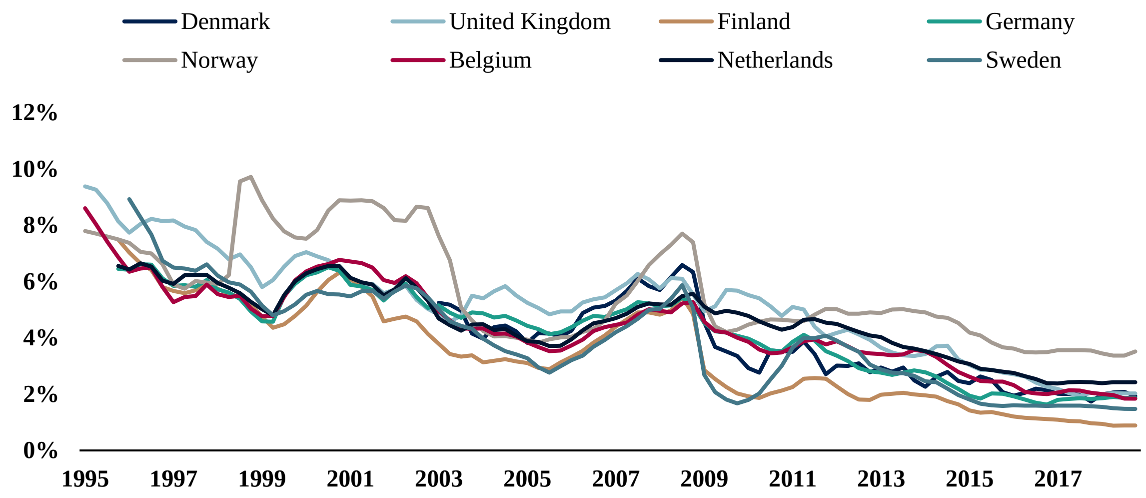
The interest rate reporting method has changed from being country-specific to follow the European Central Bank's (ECB) standards. Before 2003, the European countries collected mortgage information autonomously with different methodologies across the countries. The ECB reported the lending rates in the Retail Interest Rates (RIR) survey. However, data with different term structures, maturities, and interest rate fixations, is less suited for cross-country comparison. To improve the quality of the data reported, the ECB implemented the MFI Interest Rate (MIR) statistics, where monetary financial institutions in the Euro area are legally obliged to report comparable lending rates. Monetary financial institutions report the rates monthly,[11] and the new legislation from ECB ensures comparability of the cost of borrowing[12] for households across European countries (Eurostat, 2019). This reporting method ensures consistency and is the preferred lending rate for the self-collected dataset. In discussions with national statisticians, we collect the most suitable data from the RIR survey in periods before 2003. The complete series are shown in **Figure 12**.

For the annual dataset, the EMF collects lending rates on new residential loans with different types of interest rate fixation. The annual lending rate is a weighted average of multiple residential loans with different fixation periods reported monthly.

[11] Central banks and money market funds are excluded from the statistics

[12] Calculated by weighting the volumes with a moving average and excludes revolving loans and overdrafts, convenience and extended credit card debt

Figure 12: Development in Lending Rates Between 1995-2018



Source: Eurostat, Various Central Banks and Statistical Bureaux

7.2.2 Tax Rate and Mortgage Deduction Rate

Seven out of the eight countries in our quarterly dataset allow for some degree of tax deductibility on mortgages over the sample period. The policy functions as an indirect subsidy of house purchase by reducing the cost of borrowing. Hence, we collect the tax rate levied on the capital gains and personal income[13] of individuals to adjust the lending rates to reflect the true cost of borrowing. The countries included in the dataset are similar with relatively high tax rates, which is a typical trait in Northwestern European countries. The same tax rate is included in the annual and quarterly dataset and is collected from the OECD database (2019). The tax rates are reported annually for all countries and are revised each year by government authorities. Hence, the annual tax rate is included as identical observations for all quarters within a given year.

Further, the effect of the tax rate on the cost of borrowing is dependent on the national policies on mortgage interest deduction. The deduction policies are subject to changes over the sample period and range from no deduction (0%) to full deduction (100%). The allowable tax deduction rate for each country yearly can be found in **Table 26** in **Appendix B**, and demonstrates how national policies have changed over time. The deduction rate is included in the self-collected dataset and the dataset received from the EMF.

[13] Adjusted for allowable tax reliefs

7.2.3 The Cost of Borrowing

We calculate the after-tax interest rate variable for country, i, at time, t, as:

$$After\_Tax\_Interest\_Rate_{i,t} = INTEREST_{i,t} \cdot \left(1 - (\tau \cdot \rho)\right)_{i,t} \tag{26}$$

Where

$\tau = Tax\ rate$

$\rho = Percentage\ of\ allowed\ mortgage\ interest\ rate\ tax\ deduction$

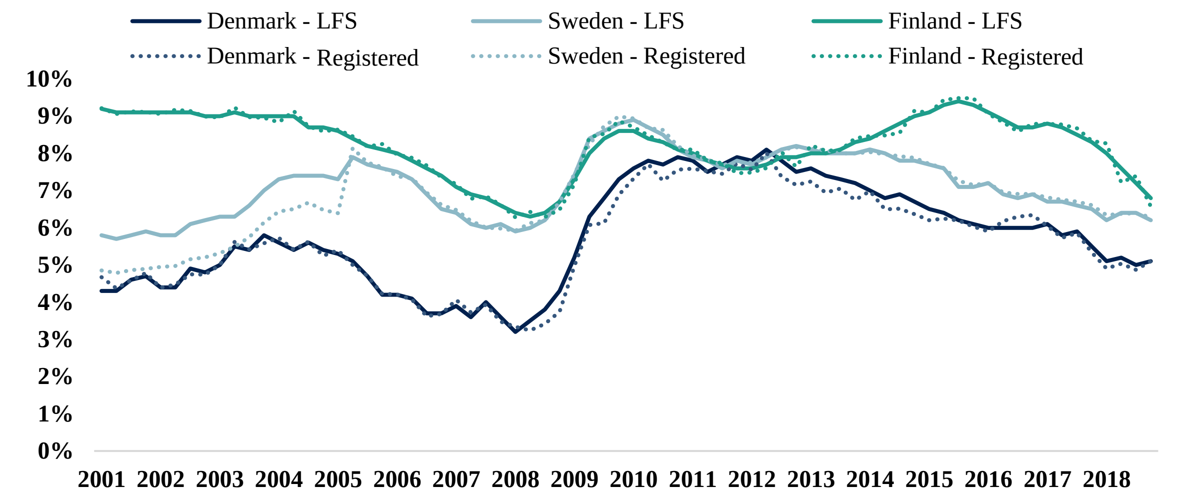
We expect the deduction policy to be positively correlated with house prices as it functions as an indirect subsidy of house purchases. Further, we expect the interest rate variable to be negatively correlated with house prices, as it increases the user cost of house ownership. In total, we expect the after-tax interest rate to be negatively correlated with the house prices, representing the final user cost to homeowners.

7.3 The Unemployment Rate

The unemployment rate is defined as the number of unemployed people as a percentage of the labour force (OECD, 2019). Commonly, the unemployment rate is based on the number of people that register as unemployed with the national public welfare agency, which is a precondition to be granted financial support from the government. This is referred to as the registered unemployment rate. Despite the incentives to register, some people search for new jobs outside the public system, which leads to a measurement error in the registered numbers. Most European countries address this issue by conducting a labour force survey (LFS) based on a series of personal interviews (Eurostat, 2019). The unemployment rate from the LFS is assumed to give a more realistic estimate of the actual unemployment rate. The registered unemployment rate and LFS unemployment rate are presented in **Figure 13** for selected countries, and the graph indicates a difference between the two rates. In general, this is not an issue for the model if the difference between the two series remains constant over time, due to the transformation of the unemployment variable.[14]

[14] The unemployment rate variable is included on logarithmic form for all regression models

Figure 13: LFS Survey vs Registered Unemployment Between 2001-2018



Source: OECD and Eurostat

From an examination of **Figure 13,** it is evident that the difference between the two series is non-constant across time. The relationship is usually altered during periods of low growth in the GDP and is mainly due to limited incentives for people entering the labour force to register with the national welfare agency if they fail to find a job (Statistics Norway, 2017). In most European countries, applicants looking for their first job are not entitled to social benefits similar to those for unemployed people that previously held a job. Consequently, people who recently entered the labour force more often choose not to register with the welfare agency, and the difference in the unemployment numbers increases if this group increases.

The registered numbers are a potential weakness due to measurement error, and hence we prefer the numbers from the LFS survey. The data is collected from the Eurostat database and is included in the quarterly and annual dataset, as the EMF does not report the unemployment rate. The unemployment rate is expected to have a negative correlation with the house prices, as being unemployed reduces the purchasing power of individuals, which in turn reduces the demand for dwellings.

7.4 The Nominal Income

The development of wages relative to house prices is commonly used to gauge the health of the housing market. We collect the compensation to employees series from the quarterly national accounts of each country to measure the development in wages. The series follow the CQRSA[15] format, which makes the numbers incomparable across countries in their original form. To make the series comparable, we create a country-specific index with 1995 as the base year. The national index brings the wage development on a more comparable format as most disturbances from currency fluctuations are avoided. The index is displayed in **Figure 14** for all countries in our collected dataset[16] and can be expressed as:

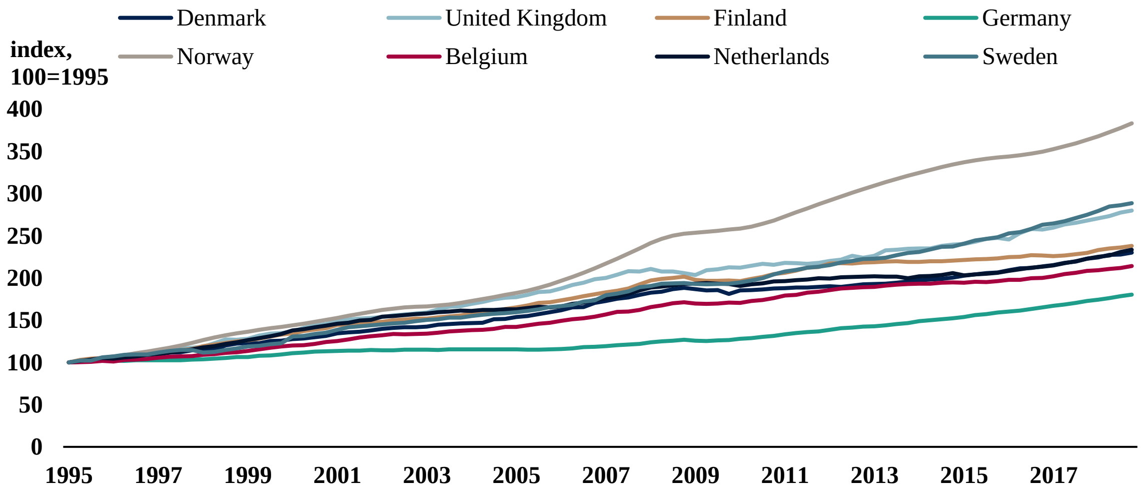
$$Wage\_Index_t = 100 \cdot \frac{CtE_t}{CtE_{1995}} \qquad (27)$$

$$CtE = Compensation\ to\ Employees$$

According to the EMF, household disposable income is the collective income of the members of a household who are 15 years or older. The dataset from the EMF includes the disposable income of households at current prices, collected from the annual-macro-economic database of the European Commission (AMECO).

The wage variable is expected to be positively correlated with the development in house prices with higher income increasing purchasing power, which leads to increased demand for dwellings.

Figure 14: Development in Nominal Income Between 1995-2018



Source: Eurostat and SSB

[15] National currency, current prices, quarterly levels, seasonally adjusted.
[16] Note that the Norwegian figures used in the original Jacobsen and Naug model are transformed into an index in this graph for the purpose of comparison.

7.5 The Housing Stock

The housing stock is defined as the number of dwellings in residential and non-residential buildings and is collected from the ECB which receives the data from National Central Banks (NCB) annually. The variable is reported in compliance with the target definitions from the ECB to ensure comparability across countries. We use the Denton-Cholette method[17] to disaggregate the annual observations to quarterly observations. This is in line with the disaggregation method used by Jacobsen and Naug (2004). For the annual dataset, the EMF uses national experts and national statistics offices to collect the total dwelling stock.

We expect the housing stock to be negatively correlated with house prices as an increased number of dwellings reduces the pressure on the existing housing stock.

7.6 The Consumer Confidence Index

The Norwegian consumer confidence index (CCI) follows an American survey format and is constructed based on five questions asked in personal interviews by Kantar TNS[18]. The European commission conduct similar interviews monthly, but the questions asked differ to some degree from the American questionnaire (Eurostat, 2019). The European survey consists of 12 questions, displayed in **Table 28** in **Appendix B**, and the included confidence indicator is an equally weighted average of the four questions found to be the most relevant. The question about the future unemployment rate is not included in the European confidence index as opposed to the Norwegian index. The questions included in the European index are highlighted in **Table 28**. The EMF does not report any expectations indicator for the annual data set. Hence, we use the CCI from the European Commission for both the quarterly dataset and the annual dataset.

The index is expected to correlate positively with the house prices, as a more positive view on future financial situation increases the demand for dwellings.

[17] Where the average of the quarters is consistent with the annual data
[18] See table **Table 27 Appendix A** for exact questions

8. Stationarity

In the following section, we evaluate the potential presence of a unit root process in the variables included in the models. The variables analysed for each country are the logarithm of the nominal house price index, the unemployment rate, the consumer confidence index, the logarithm of the disposable income, the after-tax interest rates, and the logarithm of the housing stock.

It is important to test the variables for the order of integration to determine which form of the variables should be included in the models to avoid spurious relationships. We use the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test to evaluate all variables in the datasets. We perform the Augmented Dickey-Fuller tests multiple lag configurations and adjusted for both drift and trend. If the null hypothesis of non-stationarity cannot be rejected, we first-difference the variable and perform the tests on the differenced variable to determine if the variable is integrated of first order.

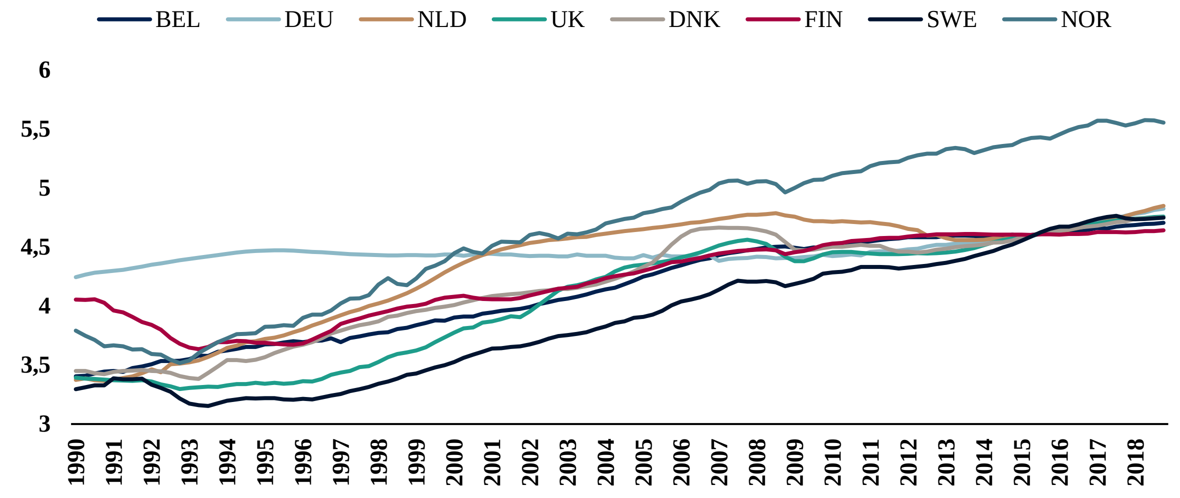
The unit root tests and a visual presentation of the differenced variables are found in **Appendix B**.

8.1 The Nominal House Price Index

Figure 15 displays the development in the logarithm of the house price index from 1990 to 2018 for the countries in the quarterly dataset. From the graph, we suspect that the time-series have a deterministic trend. This is rejected by the ADF tests and the PP test for all countries, as we cannot reject the null hypothesis of non-stationary even after correcting for trend, drift, and different levels of lags. Hence, we conclude that the nominal house price not is stationary at levels for any of the countries.

We difference the variable and test for stationarity. We conclude that the differenced housing price indexes are stationary as most of the ADF tests and the PP test reject the null hypothesis of non-stationarity on the differenced housing price index, hence the housing price index is integrated of first order, I(1). A graphical assessment of the differenced variables in **Figure 50** in **Appendix B** shows that the variable tends to fluctuate around a constant mean.

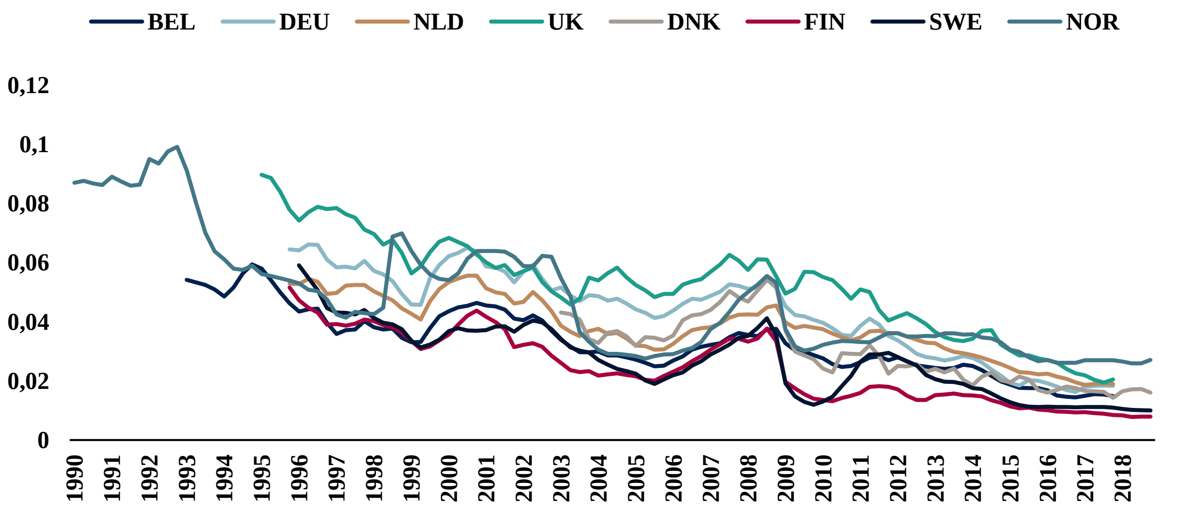
Figure 15: Development in Log Nominal House Prices 1990-2018



8.2 After-Tax Interest Rate

The interest rates in Northwestern European countries have been decreasing since the middle of the 1990s, and from **Figure 16,** the rates appear to be consistent with a random walk with drift. Non-stationarity is supported by the ADF-tests the PP test for all countries. Hence, we difference the variable for all countries, and the tests reject the null hypothesis of non-stationarity. Consequently, we conclude that the interest rate is integrated of first order, I(1). The differenced interest rates can be found in **Figure 51** in **Appendix B**.

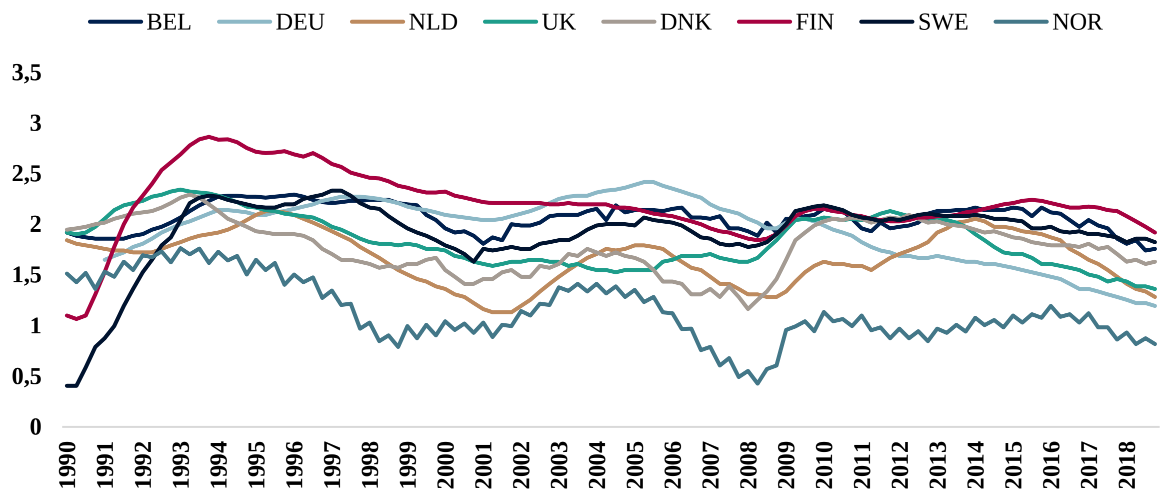
Figure 16: After-Tax Interest Rate 1990-2018



8.3 The Unemployment rate

Figure 17 displays the unemployment rate between 1990 and 2018. Neither the ADF tests nor the PP test can reject the presence of unit root for any of the countries. Hence, we difference the variables, and from **Figure 52** in **Appendix B**, it appears that the variable for all countries is stationary after differencing. This is supported by the ADF tests and the PP tests, and we conclude that the unemployment rate is stationary for all countries after differencing. Hence, the unemployment rate is integrated of first order, I(1).

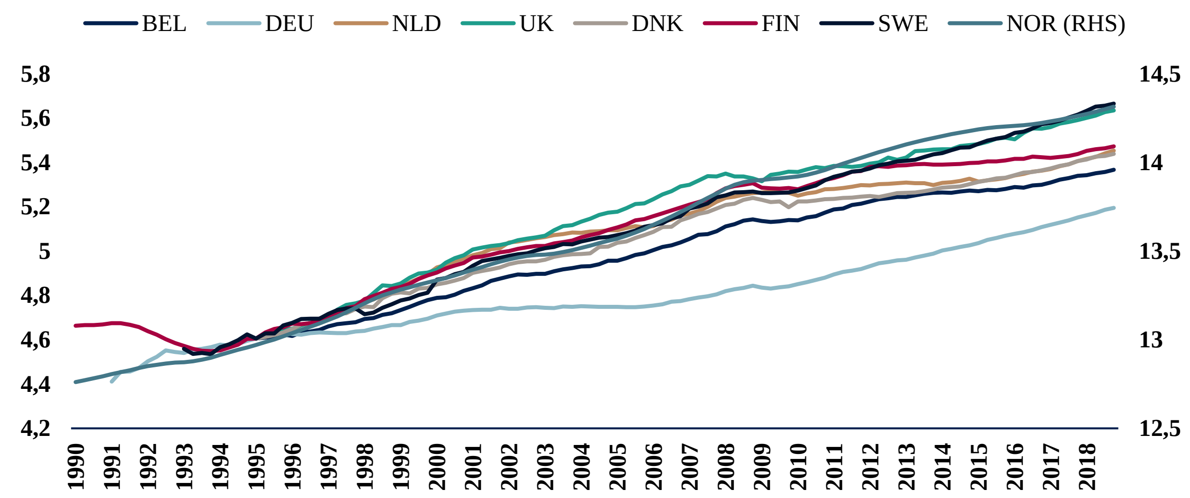
Figure 17: Development in Log Unemployment Rate 1990-2018



8.4 Nominal Disposable Income

From **Figure 18,** we infer that the nominal disposable income has been more or less increasing every quarter since 1994 for all countries, though the pace of this has varied. We do not expect the income to be stationary at level as changes to an individual's income are expected to be permanent. For example, a raise due to good results or increased responsibility at work is, in most cases, permanent. Hence, it is reasonable to believe that the nominal income is not stationary at level. This is confirmed when we apply the PP tests and the ADF tests, as we cannot reject the null hypothesis of non-stationarity for any of the countries in our self-collected dataset. Hence, we difference the variable, and the tests confirm that all countries, except Norway, are stationary after differencing. Hence, we cannot reject that the income variable for Norway is integrated of second order. Nonetheless, we assume this to be unlikely, given the characteristics of the macroeconomic variable.

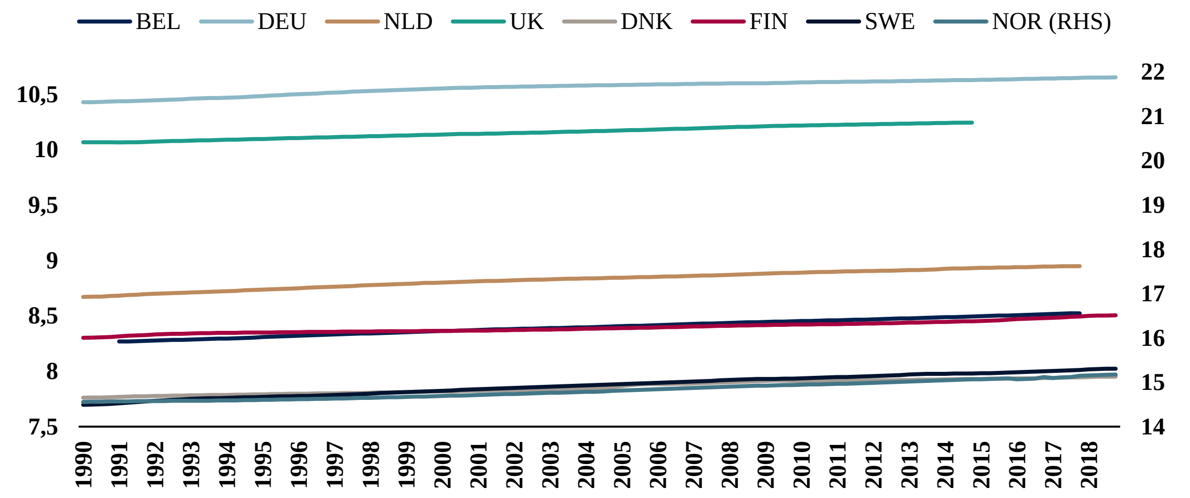
Figure 18: Log Disposable Income 1990-2018



8.5 Housing Stock

The housing stock in **Figure 19** appears to have been increasing since 1990 in all countries. It is also reasonable to assume that a shock to the housing stock is permanent, as a dwelling is functioning for several decades after construction. Hence, we do not expect the housing stock to be stationary at level. All the ADF tests and the PP tests confirm non-stationarity at level for all countries. As the variable appears to be non-stationary at levels, we difference the variable for all countries. However, the ADF tests and PP tests cannot reject non-stationarity for the differenced variable for several countries. This is consistent with Anundsen & Jansen (2013), who find the Norwegian housing stock to be integrated of second order. However, they treat this variable as integrated of order one, as is done in most econometric analysis.

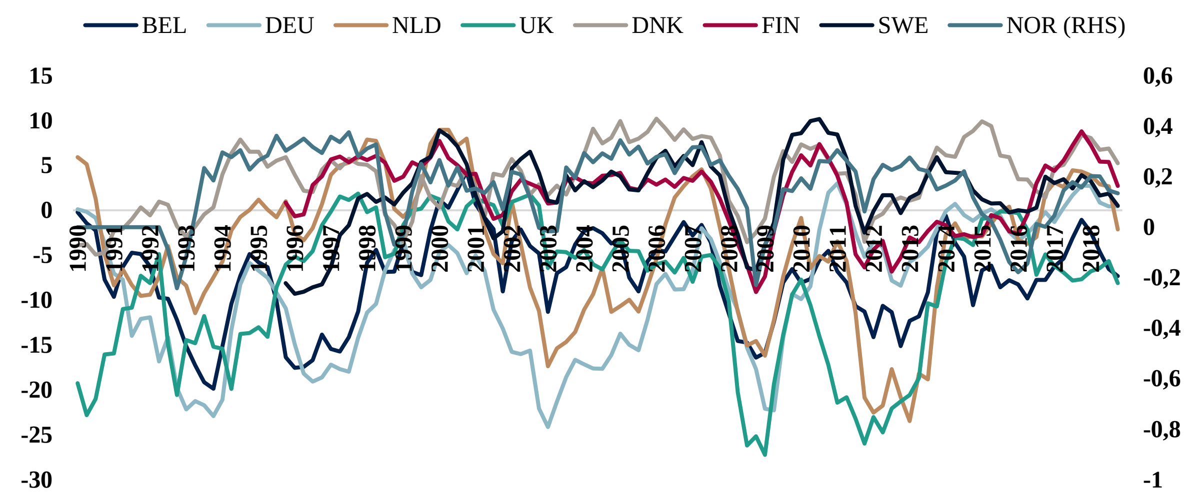
Figure 19: Log Housing Stock 1990-2018



8.6 Consumer Confidence Index

Figure 20 displays the consumer confidence index for all countries between 1990 and 2018, and appears to follow a random walk. The stationarity tests at level have conflicting results, which makes it difficult to conclude if the variable is stationary. Hence, we include tests for the differenced variable. All tests clearly reject the null hypothesis of non-stationarity. Although Jacobsen and Naug (2004) include this variable at levels, we conclude that the variable is integrated of first order, I(1).

Figure 20: Development in Consumer Confidence Index 1990-2018



8.7 Stationarity Tests for the Annual Data

We also test the annual dataset for presence of a unit root. An issue with the dataset is the limited number of observations, varying between 16 and 33, which makes the assessment of unit root more difficult. The study by Arltová and Fedorová (2016) finds the ADF tests and PP tests to have low power in the case of T=25, and hence they have a high probability of committing a type 2 error by accepting a false hypothesis of non-stationarity. We therefore use the KPSS test, as discussed in section 5.6.

The results from the KPSS tests indicate that we cannot reject stationarity for the differenced variables, with the exception being the housing stock for the Netherlands and the unemployment rate for Germany. Hence, the differenced variables are included in the final regression model without risking spurious results. In addition, the test cannot reject the null hypothesis of stationarity in level form for the CCI variable. The ADF tests and PP tests show varying results, but we consider the results less relevant, given the issues with small samples. The results from the KPSS tests, in addition to the nature of the included variables, lead us to conclude that the time series are integrated of order one. Hence, the variables can be included in the regression model after differencing. An overview of the KPSS tests for the annual dataset is found in **Table 30** in **Appendix B**

9. Model Estimation

In this section, we test our first hypothesis:

The model proposed by Jacobsen and Naug is relevant in an international context and can be used to understand the effects of fundamental factors in multiple national housing markets in Northwestern Europe.

We start by analysing the adjusted confidence index model, which is part of the final house price model, then, we analyse the specifications of the house price model. The analyses of the CCI models and the house price models follow the same structure; Firstly, the Norwegian model with original estimation period is evaluated relative to the same model using an extended period. This is to test if the model is still relevant to explain the Norwegian market, or if the model has lost relevance when extending the estimation period. Secondly, if the model is relevant for the extended period, we evaluate its potential for generalisation to a broader Northwestern European market and evaluate the effects.

Following the analyses, we evaluate the validity of the results and our conclusions. The regression is evaluated by examining the independence, constant variation, and normality of the error terms, using both graphical and statistical tests. Next, we create an annualised model based on Jacobsen and Naug's (2004) model specifications with the EMF dataset. We then analyse the differences within each country. Similar results from the annualised model would support the conclusions from models using the self-collected dataset.

9.1 Model Analysis

The models are estimated for each Northwestern European country and the number of observations is dependent on the reliability and availability of the data, which vary across countries.

9.1.1 The Consumer Conficence Idex Model Estimation

We start by evaluating whether the interest rate and unemployment rate are still relevant in explaining the variation in the confidence index after increasing the estimation period. Next, we evaluate their relevance for the selected countries. The expected sign of the relationship and the estimated signs are summarized in **Table 4**, while the regression models are displayed in **Table 5**.

Table 4 - Expectations and Estimated Signs of the Coefficients in the CCI Model

	Expected Direction	Original NOR	Extended NOR	BEL	GER	NLD	UK	DNK	FIN	SWE
Constant	+/−	−	−	−	−	−	−	+	−	−
$\Delta INTEREST(1\text{-}\tau)_t$	−	−	−	+	−	+	+	−	+	+
$\Delta unemployment_t$	−	−	−	−	−	−	−	+	+	+
E_{t-1}	−	−	−	−	−	−	−	−	−	−
$INTEREST(1\text{-}\tau)_{t-1}$	−	−	−	−	−	−	+	−	−	−
$unemployment_{t-1}$	−	−	+	+	+	+	+	+	+	+

The Extended Norwegian sample

The Norwegian models are estimated using data received from Bjørn Naug.[19] In the extended model, we find highly significant effects from interest rate and unemployment rate, indicating that the two variables are still relevant in explaining changes to the confidence index. We find that the lagged unemployment rate has a small positive effect when increasing the sample size, but this variable is not significant in any of the models. The number of observations has more than doubled for the extended model, while the R^2 has dropped from 0.81 to 0.57. This implies that, although the variables still appear to be relevant, they explain less of the variation in the confidence index.

A possible explanation is that the extended model includes an extreme financial event that is not present in the original estimation period. The time series in the original model comprise a period with steady growth in house prices, commencing at the end of the Nordic banking crisis in 1992, and ending a few years before the financial crisis in 2008. In contrast, the extended dataset includes data from the financial crisis in 2008, an extreme event where fundamental relationships between the interest rate and house price were altered from a negative correlation to a positive correlation. In the event of a financial crisis, the central banks usually undertake an expansive monetary policy to turn the economy around. However, we consider the possibility that lower interest rates in a crisis have limited effect on expectations to households' future financial situation due to the negative sentiment and high degree of uncertainty. Consequently, by including this extreme event in the dataset, the

[19] The coefficients for the original model deviate somewhat from the results in Jacobsen and Naug's (2004) article. Bjørn Naug explains that it is due to adjustments to the dataset. Still, the coefficients are similar in absolute terms, and all signs on the coefficients are equal to the original model.

coefficient of determination may be reduced as the interest rate becomes less relevant in explaining much of the variation in expectations.

We estimate an expectations model in **Table 23** in **Appendix A** that accounts for the financial crisis, but the results are counter-intuitive. The estimated model suggests that the financial crisis had a positive effect on expectations for the future, which is unlikely. Also, we find that the interaction variables composed of the financial crisis dummy and the included interest rate variables have an additional negative effect during the crisis. We find these effects unlikely to be true and hence, including a financial dummy does not appear to improve the model.

We conclude that the interest rate and the unemployment rate are still relevant in explaining the Norwegian confidence index, but that including the financial not appear to improve the models. Hence, so we include the original expectations model in the final house price model.

Table 5 - Results from the Expectations Models

	Dependent variable: ΔE_t								
	Original Q1'92 – Q2'04	**NOR** Q1'92 – Q4'18	**BEL** Q2'93 – Q4'17	**GER** Q1'96 – Q4'17	**NLD** Q1'96 – Q4'17	**UK** Q2'95 – Q4'17	**DNK** Q3'03 – Q4'18	**FIN** Q2'98 – Q4'18	**SWE** Q2'01 – Q4'18
ΔINTEREST(1-τ)$_t$	-12.90***	-11.29***	443.09***	-62.47	461.77**	29.33	-28.57	62.53	57.84
	(1.89)	(1.87)	(147.81)	(110.05)	(190.36)	(112.17)	(98.25)	(99.08)	(129.52)
Δunemployment$_t$	-0.44**	-0.50***	-2.76	-52.69***	-10.29	-23.90**	4.48	26.67**	3.55
	(0.17)	(0.13)	(5.53)	(13.32)	(11.30)	(11.85)	(4.96)	(10.48)	(9.38)
E_{t-1}	-0.13	-0.15***	-0.16***	-0.25***	-0.13*	-0.10	-0.12	-0.05	-0.27***
	(0.10)	(0.05)	(0.06)	(0.07)	(0.07)	(0.07)	(0.09)	(0.07)	(0.09)
INTEREST(1-τ)$_{t-1}$	-0.65	-0.52	-25.50	-74.29**	-11.71	11.24	-28.33	-41.97**	-29.71
	(0.95)	(0.41)	(24.89)	(30.51)	(38.64)	(24.05)	(34.00)	(18.40)	(32.33)
unemployment$_{t-1}$	-0.02	0.01	2.54	0.79	2.67*	0.95	0.19	4.61***	4.31*
	(0.03)	(0.03)	(2.60)	(1.73)	(1.52)	(2.39)	(1.46)	(1.62)	(2.56)
Q1	0.21***	0.20***	0.55	0.26	0.08	-0.22	0.33	0.21	0.35
	(0.05)	(0.03)	(0.74)	(0.68)	(0.95)	(0.83)	(0.70)	(0.52)	(0.71)
Q2	0.09***	0.07***	-0.13	-0.09	-0.40	-0.50	0.23	0.07	0.05
	(0.02)	(0.02)	(0.73)	(0.68)	(0.96)	(0.84)	(0.77)	(0.52)	(0.69)
Q3	0.22***	0.18***	-0.30	-0.27	-0.51	-0.53	0.02	-0.04	-0.02
	(0.04)	(0.03)	(0.74)	(0.68)	(0.96)	(0.83)	(0.75)	(0.52)	(0.70)
Constant	-0.06	-0.08***	-5.41	-0.88	-4.16	-2.82	0.99	-8.74**	-7.12
	(0.07)	(0.03)	(5.20)	(2.30)	(3.30)	(3.29)	(3.54)	(3.41)	(5.37)
Observations	46	105	99	88	88	91	63	83	71
R^2	0.81	0.57	0.20	0.29	0.19	0.13	0.13	0.26	0.20
Adjusted R^2	0.76	0.54	0.12	0.22	0.10	0.04	-0.003	0.17	0.09
Residual Std. Error	0.05 (df = 37)	0.06 (df = 96)	2.59 (df = 90)	2.25 (df = 79)	3.15 (df = 79)	2.78 (df = 82)	1.93 (df = 54)	1.67 (df = 74)	2.07 (df = 62)
F Statistic	19.14*** (df = 8; 37)	16.22*** (df = 8; 96)	2.73*** (df = 8; 90)	4.11*** (df = 8; 79)	2.27** (df = 8; 79)	1.48 (df = 8; 82)	0.98 (df = 8; 54)	3.17*** (df = 8; 74)	1.90* (df = 8; 62)

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Relevance for the Additional Northwestern European Market

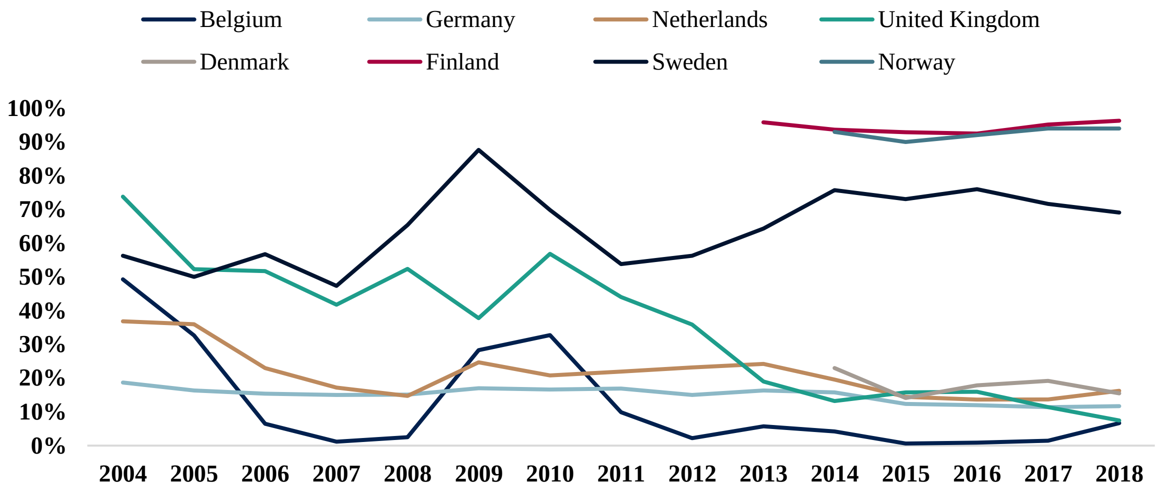
We estimate the modified confidence indicator using the European survey discussed in section 7.6. The Norwegian index is constructed using a different set of questions and is on a different scale, so a direct comparison between Norway and the other European countries is not possible.

Firstly, the regression indicates a significant negative relationship between the unemployment rate and the confidence index in only three of the selected countries. This result can be seen in relation to the different survey styles, where unemployment expectations are specifically asked for in the European survey, but not included when Eurostat creates the final index. Hence, we reason that the unemployment rate is less influential in the European index, which can explain why most countries find no significant negative relationship between expectations and unemployment rate.

Secondly, the effect of interest rate changes on expectations is not consistent across the countries. Jacobsen and Naug (2004) find that the expectations of Norwegian households are strongly correlated with the interest rate, but it is not evident that this is a consistent pattern across Northwestern Europe. Jacobsen and Naug (2004) argue that interest rates are positively correlated with housing costs, as most homeowners debt-finance the purchase of their first dwelling. Expectations regarding the future financial situation are, in part, determined by expectations of future housing cost, which in turn is determined by expectations for the interest rate. For changes in the interest rate to affect the housing cost and, in turn, expectations for European households, they must on average have substantial residential loans, and the loans must be sensitive to interest rate changes.

Figure 21 demonstrates why the Northwester European countries' expectations may be less influenced by changes in interest rates. Norwegian households have a tradition of taking on mortgages with floating interest rates, only matched by Finland and Sweden in the sample. Most countries in the sample have a high share of fixed interest rate loans, lowering the effect of interest rate changes on the household economy. Hence, the effect of interest rates is less relevant to housing costs, which is further supported by the regression results where countries with mostly fixed interest rates find no, or positive, significant effects of interest rates. This cultural difference is a possible explanation for the regression results and implies that the adjustment of the index is less relevant for countries outside Norway.

Figure 21: Development in Gross Lending with Variable Interest Rate 2004-2018



Source: The EMF

Conclusion

The interest rate and unemployment rate are still relevant in explaining the changes to the Norwegian confidence index, but this is not evident in the Northwestern European countries. Hence, in the Northwestern European countries, it appears to be less relevant to adjust the confidence index for expectations to the interest rate and the unemployment rate. Nevertheless, the adjusted expectations indicator is included in the housing models for all European countries to ensure comparability.

9.1.2 House Price Model Analysis

We analyse the house price model using the same procedure as for the confidence index. First, we estimate the model on the extended Norwegian sample to gauge the model's relevance in explaining an extended period. In relation to this, we evaluate the effects during the financial crisis by including a dummy variable and interaction variables. Next, we evaluate the relevance of the model in explaining the housing market in the selected Northwestern European countries. The house price variable for the Northwestern European market is seasonally adjusted and, hence, not directly comparable to the unadjusted house price index for the Norwegian model. To ensure comparability, we estimate a Norwegian model using the adjusted house price. This is used as the relevant extended Norwegian model when we compare it to the estimated Northwestern European countries. An overview of the expected sign and the estimated sign of the coefficients is summarised in **Table 6**.

Table 6 - Expectations and Estimated Signs of the Coefficients in the Final Model

	Expectation	Original NOR	Extended NOR	BEL	GER	NLD	UK	DNK	FIN	SWE
Constant	+/–	+	+	–	+	–	+	–	–	+
$\Delta income_t$	+	+	+	+	–	+	+	–	–	+
$\Delta INTEREST(1\text{-}\tau)$	–	–	–	+	–	–	+	–	–	–
$\Delta INTEREST(1\text{-}\tau)_{t-1}$	–	–	–	+	+	+	+	–	–	+
$EXPEC_t$	+	+	+	–	+	+	+	+	+	+
$houseprice_{t-1}$	–	–	–	+	–	–	–	+	+	–
$INTEREST(1\text{-}\tau)_{t-1}$	–	–	–	–	–	–	–	–	–	–
$unemployment_t$	–	–	–	–	–	–	–	–	–	–
$(income\text{-}housingstock)_{t-1}$	+	+	+	–	+	–	–	–	–	–

The Extended Norwegian Sample

The following sections involve an analysis of the differences between the Norwegian models, and the analysis is separated into short-run effects and long-run effects.

Short-Run Effects

The short-run interest rate effect in the extended model is in line with the original model, displayed in **Table 7**. In the extended model, a one percent change in the contemporaneous interest rate, with the tax rate from 2004, lead to a negative change in housing prices of two percent,[20] consistent with the findings from the original model.[21] On the other hand, the lagged differenced interest rate becomes insignificant in explaining the difference in house prices when extending the estimation period. We hypothesise that the inclusion of the financial crisis in 2008 in the extended sample can be an explanation for the reduced effect. This is due to Norges Bank (2008) acknowledging that the model does not capture the short-run fluctuations of the financial crisis, and concludes "*the relationship identified in the model may change markedly in the current situation of unusually high uncertainty about the outlook for both the economy and house prices"*. In addition, the short-run relationship between interest rates and house prices is often altered during extreme financial events, and for a short period, the lending rates and house prices correlated positively.[22]

We test the hypothesis of a changed relationship between the interest rate and the house prices by including a dummy variable for the financial crisis. Further, to account for the

[20] $-2.81 \cdot (1 - 0.28 \cdot 100\%) = -2.02$ percent.
[21] $-3.05 \cdot (1 - 0.28 \cdot 100\%) = -2.20$ percent.
[22] See discussion in 9.1.1 for discussion of the effect of the financial crisis.

altered relationship between short-run interest rates and house prices, we include interaction terms. We expect the financial crisis dummy to be negative as house prices dropped in this period, while the interest rate interaction terms are expected to be positive due to the altered relationship between house prices and the interest rate.

The model that accounts for the financial crisis is displayed in **Table 7**. Firstly, we find a significant negative effect of the financial crisis on house prices. The contemporaneous short-run interest rate is still negative and significant, and the effect is stronger before and after the financial crisis.[23] The contemporaneous interaction term is highly significant and positive, supporting our hypothesis of an altered relationship during the financial crisis. In addition, the lagged short-run effect of interest rate becomes significant at the 10 percent level, and the model shows a somewhat better fit. By isolating the disturbances from the financial crisis, we make the effects from the extended model more comparable to the original model. Accounting for the financial crisis appears to improve the results for the short-run interest effect and improve the comparability with the original model.

Next, the income variable is insignificant in the original model, the extended model, and the model accounting for the financial crisis. The original model and the extended models indicate a positive effect from income, while the model accounting for the financial crisis has a marginal negative effect. Further, the expectations index has a similar effect in all models but is not significant in the original nor the model that accounts for the financial crisis. In general, we find that the short-term effects support the relevance of both models when extending the estimation period.

[23] $-3.41 \cdot (1 - 0.28 \cdot 100\%) = -2.45$ percent.

Table 7 - Estimated Norwegian Models

	Dependent variable: **Δhouseprice$_t$**		
	NOR Original Q2'90 – Q4'18	**NOR Extended** Q2'90 – Q4'18	**NOR Financial Crisis** Q2'90 – Q4'18
$\Delta income_t$	0.68	0.61	-0.05
	-1.16	-0.52	-0.5
$\Delta INTEREST(1\text{-}\tau)_t$	-3.05***	-2.81***	-3.41***
	-0.5	-0.48	-0.47
$\Delta INTEREST(1\text{-}\tau)_{t-1}$	-1.78***	-0.81	-0.91*
	-0.54	-0.49	-0.47
$EXPEC_t$	0.02	0.03***	0.02*
	-0.03	-0.01	-0.01
$houseprice_{t-1}$	-0.14***	-0.09***	-0.10***
	-0.03	-0.02	-0.02
$INTEREST(1\text{-}\tau)_{t-1}$	-0.42	-0.96***	-1.05***
	-0.38	-0.21	-0.19
$unemployment_t$	-0.05**	-0.02	-0.05***
	-0.02	-0.01	-0.01
$(income\text{-}housingstock)_{t-1}$	0.25***	0.13***	0.14***
	-0.06	-0.05	-0.04
Q1	0.04***	0.04***	0.04***
	-0.01	-0.005	-0.004
Q2	0.02***	0.02***	0.02***
	-0.01	-0.004	-0.004
Q3	-0.001	0.01	0.01**
	-0.01	-0.005	-0.004
Financial_Crisis_Dummy			-0.03***
			-0.01
$\Delta INTEREST(1\text{-}\tau)_t \cdot$ Financial_Crisis_Dummy			2.94***
			-1.1
$\Delta INTEREST(1\text{-}\tau)_{t-1} \cdot$ Financial_Crisis_Dummy			-1.76
			-1.11
Constant	1.03***	0.63***	0.74***
	-0.19	-0.14	-0.13
Observations	56	115	115
R^2	0.86	0.72	0.78
Adjusted R^2	0.82	0.69	0.74
Residual Std. Error	0.02 (df = 44)	0.02 (df = 103)	0.02 (df = 100)
F Statistic	24.52*** (df = 11; 44)	24.10*** (df = 11; 103)	24.65*** (df = 14; 100)
Note:			*p<0.1; **p<0.05; ***p<0.01

Long-Run Effects

The coefficient of the lagged house price explains how house prices are affected when the short-run independent variables deviate from the estimated long-term relationship. Hence, it measures the speed of adjustment back to the equilibrium. For the error correction model to possess the mean-reverting property, the lagged house price coefficient must be negative and significant. Hence, we place great emphasis on the results from error correction term when evaluating the performance of the model for the extended period.

In the extended models, we find negative error correction terms, significant at the 1 percent significance level, indicating that prices revert towards the equilibrium in the event of short-run price deviations. To return to the long-run equilibrium, the extended model that accounts for the financial crisis estimates that house prices takes 9.5 quarters, or 2.4 years, to return to the equilibrium,[24] similar to the extended model not adjusted for the financial crisis. The correction mechanism appears to be slower when estimated on the extended period, as the original model implies that house prices takes about 1.7 years[25] to return to the long-run equilibrium.

We find the effect of permanent changes in the long-run independent variables by dividing the long-run coefficients with the error correction term. **Table 8** illustrates the long-run relationships for the Norwegian models, and all variables have the expected signs.

Table 8 - Norwegian Long-Run Effects

Long-Term Effects	Original	NOR Extended	NOR Extended Financial Crisis
Years to Get Back to Long-Run Equilibrium	1.66	2.65	2.37
After-Tax Interest Rate	-3.00	-10.67	-10.50
Unemployment Rate	-0.36	-0.22	-0.50
Disposable Income minus Housing stock	1.79	1.44	1.40

[24] $\frac{-1}{\ln(1+(-0.10))} = 9.49\ quarters$

[25] $\frac{-1}{\ln(1+(-0.14))} = 6.63\ quarters$

A permanent change in the interest rate has a strong effect in the extended models. One percent permanent increase in interest rates leads to about 7.6 percent[26] decrease in house prices in the long-run. The negative relationship is in line with theory and expectations, but the effect is severely higher than the effect estimated using the original estimation period.[27] Differences in the error correction term explain a part of this deviation. Notably, the effect from interest rates seems to be stronger in the long run compared to the short run for the extended model, even after accounting for the financial crisis. This is reasonable as individuals have limited flexibility in the short run, and home owners usually need time to adjust to changed interest rates.

The effect from a permanent increase in the unemployment rate is a negative long-run effect on house prices. The extended model accounting for the financial crisis indicates that a one percent permanent increase leads to a 0.5 percent decrease in house prices,[28] relatively similar to the original model. The result further supports our hypothesis that accounting for the financial crisis improves the model, as the effect of the unemployment rate is insignificant without the financial crisis variables.

The combined income and housing stock variable is significant in all models. The extended models estimate a positive long-run effect of 1.4 percent, implying that an increase of one percent in the trend in the disposable income relative to the trend in the housing stock leads to a permanent 1.4 percent increase in house prices. If the trend in housing stock increases more than the trend in disposable income, house prices are expected to decrease.

Conclusion

The short-run effects of interest rates and expectations are still present after extending the estimation period. The mean-reverting error term is negative and significant in both the extended models, but the adjustment speed is somewhat slower compared to the original model. In the long run, we find the expected relationship between house prices and the interest rate, the unemployment rate, and the combined income and housing stock variable to be present in the model that isolates the financial crisis effect. In total, we find the original model specification relevant in explaining the Norwegian house market for the extended period, and the model further improves after accounting for the financial crisis.

[26] Extended financial crisis model: $10.5 \cdot (1 - 0.28) = 7.56$ percent. Extended model: $10.67 \cdot (1 - 0.28) = 7.68$ percent.
[27] $4.5 \cdot (1 - 0.28) = 3.2$ percent.
[28] Note that it is not a 1 percentage point change in unemployment, but a 1 percent change in unemployment.

Modelling the Housing Market in the Northwestern European Countries

We expect the adjusted model to be similar to the unadjusted model in the long run, and the short run effects to be different as an adjusted house price index reduces the short-run fluctuations. Our findings from the extended Norwegian models indicate that financial crisis variables should be included when estimating the model on time series spanning the financial crisis. As such, we include financial crisis effects when we estimate the European models. In addition, we estimate a Norwegian model using a seasonal adjusted house price index to bring the model into a format comparable to the Northwestern European models. The identified effects in **Table 9** have signs in line with expectations. Also, there are no significant quarterly effects in the adjusted model, in line with expectations as the house price index accounts for seasonal variation.

Short-Run Effects

Firstly, the effect of contemporaneous changes to the income is not significant for any country, which is in line with the extended Norwegian model. Hence, the short-run effect from changes to the income seems to be of no relevance in explaining the house prices with Jacobsen and Naug's model specification. We find no support for including the adjusted expectations index in the Northwestern European models, as the estimated effect seems to be of no relevance to the short-term house prices in the European market.

The short-run effects of the interest rate in the selected countries differ substantially from the Norwegian model with no significant effects, except for Finland. Hence, the argument that housing demand reacts quickly to changes in market rates finds support in Norway, but among the Northwestern European countries, no countries except Finland, support this claim. We reason that **Figure 21** is relevant to understand the results, as Finland, alongside Norway, is the only country in the sample with almost exclusively floating mortgage interest rates. The model estimates a significant positive correlation between short-run interest rates and house prices in the Netherlands and Denmark. The high share of fixed-rate mortgages provides a potential explanation, but the results may indicate that the model specification does not capture the true effect of the interest rate, as the relationship is found to be negative in other studies. In summary, the short-run effects in the model appear to have limited support outside the Norwegian market.

Table 9 – Estimated Northwestern European House Price Models

	Dependent variable: **Δhouseprice$_t$**							
	Adj. NOR Q2'90 – Q4'18	**BEL** Q2'95 – Q4'17	**GER** Q2'96 – Q4'17	**NLD** Q2'96 – Q4'17	**UK** Q3'95 – Q4'17	**DNK** Q3'03 – Q4'18	**FIN** Q2'96 – Q4'18	**SWE** Q3'96 – Q4'18
Δincome$_t$	0.10	0.09	-0.17	0.12	0.18	-0.07	0.07	0.07
	(0.39)	(0.25)	(0.34)	(0.17)	(0.19)	(0.22)	(0.20)	(0.18)
ΔINTEREST(1-τ)	-0.85**	0.65	-0.50	-0.10	1.08	-0.07	1.07	-1.86
	(0.36)	(0.90)	(0.60)	(0.64)	(0.68)	(0.86)	(0.87)	(1.25)
ΔINTEREST(1-τ)$_{t-1}$	-1.25***	-0.14	0.91	1.51**	1.08	1.54*	-2.24**	1.56
	(0.36)	(0.91)	(0.64)	(0.65)	(0.71)	(0.87)	(0.94)	(1.16)
EXPEC$_t$	0.02***	-0.0000	0.0000	0.0000	0.0000*	0.0000	0.0000	0.0000
	(0.01)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
houseprice$_{t-1}$	-0.08***	0.03	-0.02	-0.03***	-0.03***	0.04	-0.01	-0.01
	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)	(0.03)	(0.04)	(0.04)
INTEREST(1-τ)$_{t-1}$	-0.78***	-0.60**	-0.28	-1.59***	-0.48*	-3.39***	-0.94***	-1.14***
	(0.15)	(0.29)	(0.33)	(0.23)	(0.27)	(0.36)	(0.27)	(0.32)
unemployment$_t$	-0.03**	-0.02	-0.01	-0.04***	-0.03***	-0.05***	-0.02	0.0002
	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
(income-housingstock)$_{t-1}$	0.10***	-0.11*	-0.0001	-0.09***	-0.001*	-0.37***	-0.08	-0.04
	(0.04)	(0.07)	(0.08)	(0.02)	(0.001)	(0.06)	(0.06)	(0.07)
Q1	0.004	-0.002	0.0004	-0.001	0.002	-0.002	0.0002	-0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)	(0.003)	(0.004)
Q2	-0.002	-0.0001	-0.001	-0.001	-0.003	-0.01	-0.001	-0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.01)	(0.005)	(0.003)	(0.004)
Q3	0.002	0.001	0.001	-0.003	-0.005	-0.005	0.0001	0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)	(0.003)	(0.004)
Financial_Crisis_Dummy	-0.02***	-0.003	0.001	-0.003	-0.02***	0.01	0.002	-0.004
	(0.01)	(0.01)	(0.01)	(0.004)	(0.01)	(0.01)	(0.005)	(0.01)
ΔINTEREST(1-τ)$_t$ · Financial_Crisis_Dummy	0.14	1.22	-0.02	1.01	3.91**	0.56	-1.93*	1.36
	(0.85)	(2.25)	(1.84)	(1.53)	(1.48)	(1.08)	(1.15)	(1.43)
ΔINTEREST(1-τ)$_{t-1}$ · Financial_Crisis_Dummy	-0.72	0.81	-0.61	0.79	0.90	-2.46**	1.14	-2.05
	(0.85)	(2.14)	(1.79)	(1.49)	(1.50)	(1.18)	(1.06)	(1.32)
Constant	0.52***	-0.43	0.14	-0.05	0.20***	-0.99***	-0.16	-0.01
	(0.10)	(0.34)	(0.49)	(0.13)	(0.05)	(0.31)	(0.34)	(0.35)
Observations	115	91	87	87	90	62	91	90
R^2	0.65	0.26	0.32	0.79	0.58	0.85	0.57	0.35
Adjusted R^2	0.60	0.12	0.18	0.74	0.50	0.80	0.50	0.23
Residual Std. Error	0.01 (df = 100)	0.01 (df = 76)	0.01 (df = 72)	0.01 (df = 72)	0.01 (df = 75)	0.01 (df = 47)	0.01 (df = 76)	0.01 (df = 75)
F Statistic	13.08*** (df = 14; 100)	1.90** (df = 14; 76)	2.37*** (df = 14; 72)	18.88*** (df = 14; 72)	7.41*** (df = 14; 75)	18.63*** (df = 14; 47)	7.30*** (df = 14; 76)	2.86*** (df = 14; 75)

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Long-Run Effects

The long-run effects in the European countries are more in line with expectations. We find a significant negative effect of interest rates in all countries, except for Germany, and multiple countries find a significant effect from permanent changes to the unemployment rate. The only counter-intuitive long-run effect is growth in income adjusted for growth in the housing stock, which we find to be positive in some countries. The results from this variable contrast to the Norwegian model and may indicate that this variable is specific to the Norwegian housing market.

For the model specification to be relevant in explaining the long-run relationships between house prices and the independent variables, the error correction term must be <-1, 0>. A value greater than zero implies divergence from equilibrium, and leads to an unstable system as a positive short-term deviation in house prices at time t leads to further deviation at time $t+1$ (Mukhtar & Rasheed, 2010). Further, an insignificant error correction term can potentially ruin the long-term interpretation, as we cannot reject the null hypothesis of the coefficient being equal to zero. This, in turn, leads to a meaningless interpretation of the long-run effects as it would be indefinite. We find an insignificant error term for Belgium, Germany, Denmark, Finland, and Sweden, which indicate that the model is not suited in explaining the long-run effects in these markets.

We conclude that the Netherlands and the UK are the only countries in the European dataset that have valid long-run interpretations. Hence, we focus on these two countries when evaluating the long-run effects on house prices. **Table 10** shows the estimated convergence time and long-run effects for all countries. In terms of fill colour, blue highlights the three countries with mean-reverting properties, while no fill indicates the countries where we cannot conclude that the mean-reverting property is present.

Table 10 - Long-Run Effects in the Northwestern European Countries

Long-Term Effects	Adj. NOR	BEL	GER	NLD	UK	DNK	FIN	SWE
Years to Long-Run Equilibrium	3.0	-8.5	12.4	8.2	8.2	-6.4	24.9	24.9
INTEREST(1-τ)	-9.8	20.0	-14.0	-53.0	-16.0	84.8	-94.0	-114.0
unemployment	-0.4	0.7	-0.5	-1.3	-1.0	1.3	-2.0	0.0
Income minus Housing stock	1.3	3.7	0.0	-3.0	-0.0	9.3	-8.0	-4.0

Table 10 indicates that a one percentage point permanent increase in the interest rate in 2017 for the Netherlands and the UK leads to a 42 percent[29] and 16 percent[30] decrease in house prices in the long run, respectively. The size of the effects appears big, especially in the Dutch housing market, despite the interest rates and the error-correction terms being significant. The same is true for the effect of permanent changes to the unemployment rate. If the unemployment level is 4.0 percent in period t, then a one percent increase results in an unemployment rate of 4.04 percent in period $t + 1$. We do not consider it likely that such a small change to the unemployment rate decreases house prices, with 1.3 percent and 1 percent for the Netherlands and the UK, respectively. Lastly, the income minus housing stock variable has a contra-intuitive effect in the Netherlands and no effect in the UK.

To summarise, the two European countries with valid long-run interpretation do not seem economically reasonable and indicate that no European country finds realistic effects with the model specification. This further weakens our hypothesis that the model proposed by Jacobsen and Naug (2004) is appropriate in explaining changes in the European housing market.

Conclusion

The model specification does not appear relevant to describe the housing market in any of the selected countries. The short-term effects have limited relevance in the Northwestern European market, where the interest rates and expectation index are insignificant. Further, the mean-reverting property cannot be confirmed for most countries, invalidating the long-run interpretation. Only the Netherland and the UK find the mean-reverting effect, but the long-run effects from unemployment appear large and the income minus housing stock variable has the wrong sign. In addition, the interest rate effect in the Netherlands appear big. In total, we conclude that the model specification is unsuited for the Northwestern European market.

9.2 Annualised Models

We test the quarterly model results to ensure that the conclusions we draw are valid, and the model is evaluated by creating annualised models using the EMF dataset. The implications

[29] $-53.0 \cdot (1 - 0.216 \cdot 100\%) = -41.55$
[30] $-16.0 \cdot (1 - 0.274 \cdot 0\%) = -11.62$

of annualising the models are twofold; first, the seasonal effects are removed; second, the short-term effects now span a wider period.

To isolate the effect of annualising, we estimate an annual Norwegian model using the original dataset from Bjørn Naug. Similarities between the quarterly model and the annualised model are an indication that the effects are comparable after annualizing, as all factors except for the frequency of the data are unchanged. We focus on the long-run solution and the mean-reverting property of the models in the following section, as the short-run effects in the annualised models capture a wider period, and hence are incomparable. Consistent long-term effects between the annualised models and the quarterly models would further support our conclusions on model misspecification for the European market.

Error Correction Term

A comparable metric for within-country analysis is the adjustment speed of the two models. **Table 11** displays the error correction term for the quarterly and annualised models and is based on **Table 9** and **Table 12**, respectively . We find similar results for the Norwegian models, indicating that the mean-reverting property is relatively unaffected by annualising. Consequently, we assume that the annualised error term has a valid interpretation for the Northwestern European countries.

The results for the annualized models mostly support our conclusion of misspecification for the Northwestern European market. No countries, except Denmark, have a valid mean-reverting property. The models for Germany, the UK, Finland, and Sweden do not have a significant error correction term, and Belgium has an error correction term lower than -1, indicating that house prices return to the long-run equilibrium in less than a year. Hence, the model is unstable and does not converge in the long run. Compared to the Norwegian model, we conclude that the error correction terms deviate to a greater extent, which indicates that either the datasets are incomparable or that the models are misspecified

Table 11 - Number of Years to Revert to Equilibrium for the Models

	NOR Extended Financial Crisis	NOR adj.	BEL	GER	NLD	UK	DNK	FIN	SWE
Quarterly Model	2.37	2.99***	-8.40	12.30	8.2***	8.2***	-6.30	24.80	24.80
Annual Model	2.00***	2.00***	NM	36.50	6.48	2.75*	4.63**	3.15	19.10
Difference	0.37	0.99	NM	-24.2	1.72	5.45	-10.93	21.65	5.70

Table 12 - Results from Jacobsen & Naug's Model Specifications on the Annual Dataset

	Dependent variable: **Δhouseprice**							
	NOR	**BEL**	**GER**	**NLD**	**UK**	**DNK**	**FIN**	**SWE**
	1990-2018	2002-2017	1992-2017	2002-2017	2002-2017	1992-2018	1992-2017	1998-2018
$\Delta income_t$	-0.833	8.060^{**}	0.717^{**}	-0.255	0.336	0.166	-0.541	-0.307
	(0.822)	(2.800)	(0.246)	(0.251)	(0.251)	(0.403)	(0.462)	(0.232)
$\Delta INTEREST(1-\tau)$	-6.086^{***}	4.593	0.016	-5.037^{*}	-0.131	-0.861	-8.151^{**}	-0.233
	(1.278)	(6.808)	(0.542)	(2.111)	(3.418)	(1.252)	(2.775)	(2.152)
$\Delta INTEREST(1-\tau)_{t-1}$	3.207^{**}	4.288	-0.313	-0.260	-3.789	-0.263	-1.975	-1.625
	(1.301)	(4.921)	(0.522)	(1.380)	(2.865)	(1.044)	(1.932)	(1.517)
$EXPEC_t$	0.000	-0.00000	0.00000	0.00000^{**}	-0.00000	0.00000	0.00000	0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
$houseprice_{t-1}$	-0.393^{***}	-1.557^{**}	-0.027	-0.143	-0.304^{*}	-0.194^{**}	-0.272	-0.051
	(0.079)	(0.489)	(0.134)	(0.083)	(0.139)	(0.075)	(0.254)	(0.086)
$INTEREST(1-\tau)_{t-1}$	-5.324^{***}	-0.172	-0.233	-8.659^{***}	0.897	-3.380^{*}	-8.134^{***}	-2.978
	(1.380)	(5.263)	(0.588)	(1.221)	(2.312)	(1.769)	(2.231)	(2.336)
$unemployment_t$	-0.149^{*}	0.758^{**}	-0.036	-0.194^{***}	-0.029	-0.240^{***}	-0.270^{**}	-0.089
	(0.074)	(0.275)	(0.022)	(0.026)	(0.106)	(0.047)	(0.117)	(0.055)
$(income\text{-}housingstock)_{t-1}$	0.454^{**}	5.545^{**}	0.007	-0.804^{***}	0.495	-0.010	-0.277	-0.041
	(0.192)	(1.930)	(0.173)	(0.150)	(0.344)	(0.203)	(0.418)	(0.122)
Financial_Crisis_Dummy	-0.115^{***}	-0.093	0.014	0.038^{*}	-0.040	-0.063	0.046	-0.010
	(0.035)	(0.071)	(0.016)	(0.015)	(0.069)	(0.048)	(0.061)	(0.037)
$\Delta INTEREST(1-\tau) \cdot$ Financial_Crisis_Dummy	-0.194	-4.498	0.977	4.007	1.537	-1.808	5.052	0.166
	(2.014)	(7.550)	(2.088)	(2.560)	(4.793)	(2.516)	(4.186)	(1.926)
Constant	2.309^{***}	-15.062^{**}	0.183	4.279^{***}	-0.513	1.430^{*}	3.065^{***}	0.704^{**}
	(0.396)	(5.549)	(0.568)	(0.532)	(1.223)	(0.691)	(0.682)	(0.229)
Observations	29	16	26	16	16	27	26	21
R^2	0.854	0.881	0.775	0.970	0.904	0.774	0.907	0.765
Adjusted R^2	0.773	0.642	0.624	0.911	0.712	0.632	0.845	0.530
Residual Std. Error	0.037 (df = 18)	0.038 (df = 5)	0.015 (df = 15)	0.013 (df = 5)	0.039 (df = 5)	0.039 (df = 16)	0.049 (df = 15)	0.023 (df = 10)
F Statistic	10.537^{***} (df = 10; 18)	3.685^{*} (df = 10; 5)	5.153^{***} (df = 10; 15)	16.263^{***} (df = 10; 5)	4.710^{*} (df = 10; 5)	5.469^{***} (df = 10; 16)	14.591^{***} (df = 10; 15)	3.256^{**} (df = 10; 10)

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Long-Run Solution

The long-run solution further indicates that the model specification is less relevant for the European market. The interest rate effect has the expected sign and is significant across the included countries when estimated on a quarterly frequency, but is insignificant in explaining house prices for most countries in the annualised model. We expect the effect of the long-run interest rate in the annualised model to be reduced as the short-run interest variables rate span a wider period, which makes it more difficult to conclude that the long-run variable is significant. However, in the annualised Norwegian model, we find the long-run effect[31] of interest rate on house prices to be almost identical to the effect in the quarterly model.[32] Hence, the long-run effect of the interest rate remains unaffected by annualising. This indicates that if the EMF dataset is more accurate in describing the Northwestern European markets, the annualised model for the European countries would find significant negative effects for the long-run interest rate on house prices. As we find limited support for the effect of the interest rate using the EMF dataset, our conclusion of model misspecification for the European countries in section 9.1 is further supported.

The unemployment rate variable is negative and significant for the Norwegian model and indicates that the annualised model also captures the long-run effect of the variable. The annualised European models support the results from the quarterly models, as five of the countries in the total sample find the variable to be significant, indicating that both the quarterly and annual models capture the effect of the unemployment rate among the additional countries.

Next, the results for the income minus housing stock variable improves somewhat in the annualized model, relative to the quarterly model. The Netherlands is the only country with a significant counter-intuitive effect after annualizing, and the model for Belgium finds a strong positive effect from changes in the trend of income relative to the trend in housing stock. Despite these improvements, the Norwegian model finds no significant effect from the difference in trends, indicating that the variable is difficult to capture in the annualised models.

[31] $Annual\ long\text{-}run\ effect\text{:}\ \frac{-5.324}{0.393} = -13.55 \cdot (1 - \tau \cdot \rho)$

[32] $Quarterly\ long\text{-}run\ effect\text{:}\ \frac{-0.78}{0.08} = -9.75 \cdot (1 - \tau \cdot \rho)$

Conclusion

The results in the Norwegian annualised model are similar to the results from the quarterly model, indicating that annualising is relevant to evaluating the long-run solution and mean-reverting property. However, we find limited support for the model specification in the annualised Northwestern European models, despite using a different dataset. The results from the annualised models support the conclusion of misspecification for the Northwestern European housing market. To conclude, we find that the original model specification is still relevant in explaining the Norwegian housing market, while it is less suited for a generalisation to the broader European market.

9.3 Model Validity

The error terms from the estimated models are examined to determine if they possess a non-random structure, which indicates that the model fits the data poorly. To conclude on the model fit, we test the error terms for non-constant variance, independence, and normality. We perform a Breusch-Pagan test and analyse several plots to investigate the variance in the error terms. Independence in the error terms is tested by conducting the Durbin-Watson test and the Breusch-Godfrey test, and by analysing the error terms for patterns. Lastly, we check for normality by examining both a density histogram and a QQ-plot of the error terms, in addition to performing the Shapiro-Wilk test and the Kolmogorov-Smirnov test. All plots and a detailed discussion of the results are located in **Appendix A**, and we summarise the results from all tests on the quarterly models in **Table 13**. Moreover, the validity tests for the annual models can be found in **Table 25** in **Appendix A.**

Table 13 - Validity Tests for the Quarterly Models

p-values	NOR Extended Financial Crisis	Adj. NOR	BEL	GER	NLD	UK	DNK	FIN	SWE
Homoscedasticity									
Breusch-Pagan	0.713	0.402	0.308	0.275	0.189	0.009	0.089	0.151	0.097
Autocorrelation									
Durbin-Watson	0.040	0.004	0.595	0.002	0.015	0.001	0.002	0.000	0.000
Breusch-Godfrey	0.087	0.018	0.007	0.000	0.000	0.015	0.020	0.000	0.001
Normality									
Shapiro-Wilks	0.735	0.509	0.000	0.000	0.001	0.003	0.445	0.158	0.561
Kolmogorov-Smirnov	0.988	0.739	0.117	0.203	0.730	0.541	0.662	0.867	0.899
Anderson-Darling	0.852	0.282	0.007	0.000	0.062	0.004	0.304	0.351	0.686

All plots and the Breusch-Pagan test indicate few issues with heteroscedasticity in the European models, except for the Swedish model and the Norwegian model where the null hypothesis of homoscedastic error terms is rejected. The extended Norwegian model supports the model specification by Jacobsen and Naug (2004), but the presence of heteroscedasticity may lead to biased standard errors and hence, wrong conclusion regarding the significance of the coefficients.

Next, we conclude that serial correlation in the error terms is present in all the estimated models, leading to dependent error terms. This supports the conclusion that the model specification is not suitable for explaining the housing market for the countries in the self-collected dataset but also indicates that the Norwegian model is misspecified.

Finally, the Shapiro-Wilks test[33] (Mohd Razali & Yap, 2011) indicate that Belgium, Germany, the Netherlands, and the UK have a non-normal distribution. This may invalidate the inference but is unlikely to be a problem given the sample size.

9.4 Model Conclusion

This chapter evaluate the hypothesis:

The model proposed by Jacobsen and Naug is relevant in an international context and can be applied to multiple national housing markets in the Northwestern Europe.

Our first finding is that the expectation index is explained mainly by expectations for the interest rate and unemployment rate in Norway. However, this appears not to be the case for the remaining Northwestern European countries. Cultural differences in the use of mortgages and the Norwegian and European surveys emphasising different aspects of the economy are likely explanations for the results.

Secondly, we evaluate the Northwestern European housing market using Jacobsen and Naug's model (2004). The estimation on the extended Norwegian sample shows similar results to the original model, but the interest rate effect is less important in explaining short-

[33] The Shapiro-Wilks test is assumed to be the most powerful of the three included normality tests (Mohd Razali & Yap, 2011).

run changes to the house price. We suspect that the relationship between interest rates and house prices is altered during the financial crisis, and, as such, we isolate the disturbances from the financial crisis by including a dummy variable and interaction variables, to make the effects from the extended model more comparable to the original effects. We find that the financial crisis negatively impacted house prices and that the relationship between the house price and the interest rates is altered. Hence, including financial crisis dummies improve the models. The effects are similar, and we conclude that the model specification is relevant in explaining the Norwegian housing market.

For the remaining European countries, we use the original model specification and include the financial crisis variables to ensure comparability. We find no short-run effects and only the UK and the Netherlands possess the mean reverting property necessary to evaluate the long-run effects, but the long-run effects of these countries appear to be very large. To further test the model specification, we create annualised models for each European country using the EMF dataset. The results from the annualised models support the findings from the quarterly models. Hence, we conclude that the model specification has limited potential for generalisation to a broader Northwestern European market.

10. Panel Vector Error Correction Model

In this section, we test our second hypothesis:

The long-run dynamics in the Northwestern European housing market can be explained by recognised fundamental factors.

The results from chapter 9 imply that the original model specification is not optimal to describe the Northwestern European housing market. In this chapter, we create a Panel Vector Error Correction Model (PVECM) utilising the panel data dimension of the quarterly dataset. We emphasise keeping the model specification simple, with four recognized[34] fundamental factors affecting house prices: the interest rate, the unemployment rate, the disposable income, and the number of completed dwellings. In section 8.5, we find the housing stock to be integrated of second order, which makes it difficult to find cointegrated relationships, as the other included variables are integrated of first order. Hence, the number of completed dwellings is preferred to the housing stock as it is integrated of first order.

10.1 Building a Panel Vector Error Correction Model

The remaining chapter works through the steps to deriving the final PVECM. First, the presence of unit root is discussed. Second, we use different information criteria to determine the appropriate number of lags to use in the model and the test for cointegration. We then test for cointegrated relationships between unit root processes of the same order. In the event of cointegrated relationships, the PVECM is estimated, based on the conclusions from preceding steps. Finally, the results are compared to relevant research and theory before the properties of the PVECM are evaluated.

10.1.1 Unit Root Process

The use of PVECM is dependent on the existence of cointegrated relationships between the included variables. The requirements for cointegration is described in section 5.7, and for variables to be cointegrated, the variables must be in the same order of integration. The conclusion from chapter 8 is that all included variables are integrated of first order, indicating that several cointegration relationships potentially exist among the variables.

[34] See Literature review, chapter 3, for supporting research.

Hence, the cointegration test in section 10.1.3 should not be limited to estimating only one cointegrated relationship. This implies that the more dynamic Johansen test is to be preferred to the more static Engle-Granger alternative.

10.1.2 Determining the Number of Lags

We use two information criteria to properly evaluate the appropriate number of lags to include in the final PVECM and the cointegration test. To identify the correct lag structure is important to avoid problems arising from underfitting or overfitting. By including more lags, the PVECM becomes more complex and increases the probability of overfitting the model to the data. To adhere to the intention of keeping the model specification simple, we limit the number of maximum lags to four, in line with the quarterly format of the data. This may contradict with optimal lag structure, but limits the potential complexity arising from a long lag structure.

We calculate the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) values for five lag structures to determine the number of lags. The lag structure that minimises the score is the preferred specification of the model, and in many cases, the AIC and the BIC agree on the number of lags to include (Burnham & Anderson, 2002). We find the values by re-estimating the model five times using the different lag structures.

The criteria results in **Table 14** suggest conflicting lag structures. We place most emphasis on the results from the BIC, following the findings of Bewley & Yang (1998), where they argue that BIC is preferred in relation to cointegration analysis. In addition, if the two selection criteria conflict, the AIC tends to suggest more complex lag structures than BIC as the latter penalise complexity more heavily (Dziak, Coffman, Lanza, & Li, 2012). To keep the model specification simple, the BIC is preferred as it rarely suggests overly complex lag structures. On the other hand, the BIC run the risk of selecting a too simple structure, but a potentially oversimplified model is a more acceptable risk than a potentially over-complex model resulting from the AIC.

Table 14 - AIC vs BIC with Different Lags

	AIC	BIC
Lag=0	-28.66	-28.49
Lag=1	-30.74	-30.40
Lag=2	-31.80	-31.29
Lag=3	-31.82	-31.14
Lag=4	-31.94	-31.07

10.1.3 Cointegration

The Johansen test is used to estimate the number of cointegrated relationships among the variables properly. The test is preferable to the original Engle-Granger test as it allows more than one cointegrated relationship to exist among the variables. The test reports both the Trace statistic and Max-Eigen statistic, with the null- and alternative hypotheses stated in section 5.7. For the test, we choose the number of lags to be two, following the discussion from section 10.1.2.

The Johansen test is displayed in **Table 15** and rejects the first null hypothesis of no cointegrated vectors $(r = 0)$, with a p-value of zero for both tests. The result implies that cointegrated vectors exist among the variables. Next, the null hypothesis of maximum one cointegrated vector $(r = 1)$ is tested against the alternative of more than one cointegrated vector. The Trace value and the Max-Eigen value have p-values close to zero. Hence, both tests reject the null hypothesis and we proceed to test with $r = 2$. The results from the null hypothesis of at most two cointegrated relationships have conflicting results from the two tests. The null hypothesis is rejected by the Trace statistic with a p-value of 0.0037, while the Max-Eigen test cannot reject the null hypothesis of at most two cointegrated relationships. Further, the results from the next rank find that the Trace statistic cannot reject the hypothesis of more than three cointegrated relationships. We assume two cointegrated relationships for the final model.

Table 15 - Johansen Fisher Panel Cointegration Test

Johansen Fisher Panel Cointegration Test	
Series	*houseprice, housing_completed, income, unemployment, INTEREST(1-τ)*
Sample (adjusted):	Q1'95 - Q4'18
Included oberservations after adjustments:	768
Lag interval (in first differences)	2
Trend assumption	linear deterministic trend

Hypothesised No. of CE(s)	**Fisher Stat.* (from Trace test)**	**Prob.**	**Fisher Stat.* (from Max-Eigen test)**	**Prob.**
None	118.70	0.00	67.85	0.00
At most 1	64.08	0.00	40.76	0.00
At most 2	35.25	0.00	25.43	0.06
At most 3	21.40	0.16	20.24	0.21
At most 4	18.89	0.27	18.89	0.27

*probabilites are computed using asymptotic chi-squared distribution

10.2 The Estimated Model

The PVECM is estimated on a quarterly frequency with an unbalanced panel consisting of the eight countries used for time series estimation in chapter 9. The implementation is based on the findings from section 10.1.2 and 10.1.3, with the assumption of a constant cointegration rank for all countries. The PVECM is expressed with the included variables:

$$\Delta y_{i,t} = \beta_0 + \sum_{h=1}^{2} \beta_{i,1} \Delta y_{t-h} + \sum_{h=1}^{2} \beta_{i,2} \Delta x_{1_{t-h}} + \sum_{h=1}^{2} \beta_{i,3} \Delta x_{2_{t-h}} + \sum_{h=1}^{2} \beta_{i,4} \Delta x_{3_{t-h}} + \sum_{h=1}^{2} \beta_{i,5} \Delta x_{4_{t-h}} + \Pi_i ECT_{i,t-1} + \varepsilon_{i,t} \tag{28}$$

$$y = house\ price$$
$$x_1 = housing\ completions$$
$$x_2 = disposable\ income$$
$$x_3 = unemployment\ rate$$
$$x_4 = \text{INTEREST}\ (1 - \tau)$$
$$ECT = Error\ Correction\ Term$$
$$i = 1, \dots, 8$$

With

$$ECT_{i,t-1} = \delta_{i,1} y_{i,t} + \delta_{i,2} x_{1_{i,t}} + \delta_{i,3} x_{2_{i,t}} + \delta_{i,4} x_{3_{i,t}} + \delta_{i,5} x_{4_{i,t}}$$

In equation (27), small letters indicate that the variables are measured on a logarithmic scale. i is still a cross-sectional index for the Northwestern European countries while t indicates the time period. $\Delta houseprice_{i,t}$ represents the logarithmic first difference of house prices, and $\beta_{i,h}$ represents the short-run effect for country i at lag h for each variable on the logarithm of house prices. Further, $\Pi_i ECT_{i,t-1}$ represents the error correction term of the model and $\Pi_\mathrm{i} < 0$ is required for the model to have the desired mean-reverting property.

The estimated PVECM with quarterly observations for the period 1995-2018 is presented in **Table 16**, and we evaluate the results for the differenced short-term effects, the error correction term, and the long-term effects in the following sections. The results are interpreted as the overall changes to house prices in the event of changes in the variables for the collective Northwestern European countries.

Table 16 - Estimated Panel Vector Error Correction Model with 2 Lags

Vector Error Correction Estimates				
Sample (adjusted):	Q1'95 - Q4'18			
Included observations after adjustments:	663			
Lags:	2			
Rank:	2			
Dependent Variable	Δ*house_price*			
Long-run effects	Coefficient	Standard Error	t-value	p-value
house_price	1.00			
housing_completed	0.00			
income	-0.04	0.02	-2.78	0.01
unemployment	0.87	0.11	7.88	0.00
INTEREST(1-τ)	2.24	2.03	1.10	0.27
Constant	-5.83			
Short-run effects	Coefficient	Standard Error	t-value	p-value
CointEq1	-0.0174	0.0026	-6.6251	0.00
CointEq2	0.0022	0.0005	4.7340	0.00
$\Delta house\_price_{t-1}$	0.43	0.04	11.24	0.00
$\Delta house\_price_{t-2}$	0.04	0.04	1.08	0.28
$\Delta housing\_completed_{t-1}$	0.02	0.03	0.76	0.45
$\Delta housing\_completed_{t-2}$	-0.02	0.03	-0.79	0.43
$\Delta income_{t-1}$	0.10	0.08	1.26	0.21
$\Delta income_{t-2}$	0.00	0.08	-0.03	0.97
$\Delta unemployment_{t-1}$	-0.04	0.01	-3.68	0.00
$\Delta unemployment_{t-2}$	0.03	0.01	2.63	0.01
$\Delta INTEREST(1-\tau)_{t-1}$	-0.59	0.25	-2.33	0.02
$\Delta INTEREST(1-\tau)_{t-2}$	-0.09	0.26	-0.35	0.73
Constant	0.00	0.00	4.10	0.00
Properties				
R-squared	0.41			
Adj. R-squared	0.40			
Sum sq. Residuals	0.12			
S.E. equation	0.01			
F-statistic	37.97			
Log likelihood	1918.87			
Akaike AIC	-5.75			
Schwarz SC	-5.66			
Mean dependent	0.01			
S.D. dependent	0.02			

10.2.1 Short-Run Effects

The model specification includes two coefficients for the differenced variables, following the proposed lag structure. We find that house prices are affected by the first lag of house prices, the first lag of after-tax interest rate, and both the first lag and the second lag of the unemployment rate. The significant short-run variables from the model are consistent with previous research on short-run effects in the housing market[35]. We find house prices to follow a trend, where a one percent change in house prices is followed by a 0.43 percent change in the same direction the next quarter. Further, positive changes to the mortgage interest rate before tax deduction have a negative effect on house prices in the short run, as a one percentage point increase in the preceding quarter results in a 0.59 percent decrease in house prices. Lastly, changes to the unemployment rate have conflicting short-run effects. Changes to the unemployment rate in the preceding quarter have a negative effect on house prices, but the effect is offset in the next quarter.

The remaining short-term coefficients in the model are not statistically significant. Hence, the model does not find any short-run effect from either the supply side, represented by the number of completed dwellings, or from the disposable income. The number of completed dwellings is relatively stable over time, and it is reasonable to assume that house prices are more affected by trends in the supply side. Hence, we do not expect the number of completed dwellings to influence short-run price fluctuations. The insignificant results for the short-run effect of the disposable variable are in line with the results from the estimated country-specific models.

10.2.2 The Error Correction Term

The error correction term, *CointEq1*, in **Table 16** is negative and significant. Hence, we find a reverting trend to the long-run equilibrium following short-term deviations, where the reversion to the long-run equilibrium materialises gradually over time with multiple short-run adjustments. The correction mechanism appears slow compared to our expectations as a short-run deviation from the estimated equilibrium is corrected gradually over the next 14 years[36]. Nonetheless, the slow adjustment speed can be reasonable for the housing market,

[35] See literature review in section 3, (Égert & Mihaljek, 2007) and (Adams & Füss, 2010)

[36] $\frac{1}{4} \cdot \frac{-1}{\ln(1-0.0174)} = 14.24\ years$

with intervention from central banks and national governments, and potential impacts from external factors.

10.2.3 Long-Run Effects

The long-run equilibrium is estimated by eliminating all short-run fluctuations. We set all short-run variables equal to zero and solve the model with respect to the dependent variable, $houseprice$. We derive the long-run solution in the following equations:

$$1 \cdot y + 0 \cdot x_1 - 0.042x_2 + 0.875x_3 + 2.245x_4 = 0 \tag{29}$$

And solve for the dependent variable:

$$y = 0.042x_2 - 0.875x_3 - 2.245x_4 \tag{30}$$

Equation (30) represents the long-run equilibrium. The cointegration specification removes the potential for analysis of the long-run effects from the supply side. All the remaining long-run effects have the expected sign in line with the theory discussed in chapter 4, and we find the effects of disposable income and unemployment rate to have a significant effect, while the interest rate is insignificant.

A one percent permanent increase in the income level results in long-run house prices increasing by 0.042 percent. We do not estimate the effect of changes to the income individually in the models in chapter 9, but the effect from a one percent increase in income relative to the housing stock in the extended Norwegian model, where we concluded that the model specification is relevant, indicates that house prices increase by 1.4 percent in the long run. As such, the changes to the income levels in the Northwestern European market appear to have a lower effect. Further, a one percent increase in the general Northwestern European unemployment level is associated with a 0.875 percent decrease in long-run house prices. In section 9.1.2, we reason that the effect from the long-run unemployment rate in the extended Norwegian model is high, but it appears to be even more severe outside Norway when estimated using the PVECM. Overall, the long-run results are in line with expectations, except for the insignificant interest rate effect.

10.2.4 Granger Causality

We test for causality using the Granger causality test to investigate if spurious relationships are present. We assume that the first assumption for the test is satisfied,[37] due to the dynamic nature of the model. The second assumption regarding causality from future values is ambiguous.

The assumption states that the future cannot affect the present, which is violated if expectations regarding future values affect the value of present variables (Parker, 2012). Expectations of future values are likely highly correlated with the realised values in the future, and if these expectations affect individuals´ choice of value, the assumption does not hold. We evaluate whether expectations about future house prices impact the present values of the independent variables included, and we focus on the housing supply and the interest rate as we find these variables most likely to violate the assumption.

Firstly, the housing supply is decided by evaluating the expected sales price relative to the construction costs. Corder and Roberts (2008) argue that builders base decisions on the sales price they expect to achieve when the property is completed. If the construction companies expect the sales price to satisfy the required rate of return, they build the dwelling. Hence, expectations about future house prices may impact the present value of the construction variable, which is a violation of the assumption.

Secondly, the future values of house prices may affect present interest rates. The mortgage interest rate is impacted by several factors, including the policy rate of the central bank (Klovland, 2019). Banks use an increase in policy rates to justify an increase in mortgage interest rates, which has been the case in Norway following four recent interest hikes[38] (DNB, 2019; Nordea, 2019). The potential violation of the assumption arises from the considerations the central banks make when deciding the policy rate. Although the official mandate of the ECB and most central banks is to control the price level in the economy, they also consider the implications for the broader economy (Sørensen & Lichtenberger, 2007; EU, 2019). A similar consideration is also made by the Norwegian central bank when evaluating the policy rate (Hovland, 2017), and the regulation for the Norwegian central

[37] See section 5.11 for theory and requirements for the Granger test to identify a causal relationship
[38] An article written in English regarding the interest hike and response of commercial banks is presented by Berglund (2019), see references for further details.

bank from 2017 states that the monetary policy should stabilise the economy and control the price level (Olsen, 2019). The housing market is an important part of the economy that central banks take into consideration when evaluating the economic development (Olsen, 2017). Hence, expectations of future house prices may impact the final interest rate of mortgages through the policy rate.

In summary, if these two variables are affected by future house prices, the estimated Granger causality is invalid. We consider this when we evaluate the results presented in **Table 17**. We find a Granger causal relationship from the interest rate and the unemployment rate to house prices, which implies that the two variables are relevant in forecasting house prices. In addition, the Granger test performs a joint test of the null hypothesis that all the independent variables fail to explain house prices, which is rejected. Hence, we are confident that the model is relevant in explaining changes in house prices for the Northwestern European market.

Nonetheless, as the Granger test finds only predictive causality, we cannot postulate true causality. In addition, the discussion of the Granger assumptions indicates that the assumptions can be violated, which invalidate the results from **Table 17**.

Table 17 – The Granger Causality Test

VEC Granger Causality/Block Exogeneity Wald Tests			
Sample (adjusted):	Q1'95 - Q4'18		
Included Observations	663		
Dependent Variable	Δ*house_price*		

Excluded	**Chi-sq**	**df**	**Prob**
Δ*housing_completed*	0.65	2	0.72
Δ*income*	1.60	2	0.45
Δ*unemployment*	25.88	2	0.00
Δ*INTEREST(1-τ)*	6.31	2	0.04
All	33.24	8	0.00

10.3 Validity of the Estimated Model

We perform validity tests on the estimated PVECM to evaluate the model specification. The focus is on the residual tests for non-normality and serial correlation. Violation of the assumptions may influence the reliability of inference from the estimated coefficients in the model.

10.3.1 Normality

Normality in the error terms is a precondition for interpreting the significance of the estimated coefficients.[39] A larger sample indicates that a break in the normality assumption becomes more trivial (Pallant, 2007). Altman & Bland (1995) argue that for samples containing hundreds of observations, the distribution of the data can be ignored. With quarterly observations for all variables for more than 20 years from eight different countries, potential non-normality reported by the Jarque-Bera test is less problematic. Nonetheless, we report the Jarque-Bera results in **Table 18**.

The test results strongly reject the null hypothesis of normally distributed residuals, which implies that the significance of the estimated coefficients becomes subject to uncertainty. Normality tests are, in general, more sensitive to small violations in the case of large sample sizes, which result in the Jarque-Bera test rejecting the normality assumption for the model. Considering the arguments from Pallant (2007) and Altman & Bland (1995), we do not consider it a problem.

Table 18 - Jarque Bera Test

VEC Residual Normality Tests	
Sample (adjusted):	Q1'95 - Q4'18
Included Observations	663
Orthogonalization:	Residual Covariance (Urzua)
Null Hypothesis:	Residuals are multivariate normal

Component	Jarque-Bera	df	Prob
1	241.59	2	0.00
2	484.15	2	0.00
3	979.74	2	0.00
4	199.37	2	0.00
5	336.32	2	0.00
Joint	3734.67	105	0.00

[39] See section 5.4 for more on normality.

10.3.2 Serial Correlation

Next, the model is evaluated for any presence of serial correlation in the error terms. Serial correlation affects the standard errors and, hence, the estimated test statistics. We find it necessary to evaluate the lag length selected in section 10.1.2 to ensure that the standard errors are not biased.

The results in **Table 19** indicate a strong presence of serial correlation for multiple lag structures up to $h = 11$, which is the first lag structure that cannot reject the null hypothesis of no serial correlation. This has implications for the estimated model and the credibility of the conclusions drawn from the analysis of the short-run and the long-run effects. The test results indicate that the PVECM should be re-specified with $h = 10$ lags[40] to be free from serial correlation and allow for valid conclusion of the coefficients (Canova, 2007). The use of several lags conflicts with the ambition of keeping the model specification simple, but finds support from the lower AIC value of -32.89 for the re-specified model.

Table 19 - LM Test for Autocorrelation

VEC Residual Serial Correlation LM tests						
Sample (adjusted):	Q1'95 - Q4'18					
Included Observations	663					
Null hypothesis:	No serial correlation at lag h					
Lag	LRE*stat	df	Prob.	Rao F-stat	df	Prob
1	56.23	25	0.00	2.26	(25, 2382.7)	0.00
2	93.01	25	0.00	3.78	(25, 2382.7)	0.00
3	94.69	25	0.00	3.84	(25, 2382.7)	0.00
4	425.93	25	0.00	18.56	(25, 2382.7)	0.00
5	107.28	25	0.00	4.37	(25, 2382.7)	0.00
6	44.21	25	0.01	1.78	(25, 2382.7)	0.01
7	47.99	25	0.00	1.93	(25, 2382.7)	0.00
8	185.93	25	0.00	7.70	(25, 2382.7)	0.00
9	40.66	25	0.02	1.63	(25, 2382.7)	0.02
10	46.25	25	0.01	1.86	(25, 2382.7)	0.01
11	24.25	25	0.51	0.97	(25, 2382.7)	0.51

[40] $h = 10$ follows from the result of $h = 11$ for the unrestricted VAR model in the LM test.

10.4 Re-estimating the Model

We estimate the re-specified model with all the assumptions from the first PVECM, except for the increased lag length, which increases complexity. However, we are most interested in the long-run solution for the housing market, and an increased lag length does not incur greater complexity in interpreting the long-run effects. The increased number of lags reduce the degrees of freedom as each lag consumes an observation. Nonetheless, the large sample size ensures that we still have enough observations to estimate the model. The new lag structure frees the model from serial correlation but does not guarantee that the new model is optimal to describe the underlying dataset. By increasing the number of lags, we run the risk of overfitting the model to the dataset. Problems with overfitting result in potentially wrongly estimated effects and limit the applicability of the model.

10.4.1 Results from the Re-Estimated Model

The new model is displayed in **Table 20**, and we find similar results from the re-estimated model with ten lags compared to the results from the model with two lags. The short-run dynamics of the model are more complex as additional eight coefficients for each variable capture the effects. Still, we find significant short-run effects for the lagged house price, the lagged unemployment rate, and the lagged interest rate. When looked at in more detail, the house prices are in the short-run affected by the first, seventh, and tenth lag of house prices, the fourth lag of the unemployment rate and the first and seventh lag of the interest rate. The remaining short-run coefficients are not significantly different from zero. Hence, the housing stock and income variables remain irrelevant in explaining short-run variations when the increasing number of lags.

The error correction term is still negative and significant, which implies that house prices revert towards the long-run equilibrium following short-run deviations. The coefficient of the error term is smaller for the re-estimated model, which implies that the adjustment speed is slower compared to the first PVECM. The long-run solution is derived using the same procedure as for the first model, and the new solution is given by:

$$y = 0.095x_2 - .463x_3 - 5.617x_4 \tag{31}$$

$$y = house\ price$$

$$x_2 = disposable\ income$$

$$x_3 = unemployment\ rate$$

$$x_4 = \text{INTEREST}\ (1 - \tau)$$

In the new model, we find the coefficients of income and interest rate to be about twice the size compared to the first model, while the effect of the unemployment rate coefficient is reduced. In addition, all variables are now significant in the long-run solution. This is more in line with our expectations based on theory and similar studies.

The disposable income has a stronger effect on house prices compared to the first model, as a one percent permanent increase in the disposable income level in Northwestern Europe is associated with a 0.1 percent increase in long-run house prices. The effect is still small relative to our findings from the extended Norwegian model but is a less relevant comparison as the model specification does not include disposable income separately in the long-run. Further, the effect of permanent changes in the unemployment rate is almost identical to the estimated effect from the Norwegian extended model and Jacobsen and Naug's (2004) findings. This suggests that a permanent change in the unemployment rate of one percent changes house prices by 0.5 percent, and we infer that this factor is equally important for the Norwegian market as for the broader Northwestern European market. Further, we argue this to be evidence for the importance of the unemployment rate in explaining changes in long-run house prices, in line with numerous studies.[41]

The long-run effect of interest rate is significant in the re-estimated model. A one percentage point permanent increase in the interest rates in the Northwestern European market results in a 5.6 percent decrease in overall house prices. The estimated effect is greater than the estimated long-run effect of 4.47 percent identified by Jacobsen and Naug (2004), and smaller than the 10.5 percent effect we find in the extended Norwegian model. Hence, our findings from the re-estimated model substantiate the conclusions from studies[41] that argue in favour of the importance of the interest rate in determining house prices.

We find the long-run effects of both the interest rate and the unemployment rate in the PVECM to be similar to the estimated long-run effects for the Norwegian market identified by Jacobsen and Naug (2004), despite different, unrelated datasets and inherently different model specifications for the two analyses. The consistent results support the effects from the estimated PVECM, and if we assume both models to be relevant in explaining the housing

[41] Égert & Mihaljek (2007), Adams & Füss (2010), Andrews (2010).

market, the result implies that a permanent change to any of the explanatory variables in Northwestern Europe is expected to cause Norwegian house prices to move proportionally with the estimated trend for the broader market.

We test the PVECM with ten lags for predictive causality using the Granger causality test. The results are similar and support the conclusion from the first PVECM that a causal relationship exists from the interest rate and the unemployment rate to house prices. There are only minor changes to the results, with the causal relationship from interest rates to house prices significantly at a one percent level. The joint test for causality is highly significant, which indicates that the new model is relevant in explaining house prices.

Table 20 - Estimated Panel Vector Error Correction Model with 10 Lags

Vector Error Correction Estimates				
Sample (adjusted):	Q1'95 - Q4'18			
Included observations after adjustments:	599			
Lags:	10			
Rank:	2			
Dependent Variable	$\Delta house\_price$			

Long-run effects	Coefficient	Standard Error	t-value	p-value
house_price	1.000			
housing_completed	0.000			
income	-0.095	0.018	-5.176	0.00
unemployment	0.463	0.139	3.326	0.00
INTEREST(1-τ)	5.617	2.837	1.980	0.05
Constant	-4.91			

Properties	
R-squared	0.52
Adj. R-squared	0.48
Sum sq. Residuals	0.08
S.E. equation	0.01
F-statistic	11.58
Log likelihood	1811.06
Akaike AIC	-5.87
Schwarz SC	-5.48
Mean dependent	0.01
S.D. dependent	0.02

Short-run effects	Coefficient	Standard Error	t-value	p-value	**Short-run effects**	Coefficient	Standard Error	t-value	p-value
CointEq1	-0.008	0.00	-3.03	0.00	Constant	0.00	0.00	0.94	0.35
CointEq2	0.000	0.00	0.87	0.39					
$\Delta house\_price_{t-1}$	0.42	0.04	10.17	0.00	$\Delta income_{t-6}$	0.02	0.08	0.31	0.76
$\Delta house\_price_{t-2}$	0.04	0.05	0.88	0.38	$\Delta income_{t-7}$	-0.04	0.08	-0.44	0.66
$\Delta house\_price_{t-3}$	0.06	0.05	1.25	0.21	$\Delta income_{t-8}$	-0.06	0.08	-0.73	0.46
$\Delta house\_price_{t-4}$	0.00	0.05	-0.10	0.92	$\Delta income_{t-9}$	-0.03	0.08	-0.39	0.69
$\Delta house\_price_{t-5}$	0.02	0.05	0.52	0.60	$\Delta income_{t-10}$	0.04	0.08	0.52	0.60
$\Delta house\_price_{t-6}$	-0.07	0.05	-1.53	0.13	$\Delta unemployment_{t-1}$	-0.03	0.01	-1.93	0.05
$\Delta house\_price_{t-7}$	0.12	0.04	2.79	0.01	$\Delta unemployment_{t-2}$	0.00	0.01	-0.01	0.99
$\Delta house\_price_{t-8}$	0.08	0.04	1.73	0.08	$\Delta unemployment_{t-3}$	-0.01	0.02	-0.78	0.43
$\Delta house\_price_{t-9}$	0.08	0.04	1.83	0.07	$\Delta unemployment_{t-4}$	0.06	0.02	3.91	0.00
$\Delta house\_price_{t-10}$	-0.15	0.04	-3.60	0.00	$\Delta unemployment_{t-5}$	-0.02	0.02	-1.26	0.21
$\Delta housing\_completed_{t-1}$	0.07	0.06	1.11	0.27	$\Delta unemployment_{t-6}$	-0.01	0.01	-0.87	0.38
$\Delta housing\_completed_{t-2}$	-0.07	0.11	-0.60	0.55	$\Delta unemployment_{t-7}$	-0.02	0.01	-1.67	0.09
$\Delta housing\_completed_{t-3}$	-0.06	0.12	-0.52	0.60	$\Delta unemployment_{t-8}$	0.03	0.02	1.74	0.08
$\Delta housing\_completed_{t-4}$	0.04	0.12	0.30	0.76	$\Delta unemployment_{t-9}$	-0.01	0.01	-1.00	0.32
$\Delta housing\_completed_{t-5}$	0.15	0.12	1.20	0.23	$\Delta unemployment_{t-10}$	-0.03	0.01	-1.79	0.07
$\Delta housing\_completed_{t-6}$	-0.11	0.12	-0.87	0.38	$\Delta INTEREST(1-\tau)_{t-1}$	-0.97	0.27	-3.61	0.00
$\Delta housing\_completed_{t-7}$	-0.07	0.12	-0.60	0.55	$\Delta INTEREST(1-\tau)_{t-2}$	-0.40	0.29	-1.41	0.16
$\Delta housing\_completed_{t-8}$	0.08	0.12	0.68	0.49	$\Delta INTEREST(1-\tau)_{t-3}$	-0.53	0.30	-1.79	0.07
$\Delta housing\_completed_{t-9}$	0.01	0.11	0.09	0.93	$\Delta INTEREST(1-\tau)_{t-4}$	-0.21	0.30	-0.72	0.47
$\Delta housing\_completed_{t-10}$	-0.01	0.06	-0.14	0.88	$\Delta INTEREST(1-\tau)_{t-5}$	-0.28	0.29	-0.95	0.34
$\Delta income_{t-1}$	0.04	0.09	0.52	0.61	$\Delta INTEREST(1-\tau)_{t-6}$	-0.33	0.29	-1.14	0.26
$\Delta income_{t-2}$	0.04	0.08	0.42	0.68	$\Delta INTEREST(1-\tau)_{t-7}$	-0.65	0.29	-2.25	0.02
$\Delta income_{t-3}$	-0.01	0.08	-0.13	0.90	$\Delta INTEREST(1-\tau)_{t-8}$	-0.40	0.29	-1.40	0.16
$\Delta income_{t-4}$	-0.01	0.08	-0.09	0.93	$\Delta INTEREST(1-\tau)_{t-9}$	0.16	0.27	0.58	0.56
$\Delta income_{t-5}$	0.03	0.08	0.34	0.74	$\Delta INTEREST(1-\tau)_{t-10}$	-0.12	0.26	-0.48	0.63

10.4.2 Validity of the Re-Estimated Model

We evaluate the new model specification by applying the Jarque-Bera test for normality and the LM test for serial correlation to determine if the validity has improved following the re-estimation.

Normality

The results from the Jarque-Bera test displayed in **Table 21** are similar to the first model. The sample size is still large for the re-estimated model, despite the high number of lags, and the reasoning from section 10.3.1 is still relevant to explain why we assume the reported non-normality from the Jarque-Bera test to be less important.

Serial Correlation

The new model is estimated to address the issue of serial correlation in the error terms. We perform the LM test on the re-estimated model displayed in **Table 22**, and the results indicate that increasing the number of lags to ten successfully removes the serial correlation. The test cannot reject the null hypothesis of no serial correlation for one lag, implying that the model is free of serial correlation. Hence, we expect the re-estimated model to be closer to the *true* model for explaining the long-run dynamics in the housing market.

Table 21 - Jarque-Bera Test of the Panel Vector Error Correction Model with 10 lags

VEC Residual Normality Tests	
Sample (adjusted):	Q1'95 - Q4'18
Included Observations	599
Orthogonalization:	Residual Covariance (Urzua)
Null Hypothesis:	Residuals are multivariate normal

Component	**Jarque-Bera**	**df**	**Prob**
1	241.59	2	0.00
2	484.15	2	0.00
3	979.74	2	0.00
4	199.37	2	0.00
5	336.32	2	0.00
Joint	3734.67	105	0.00

*Approximate p-values do not account for coefficient estimation

Table 22 - LM Test of the Panel Vector Error Correction model with 10 lags

VEC Residual Serial Correlation LM tests						
Sample (adjusted):	Q1'95 - Q4'18					
Included Observations	599					
Null hypothesis:	No serial correlation at lag h					
Lag	**LRE*stat**	**df**	**Prob.**	**Rao F-stat**	**df**	**Prob**
1	29.56	25	0.24	1.18	(25, 1996.4)	0.24
2	32.09	25	0.16	1.29	(25, 1996.4)	0.16
3	25.40	25	0.44	1.02	(25, 1996.4)	0.44

10.5 Panel Vector Error Correction Model Conclusion

This chapter evaluates the second hypothesis:

The long-run dynamics in the Northwestern European housing market can be explained by recognised fundamental factors.

We find two cointegrated relationships among the included variables in the dataset, which allow for the use of a panel vector error correction model. Initially, we estimate a model with two lags to adhere to the ambition of limiting the complexity of the model specification. We find short-run effects from the interest rate and the unemployment rate, in line with theory and numerous studies. The insignificance of the variable representing the supply side is expected as the number of completed dwellings is stable across the estimation period. We do not find short-run effects from changes in the disposable income, which indicate that changes to disposable income do not materialise in the housing market within two quarters. The long-run shifts are affected by permanent changes to the unemployment rate and the disposable income, where a one percent permanent increase in the variables is associated with a 0.87 percent decrease and 0.04 percent increase in house prices, respectively. The result for changes in the long-run interest rate is somewhat counter-intuitive as we cannot conclude that the interest rate has a significant effect on house prices.

We find strong evidence of serial correlation in the error terms, and consequently, we re-estimate the model with the optimal lag length indicated by the LM test. Again, we find the short-run changes in the house prices to be affected by the interest rate and the unemployment rate. Moreover, the interest rate is significant in the re-specified model, and the effect is similar to our findings in section 9.1.2 on the Norwegian market. We conclude that the interest rate is a fundamental factor in explaining changes to the house prices. The estimated effect for the Northwestern European market is a 5.6 percent decrease in house prices in the event of a permanent increase of one percentage point in the interest rates. Further, we still find evidence for the importance of permanent changes to the unemployment rate and disposable income in explaining changes to the long-run house prices. The long-run effect of a one percent increase in the unemployment rate results in a 0.5 percent decrease in the house prices, while a one percent increase in disposable income is associated with a 0.1 percent increase. Hence, we conclude that the interest rate, the unemployment rate, and the disposable income explain long-run dynamics in the Northwestern European housing market. If we assume both Jacobsen and Naug's original model (2004) and our estimated PVECM model to be relevant in explaining the housing market, the consistent results imply that a permanent change to any of the explanatory variables in Northwestern Europe is expected to cause Norwegian house prices to move proportionally with the estimated trend for the broader market.

11. Concluding Remarks

This thesis set out to understand the dynamics of the housing market in Northwestern European countries. The variables identified by Jacobsen and Naug for the Norwegian housing market in 2004 serve as a foundation for the analysis and we construct a dataset covering the relevant variables for eight Northwestern European countries, measured on a quarterly frequency.

The initial analysis addresses the international relevance of the original model specification and test the hypothesis: *The model proposed by Jacobsen and Naug is relevant in an international context and can be used to understand the effects of fundamental factors in multiple national housing markets in Northwestern Europe.*

We test the hypothesis by evaluating the model's relevance when implemented on national housing markets in the Northwestern European region. First, we study the relevance of the model in explaining house prices for the extended Norwegian sample and conclude that the specification should account for the abnormal market conditions during the financial crisis in 2008. We conclude that the financial crisis had a negative impact on house prices and that interest rates and house prices were positively correlated in the period. To account for the positive relationship, we adjust the effect from short-run interest rates for an altered relationship during the crisis, before we test the model specification on the seven additional housing markets.

Our findings provide evidence against the hypothesis of the model's relevance outside the Norwegian market. The short-run effects are insignificant in the national models, and we conclude that the model is unable to capture short-run changes in the house prices for all countries. We obtain promising long-run effects for the relevance of interest rate and unemployment rate in two countries outside Norway, but the effects appear very large relative to similar studies on the European market. The findings from the quarterly model are tested against an additional, annualised, dataset, but yield similar results. Hence, we reject the first hypothesis and conclude that the model specification does not capture the dynamics of the national housing markets in the Northwestern European region.

Our findings in the first part of our analysis make several contributions to the current literature. First, to the best of our knowledge, no existing study analyses the international relevance of the model specification proposed by Jacobsen and Naug (2004). Hence, we provided further insight on the applicability of the model by evaluating the potential for generalisation to national housing markets in the Northwestern European region. Second, existing literature evaluating the model of Jacobsen and Naug (2004) does not include the financial crisis in the sample. Hence, we contribute to the literature by accounting for the abnormal effects of the financial crisis, and the altered relationship between short-run interest rates and house prices during the period.

The objective of the second analysis is to establish whether a long-run relationship between house prices and the variables from Jacobsen and Naug's model exist for the broader Northwestern European market. Hence, we test the following hypothesis: *The long-run dynamics in the Northwestern European housing market can be explained by recognised fundamental factors.*

The analysis supports the presence of long-run relationships between the variables, and we find that the long-run changes in house prices are affected by permanent changes to the unemployment rate, the lending rate, and the disposable income. From the estimated PVECM, we find the long-run effect of a one percent permanent increase in the unemployment rate to have a negative effect of 0.5 percent on house prices in the long run. Further, a one percent permanent increase in disposable income results in an increase in long-run house prices by 0.1 percent, while a one percentage point permanent increase in lending rates result in a 5.5 percent decrease in the overall house prices in the long run. In addition, we find that house prices in the short run are influenced by changes to the lending rate and changes in unemployment rate.

The findings from the second analysis yield additional insights regarding the Norwegian model estimated by Jacobsen and Naug (2004). The results of permanent changes to the unemployment rate and lending rate are similar to the results from the original paper by Jacobsen and Naug, as they find negative effects of 0.45 percent and 4.47 percent, respectively. This result indicates that the long-run dynamics in the Norwegian market are consistent with the dynamics in the broader Northwestern European market following changes to the included variables.

In summary, we accept our second hypothesis, in line with expectations and existing literature, and conclude that the long-run dynamics of the Northwestern European housing market can be explained by at least three of the variables included in the model by Jacobsen and Naug.

For future studies, the model proposed by Jacobsen and Naug should be tested on national markets outside the Northwestern part of Europe to understand the applicability of the model specification. Moreover, it would be interesting to change the lags and exclude some of the variables, or include other variables, in Jacobsen & Naug's model to identify the fundamental drivers and their effects in Denmark, Sweden, Finland, Germany, the UK, Belgium, and the Netherlands. We also believe the fundamental variables we identify in the PVECM should be tested on other economies to see if the effects differ. We recommend starting with North America due to similarities with our selected countries and data availability. Lastly, the PVECM should be applied on regional markets within the Northwestern European countries to see if this yields similar results as the country-specific models we identify. In our view, Norway would be the best country to start with as we find consistent results between the PVECM and the Norwegian country-specific model.

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Appendix A Chapter 9

Table 23 - Results from the Expectations Model Including Financial Crisis Effects

	Dependent variable: **ΔExpectations**								
	Original	**NOR**	**BEL**	**GER**	**NLD**	**UK**	**DNK**	**FIN**	**SWE**
	Q1'92 – Q2'04	Q1'92 – Q4'18	Q2'93 – Q4'17	Q1'96 – Q4'17	Q1'96 – Q4'17	Q2'95 – Q4'17	Q3'03 – Q4'18	Q2'98 – Q4'18	Q2'01 – Q4'18
ΔINTEREST$(1-\tau)_t$	-12.90***	-11.75***	501.76***	-82.42	538.71***	-12.36	124.45	183.30	423.29**
	(1.89)	(1.89)	(149.33)	(96.62)	(190.20)	(110.37)	(121.03)	(127.65)	(160.66)
Δunemployment$_t$	-0.44**	-0.47***	-4.57	-72.46***	-29.68**	-32.15***	3.05	8.88	-0.64
	(0.17)	(0.13)	(5.45)	(13.19)	(12.01)	(11.25)	(4.88)	(11.30)	(8.34)
Expectations$_{t-1}$	-0.13	-0.11**	-0.19***	-0.31***	-0.22***	-0.13**	-0.28***	-0.12*	-0.38***
	(0.10)	(0.05)	(0.06)	(0.06)	(0.07)	(0.06)	(0.09)	(0.07)	(0.08)
INTEREST$(1-\tau)_{t-1}$	-0.65	-0.06	-17.06	-27.94	5.91	28.76	-13.57	-25.22	8.79
	(0.95)	(0.42)	(24.44)	(27.52)	(36.78)	(22.57)	(31.55)	(19.73)	(28.32)
unemployment$_{t-1}$	-0.02	-0.03	0.75	-1.40	1.58	-1.29	-1.77	4.33**	2.68
	(0.03)	(0.03)	(2.90)	(1.59)	(1.58)	(2.27)	(1.50)	(1.98)	(2.19)
Q1	0.21***	0.19***	0.65	0.53	0.13	-0.33	0.16	0.33	0.48
	(0.05)	(0.03)	(0.73)	(0.58)	(0.91)	(0.75)	(0.69)	(0.49)	(0.60)
Q2	0.09***	0.07***	-0.16	0.03	-0.68	-0.74	-0.25	0.11	0.11
	(0.02)	(0.02)	(0.71)	(0.59)	(0.91)	(0.76)	(0.75)	(0.48)	(0.58)
Q3	0.22***	0.17***	-0.29	-0.22	-0.54	-0.54	-0.32	-0.04	-0.003
	(0.04)	(0.03)	(0.72)	(0.59)	(0.90)	(0.75)	(0.71)	(0.49)	(0.58)
Financial_Crisis_Dummy		0.32***	26.53**	33.24***	66.32***	68.43***	7.06**	7.36***	7.32***
		(0.10)	(11.25)	(7.70)	(20.14)	(14.97)	(3.37)	(2.19)	(2.01)
ΔINTEREST$(1-\tau)$ · Financial_Crisis_Dummy		-4.41	-818.80*	-354.80	-1,413.23**	-474.37	-360.29**	-303.87*	-569.68***
		(4.04)	(484.72)	(318.81)	(547.62)	(301.14)	(161.30)	(173.75)	(173.50)
INTEREST$(1-\tau)_{t-1}$ · Financial_Crisis_Dummy		-7.99***	-806.28**	-742.04***	-1,607.56***	-1,211.20***	-222.81***	-254.26***	-304.37***
		(2.35)	(330.43)	(156.75)	(486.25)	(262.75)	(82.54)	(77.88)	(66.52)
Constant	-0.06	-0.06*	-2.13	0.83	-3.51	0.06	5.34	-8.60**	-4.44
	(0.07)	(0.03)	(5.74)	(2.05)	(3.23)	(3.09)	(3.51)	(4.10)	(4.55)
Observations	46	105	99	88	88	91	63	83	71
R^2	0.81	0.63	0.26	0.51	0.31	0.32	0.31	0.38	0.46
Adjusted R^2	0.76	0.58	0.17	0.43	0.21	0.22	0.16	0.28	0.36
Residual Std. Error	0.05 (df = 37)	0.06 (df = 93)	2.52 (df = 87)	1.92 (df = 76)	2.97 (df = 76)	2.51 (df = 79)	1.77 (df = 51)	1.56 (df = 71)	1.74 (df = 59)
F Statistic	19.14*** (df = 8; 37)	14.16*** (df = 11; 93)	2.85*** (df = 11; 87)	7.05*** (df = 11; 76)	3.06*** (df = 11; 76)	3.33*** (df = 11; 79)	2.08** (df = 11; 51)	3.93*** (df = 11; 71)	4.64*** (df = 11; 59)
Note:									*p<0.1; **p<0.05; ***p<0.01

Validity of the Estimated Models in Chapter 9.1.2

The residuals from the estimated models is examined in the following section to determine whether we have some issues with heteroscedasticity, autocorrelation, or normality. To check for heteroscedasticity, we perform a Breusch-Pagan test and analyse several plots of the residuals. Autocorrelation is examined using plots of the residuals and by conducting the Durbin-Watson test and Breusch-Godfrey test. Lastly, we check for normality by analysing both a density histogram of the residuals and a QQ-plot, before we perform the Shapiro-Wilk test and the Kolmogorov-Smirnov test.

Heteroscedasticity

We start by looking for patterns in the graphs where we plot residuals against fitted values and residuals against time. **Figure 22** and **Figure 23** show the residuals plotted against time while the residuals plotted against fitted values are displayed further down in the appendix. There does not appear to be any clear trend or patterns in the plots, but the spread of the residuals between 2008 and 2010 is somewhat higher than the rest of the sample period. This is not surprising as the period is characterised by decreasing housing prices coupled with decreasing interest rates, which contradicts both theory and the estimated models. Hence, the models are less accurate in this period, which in turn leads to lower fit and larger residuals. The Breusch-Pagan test confirms that there are no issues with heteroscedasticity for all countries except for Norway and Sweden, which have p-values of 0.03. Presence of heteroscedasticity does not cause bias in our estimated variables, but it tends to underestimate the variance, which can lead to misleading conclusions regarding the significance of the coefficients.

Figure 22: Residuals vs Time for Belgium, Germany, the Netherlands and the UK

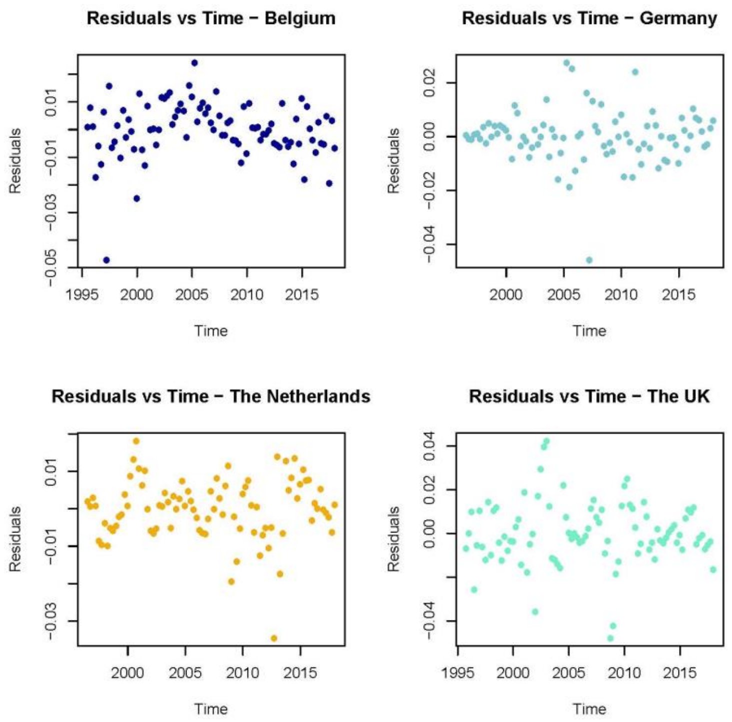
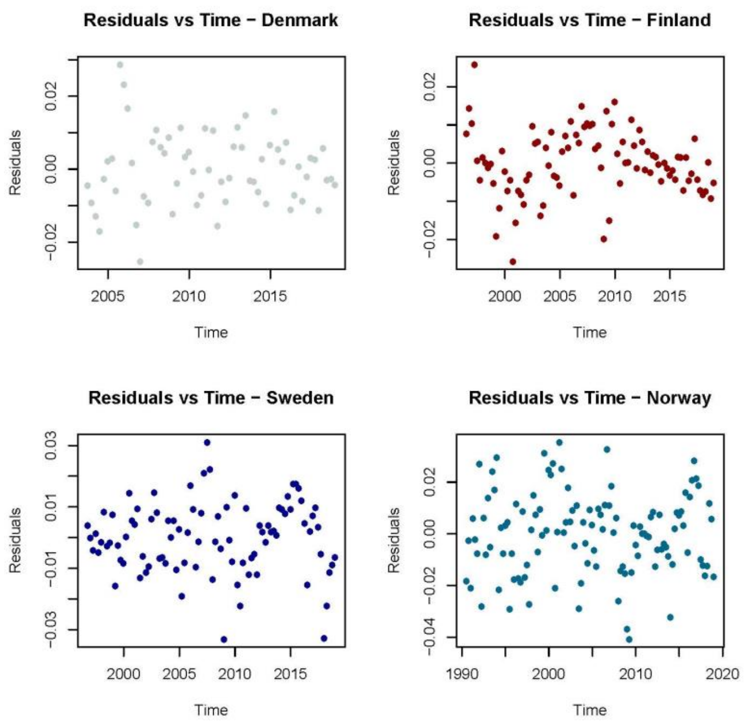


Figure 23: Residuals vs Time for Denmark, Finland, Sweden and Norway



Serial Correlation

The residual plots in **Figure 22** and **Figure 23** do not show any signs of patterns over time, and as such, we do not expect to find any serial correlation in our models. However, we create ACF plots for all countries displayed in **Figure 24** and **Figure 25**, which is more effective in detecting the potential presence of serial correlation. We see that the first lag is significant in the Netherlands, Germany, the UK, Finland, and Sweden. Moreover, some lags exceed the 95 percent significance level, but this could be by chance. We conclude that there exists some form of positive autocorrelation in Germany, the Netherlands, the UK, Finland, and Sweden based on the ACF plots.

Figure 24: ACF plots for Belgium, Germany, the Netherlands and the UK

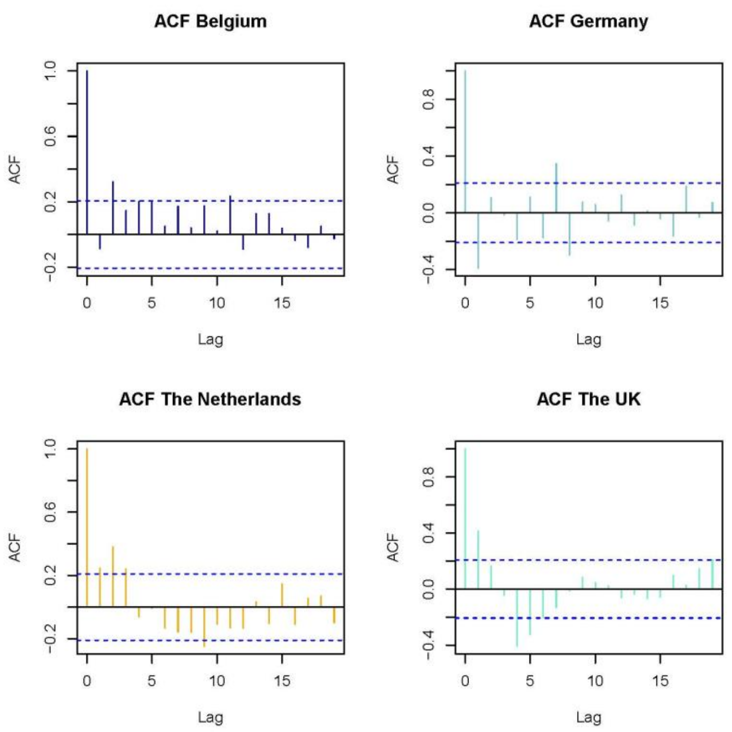
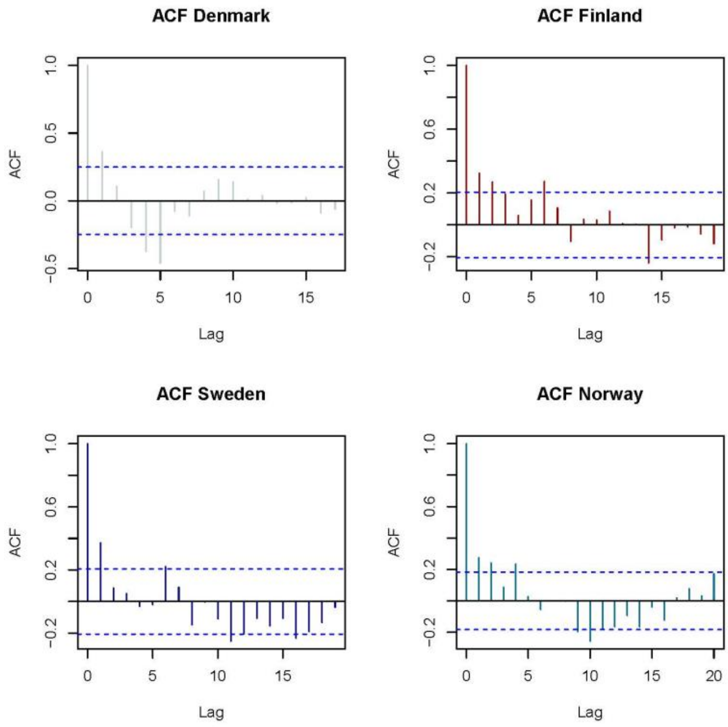


Figure 25: ACF plots for Denmark, Finland, Sweden and Norway



To investigate the presence of autocorrelation further, we conduct the Durbin-Watson and Breusch-Godfrey tests. These tests reject the null-hypothesis of no autocorrelation, with the exceptions being the Durbin-Watson test for Belgium. Hence, we conclude that there exists positive autocorrelation in all models except for Germany where the tests conclude that there exists a negative autocorrelation. In the presence of autocorrelation, the OLS estimator is no longer BLUE, but still unbiased. For models with positive autocorrelation, this implies that the standard errors could be underestimated, which in turn can lead us to wrongly conclude that the coefficients are significant.

Normality

Lastly, we check if there are any issues with normality in the models. The density plots in **Figure 26** and **Figure 27** show no apparent signs of violation of the normality assumptions. There are, however, some outliers in Belgium, Germany, and the Netherlands that make the plots look slightly skewed. Further, we analyse the QQ-plots, where we find the same outliers. We perform the Shapiro-Wilk test and the Kolmogorov-Smirnov test for normality displayed in **Table 24**. The Kolmogorov-Smirnov test cannot reject the null hypothesis of normality for any country, but it is, in general, less powerful than the Shapiro-Wilk test. The Shapiro-Wilk test rejects the null hypothesis of normality for Belgium, Germany, the

Netherlands, and the UK at the 5 percent significance level. Hence, we conclude that there are some issues with normality in the models for Belgium, Germany, the Netherlands, and the UK-model. The estimated coefficients are still unbiased, but there might be a problem with the standard errors.

Table 24 – Validity Tests

p-values	BEL	GER	NLD	UK	DNK	FIN	SWE	NOR
Homoscedasticity								
Breusch-Pagan	0.164	0.166	0.105	0.158	0.063	0.194	0.025	0.029
Autocorrelation								
Durbin Watson	0.663	0.999	0.004	0.000	0.001	0.000	0.000	0.000
Breusch-Godfrey	0.005	0.001	0.000	0.000	0.014	0.000	0.001	0.001
Normality								
Shapiro-Wilk	0.000	0.000	0.003	0.003	0.876	0.654	0.561	0.872
Kolmogorov-Smirnov	0.331	0.197	0.447	0.541	0.941	0.920	0.899	0.980

Figure 26: Density Plots for Belgium, Germany, the Netherlands and the UK

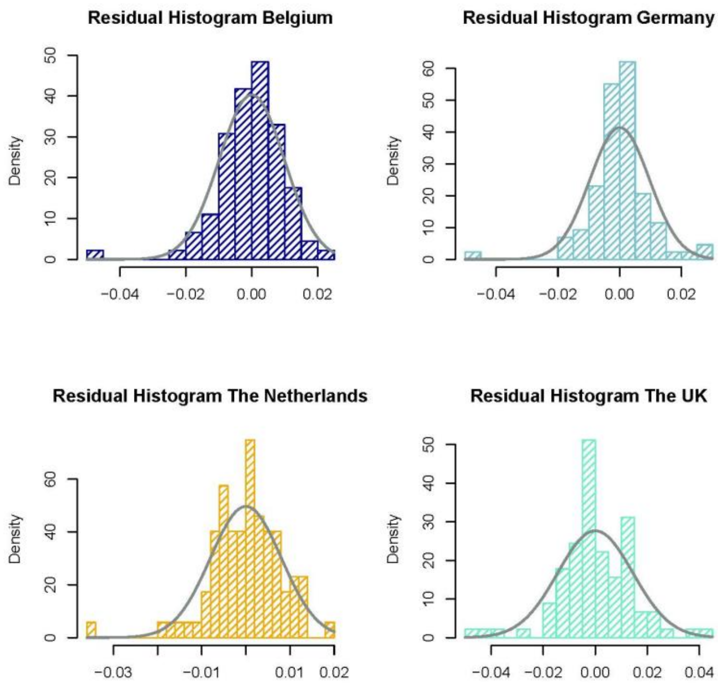


Figure 27: Density Plots for Denmark, Finland, Sweden and Norway

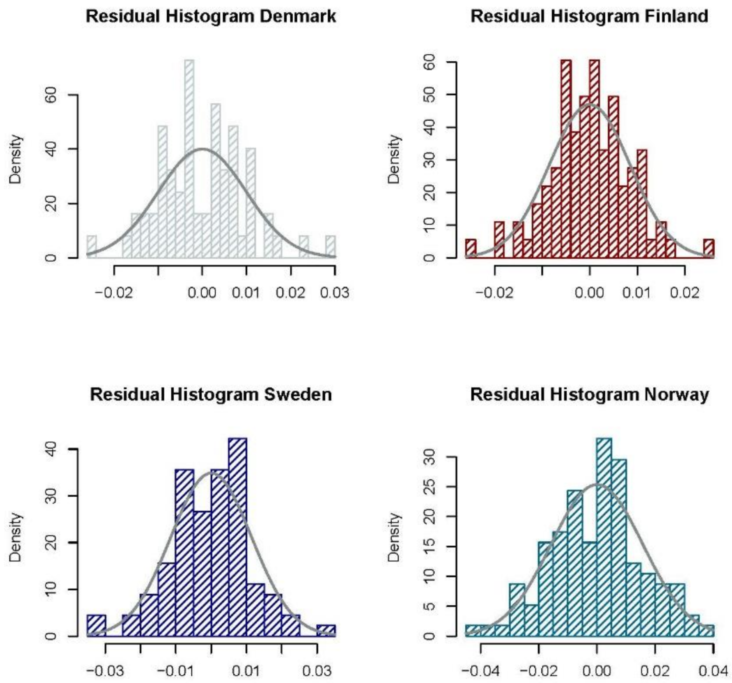


Figure 28: Residuals Belgium

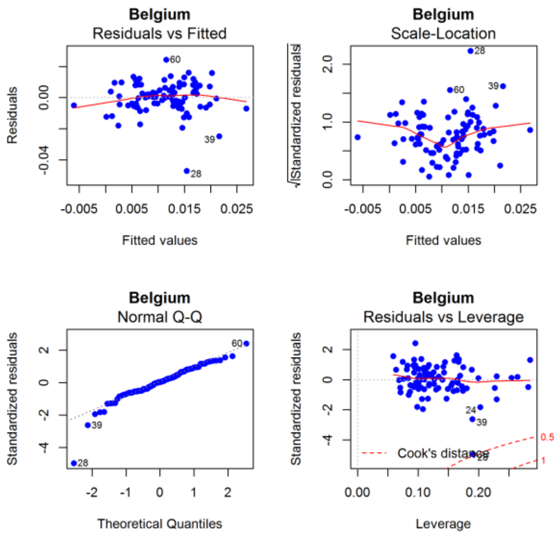


Figure 29: Residuals Germany

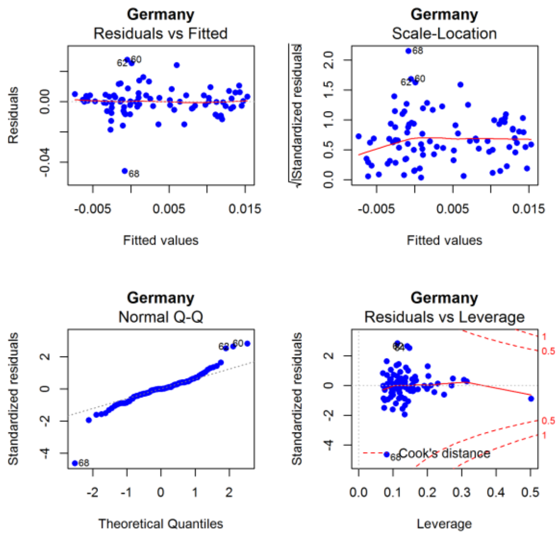


Figure 30: Residuals UK

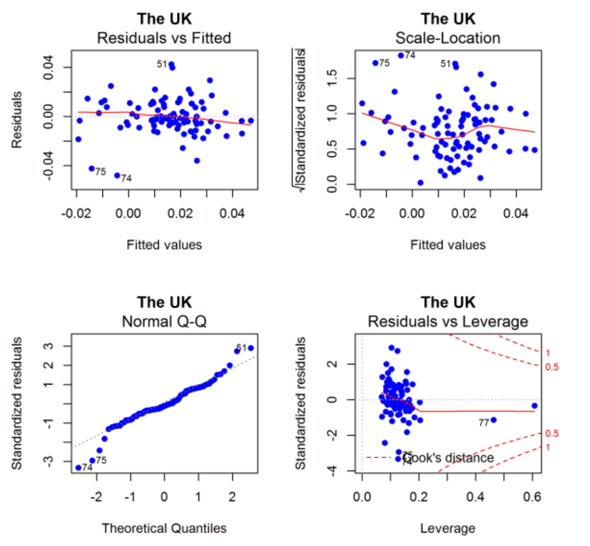


Figure 31: Residuals Netherlands

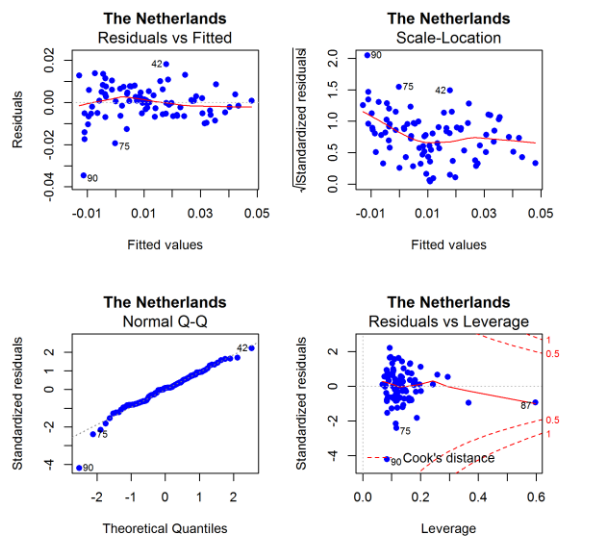


Figure 32: Residuals Denmark

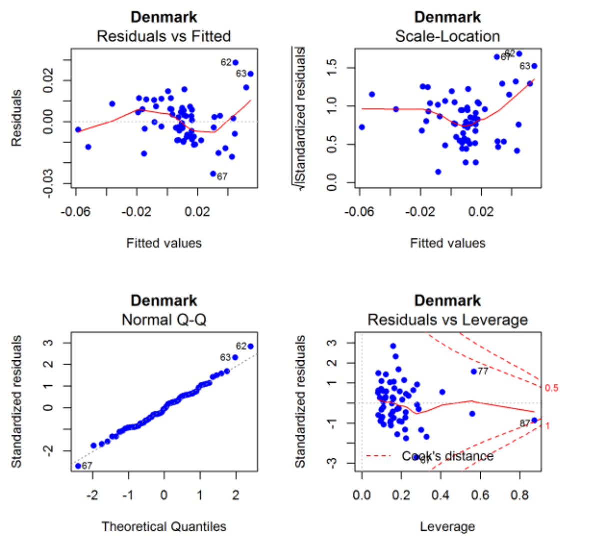


Figure 33: Residuals Finland

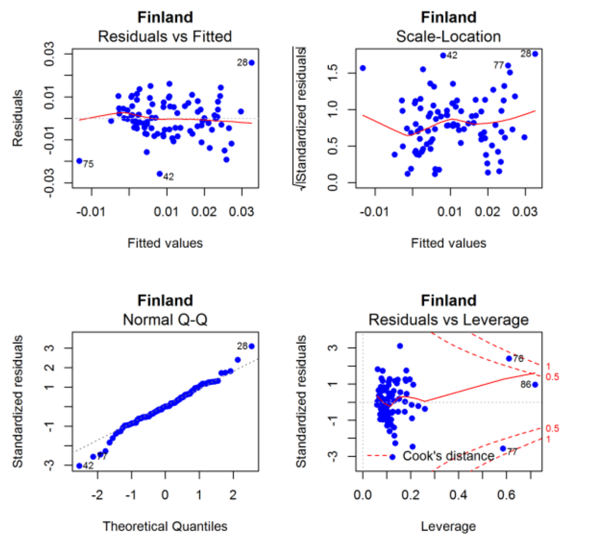


Figure 34: Residuals Sweden

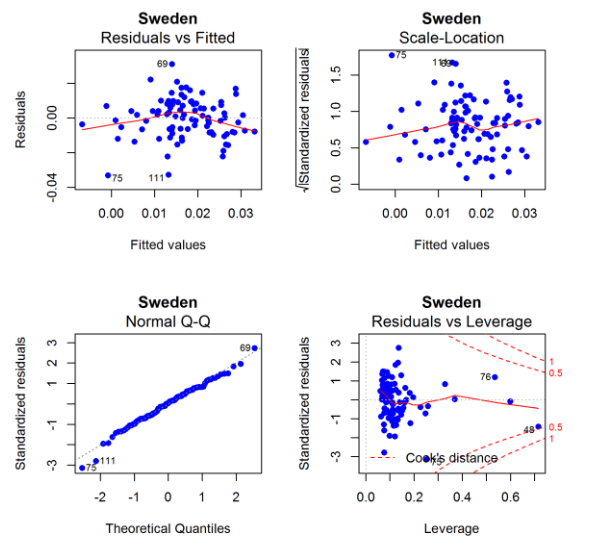
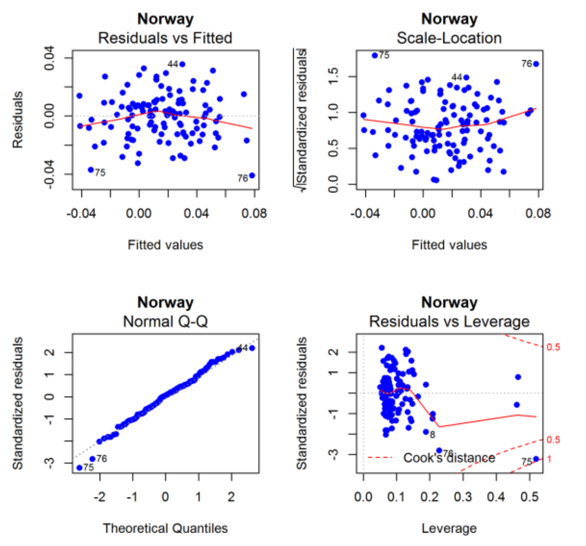


Figure 35: Residuals Norway



Residuals Annual Model

Table 25 - Validity Tests Annual Models

p-values	NOR	BEL	GER	NLD	UK	DNK	FIN	SWE
Homoscedasticity								
Breusch-Pagan	0.95	0.19	0.44	0.24	0.55	0.84	0.09	0.40
Autocorrelation								
Durbin Watson	0.22	0.19	0.20	0.84	0.39	0.01	0.08	0.01
Breusch-Godfrey	0.92	0.01	0.18	0.00	0.00	0.09	0.23	0.01
Normality								
Shapiro-Wilks	0.67	0.21	0.14	0.57	0.48	0.05	0.76	0.05
Kolmogorov-Smirnov	0.96	0.59	0.98	0.56	0.56	0.46	0.57	0.27
Anderson-Darling	0.59	0.14	0.50	0.27	0.47	0.03	0.51	0.03

Figure 36: Annual Residuals vs Time for Belgium, Germany, the Netherlands and the UK

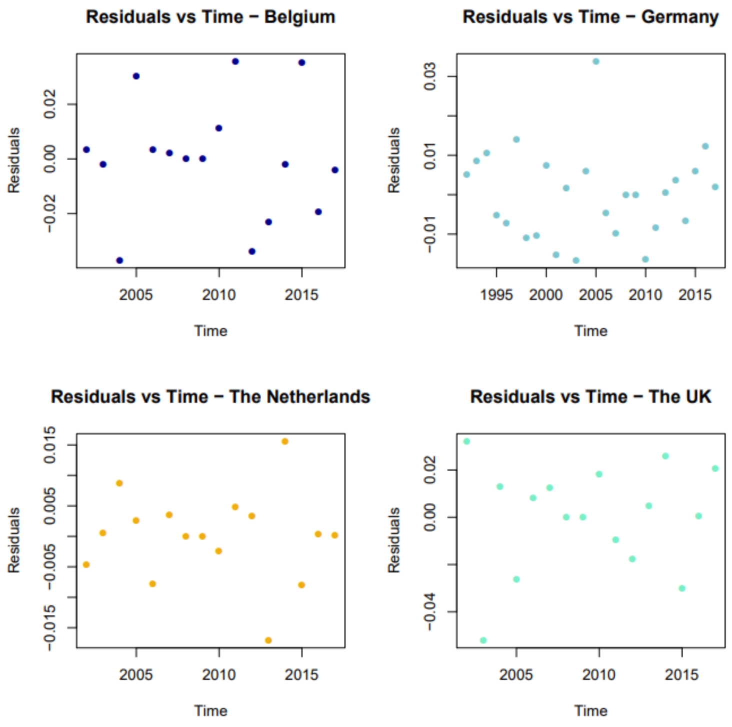


Figure 37: Annual Residuals vs Time for Denmark, Finland, Sweden and Norway

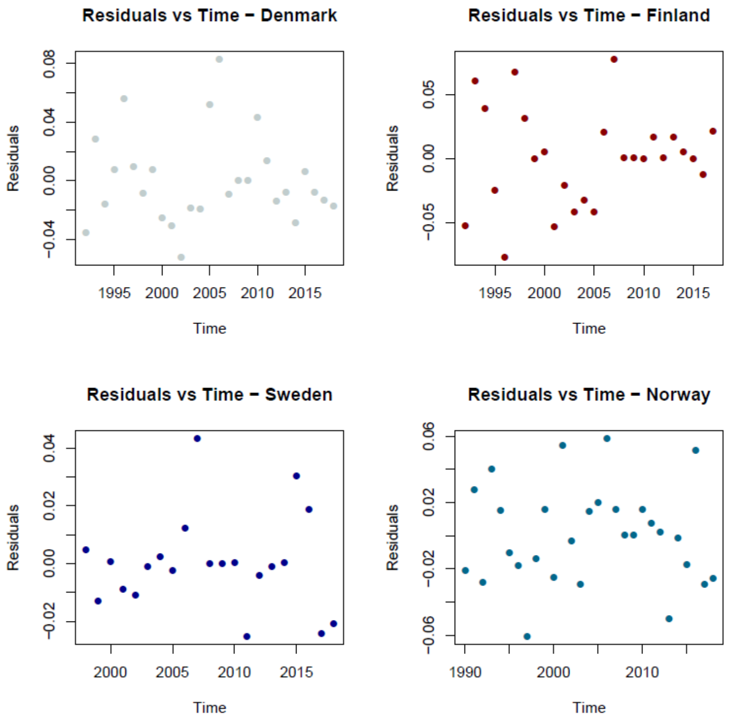


Figure 38: Annual ACF plots for Belgium, Germany, the Netherlands and the UK

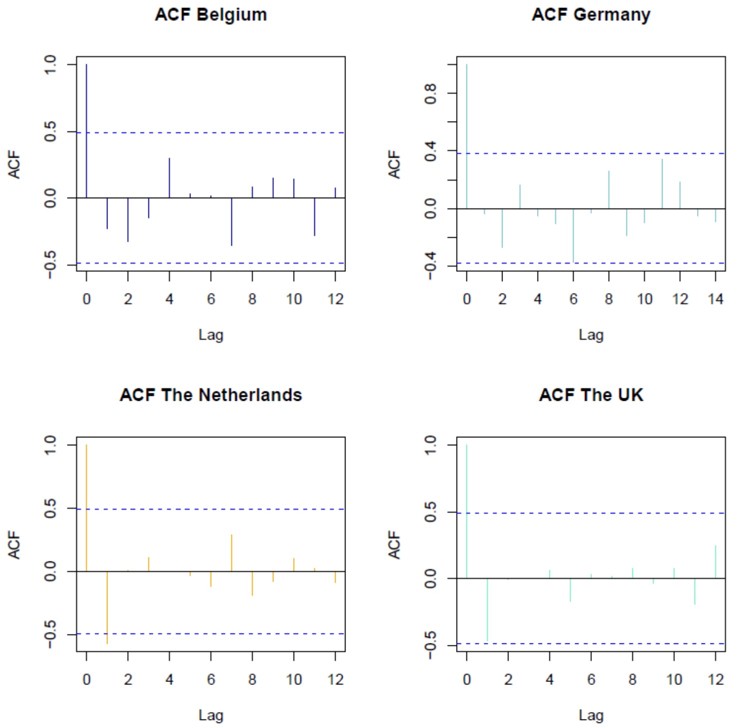


Figure 39: Annual ACF plots for Denmark, Finland, Sweden and Norway

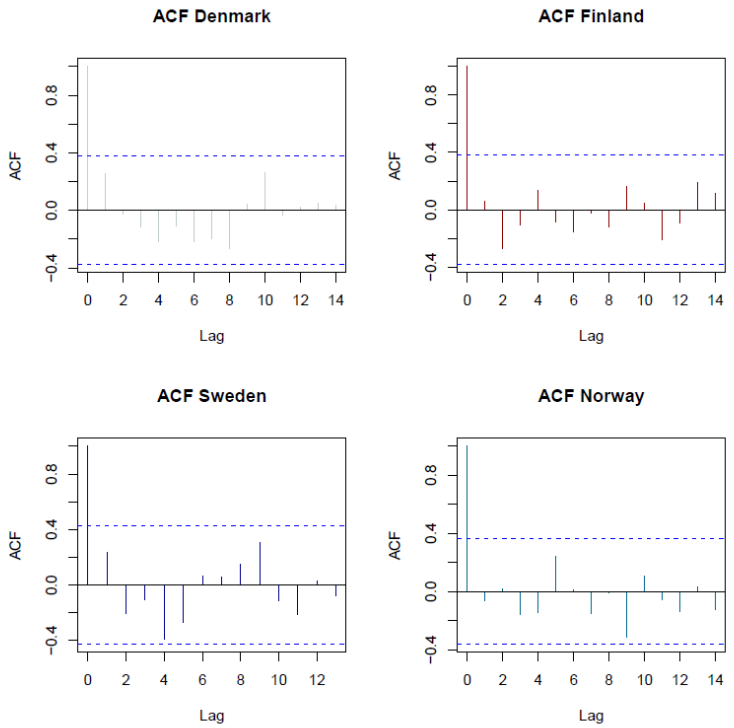


Figure 40: Annual Density Plots for Belgium, Germany, the Netherlands and the UK

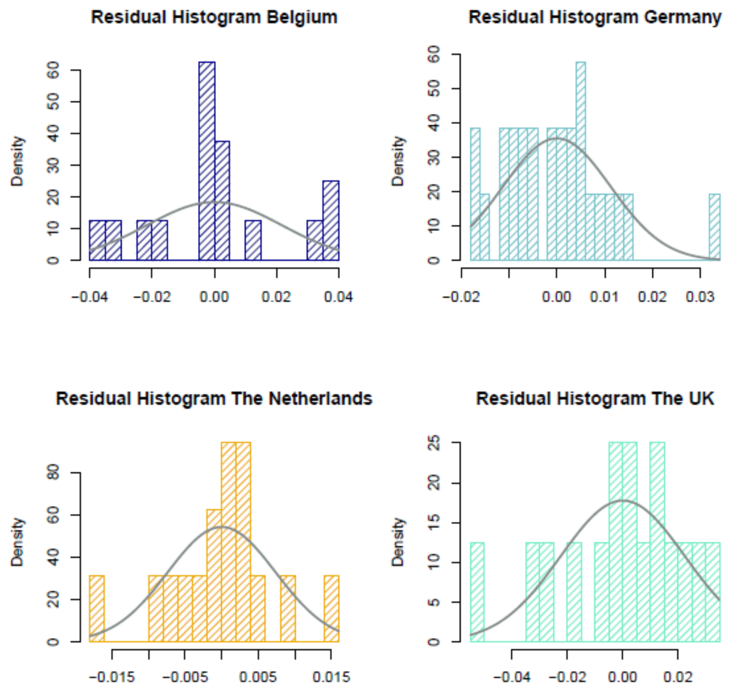


Figure 41: Annual Density Plots for Denmark, Finland, Sweden and Norway

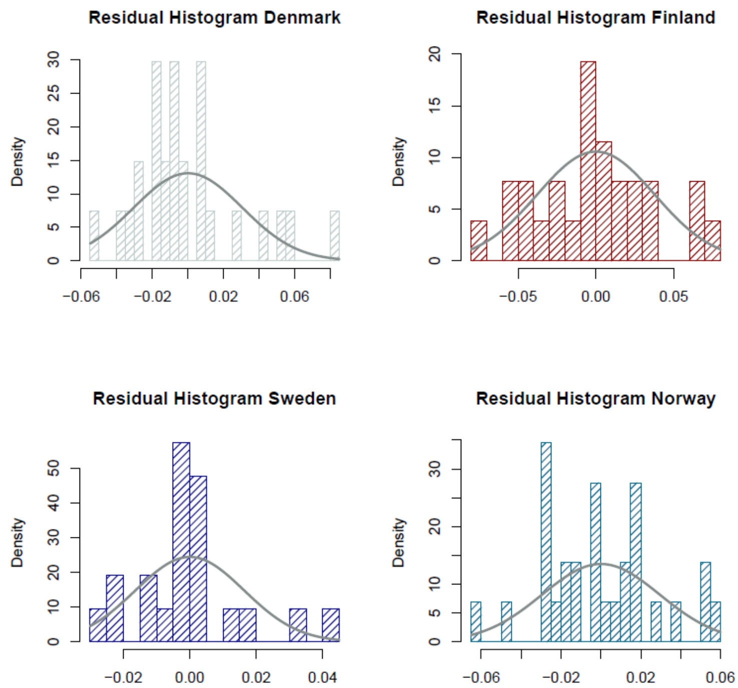


Figure 42: Annual Residuals Belgium

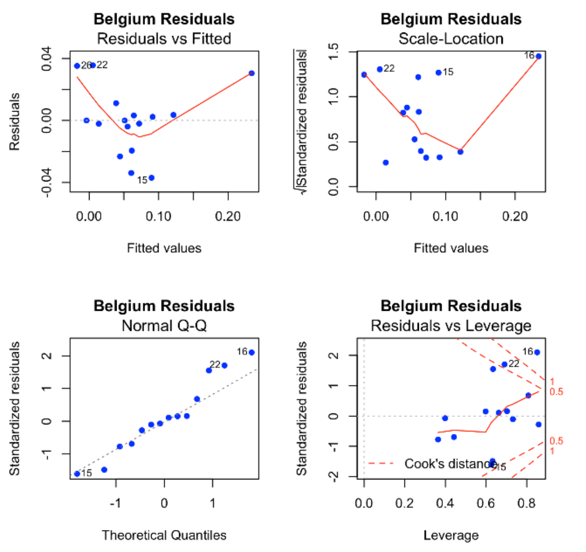


Figure 43: Annual Residuals Germany

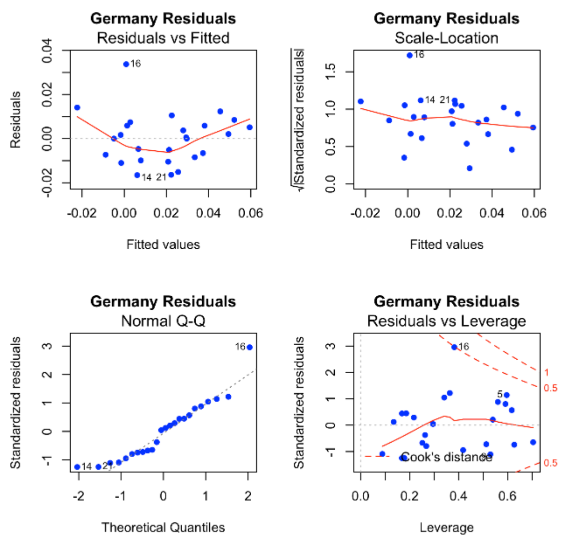


Figure 44: Annual Residuals the Netherlands

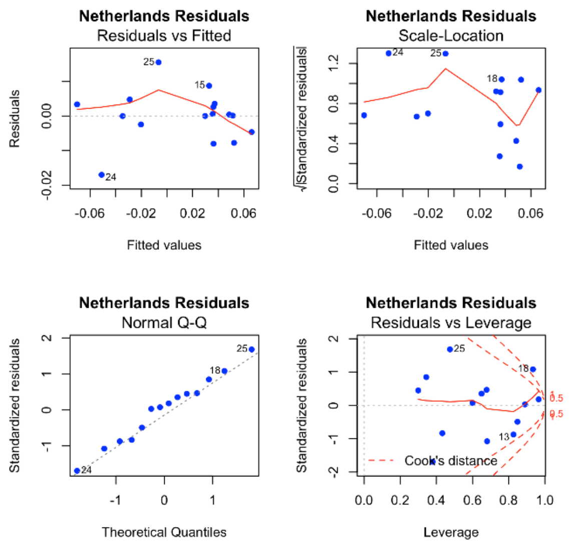


Figure 45: Annual Residuals the UK

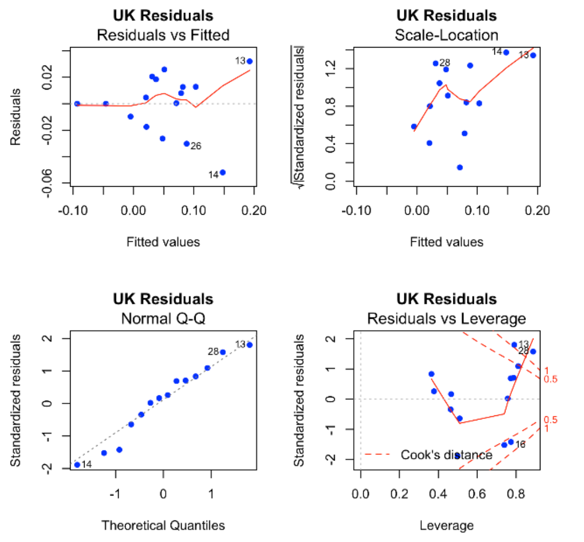


Figure 46: Annual Residuals Denmark

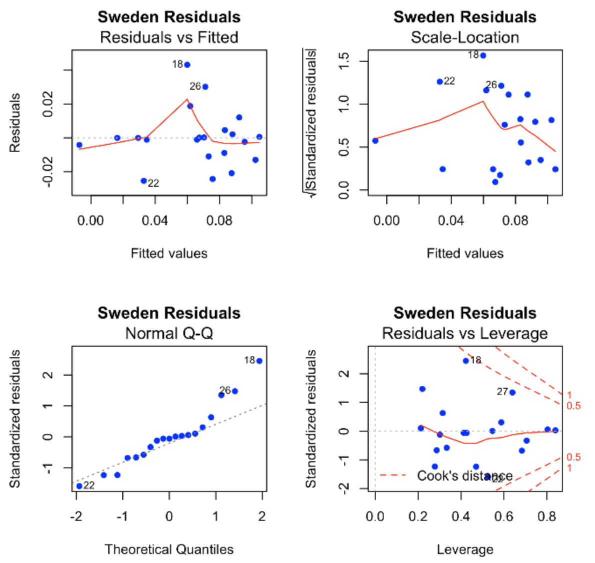


Figure 47: Annual Residuals Finland

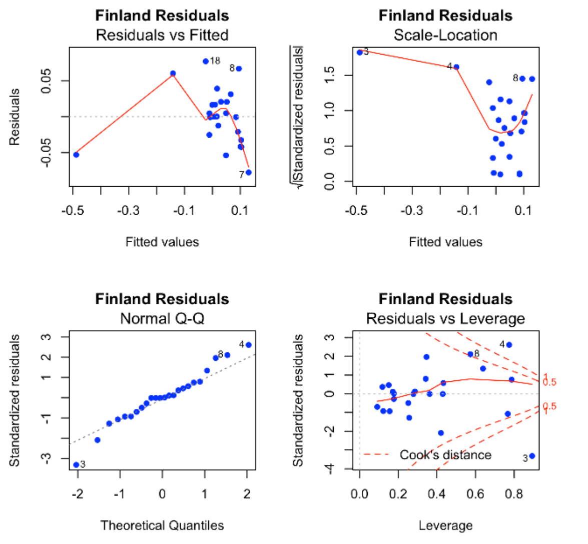


Figure 48: Annual Residuals Sweden

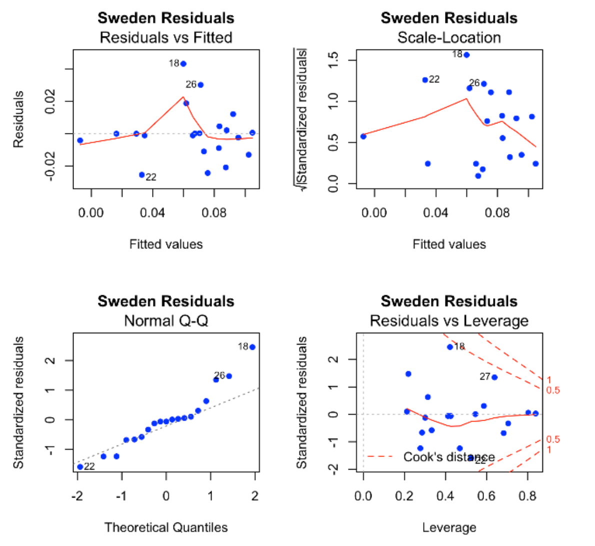
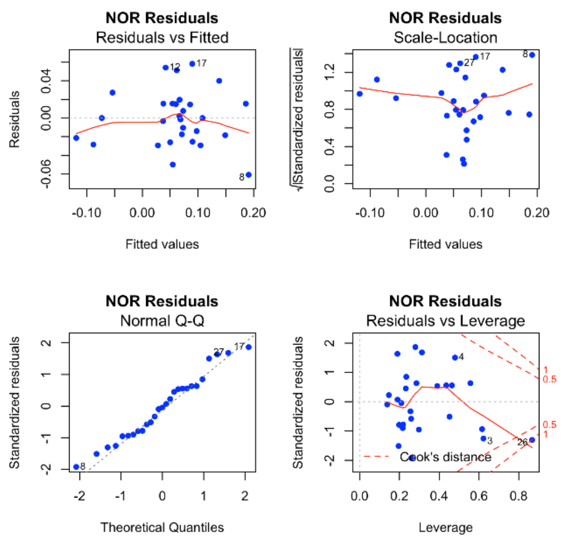


Figure 49: Annual Residuals Norway



Appendix B Other Chapters

Table 26 - Mortgage Interest Deduction Rate

Year	NOR	DNK	GER	SWE	FIN	BEL	NLD	UK
1990	100 %	73 %	0 %	100 %	100 %	100 %	100 %	25 %
1991	100 %	73 %	0 %	100 %	100 %	100 %	100 %	25 %
1992	100 %	73 %	0 %	100 %	100 %	100 %	100 %	25 %
1993	100 %	73 %	0 %	100 %	100 %	100 %	100 %	25 %
1994	100 %	50 %	0 %	100 %	100 %	100 %	100 %	20 %
1995	100 %	50 %	0 %	100 %	100 %	100 %	100 %	15 %
1996	100 %	50 %	0 %	100 %	100 %	100 %	100 %	15 %
1997	100 %	50 %	0 %	100 %	100 %	100 %	100 %	15 %
1998	100 %	50 %	0 %	100 %	100 %	100 %	100 %	10 %
1999	100 %	46 %	0 %	100 %	100 %	100 %	100 %	10 %
2000	100 %	46 %	0 %	100 %	100 %	100 %	100 %	10 %
2001	100 %	46 %	0 %	100 %	100 %	100 %	100 %	0 %
2002	100 %	33 %	0 %	100 %	100 %	100 %	100 %	0 %
2003	100 %	33 %	0 %	100 %	100 %	100 %	100 %	0 %
2004	100 %	33 %	0 %	100 %	100 %	100 %	100 %	0 %
2005	100 %	33 %	0 %	100 %	100 %	100 %	100 %	0 %
2006	100 %	33 %	0 %	100 %	100 %	100 %	100 %	0 %
2007	100 %	33 %	0 %	100 %	100 %	100 %	100 %	0 %
2008	100 %	33 %	0 %	100 %	100 %	100 %	100 %	0 %
2009	100 %	33 %	0 %	100 %	100 %	100 %	100 %	0 %
2010	100 %	33 %	0 %	100 %	100 %	100 %	100 %	0 %
2011	100 %	33 %	0 %	100 %	100 %	100 %	100 %	0 %
2012	100 %	33 %	0 %	100 %	85 %	100 %	100 %	0 %
2013	100 %	33 %	0 %	100 %	80 %	100 %	100 %	0 %
2014	100 %	33 %	0 %	100 %	75 %	100 %	100 %	0 %
2015	100 %	33 %	0 %	100 %	65 %	100 %	100 %	0 %
2016	100 %	33 %	0 %	100 %	55 %	100 %	100 %	0 %
2017	100 %	33 %	0 %	100 %	45 %	100 %	100 %	0 %
2018	100 %	33 %	0 %	100 %	35 %	100 %	100 %	0 %

Table 27 - Norwegian Questions for the CCI

1	Vil du si at økonomien i din husstand er bedre eller dårligere enn for ett år siden, eller er det ingen forskjell?
2	Tror du at økonomien i din husstand vil komme til å bli bedre eller dårligere om ett år eller vil det ikke bli noen forskjell?
3	Dersom vi ser på den økonomiske situasjonen for hele Norge, vil du si at økonomien i landet generelt er bedre eller dårligere enn for ett år siden eller er det ingen forskjell?
4	Tror du at den økonomiske situasjonen i Norge kommer til å bli bedre eller dårligere om ett år eller vil det ikke bli noen forskjell?
5	Tror du at det nå er et godt tidspunkt for befolkningen generelt å kjøpe større husholdningsartikler eller tror du at det er et dårlig tidspunkt?

Table 28 - European Questions for the CCI

1	Financial situation over last 12 months
2	Financial situation over next 12 months
3	General economic situation over last 12 months
4	General economic situation over next 12 months
5	Price trends over last 12 months
6	Price trends over next 12 months
7	Unemployment expectations over next 12 months
8	Major purchases at present
9	Major purchases over next 12 months
10	Savings at present
11	Savings over next 12 months
12	Statement on financial situation of household

Table 29 - Stationarity Tests on the Quarterly Dataset

ADF-test with k=0	BEL	GER	NLD	UK	DNK	FIN	SWE	NOR
Log Nominal House Price Index	0.99	0.99	0.97	0.96	0.98	0.04	0.22	0.63
Unemployment rate	0.62	0.27	0.97	0.95	0.93	0.01	0.15	0.27
Consumer Confidence Index	0.09	0.15	0.42	0.43	0.08	0.44	0.24	0.01
Log Disposable Income	0.99	0.99	0.47	0.72	0.77	0.84	0.43	0.99
After Tax Interest Rate	0.56	0.56	0.66	0.43	0.57	0.33	0.16	0.57
Log Housing Stock	0.96	0.60	0.86	0.85	0.98	0.99	0.50	0.46

ADF-test with k=0	BEL	GER	NLD	UK	DNK	FIN	SWE	NOR
Differenced Log Nominal House Price Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Differenced Unemployment Rate	0.01	0.03	0.05	0.01	0.01	0.06	0.01	0.01
Differenced Consumer Confidence Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Differenced Log Disposable Income	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.68
Differenced After Tax Interest Rate	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Differenced Log Housing Stock	0.02	0.05	0.01	0.35	0.16	0.72	0.17	0.01

ADF-test with k=4	BEL	GER	NLD	UK	DNK	FIN	SWE	NOR
Log Nominal House Price Index	0.93	0.99	0.34	0.90	0.72	0.52	0.01	0.50
Unemployment rate	0.07	0.38	0.16	0.62	0.62	0.01	0.01	0.01
Consumer Confidence Index	0.11	0.01	0.26	0.37	0.02	0.02	0.01	0.01
Log Disposable Income	0.83	0.99	0.14	0.48	0.61	0.35	0.41	0.53
After Tax Interest Rate	0.21	0.42	0.42	0.73	0.10	0.046	0.01	0.14
Log Housing Stock	0.66	0.28	0.99	0.99	0.79	0.48	0.74	0.23

ADF-test with k=4	BEL	GER	NLD	UK	DNK	FIN	SWE	NOR
Differenced Log Nominal House Price Index	0.32	0.40	0.29	0.21	0.21	0.02	0.01	0.01
Differenced Unemployment Rate	0.08	0.15	0.09	0.05	0.01	0.09	0.03	0.06

Differenced Consumer Confidence Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Differenced Log Disposable Income	0.04	0.01	0.55	0.20	0.20	0.07	0.03	0.31
Differenced After Tax Interest Rate	0.01	0.01	0.01	0.01	0.08	0.01	0.01	0.01
Differenced Log Housing Stock	0.14	0.45	0.63	0.43	0.60	0.50	0.12	0.16

ADF-test with k=8	**BEL**	**GER**	**NLD**	**UK**	**DNK**	**FIN**	**SWE**	**NOR**
Log Nominal House Price Index	0.93	0.96	0.53	0.71	0.64	0.59	0.07	0.77
Unemployment rate	0.20	0.67	0.09	0.49	0.47	0.02	0.08	0.14
Consumer Confidence Index	0.39	0.13	0.51	0.67	0.19	0.76	0.04	0.04
Log Disposable Income	0.96	0.98	0.20	0.27	0.61	0.83	0.55	0.60
After Tax Interest Rate	0.01	0.62	0.41	0.74	0.20	0.056	0.06	0.02
Log Housing Stock	0.39	0.16	0.96	0.68	0.63	0.95	0.98	0.27

ADF-test with k=8	**BEL**	**GER**	**NLD**	**UK**	**DNK**	**FIN**	**SWE**	**NOR**
Differenced Log Nominal House Price Index	0.44	0.65	0.81	0.57	0.23	0.12	0.35	0.01
Differenced Unemployment Rate	0.01	0.24	0.13	0.37	0.18	0.17	0.05	0.02
Differenced Consumer Confidence Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Differenced Log Disposable Income	0.09	0.09	0.35	0.31	0.34	0.09	0.01	0.35
Differenced After Tax Interest Rate	0.05	0.12	0.32	0.07	0.32	0.04	0.03	0.01
Differenced Log Housing Stock	0.22	0.62	0.64	0.95	0.60	0.21	0.05	0.01

PP-test with short trunc	**BEL**	**GER**	**NLD**	**UK**	**DNK**	**FIN**	**SWE**	**NOR**
Log Nominal House Price Index	0.99	0.99	0.98	0.92	0.92	0.59	0.70	0.60
Unemployment rate	0.56	0.84	0.76	0.84	0.79	0.54	0.55	0.35
Consumer Confidence Index	0.03	0.07	0.15	0.40	0.02	0.10	0.07	0.02
Log Disposable Income	0.98	0.94	0.93	0.95	0.93	0.81	0.34	0.92
After Tax Interest Rate	0.31	0.39	0.48	0.44	0.51	0.09	0.04	0.34
Log Housing Stock	0.95	0.98	0.98	0.59	0.88	0.99	0.73	0.86

PP-test with short trunc	**BEL**	**GER**	**NLD**	**UK**	**DNK**	**FIN**	**SWE**	**NOR**
Differenced Log Nominal House Price Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Differenced Unemployment Rate	0.01	0.02	0.03	0.01	0.01	0.04	0.01	0.01
Differenced Consumer Confidence Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Differenced Log Disposable Income	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.22
Differenced After Tax Interest Rate	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Differenced Log Housing Stock	0.01	0.09	0.01	0.22	0.01	0.38	0.01	0.01

PP-test with long trunc	**BEL**	**GER**	**NLD**	**UK**	**DNK**	**FIN**	**SWE**	**NOR**
Log Nominal House Price Index	0.98	0.99	0.97	0.81	0.83	0.42	0.68	0.41
Unemployment rate	0.53	0.81	0.55	0.69	0.70	0.39	0.51	0.10
Consumer Confidence Index	0.22	0.38	0.36	0.53	0.30	0.52	0.66	0.07
Log Disposable Income	0.97	0.82	0.90	0.95	0.89	0.66	0.38	0.78
After Tax Interest Rate	0.37	0.55	0.51	0.51	0.55	0.24	0.25	0.49

Log Housing Stock	0.91	0.97	0.98	0.28	0.81	0.98	0.72	0.88

PP-test with long trunc	**BEL**	**GER**	**NLD**	**UK**	**DNK**	**FIN**	**SWE**	**NOR**
Differenced Log Nominal House Price Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Differenced Unemployment Rate	0.01	0.04	0.02	0.01	0.01	0.02	0.01	0.01
Differenced Consumer Confidence Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Differenced Log Disposable Income	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.46
Differenced After Tax Interest Rate	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
Differenced Log Housing Stock	0.01	0.10	0.01	0.52	0.31	0.46	0.03	0.01

KPSS with trend and short trunc	**BEL**	**GER**	**NLD**	**UK**	**DNK**	**FIN**	**SWE**	**NOR**
Log Nominal House Price Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Unemployment rate	0.10	0.01	0.01	0.01	0.01	0.04	0.08	0.01
Consumer Confidence Index	0.09	0.02	0.07	0.01	0.10	0.06	0.04	0.10
Log Disposable Income	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
After Tax Interest Rate	0.10	0.01	0.07	0.01	0.07	0.10	0.10	0.02
Log Housing Stock	0.01	0.01	0.01	0.07	0.01	0.01	0.01	0.01

KPSS with trend and short trunc	**BEL**	**GER**	**NLD**	**UK**	**DNK**	**FIN**	**SWE**	**NOR**
Differenced Log Nominal House Price Index	0.01	0.01	0.01	0.01	0.09	0.01	0.06	0.02
Differenced Unemployment Rate	0.10	0.10	0.10	0.05	0.10	0.02	0.10	0.10
Differenced Consumer Confidence Index	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Differenced Log Disposable Income	0.10	0.01	0.03	0.08	0.10	0.01	0.10	0.05
Differenced After Tax Interest Rate	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Differenced Log Housing Stock	0.10	0.01	0.10	0.01	0.07	0.01	0.10	0.09

Figure 50: Differenced Log Nominal House Prices 1990-2018

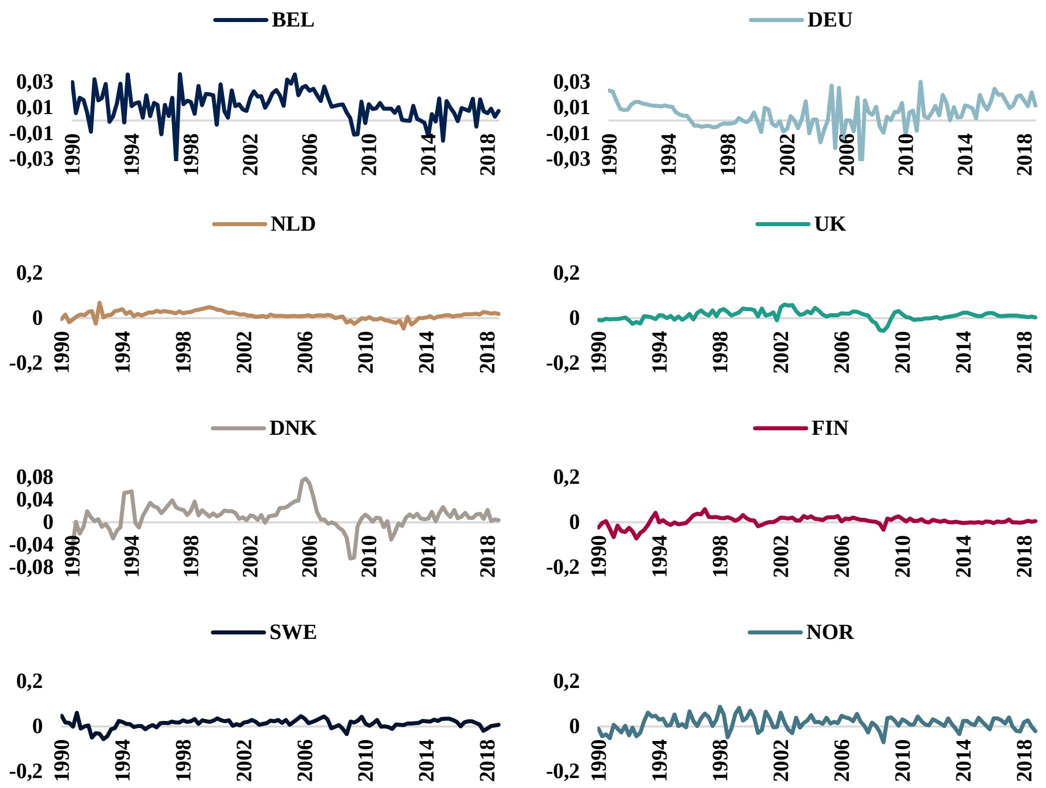


Figure 51: Differenced After-Tax Interest Rate 1990-2018

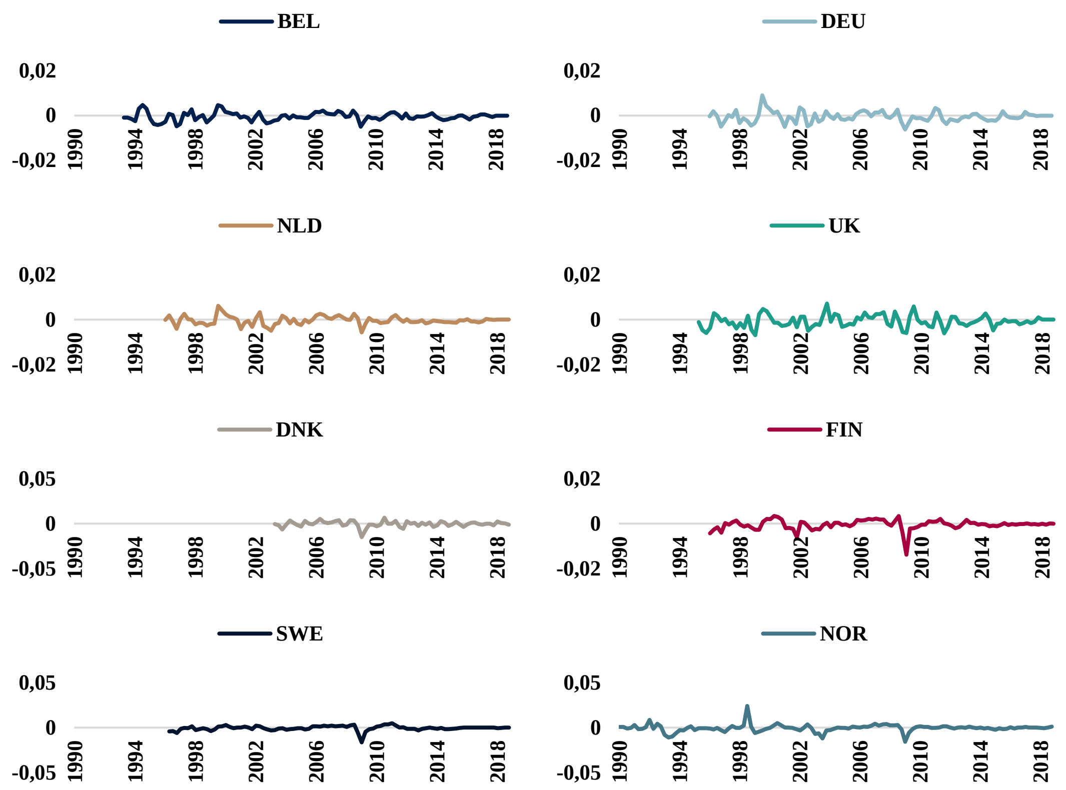


Figure 52: Differenced Log Unemployment Rate 1990-2018

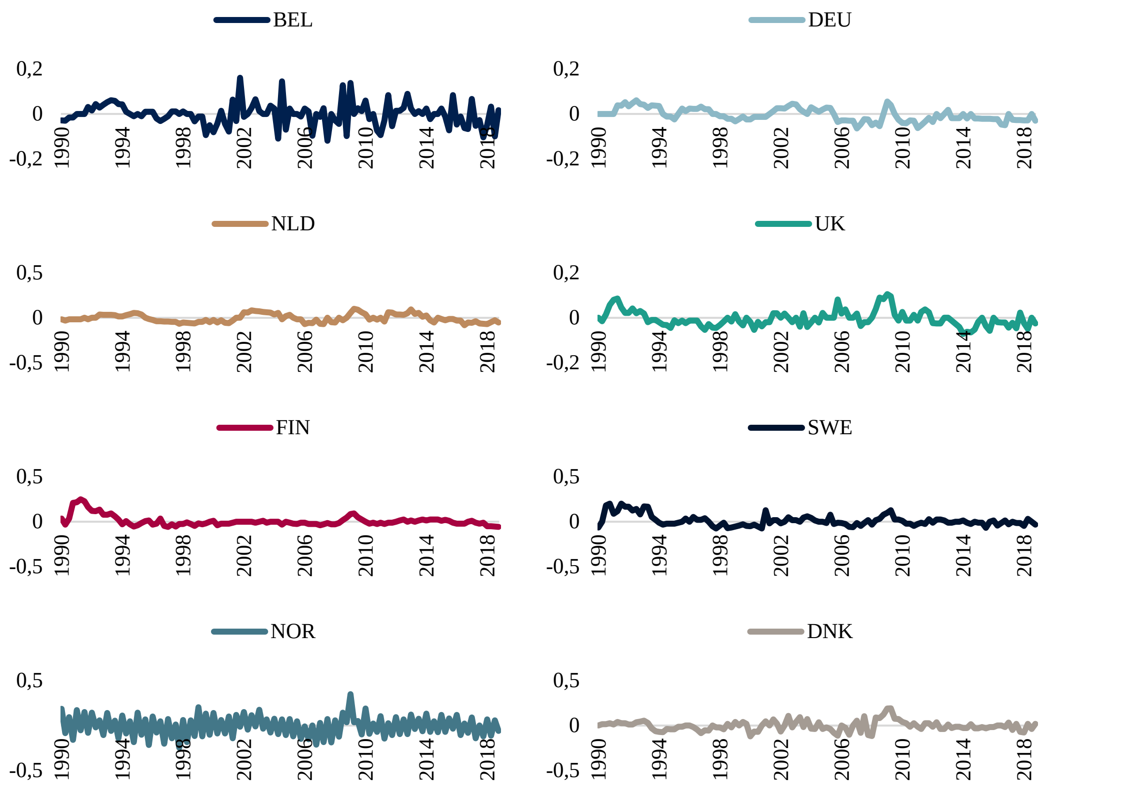


Figure 53: Differenced Log Disposable Income 1990-2018

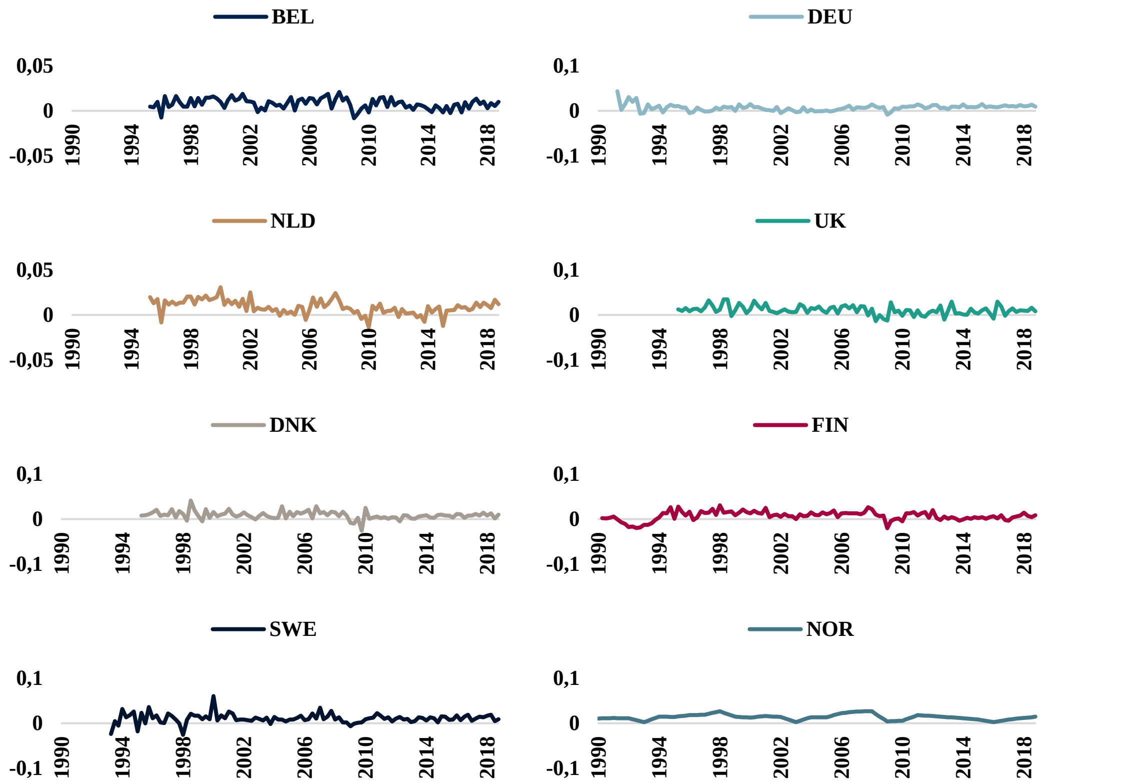


Figure 54: Differenced Log Housing Stock 1990-2018

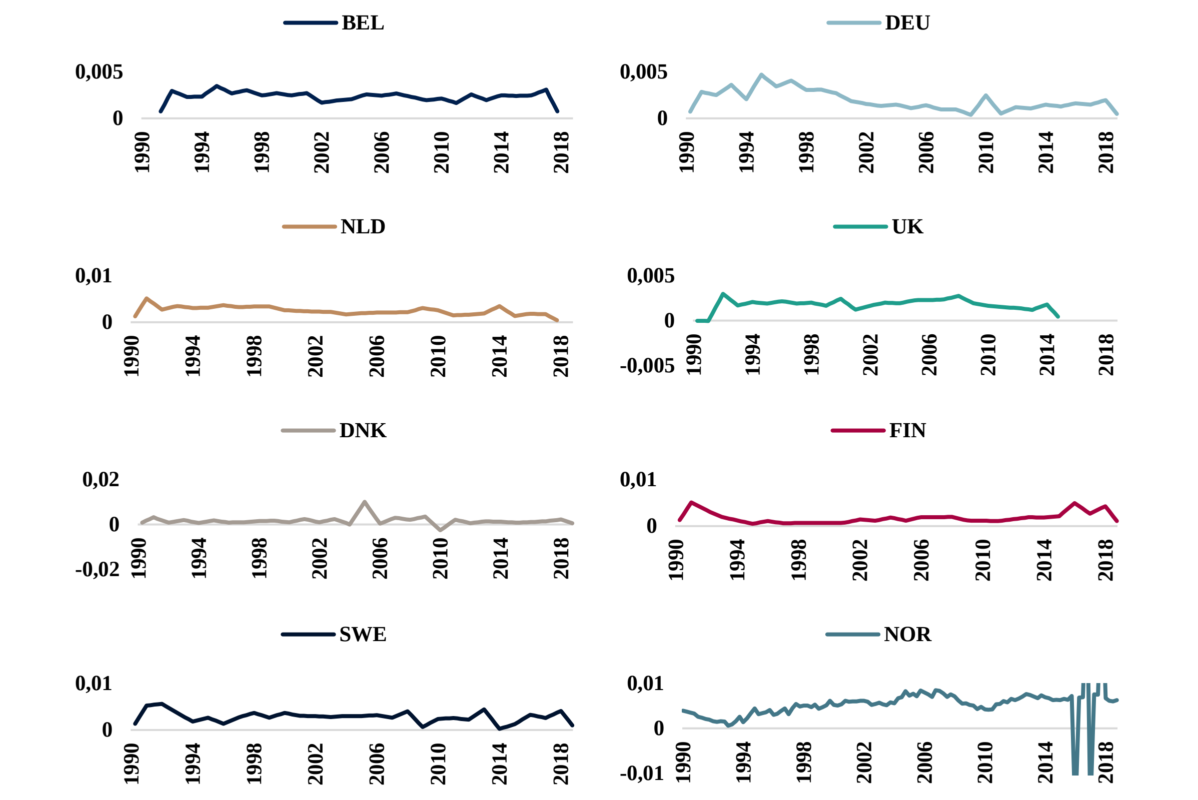


Table 30 - KPSS Test Annual Data

KPSS test long trunc	BEL	GER	NLD	UK	DNK	FIN	SWE	NOR
Log Nominal House Price Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Unemployment rate	0.10	0.05	0.08	0.03	0.10	0.10	0.06	0.10
Consumer Confidence Index	0.10	0.10	0.10	0.10	0.04	0.10	0.10	0.10
Log Disposable Income	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
After Tax Interest Rate	0.03	0.01	0.04	0.05	0.01	0.01	0.02	0.01
Log Housing Stock	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03

KPSS test long trunc	BEL	GER	NLD	UK	DNK	FIN	SWE	NOR
Differenced Log Nominal House Price Index	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Differenced Unemployment Rate	0.10	0.03	0.10	0.10	0.10	0.10	0.10	0.10
Differenced Consumer Confidence Index	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Differenced Log Disposable Income	0.06	0.10	0.04	0.07	0.05	0.10	0.10	0.10
Differenced After Tax Interest Rate	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Differenced Log Housing Stock	0.10	0.10	0.02	0.10	0.10	0.10	0.10	0.10

KPSS test short trunc	BEL	GER	NLD	UK	DNK	FIN	SWE	NOR
Log Nominal House Price Index	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Unemployment rate	0.10	0.05	0.08	0.03	0.10	0.10	0.06	0.10
Consumer Confidence Index	0.10	0.10	0.10	0.10	0.04	0.10	0.10	0.10
Log Disposable Income	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01

After Tax Interest Rate	0.03	0.01	0.04	0.05	0.01	0.01	0.02	0.01
Log Housing Stock	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03

KPSS test short trunc	**BEL**	**GER**	**NLD**	**UK**	**DNK**	**FIN**	**SWE**	**NOR**
Differenced Log Nominal House Price Index	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Differenced Unemployment Rate	0.10	0.03	0.10	0.10	0.10	0.10	0.10	0.10
Differenced Consumer Confidence Index	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Differenced Log Disposable Income	0.06	0.10	0.04	0.07	0.05	0.10	0.10	0.10
Differenced After Tax Interest Rate	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Differenced Log Housing Stock	0.10	0.10	0.02	0.10	0.10	0.10	0.10	0.10