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**Oslo Real Estate Market
Convergence**

*a convergence analysis of Oslo's real estate market between 1987-
2015*

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This thesis was written as a part of the Double Degree program between NHH MSc in Economics and Business Administration, Major Financial Economics, and EGADE Master in International Business. Neither the institutions, the supervisors, nor the censors are – through the approval of this thesis – responsible for neither the theories and methods used, nor results and conclusions drawn in this work.

Abstract

This paper has tested for beta-convergence in real estate prices between Oslo's boroughs in the time period 1987-2015, and investigated which price determinants that affect price movements between regions.

Both a graphical approach inspired by Baumol (1986), and a cross-region regression method has been used. The study shows clear indications of absolute convergence in periods with declining real estate prices, and absolute divergence in periods with increasing real estate prices. This paper finds no evidence of long-term absolute convergence or divergence. Oslo's real estate market can be broken down into three convergence groups based on structural differences and price movements. The first group consists of the inner boroughs, the second group consists of the outer west boroughs and Nordstrand, and the third group consists of the outer east boroughs.

The most important factors for price movements in the short run are migration and debt gearing. In the long run, structural differences such as: unemployment rates, education level, and geographical placements, appear to be the most important factors. New construction appears to be the highest in areas with high growth, or areas with potential for high price growth. Two boroughs with potential for future high growth in real estate prices based on the evaluation of this paper are, Gamle Oslo and Nordstrand.

Preface

This thesis is written as a part of the double degree program between NHH and EGADE, and puts an end to 7 years of education, 6 academic institutions, 5 countries, and 2 bachelor degrees.

The motivation for this paper was to get a richer understanding of Oslo's housing market before eventually purchasing my own apartment in one of the boroughs. In the process, there has been highs and lows, writing alone has been both challenging and rewarding. I have won every debate on major decisions, but there has been little help in stressful times. The wish to produce something new pushed me towards an empirical approach, and the completion of new housing indexes of Oslo's Boroughs between 1985-2002 is my personal highlight of the process. I want to give a big thank you to my two supervisors, Ola Honningdal Grytten & Juan Antonio Encisco Gonzalez for useful guidance in the process.

Oslo, December 15, 2015

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1. Introduction

1.1 Research question

An hypothesis within economic growth theories suggest that areas with initial lower housing prices, should have faster growth rates and “catch up” with initially higher housing price areas. In this paper I wish to test for any signs of convergence between the boroughs, while investigating which factors that could explain the behavior of real estate prices in Oslo. In an attempt to produce some topical output, I will use the analysis to pick out two areas that appears to have potential for excessive price growth in the future.

1.2 Limitations

In an effort to exclude potential biases, only real estate prices of apartments are used. The reason is to keep the housing stock as homogenous as possible between the boroughs.

The factor analysis is limited to focus on the time period from 2001-2015. This is partly because of data available, and partly because of the desire to focus on recent trends and movements.

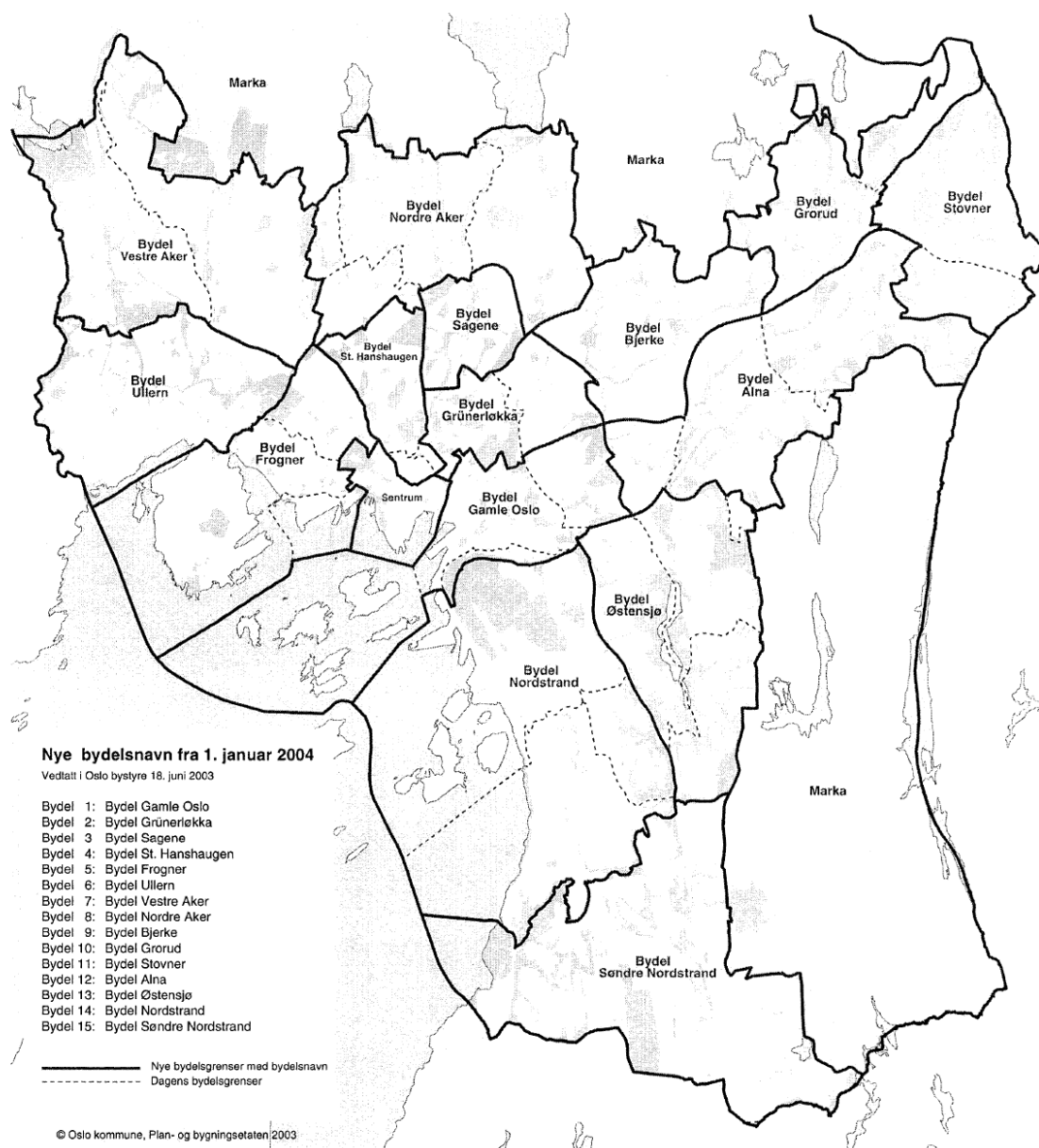
1.3 Approach

This paper has used the statistical tools Stata and StatPlus.

In chapter one, the paper goes into history, and general characteristics of Oslo and its housing market. Chapter two starts with presenting general theory on real estate prices. Before it focus in on Oslo, and potential price determinates that can explain the price movements between regions. Chapter three explains the process of making new housing indexes for the time period 1985-2002. The first part of chapter four goes into statistical theory and methods, the second part present the time periods tested for beta-convergence, and the process of making the regression models BLUE. Chapter five presents the regression output. Chapter six discuss the regression output with focus on the potential price determinants presented in chapter two.

1.4 Oslo boroughs

| Oslo East | | Oslo West | |
|-------------|-------------------|----------------|-------------|
| Inner East | Outer East | Inner West | Outer West |
| Gamle Oslo | Alna | Frogner | Nordre Aker |
| Grünerløkka | Bjerke | St. Hanshaugen | Vestre Aker |
| Sagene | Grorud | | Ullern |
| | Stovner | | |
| | Østensjø | | |
| | Søndre Nordstrand | | |
| | <i>Nordstrand</i> | | |



Background

This part of the paper gives a brief understanding of Oslo, its regions, and the historical development of the housing market.

1.5 Oslo

Oslo is the capital and the largest city in Norway, the population is estimated to be 647 767, with approximately 340 000 households. The housing stock in Oslo consists of 90% apartment buildings in the inner boroughs, and 70% if we include the outer boroughs. Oslo is a growing city and just in 2014, the population grew with over 13 000. Almost One-third of the population has family or background from outside of Norway (Oslo Kommune, 2015).

Oslo is today divided into 15 boroughs¹, and these 15 areas make the foundation for my convergence analysis. The map² on the previous page shows Oslo and it's boroughs. Above the map is a table showing which areas that can be placed under the historical categories Oslo east and Oslo west. This is the main separation, and the most well known. Oslo east and Oslo west are so dividend into 4 sub-areas, inner east, inner west, outer east, and outer west. Østensjø, Søndre Nordstrand, and Nordstrand are sometimes referred to as Oslo south (Oslo Kommune, 2015). I have for the purpose of this paper placed them under Oslo east. The convergence results are impartial of the categorical placement.

1.5.1 East and West

Oslo is split both geographically and demographically between the east- and the west side. The west side would overall be considered a wealthy area, while the east side would generally be considered more of a working class area. This separation is visible thru average income, education level, life expectancy, and housing standards. Oslo is unique

¹ Not included the city center and nature surrounding

² Official map of Oslo's boroughs gathered from Oslo Kommune

in regards to its geographical- and demographical separation, because it can be traced back more than 150 years (Høifødt, 2011).

From the 1840s, the west side expanded around the royal palace, with villas and larger dwellings as the norm. The east side grew with industry clustering around Akerselva and the main east side roads. With the vast expansion in the 1890s, the clear separation between east and west as we see it today was established. In the beginning there were some working class areas on the west side as well, like Pipervika, Vestre Vika, Balkeby, Briskeby, and Ruseløkkbakken. But they have all disappeared with time in order to make room for new commercial- and apartment buildings. Most noteworthy is perhaps how the working class area in Pipervika was removed in order to make room for Oslo city hall in the 1930s (Høifødt 2011). In 2015 we can find some of the richest areas in Norway on the west side of Oslo, and some of the poorest areas in the country on the east side of Oslo. Despite representing extremes in Oslo's real estate markets, the areas are relatively equal compared to other large European cities (Andersen, 2013).

1.5.2 Borough boundaries

The main river Akerselva generally divides east- and west side. The expression “east of the river” is widely used, and refers to the economic and social boarder between east and west. This is a bit imprecise; in reality you have areas that are considered east on both sides of the river. Sagene, Bjølsen and Hausmannområdet are west of the river, but are typical working class areas. Another widely accepted way to divide Oslo is by using the street ‘Uelands gate’ as a starting point (Høifødt, 2011).

1.5.3 Brief history of Oslo real estate market 1899-2015

After Kristianiakrakket in 1899 all new construction stopped for years, until 1911 when the local government decided to start building again. Several large working-class housing projects were carried out on the east side, upper middle class projects was mainly carried out on the west side. In the 1920- and 1930s the city grew as an industrial city and as a

result public services washed away some of the differences between east and west (Høifødt, 2011).

After the Second World War, three quarters of Oslo's population did not own their own home, and in order to stop speculation and profits on peoples need, the Norwegian government decided to regulate large portions of the housing market. The political object for the time period from 1945 until the late 1970s was to influence the housing market in a way that everybody could afford a home. An outspoken ambition was that the yearly cost of a home in Norway should not exceed 20% of an industrial workers annual income (OBOS, 2014). In an effort to reach this object, several new construction projects was started in order to offer large amounts of affordable housing. A majority of these housing projects were carried out on the east side of Oslo, making an even wider spread between east and west. In the 1970s immigration started to become a factor, building up under the separation, with the east side being far more multicultural than the west side (Høifødt, 2011).

In the 1980s the real estate market had become practically self-regulated (OBOS, 2014), and with a boom in the Norwegian economy, and deregulations in the finance sector, Oslo's real estate marked started to rise rapidly (Torsvik, 1999). The boom was followed with a recession, and from 1987 to 1992 Oslo's housing market fell with approximately 40% (Grytten, 2009). From 1992 real estate prices started to rise steadily again, and the first dramatic recession was from 2007-2009, with the overall housing market dropping up to 18% adjusted for inflation (NRK, 2012).

1.6 Characteristics of the regions

1.6.1 Oslo inner west

The region has an overall population of 90 000 and consist of the boroughs Frogner and St. Hanshaugen. Inner west has seen a population growth of 30% since 2001. One-third of the population in inner west are young adults, and net migration to inner west consist of young people moving in and families with children moving out. The unemployment rate is lower in this area than the overall Oslo, and the general education level is higher (Oslo Kommune, 2015).

1.6.2 Oslo inner East

The area consists of the boroughs Sagene, Grünerløkka, and Gamle Oslo. The overall population is 138 500. This part of Oslo has seen major new constructions and several new urban hotspots have emerged. As a result the inner east boroughs have experienced the highest net migration since 2001 with an overall increase in population of 41%. The population in inner east is dominated with young adults, and we see similar migration trends as in inner west, people aging 30-49 with kids are moving out (Oslo Kommune, 2015).

1.6.3 Outer west

The region consists of high-income areas such as Nordre Aker, Vestre Aker and Ullern, and the total population is 125 000. The population growth since 2001 has been modest compared to the inner boroughs. There are in general high education levels and low unemployment rates. The population is overall older than in the inner boroughs. There is a trend that people over fifty are moving out and towards Akershus, but net migration is positive because people aging 30-39 are moving in from the inner boroughs (Oslo Kommune, 2015).

1.6.4 Outer East

Outer East is the largest group with a population 271 000. The boroughs within outer east are the most heterogeneous of the four regions. The population growth is lower than the average of Oslo but there are substantial differences between areas. Alna, Grorud, and Stovner have high multicultural populations compared to the other boroughs. Nordstrand is geographically on the east side, but has all the characteristics of an outer west side borough. There are areas with high unemployment rates and low education levels, but there are also areas clearly showing opposite trends (Oslo Kommune, 2015).

2. Theory

In this chapter the paper goes into some general theories regarding real estate prices, before it focus on two Norwegian housing price models in order to determine which factors are most important in Oslo's real estate markets. In the end of the chapter, the paper looks at determinants and statistics that can explain different growth rates between the regions.

2.1 Convergence

In this paper the concept of convergence refers to the idea that areas with low initial housing prices should experience a faster growth rate and a “catch up effect” towards areas with initial higher housing prices.

2.1.1 Absolute and conditional convergence

The majority of convergence theories are closely linked with neoclassical theory of economic growth (Dvorokova, 2013). We separate between conditional- and absolute convergence. Absolute convergence would in its most simplistic way suggest that all housing prices in Oslo should converge towards the same common price or the same “steady state” in the long run. Conditional convergence implies that homogeneous areas, with similar characteristics and structure should convert, and that several convergence groups in the same market, could converge towards different steady states (Young & Jeffrey, 2012). The initial starting point of this paper is that Oslo's boroughs is somewhat homogenous and converges as one big group. But in the analysis part the paper will also investigate the possibilities of conditional convergence and groups that moves together.

2.1.2 Beta and sigma convergence

When testing for convergence there are two main concepts, beta- and sigma convergence. Sigma convergence is defined as the lowering of variance between economies over time (Dvorokova, 2013). If the variance were lowered over time, there could be proof of convergence. The beta convergence approach includes regressing the growth rate over the initial housing price. If the slope coefficient in the regression model has a negative value, this can be understood as convergence (Young & Jeffrey, 2012). This paper uses the beta approach to test for convergence between the boroughs. With the beta convergence approach it is possible to produce graphs and regressions that are intuitive and easy for the reader to understand. Additionally the graphical approach will also make it possible to look for clusters and convergence groups that moves together.

2.1.3 Convergence equation

The graphical approach originates from Baumol (1986), where he compared the GDP of several countries. He placed the growth rate on the Y-axis and the 1870s GDP per work our on the X-axis and tested for a downward sloping trend indicating convergence. Arguably the first regression approach can be seen in the work of Weil, Romer and Mankiw in the paper *a contribution to the empirics of economic growth* (1992). In the paper they made a cross-country regression model based on the Solow-Swan model to test for convergence between countries.

This paper uses both the graphical approach and a regression model. The regression model used in this paper is a modified version of Baumol growth equation (1986):

$$\frac{1}{T} \ln \left(\frac{P_{i,T}}{P_{i,0}} \right) = \alpha + \beta \ln (P_{i,0}) + \varepsilon_i \quad (1)$$

2.2 Spatial Equilibrium

A hypothesis within urban economics is that in the most basic way housing prices is believed to derive from a spatial equilibrium process. The work of Alonso (1964), Mills (1967) and Mutch (1969) tells us that housing demand, and housing prices within a city, should move in a way that no household would have a desire to move (Young & Jeffrey, 2012). This approach indicates that we should not look for the same real estate prices between different areas, but the same utility between the households. Spatial equilibrium advocates claim that income differences, amenities, and distance from desired areas are the most important factors in explaining difference in housing prices between regions. Spatial Equilibrium theory states that the housing price is not the main component to look at; it is the utility for the house owner that needs to be identical at different places (Glaeser & Gyourko, 2007).

In regards to Oslo, this implies that the housing prices between two boroughs could be different, but the utility should be identical between them. If this was not the case, people would have a tendency to move to the area that offered the highest utility. People would migrate between the boroughs until they all offered the same utility and no one would wish to move.

2.3 Ripple effect

Ripple effect is referring to the tendency for house prices to first rise in south-east area of Britain in an upswing, then gradually over time spread through the rest of the country (Meen, 1999). There have been attempts to explain this pattern with several theories, and a popular one has been the arbitrage and migration theory. If one area is overpriced, people will attempt to move to a cheaper area, and over time the less expensive area will see a growth in real estate prices.

The migration theory has been proven not suffice in order to clarify the ripple effect, as interregional migration flows appears to be too weak. Meen (1999) point out the higher debt ratio in the south as possibly the main determinant. High debt gearing makes

the region more sensitive to changes in unemployment, interest rates and wealth. This could explain why this region tends to be more volatile and act as a ripple starter.

In regards to Oslo, this paper does not directly test for a ripple effect but it looks into the possibility for such an effect to be present also in Oslo.

2.4 Supply and Demand

Urban real estate markets may be peculiar and idiosyncratic in a number of respects, but they still obey some basic economic principles: the principles of demand and supply (Mourouzi-Sivitanidou, 2011, p. 31).

2.4.1 Demand

The fundamental law of demand states that the quantity of demand declines with the increase of price. In terms of real estate, this tells us that with normal market conditions, more real estate should be demanded at lower prices and vice versa.

As we see from graph 2.1 the demand curve is expected to slope downwards, and the overall demand in real estate markets is considered on average to be quite price inelastic (Mourouzi-Sivitanidou, 2011). Real estate is for most people first and foremost viewed as a place they live, but it is also viewed as an investment. With a small movement in price, we do not expect the average citizen to immediately desire a new property.

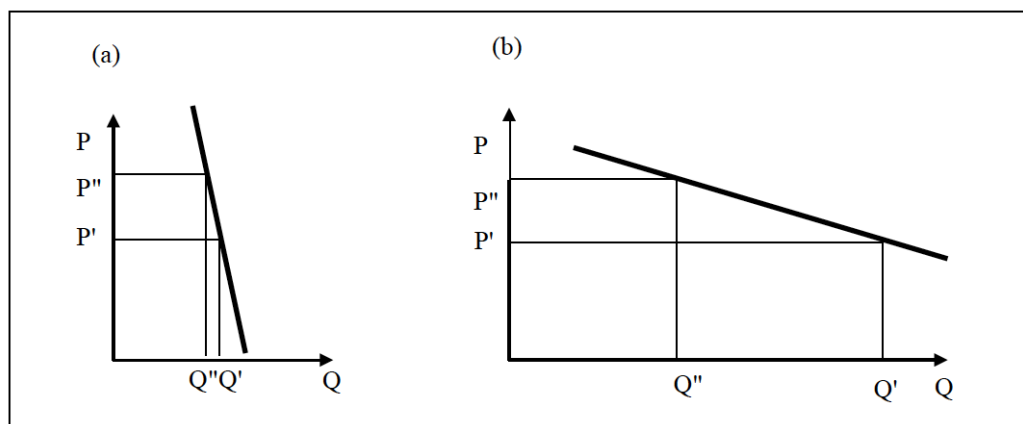


Figure 2.1: Demand curves, showing the difference in price elasticity. Source: (Mourouzi-Sivitanidou, 2011)

Price elasticity of demand is also a result of available substitutes. A luxury good should have less price elastic demand, than other products with a lot of substitutes. There are 15 boroughs in Oslo and they all work as substitutes for each other. There are arguably no equivalent substitutes to the Metropolitan area of Oslo in the whole of Norway. Therefore it is reasonable to believe that demand of the individual boroughs are more price elastic than the overall real estate market of Oslo. Price and rents are believed to be the most important endogenous determinants (Mourouzi-Sivitanidou, 2011).

Sometimes the market activity can imply that the law of demand is violated, an example of this is periods where both the demand and the real estate price are rising. Even though this phenomenon might violate the law of demand, is it perfectly understandable from economic theory. This market behavior can be understood by that the psychology behind demand, and that demand is not entirely a result from price itself, but also other factors such as belief in further price increase in the future.

Another dimension to real estate marked demands is that demand is not only affected by endogenous determinants such as price or rents but also exogenous determinants that are frequently just as important. Mourouzi-Sivitanidou (2011) point out market size, wealth, price of substitutes, and expectations to be the most important determinants of market demand along with a combination of price.

2.4.2 Supply

The real estate supply curve is best explained as two individual concepts; short- and long run. In the short-run aggregate supply the real estate quantity is in any given time is fixed. New construction projects take time, and the supply cannot immediately congregate to an increase in demand. In the US, the construction lag is considered to be at least 6-12 months for residential housing (Mourouzi-Sivitanidou, 2011). In Norway, Kongsrud (2000) argue that the short term in the real estate market should be considered 2-3 years

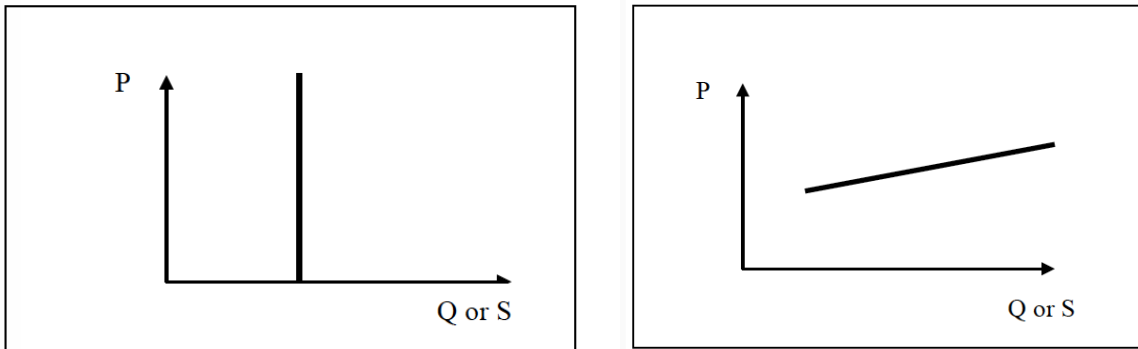


Figure 2.2: Short- and long term real estates supply curves. Source: (Mourouzi-Sivitanidou, 2011)

In that sense we could expect the Norwegian real estate market supply, to be little dynamic to short-term change in demand. In the short term the real estate supply curve would be completely inelastic, but in the long term with new construction, we can see that the supply curve tend to be more price elastic.

With construction being the most important aspect for the supply curve, space is also an important factor. Lower Manhattan will have an almost inelastic supply curve no matter how much motivation there is to new construction, as there is simply no more space to build on. Lower Manhattan is almost completely surrounded by water and the ground puts limitations on how tall you can build the structures in the long run. Space is also an issue for Oslo, with numerous discussions on high-rising dwellings. Laws are also prohibiting construction of new real estates close to nature surrounding Oslo. Space is more an issue in the long run for Oslo; today we see a lot of construction going on, both in the inner and in the outer boroughs. We can arguably draw the conclusion that the city center is closer to a limit than the outer boroughs. In that sense we can say that the real estate supply is less price elastic in the city center than in the outer boroughs.

2.4.3 Determines of new construction

Within almost all new construction projects is a fundamental desire for profit. This is the case in almost all situations, with the exceptions being after wars or natural disasters. With profit as the norm incentive for new construction, the main determinants behind new construction would therefore be: *The perceived market risk, the cost of productions, availability, and expectations regarding future real estate prices* (Mourouzi-Sivitanidou, 2011).

2.4.4 Disequilibrium

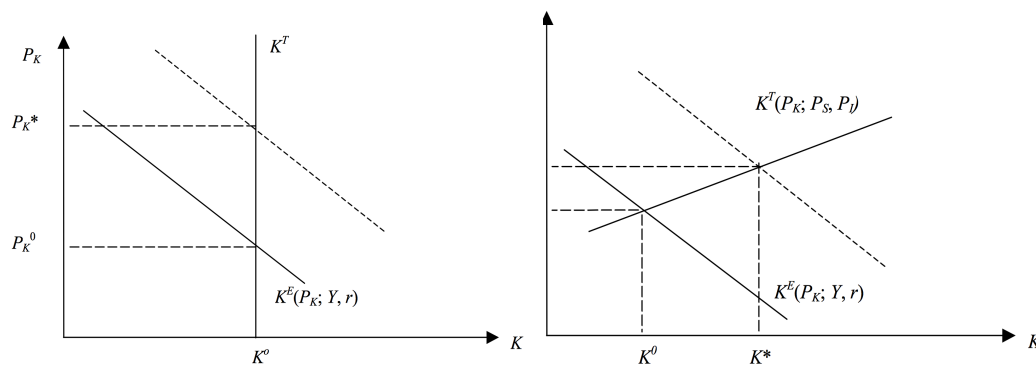


Figure 2.3 Real estate supply and demand curve. Showing how an increase in demand influences the price in the short and the long run.

Real estate prices are overall determined by the supply and demand in the market. The demand is driven by both the desire to have a place to live and as an investment possibility. We see that it is not only the price that determines the demand, but also other factors, such as expectations for future growth. The real estate supply curve is inelastic in the short run or with limited space, and a shock, increasing the demand will often raise the real estate prices quite fast, but with time the supply curve adjusts and the housing prices declines back down again.

The supply of real estate is mainly driven from a profit formula. Since the supply curve has as construction lag, the overall prices of real estate will often be found in a form for disequilibrium with rising or falling prices (Mourouzi-Sivitanidou, 2011).

2.5 Norwegian real estate pricing Models

The following will utilize two specific housing price models in order to understand the main price determinants of Oslo's real estate markets, the models are chosen because of their proven relevancy in explaining price determinants in the Norwegian real estate market.

2.5.1 Norwegian central bank housing price model

Jacobsen and Naug (2004) have produced a housing price model³ that is aiming at estimating which factors that are explaining changes in the Norwegian housing markets. Their model concludes that *interest rates, new construction, unemployment rate, and common wealth* are the main determinations of the housing prices in Norway. They also conclude that Norwegian housing prices do not seem to be driven by speculation or an unhealthy faith in future growth. According to Jacobsen and Naug (2004) the Norwegian Housing market is mainly explained by the fundamental values of real estates.

2.5.2 MODAG

MODAG is a macroeconomic model used to analyze the Norwegian Economy developed by Statistics Norway⁴. The housing model is only a small part of the total framework⁵. The main user of MODAG is the Norwegian Ministry of Finance. The housing model primarily uses endogenous variables. According to the model, real estate prices are mainly determined by the *household's real income, real interest rates after tax, quantities of real estate, and new construction*. Demands of real estates are primarily determined by price, wealth, and interest rates after taxes, while supply is mainly explained by the

³ Jacobsen and Naug's (2004) housing price model is attached in the appendix

⁴ Norwegian name: Statistisk Sentralbyrå

⁵ A graphical presentation of MODAG model of real estate prices is attached in the appendix

combination of existing stock, existing housing prices, and new construction costs (Baug & Dyvi, 2009, p.157-200).

2.6 Important determinants for Oslo

Statistic Norway and Jacobsen & Naug models seem to have a consensus regarding the main determinants for the overall Norwegian real estate market. This paper is using determinants from those models in a combination with additional factors (Grytten 2010), that possible can explain the variation of real estate prices in Oslo. In the next part, factors are combined with statics regarding Oslo.

2.6.1 Migration

Migration is an important factor in spatial equilibrium theories, arbitrage theory, and the general expected demand and supply of real estate. Oslo is a rapidly growing city and has experienced population growth over a long period (Oslo Kommune, 2015). Looking at Oslo there are several patterns worth noticing:

1. The most frequent moving activity is in and out of the inner boroughs.
2. People aging 20-29 seems to migrate towards the inner boroughs
3. High moving willingness between the boroughs.

The most frequently moving activity is in and out of the inner boroughs. People that move towards the center of Oslo are mainly young people from other regions of Norway. People that move within Oslo tend to move away from the inner boroughs and towards the outer boroughs. As citizens age they tend to move away from the city center. Therefore we can say that some of the migration regarding Oslo is age related (Stambøl, 2013).

It seems easier to move within the east- and west side separation. Andersen (2014) Points out that when people move from a east side borough, they often move towards another eastside borough or surrounding areas on the east side. Stambøl (2013) concludes that most of the migration regarding Oslo is moving from one borough to another borough. These finding supports several migration theories that people find it

easier to migrate within short areas. Migration to the west side- and the inner boroughs seems to be linked with the overall economy. In the rising economic period from 2002 to 2008 all the west side and inner boroughs have a significant rise in population. The top three areas in terms of net migration in this time period are Grünerløkka, St. Hanshaugen, and Gamle Oslo. The outer eastside boroughs seem to be more stable. We also see that the net migration to the west side- and inner boroughs fell significantly during the financial crisis in 2008. Since a large part of migration to the east side boroughs are linked with aging and immigration it appears to be less effected to changes in economic conditions (Oslo Kommune, 2015).

2.6.2 Political decisions

Political decisions, and especially where to allocate resources, sends a strong signal to the population and could affect the housing market in several ways. New construction and public spaces and amenities, could directly be affected. In addition it would play a part in the citizens beliefs in future growth. A majority of the affordable housing project and social housing project has over the years been placed on the east side of Oslo. This is not the only cause, but has been a part of creating clusters of regions with low income and social problems. This has also been visible with real estate prices in those areas. Several initiatives has been started in order to aid these regions, two the most recognizable ones are Akerselva inner east program⁶ (1994-1998), and Acting program Oslo inner east⁷ (1997-2006).

The Acting Program Oslo Inner East was started in the autumn of 1997 and 100 million NOK was founded yearly (Barstad and Skarðhamar, 2006), aiming to increase the living conditions in the boroughs Sagene-Torsov, Grünerløkka-Sofienberg, and Gamle Oslo⁸. It was a joint program between the national government and local politicians. The project was given resources directly aimed at increasing the everyday life of citizens. Examples of this measures are that schools libraries got extra funding in order to purchase computers, and public spaces was given an overhaul (Barstad, Havnen,

⁶ Norwegian name: Prosjekt Akerselva indre øst

⁷ Norwegian name: Handslingsprogram Oslo Indre Øst

⁸ Today known as Sagene, Grünerløkka, and Gamle Oslo

Skarðhamar, & Sørlie, 2006). Linking this project with housing prices and urban economics, we see that intangible amenities within these areas should have increased with as a result of these projects.

Measures aimed directly at specific areas have been tried out in several other European countries such as the Britain (New deal for communities), Germany (Die Soziale Stadt), and France (Politique de la Ville), with uncertain results, and as such we do not know all the long-term effects of public interference in specific regions. An unwanted effect could be the signal this is sending that this is a challenging area (Barstad, Havnen, Skarðhamar, & Sørlie, 2006). If we connect these findings with the migration factor earlier, we see that several of the outer east side areas actually have a negative net migration, but only when it comes to people without immigration background (Stambøl, 2013).

2.6.3 Income

Real income or wealth is emphasized as important variables in both MODAG and Jacobsen and Naugs (2004) models. With increased wealth, housing prices should generally rise. Income differences between areas can escalate over time, and increase dissimilarity in real estate prices between regions (Meen 1999). In the long run, areas with higher income are expected to have highest real estate prices. Looking at graph 2.4, boroughs with the highest income are Vestre Aker, Ullern, Frogner, Nordstrand, and Nordre Aker. Boroughs with the lowest income are Grorud, Stovner, and Alna. From 2008 to 2009 all households in high-income areas had a significant larger drop in income, than households in low-income boroughs (SSB, 2015). In times with economic growth, households in the west side areas tend to increase their income more than households in the outer east side boroughs. This observation indicates that income of west side households are closer linked with the overall economy than households in the outer east side boroughs.

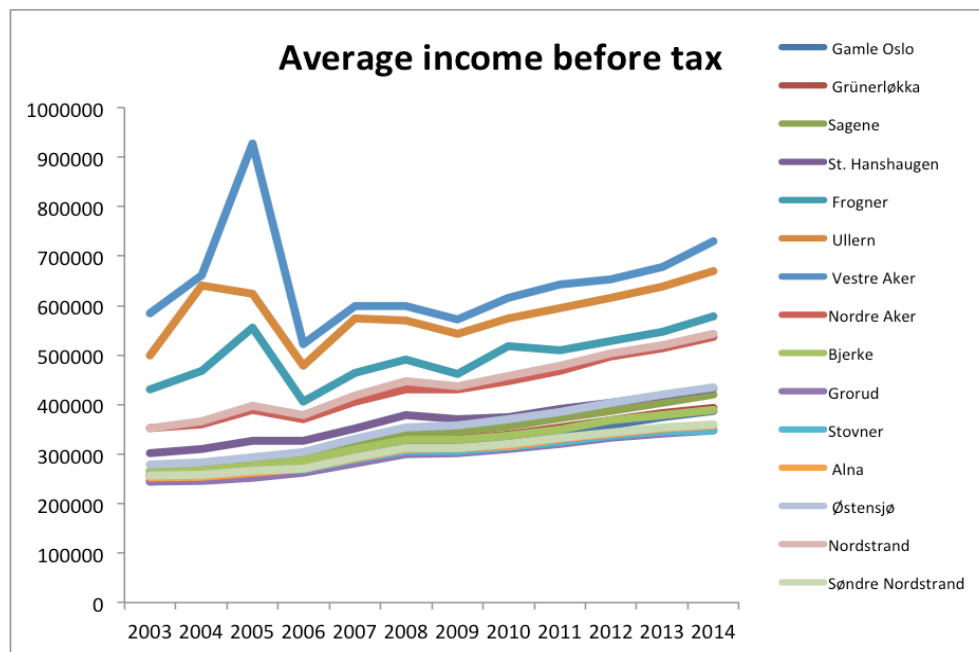


Figure 2.4: Average income before tax. Source: SSB

2.6.4 Debt

Considering debt is important when looking into real estate markets. The willingness of banks to grant loans can potentially slow down, or fuel real estate markets. Studies show that areas with a higher debt ratio could be more volatile to changes in the economic environment (Meen 1999). Graph 2.5 shows that that boroughs with the highest debt in Oslo since 2001 have been Vestre Aker, Ullern, Frogner, Nordstrand and Nordre Aker. Debt in Oslo seems to be positive correlated with income. This is in consensus with overall Norwegian households, Omholdt and Strøm (2014) concludes that household with the highest income also have the highest debt and fortune.

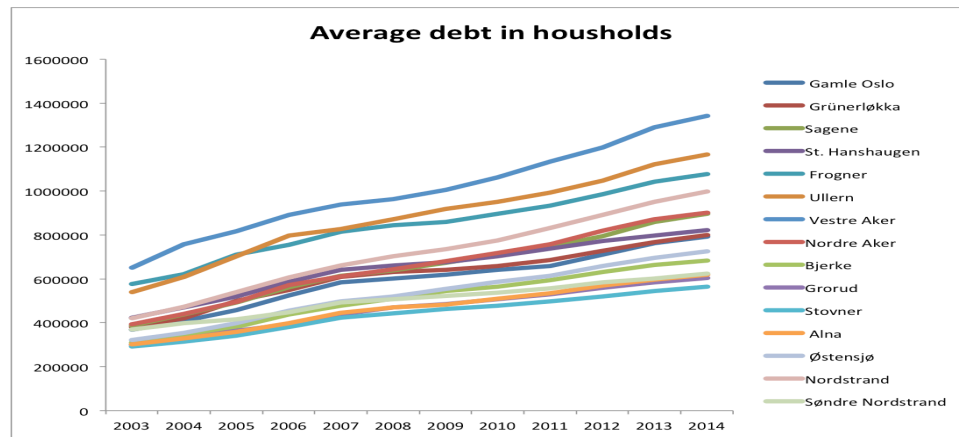


Figure 2.5: Average debt in Oslo's Households. Source: SSB

2.6.5 Debt gearing

Just looking at debt isolated has its limitations, as it doesn't give any information on how well the households can handle their debt. The demographic group with the highest debt ratios are households where the oldest partner is younger than 45, with young, or no kids (Omholdt & Strøm, 2014). Statistics tells us that this group is highly represented in the inner boroughs (Oslo kommune 2015). In an attempt to show potential debt gearing between the boroughs, I have calculated debt to yearly income⁹. From graph 2.6, the

⁹ Authors own calculations using numbers from statistics Norway

boroughs with the highest debt ratios are Sagene, Grünerløkka, and Gamle Oslo. The next group is St. Hanshaugen and Frogner. The areas with the highest debts ratios are all within the inner boroughs.

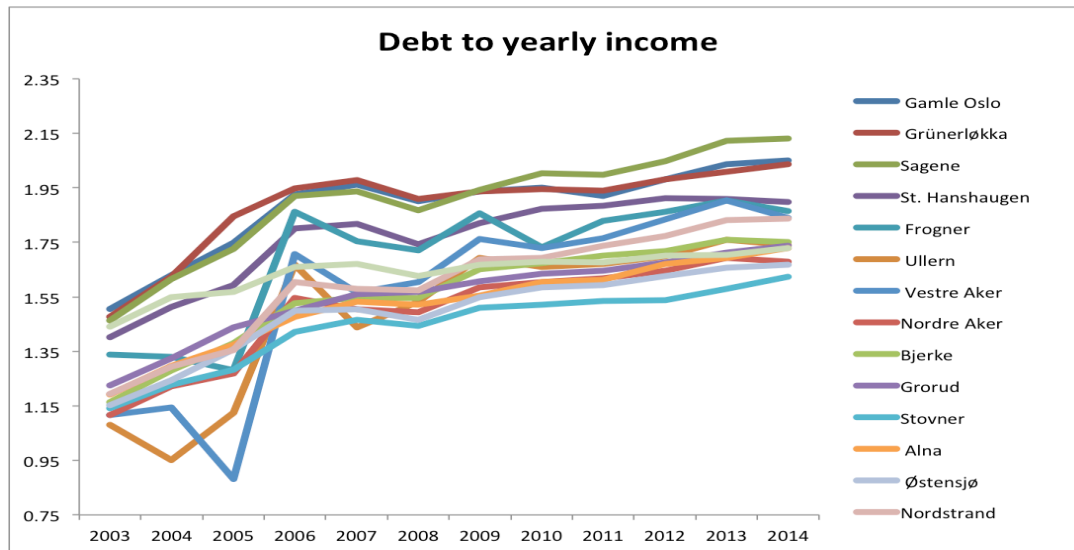


Figure 2.6 Debt to yearly income

2.6.6 Construction

New construction is the most important variable in real estate supply in the long run, as well as being a symbol of economic growth and faith in the future. It is however connected with lag, and projects are often started from uncertain forecasts (Mourouzi-Sivitanidou, 2011). When the general economic conditions changes, it takes time to start new buildings projects or walk away from projects. There is also significant costs related to walking away from already initiated constructions.

Observing at the numbers earlier, the income effect was visible almost immediately with changes in economic cycles. The overall constructions in Norway were dropping after 2007, but do to the construction lag, it is not immediately visible in finished constructions in Oslo. There is a drop between 2007 and 2008, but from 2008 to 2009 there is an increase in finished constructions. The expected drop after the financial crises is first

visible in 2010 and 2011. Since 2012 finished new constructions appears to be at the same rate as before the financial crisis.

| År | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|-------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Geografi | | | | | | | | | | | |
| Oslo i alt ¹ | 3 476 | 4 049 | 3 960 | 3 763 | 2 557 | 3 447 | 2 151 | 1 362 | 3 962 | 3 329 | 3 351 |
| Bydel Gamle Oslo | 358 | 330 | 457 | 633 | 1 017 | 475 | 387 | 137 | 1 359 | 259 | 660 |
| Bydel Grünerløkka | 484 | 613 | 557 | 728 | 106 | 889 | 337 | 267 | 529 | 867 | 669 |
| Bydel Sagene | 885 | 557 | 388 | 171 | 7 | 441 | 329 | 17 | 515 | 457 | 630 |
| Bydel St. Hanshaugen | 337 | 213 | 765 | 307 | - | 56 | 2 | - | 96 | 79 | 39 |
| Bydel Frogner | 280 | 206 | 114 | 173 | 290 | 227 | 250 | 17 | 117 | 287 | 79 |
| Bydel Ullern | 88 | 339 | 137 | 519 | 288 | 191 | 96 | 41 | 56 | 45 | 103 |
| Bydel Vestre Aker | 60 | 216 | 250 | 198 | 144 | 186 | 110 | 138 | 203 | 173 | 187 |
| Bydel Nordre Aker | 282 | 562 | 529 | 387 | 198 | 184 | 214 | 229 | 346 | 162 | 253 |
| Bydel Bjerke | 18 | 76 | 164 | 64 | 89 | 266 | 83 | 112 | 159 | 149 | 11 |
| Bydel Grorud | 54 | 30 | 80 | 5 | 4 | 75 | 27 | 24 | 41 | 9 | 28 |
| Bydel Stovner | 41 | 43 | 29 | 12 | 10 | 19 | 17 | 12 | 58 | 118 | 17 |
| Bydel Alna | 147 | 62 | 61 | 132 | 74 | 37 | 52 | 7 | 64 | 28 | 142 |
| Bydel Østensjø | 172 | 291 | 170 | 44 | 22 | 79 | 43 | 156 | 177 | 251 | 55 |
| Bydel Nordstrand | 131 | 153 | 158 | 159 | 109 | 241 | 126 | 124 | 135 | 133 | 166 |
| Bydel Søndre Nordstrand | 102 | 179 | 91 | 210 | 192 | 74 | 75 | 63 | 105 | 312 | 310 |

Figure 2.7 Total finished new constructions in Oslo. Source: Oslo Kommune

The boroughs with the most new constructions from 2005 have been Gamle Oslo, Grünerløkka, and Sagene. Before 2008 was St. Hanshaugen a fast growing area in terms of finished constructions. Boroughs with little new constructions since 2004 are Grorud and Stovner. Jacobsen and Naug (2004) predict the housing prices in the long run to drop 1.75% for every 1% increase in the real estate stock. New construction could also increase the overall value of an area, and actually increase real estate prices in the long run within certain regions (Andreassen, 2015).

2.6.7 Unemployment

The unemployment rate is an indicator on how strong the economy is, and generally an increase in real estate prices can be seen in periods with low unemployment rates. Since 1999 the Norwegian unemployment rate has been steadily under 5%. Before the financial

crises in 2008 Norway experienced constant low unemployment rates, dropping as low as under 2.5% (SSB, 2015). In this period Oslo also saw quickly rising real estate prices. Low unemployment contributes both to the general wealth in the households and to the general faith in the economy. If there are areas with more jobs and lower unemployment rates, this could encourage people to migrate towards those regions. Areas in Oslo with high employment rates are Nordstrand, Østensjø, and the west side boroughs. The regions with the highest unemployment rates are the outer east side boroughs. The inner east boroughs have unemployment rates similar to the overall average of Oslo (Oslo Kommune, 2015).

2.6.7 Interest rates

The interest rate affects real income and wealth of all the households. After recessions there has been a tendency to lower the key policy interest rate in order to stimulate economic growth. Since 2009 the interest rate has been particularly low, this is also a trend visible in the future forecasts of the Norwegian Central Bank. Meen (1999) points out that regions in Britain with higher debt ratios, appears to have more volatile real estate prices in regards to changes in interest rates. If this phenomenon is present in Oslo's real estate market, we would expect Sagene, Grünerløkka and Gamle Oslo to be the most affected by changes in interest rates.

3. Housing data 1985 - 2002

In order to test for long-term convergence or divergence I was looking for housing statistics of Oslo's boroughs as far back in time as possible. Official housing indexes only stretches back to 2003. Using Ambitas¹⁰ ownership history archive and finn.no I was able to compute my own housing indexes from 1985 to 2002. In this chapter I will briefly explain the leading theories of constructing housing indexes and explain my process.

3.1 Housing index theory

A standard housing price index measures the change in price over time in residential housing. There are several ways to make such an index, the most widely accepted ones are: simple method, hedonic method, and repeat sales method (El Mahmah , 2012). Assemble and preparing a housing index has challenges, each approach or method has weaknesses that will affect the output data (Røed Larsen & Sommervoll, 2004).

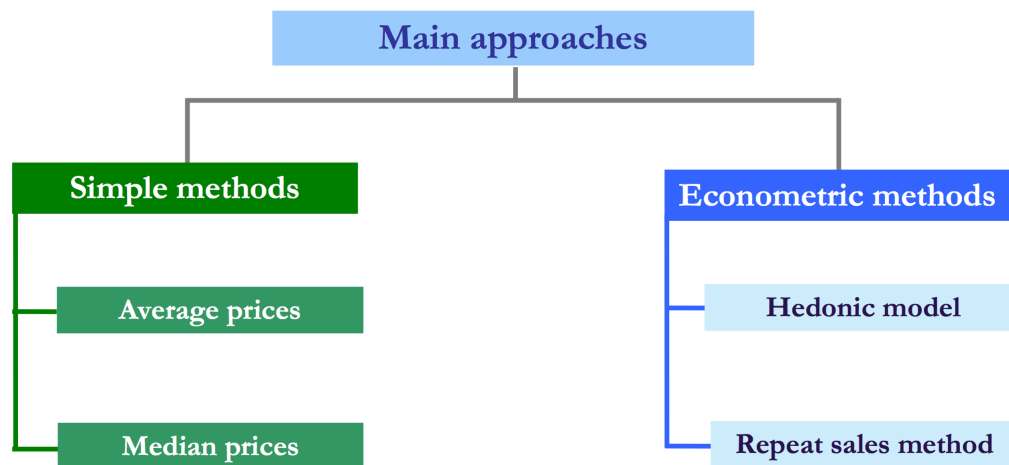


Figure 3.1 Main approaches constructing a housing index. Source El Mahmah, 2012

¹⁰ Norwegian company that works with real estate information

3.1.1 Simple method

This approach has its strength from its simplicity. The method measures the median, weighted average or the simple average of real estate prices over a given time period. This is intuitive a good method, because it tells us something about the changes in price between time A and time B. This is also the main weakness of this approach. What looks like a time trend between time A and time B can actually just be a change in the real estate characteristics or quality in the objects that has been traded in that period (Røed Larsen & Sommervoll 2004). This effect can be reduced with numbers. But problems with heterogeneity will be a factor in these types of housing indexes. Variations of this method have been, or are in use in countries like Germany, Spain and the Netherlands (El Mahmah , 2012).

3.1.2 Hedonic model

This method is based on the principle that the price of real estates can be valued from standard characteristics and its location. The estimated price index is a result of an econometric equation model where the price is an outcome of several variables. The variables could typically be: square feet, bedrooms, balcony, and location. Different models has different variables, the common denominator is that the equation is made in the interest of give the best estimate for the real housing price over a time period (Røed Larsen & Sommervoll, 2004).

Ideally this method should be able to tell how much a fireplace or a balcony should affect the total price. This ambitious idea is also this methods weakness. In order for the estimates to be good, it needs large amount of input data. There is also a question on how to exact measure characteristics and price. How close to the railroad does a house need to be in order for it to influence the price (Røed Larsen & Sommervoll, 2004). This method works best with access to a large quantity of reliable data; this method is used, or has been in countries and areas like United Kingdom, Sweden and Hong Kong (El Mahmah , 2012). Eiendom Norge uses a version of the hedonic model calculating their index for the Norwegian real estate markets (Eiendom Norge, 2015)

3.1.3 Repeat Sales method (RSM)

Considered a variant of the hedonic model. But it tries to overcome problems with heterogeneity in real estates. The approach is to look at dwellings that has been sold several times over a given time period and make an index based on how the same objects have changed in price. A commonly used version of the RSM-model was introduced in 1989, introduced by Case and Shiller. Røed Larsen and Sommervoll (2004) also used a version of this model when they looked at the overall real estate market in Oslo during the 1990s. The main challenge with this approach is that real estates that have been sold more than one time in a given time period are not representative for the overall market. A question to ask is why have these objects had a higher turnover rate than the average real estate object in the area (Røed Larsen & Sommervoll, 2004).

3.2 My housing index

3.2.1 Starting point

The starting point was to assemble raw data in order to complete housing price indexes for each of the 15 boroughs. Because of limited data available, I ruled out the hedonic model and went for a version of the simple method combined with feedback from a simplified repeat sales model.

3.2.2 Data collection

My approach consisted of merging previous sales prices with the apartments square meter and its location. I uncovered former sales prices using Ambitas previous ownership archive¹¹ and got the square meter from housing ads on finn.no. Since I used ads and ownership history archive, there were no datasets that I could merge. This method was time-consuming, because I had to write each observation individually into Excel. In total I collected 2870 observations, 693 of them were observations of real estates that had been sold two times or more, that could be used in a sales resale model.

¹¹ Norwegian name: Eierskiftehistorikk

3.2.3 Aftenposten asking price indexes

After catering data I realized that my dataset had fewer observations in the time period 1985-1989. In an attempt to make my findings more solid, I used Aftenpostens¹² archive to make an asking price index in those years to compliment my findings. I used Aftenpostens archive and looked at old real estate ads, from them I gathered asking price and the square meter. The problem with this approach is if the asking price differed a lot from the actual sales price. In total I gathered 1093 observations from Aftenposten. The Aftenposten asking price index was only used to validate the other findings.

3.2.4 Data process

The first step was to organize my data and exclude potential outliers or abnormal observations. Observations that looked suspicious when I collected them were market with red. If the same objects came out strange in a scatterplot, I made a decision whether or not to use that observation in the final calculating of the index. Figure 3.2 presents a scatterplot of the observations within the borough Ullern. The strange observations, is market with red. A polynomial trend line is also included to see the general movement of the observations. Identical charts were made of all the boroughs.

¹² Norwegian newspaper

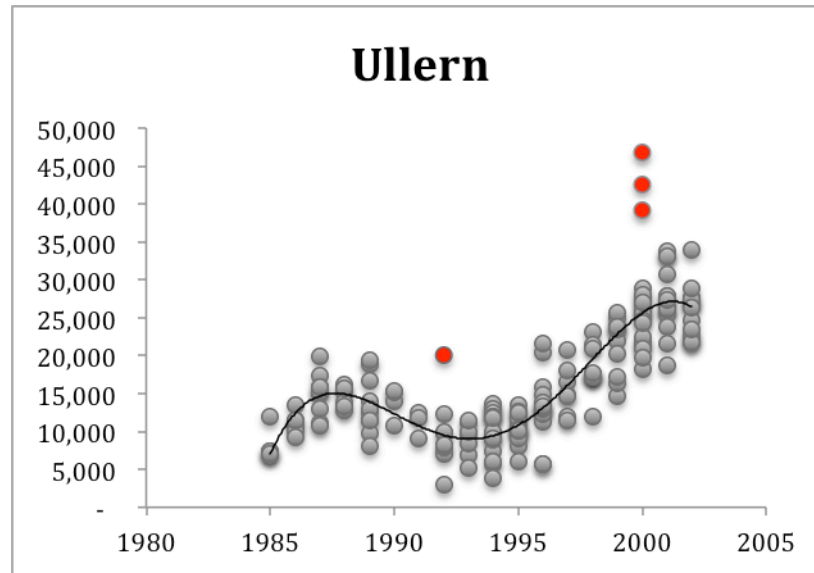


Figure 3.2 Scatter plot of the observations gathered for the borough Ullern

From this approach I was able to create housing price indexes just from the simple average year to year. The challenge was that with few observations, my index would not reflect the real time trend (Røed Larsen & Sommervoll, 2004). To counter this bias, I looked at over 600 sales resale observations to confirm and smooth my numbers.

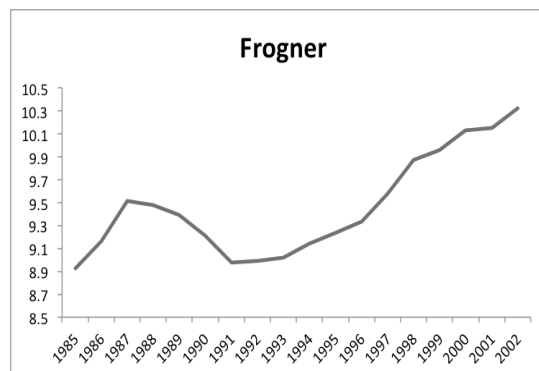
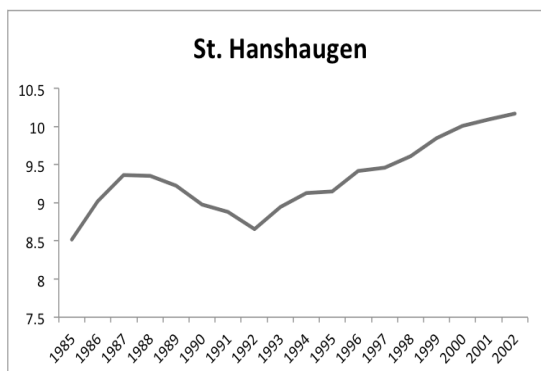
3.2.5 Stovner and Grorud

Because of the lack of observations in these two boroughs, I made one combined index of Stovner and Grorud. Combining the numbers for the two regions makes sense geographically, since they are neighboring boroughs in the outer east side of Oslo.

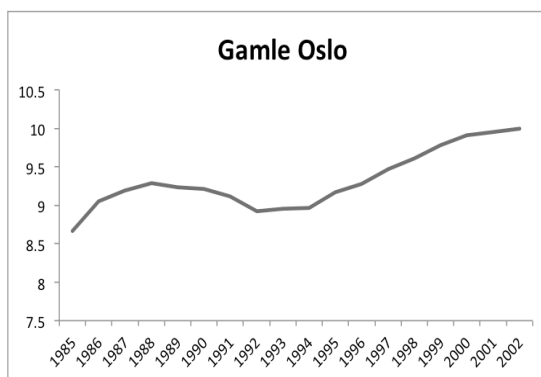
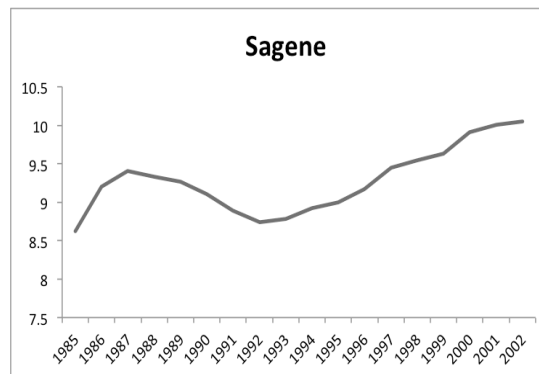
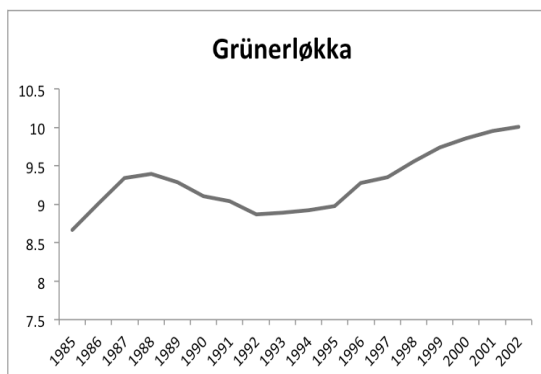
3.3 Data presentation

In this part, the paper presents all my completed real estate indexes of Oslo's Boroughs from 1985-2002. I will also include two additional graphs, of Oslo divided into the two and four regions as presented in chapter one. The Housing prices, is presented on its natural logarithm of average price per square meter. It is not adjusted for inflation; the reason is simply to keep the numbers transparent with the regression analysis.

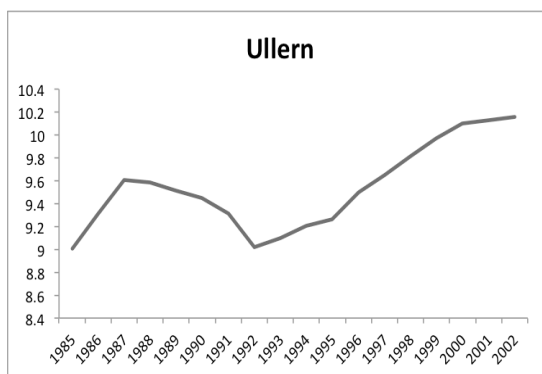
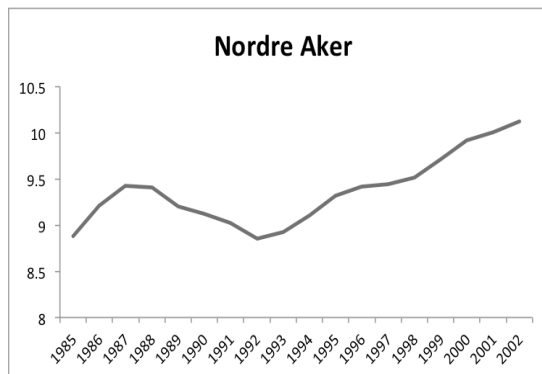
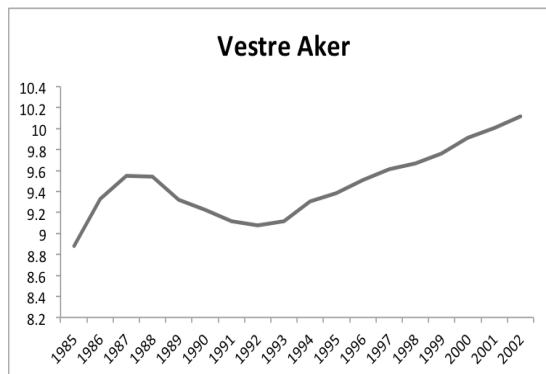
3.3.1 Inner west



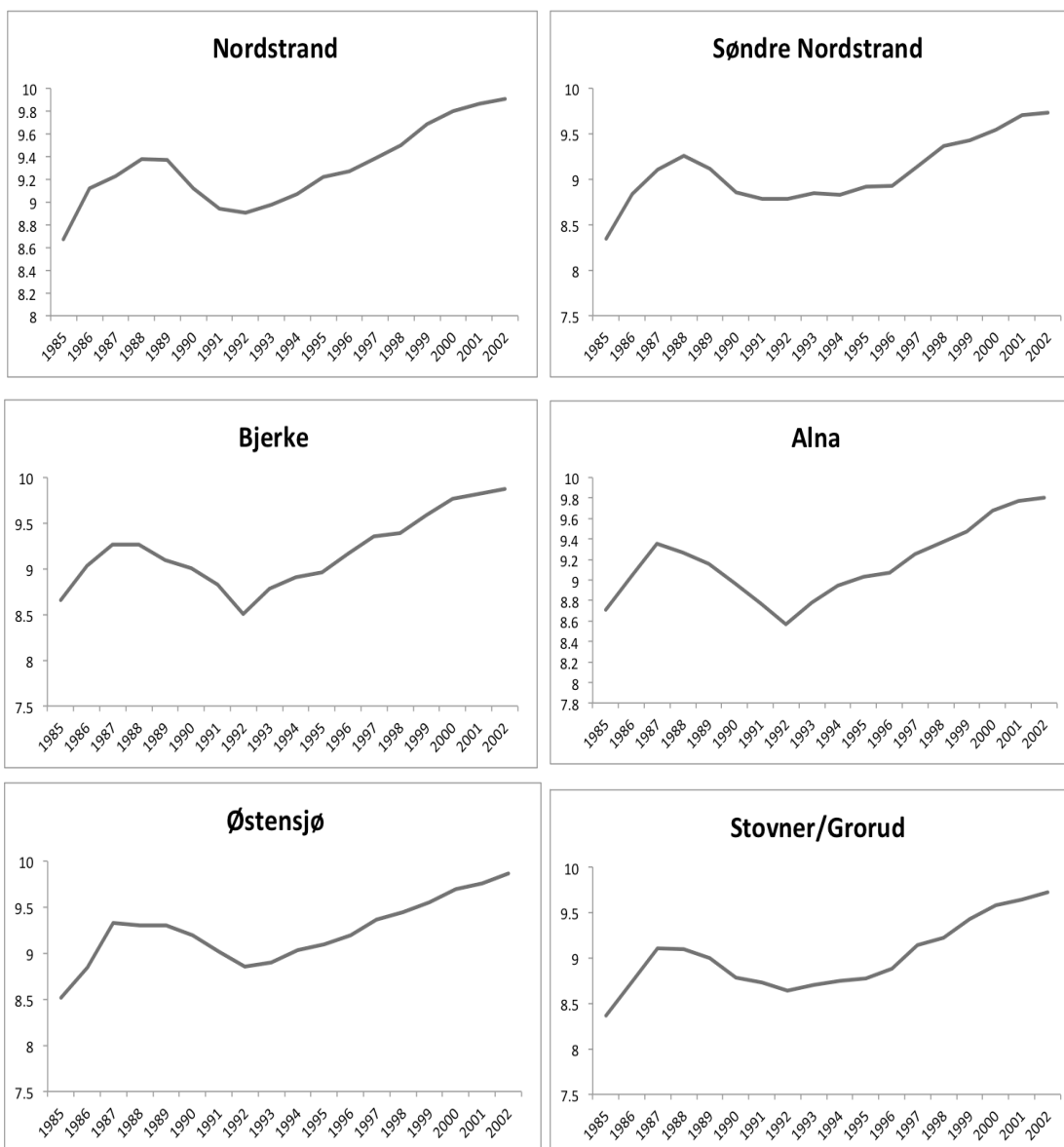
3.3.2 Inner east



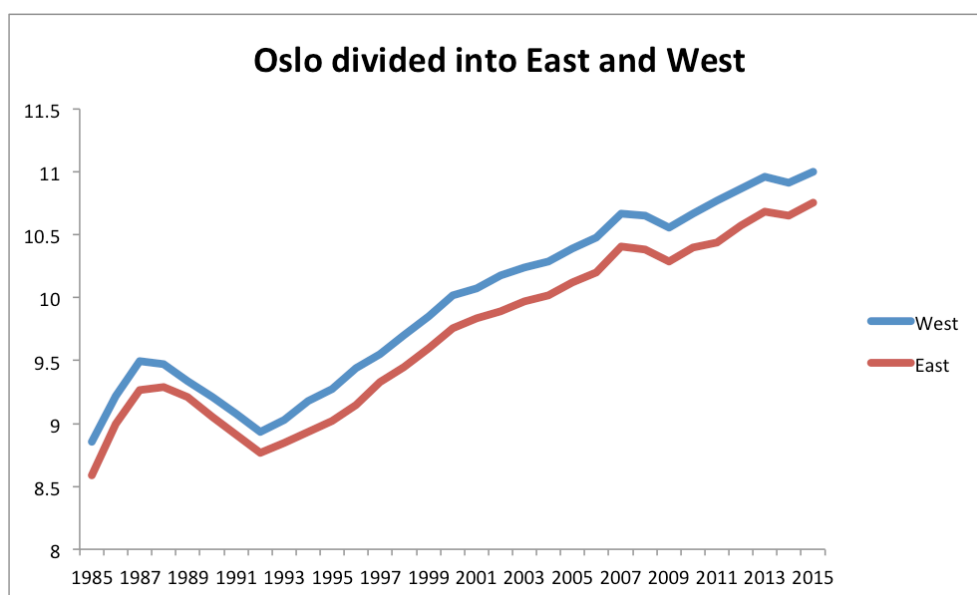
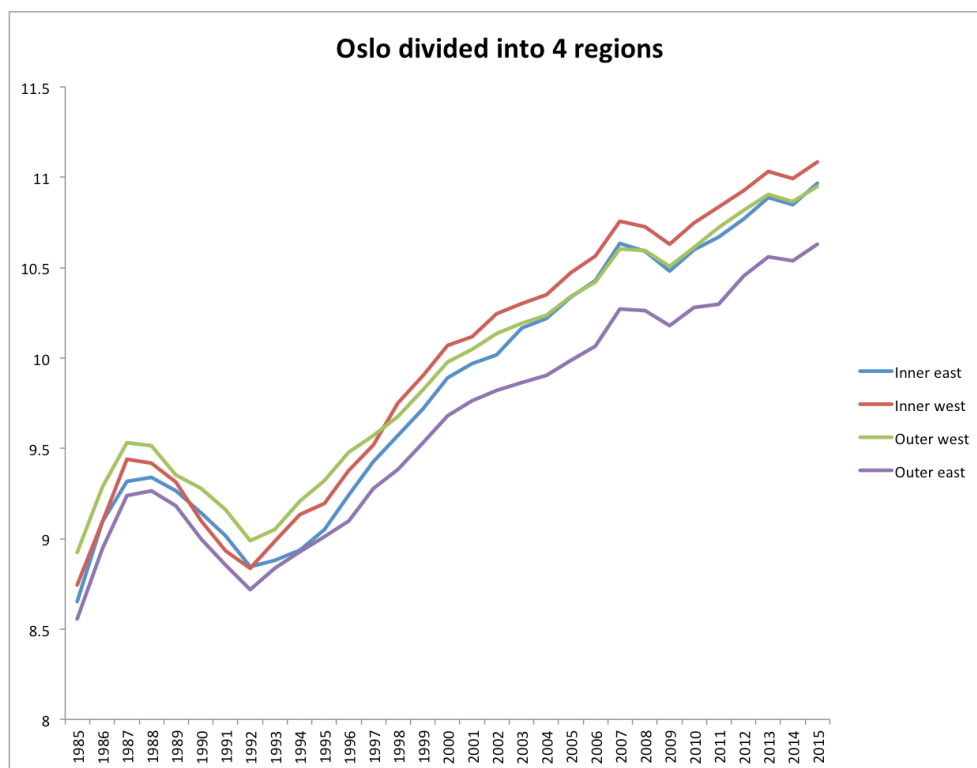
3.2.3 Outer west



3.2.4 Outer East



3.2.5 Oslo divided into regions



3.3 Reliability and Validity

3.3.1 Reliability

To my knowledge, there is no other housing index of Oslo's boroughs that reaches back to 1985. This makes it hard to distinguish how reliable my output data is, since there is no other statistics to directly compare my results with. There is on the other hand some degree of inter reliability. When comparing my index of Oslo as a whole with official indexes we see that they move and have the same overall trends. This gives an indication that the overall data output makes sense.

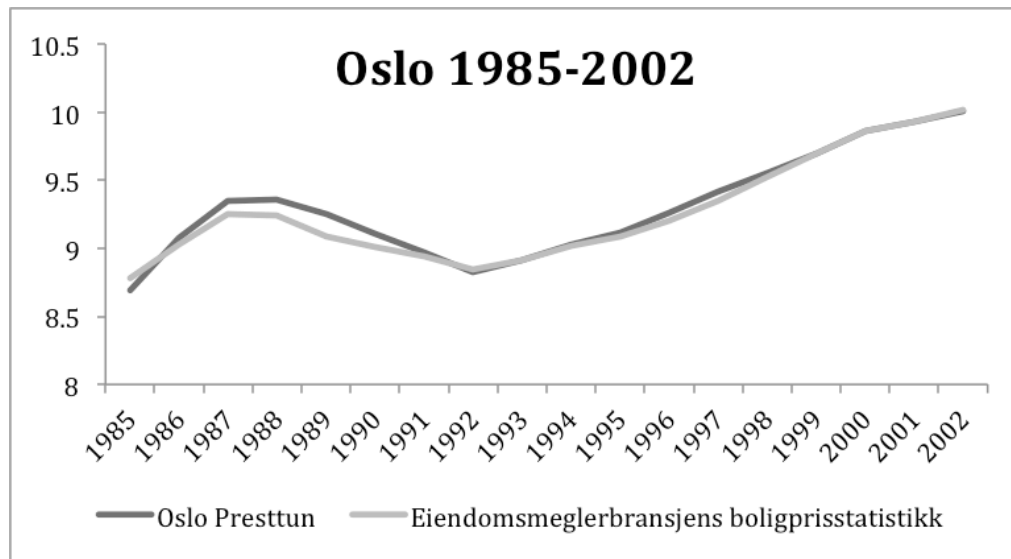


Figure 3.3 Presttun's observations compared to Eiendomsmeblerbransjens Boligprisstatistikk

My indexes seem to be too volatile on a year-to-year basis until 1990. This could be result of too few observations or the method used. The order of the price levels between the boroughs seems to come out with some consistency. We see that the west side is in general valued higher than the eastside. The boroughs that are generally considered expensive, comes out expensive in my graphs and vice versa. There is some face reliability to the indexes; they make overall sense, with some problems with volatility on a yearly basis.

3.3.2 Reproducibility

The reproducibility of my process is good. The method is transparent and possible to imitate. An argument against reproducibility is the time aspect of making the indexes.

3.3.3 Validity

The main question using the simple method is the problem with whether or not we are measuring the time trend and not just differences of characteristics in the real estates sold. Using an HP-filter to remove the trend from my indexes we can see that there are perhaps too much noise in my variables. This could indicate that I am measuring more than just the intended change in price. This is in consensus with the overall output from studying the graphs intuitively.

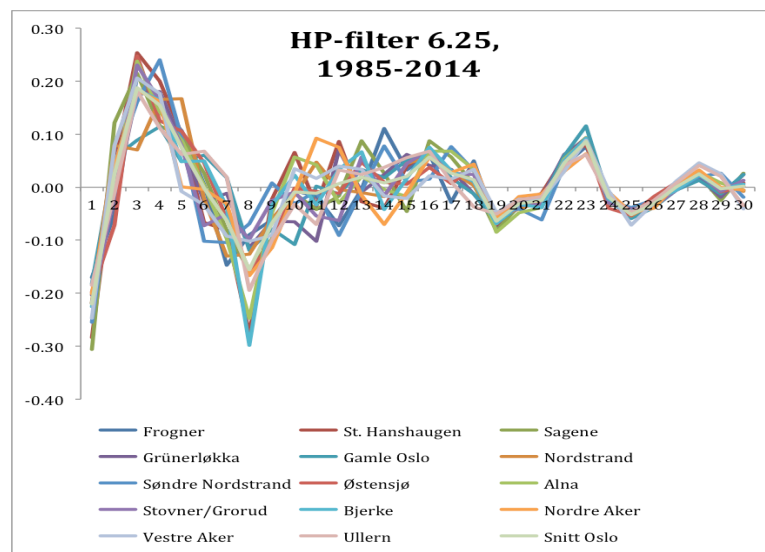


Figure 3.4 Oslo real estate prices presented with trend removed, using an HP-filter.

Housing data 2002-2015

Housing data from 2002-2015 are obtained from Eiendom Norge, a source with high credibility.

4. Statistical theory and method

In the first part of this chapter, the paper goes into statistical theory and method used. The second part presents time periods tested for beta convergence, and the process of making the regression models BLUE.

4.1 Regression

The regression analysis is considered to be one of the most powerful tools within econometrics. Regression analysis looks at the relationship between one dependent variable and one or more independent variables. The most common regression is the classical linear regression model (CLRM). This method looks at the relationship between a dependent variable and the independent variables thru a straight line: (Brooks 2014).

$$(4.1) \quad Y_t = a + \beta X_t + u_t$$

The estimation technique I am using is called ordinary least squares (OLS). The OLS method is used to fit a straight line to your data by minimizing the sum of the squared residuals. The object is to create a straight line that fit the data in a best possible way; using this method assumes that the relationship between the dependent variable and the independent variables is on a straight line.

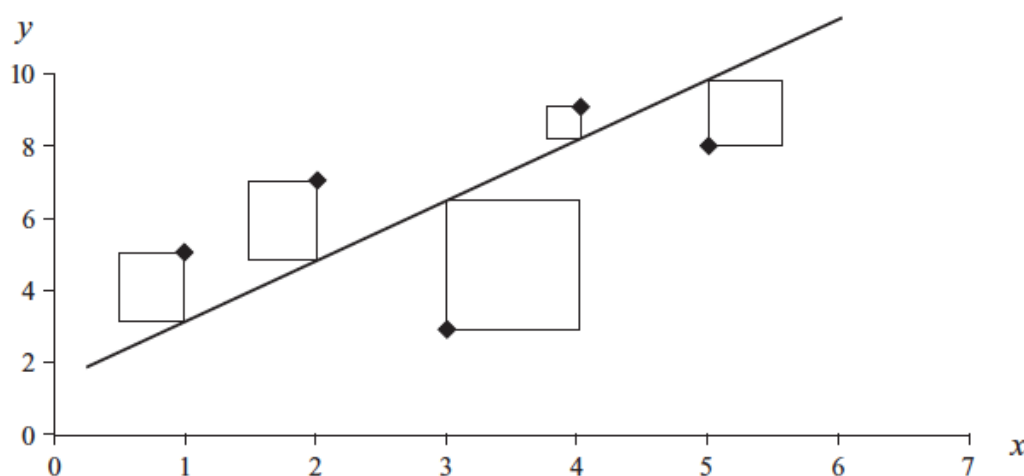


Figure 4.1 Visual presentation of OLS-method. Source: Brooks 2008

4.1.1 Assumptions using OLS

When using ordinary least squares there are several assumptions concerning the disturbance terms that should be fulfilled in order to get the best possible estimations for $\hat{\alpha}$ and $\hat{\beta}$. (Brooks 2014).

- (1) $E(\mu_t) = 0$ The average value of the error terms is zero
- (2) $\text{var}(\mu_t) = \sigma^2 < \infty$ The variance of the errors is constant
- (3) $\text{cov}(\mu_i, \mu_t) = 0$ The covariance between error terms over time
(or cross sectional) is zero.
- (4) $\text{cov}(\mu_t, x_t) = 0$ There is no connection between the error term and the
associated x-value.
- (5) $\mu_t \sim N(0, \sigma^2)$ The error terms are normally distributed

If the regression have a constant term, assumption (1) $E(\mu_t) = 0$ will never be violated, as long as assumption one holds assumption four could equally be written $\text{cov}(\mu_t, x_t) = 0$. (Brooks, 2008). Another alternative assumption is that the independent variables are non-stochastic. This is the case with most economic data (Gujarati, 2011). Since I am using a constant term in my regression and the independent variable is fixed or non stochastic I assume that both assumption 1 and 4 holds in my regressions.

In order for the estimators to be BLUE – Best linear Unbiased Estimators, assumption 1-4 needs to hold (Brooks 2014). Most real data will not immediately satisfy all those assumptions, simply because they are not made by some ideal experience (Vetroeger). Because of this it is important to know how to control for deviations from the conditions and how to deal with them.

When using cross sectional OLS regression the most common problem is with heteroskedasticity and with small sample sizes, the t- and F test could be unreliable if there are problems with the normal distribution of the error terms (Gujarati, 2011).

4.2 Heteroskedasticity

The second assumption is that the variance of the error terms is constant in all X's and over time, this is known as homoscedasticity. The residuals are a measure of the models uncertainty. If the variance in the error term is not constant the models uncertainty is irregular across observations. When we have homoscedasticity the residuals are spread around the regression line with consistency, unrelated to the independent variable. If the residuals are trending or moving with the independent variables we could have heteroskedasticity (Brooks, 2008). The problems with unequal variance in the error terms could arrive from several reasons; there could be outliers in the data sample, the form of the regression model could be wrong, or we could have problems with mixing observations regarding to scale (Gujarati, 2011). The assumption with constant variance in the error terms is mostly broken when we expect the model to have a linear trend, but in reality it does not (Brooks 2014).

Heteroskedasticity will still give consistent and unbiased coefficient estimates. But the coefficients will no longer have the minimum variance and will no longer be considered BLUE. The result is that we can no longer trust t- and f tests (Gujarati, 2011).

Heteroskedasticity tests

A way to look for heteroskedasticity is to plot the residuals from the regression against one of the independent variables. With this approach we can see if the residuals moves constant with the independent variable. If there is a pattern in the residuals this could be an indication that we are dealing with heteroskedasticity (Brooks, 2008). It is often hard to tell if we are dealing with heteroskedasticity just from looking at graphs alone, to test for heteroskedasticity there are several statistical test we can use:

4.2.1 White test

The white test is one of the most common tests used to check for heteroskedasticity. It was introduced by Halbert White (1980) and is considered to be particularly valuable because it makes few assumptions about the shape of the heteroskedasticity. White test is

built in in most statistical software's, where we immediate get the test results. The way to manually conduct a white test is as followed (Brooks 2008):

H0 is that we have homoscedasticity.

1. The first step is to run your regression model of the standard linear form and obtain the residuals, \hat{u}_t .

$$y_t = \beta_1 + \beta_2 X_{2t} + \beta_3 X_{3t} + u_t \quad (4.2)$$

2. The second step is to run an auxiliary regression with the squared residuals as the dependent variable.

$$\hat{u}_t^2 = \alpha_1 + \alpha_2 X_{2t} + \alpha_3 X_{3t} + \alpha_4 X_{2t}^2 + \alpha_5 X_{2t} X_{3t} + \alpha_6 X_{3t}^2 + v_t \quad (4.3)$$

v_t is a normally distributed disturbance term independent of u_t .

1. The interoperation of the test results can be done with two approaches. The first one is to use the F-test framework and the other is known as the Lagrange Multiplier. The Lagrange multiplier uses the R^2 from the auxiliary regression multiplied with the numbers of observations. It can be shown that $TR^2 \sim \chi^2(m)$, where m is the regressors in the auxiliary regression 4.3, excluding the constant term. We reject H0 if $X^2 >$ corresponding value from statistical table (Brooks, 2008, pp. 134-135).

4.2.2 Abridged white test

The white's chi square test is a large sample test. Including the independent variables, the squared value of the independent variables and the cross – product term is resulting in loss in degrees of freedom. The outcome is that the auxiliary regression could be very sensitive. In order to save degrees of freedom, we could reduce the test by only regressing the squared residuals on the estimated value of the dependent variable and

squares of the estimated values. This is still in the spirit of the original white test, but it saves degrees of freedom (Gujarati, 2011).

The way to conduct the Abridged white test:

H0: homoscedasticity

- (1) Step one is equal the original White test. Run your regression model of the standard linear form and obtain the residuals, \hat{u}_t .
- (2) Regress the squared residuals on the predicted Y's and the squared predicted Y's.

$$\hat{u}_t^2 = \alpha_1 + \alpha_2 PY + \alpha_3 PY^2 + v_t \quad (4.4)$$

Where PY is the predicted Y and v_t is a normally distributed disturbance term independent of u_t .

To interoperate the results you look at the F statistic of the auxiliary regression. If the P value is significant you reject H0 of Homoscedasticity (Gujarati, 2011).

4.2.3 Breush-Pagan / Cook-Weisberg test

This test is similar to the White test, but it differs because it only tests for heteroskedasticity within a linear regression model. The object is to see if the squared error term is related to one or more of the independent variables. If this is the case, it could indicate heteroskedasticity. To interoperate the result you can either look at the f-statistics or alternatively you can use the chi square statistics (Gujarati 2011).

Since the Breusch-Pagan test only looks for linear heteroskedasticity, it is best used in a combination with the white test (Berry & Feldman, n.d).

4.3 Autocorrelation in the disturbance terms

The next assumption is no autocorrelation between the error terms. The covariance between the disturbance terms should over time be zero (Brooks 2014). If the error terms are correlated, the OLS estimators will not longer be efficient and they will no longer be BLUE. The estimators will still be unbiased and consistent, but in most cases the OLS disturbance term will be underestimated and that will result in that the t values are inflated. As a consequence a coefficient could appear more significant than it actually is, and we can no longer trust the usual t- and F tests (Gujarati 2011).

The concept of autocorrelation is quite intuitive to understand in time serial data, where the error term in time t is correlated with the error term at time (t-1) or to any other past error terms (Gujarati 2011). In cross-sectional data has there often been a common assumption that there is little or no correlation in the error terms (Robinson 2008). But it is also possible with auto-correlation in some types of cross-sectional data. Brooks (2008) uses the example with profitability of banks between different regions and that a version of autocorrelation could arise in a spatial sense. When autocorrelation occurs within panel- or cross-sectional data, it is most commonly referred to as spatial correlation (Vetroeger).

Tests Autocorrelation

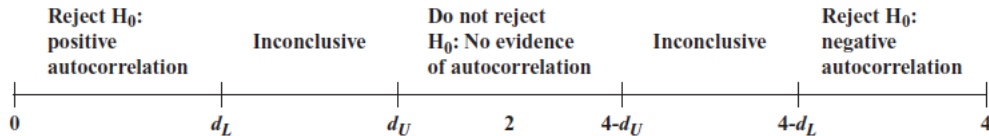
There are several ways to detect autocorrelation. As with heteroscedasticity you can look for it graphically, but it is more common to use the Durbin-Watson (DW) test and the Breusch-Godfrey (BG) test. To test for spatial correlation you can use Moran's I (UCLA, 2015)

4.3.1 Durbin-Watson

The Durbin-Watson test is used to test for first order autocorrelation. It interoperates the relationship between an error term and the previous error term. After running the initial regression, the DW value can be calculated using (Brooks, 2008):

$$DW = \frac{\sum_{t=2}^t (\hat{u}_t - \hat{u}_{t-1})^2}{\sum_{t=2}^t \hat{u}_t^2} \quad (4.5)$$

The DW statistic will always be between 0 and 4. Where 0 represent positive autocorrelation and 4 represent negative autocorrelation. 2 represent no autocorrelation. In order to interoperate the Durbin Watson statistics you have to use the “rejection and non-rejection regions for the DW test. This is given using the upper critical value (dU) and the lower critical value (dL) from the Durbin-Watson statistic table.



There are 3 conditions that has to be fulfilled in order for Durbin Watson to be valid:

-There must be no lags of dependent variable in the regression.

-The independent variables have to be non-stochastic.

-There must be a constant term in the regression

(Brooks, 2008, page 148)

4.3.2 Breusch-Godfrey Test

The Durbin-Watson test is limited because it only looks at serial correlation within the first order. If we expect autocorrelation in any other forms the Durbin-Watson test would not find it. We could manually replace (u_{t-1} with u_{t-2}) in equation 4.5. This is not recommend since the approximation only will be worse as the two time indices increases. The critical values should also be modified as a result of the changes (Brooks, 2008). Another approach is the Breusch-Godfrey test; this method is more general and tests for autocorrelation up to r th order(s 148. Brooks) The Breusch-Godfrey approach test for relationship between u_t and several of its lagged values at the same time (Brooks 2014).

When using B-G, the model of the errors under this test is (Brooks, 2008):

$$u_t = \rho_1 u_{t-1} + \rho_2 u_{t-2} + \rho_3 u_{t-3} + \dots + \rho_r u_{t-r} + v_t, \quad v_t \sim N(0, \sigma_v^2) \quad (4.6)$$

H_0 and the alternative hypothesis are:

$$H_0 : \rho_1 = 0 \text{ and } \rho_2 = 0 \text{ and } \dots \text{ and } \rho_r = 0 \quad (4.7)$$

$$H_1 : \rho_1 \neq 0 \text{ or } \rho_2 \neq 0 \text{ or } \dots \text{ or } \rho_r \neq 0$$

H_0 states that the current error term is not related to any of its former values (Brooks, 2008).

4.4 Autocorrelation in cross sectional data

Autocorrelation in cross sectional data is rather more complex than the intuitive easier to understand autocorrelation in time serial data that set in the context of time (Brooks, 2008). Autocorrelation is often viewed as not a problem in cross sectional data, and or hard to test for. Spatial autocorrelation refers to when autocorrelation arise in a spatial sense. Two or more point could be related to their distance, rather than time (UCLA, 2015). Addressing spatial autocorrelation is possible and is essential in order to make the regression estimators BLUE.

To test for autocorrelation in cross sectional data you need to make a ‘distance matrix’. The distance matrix would comprise elements that in some way measured the distance between the observations. By this approach you could test for autocorrelation between observation that are near in distance, rather than close in time (Brooks, 2008).

4.4.1 Moran’s I

A test to detect autocorrelation in spatial sense is the Moran’s I. The test is a parametric test and it test for both negative and positive spatial autocorrelation. Moran’s I test against the null hypothesis is that there is no spatial autocorrelation present. The test does this with a correlation that is weighted by inverse distances (UCLA, 2015).

In order to use the test, you need some geographically reference points of your observations. A possibility is to use the latitude and longitude coordinates, using these coordinates you have the foundation to make a distance matrix (UCLA, 2015). Before

making the matrix, you have to find the greatest euclidean distance between two points in your data set. When we know the maximum distance, we can make a matrix based on the distance between the points. When the matrix is completed, we can use the function of Moran's I and test a variable for spatial autocorrelation up against the inverse distance matrix (UCLA, 2015).

4.5 The disturbances are normally distributed

The fifth assumption is that the error terms are normally distributed. This is an important assumption because all the usual tests of significance are built on the idea that the error terms are normally distributed. Both the t- and the f test could loose their creditability without this assumption. This assumption is particular critical when we are dealing with small sample sizes (Gujarati 2011).

The most commonly accepted way to test for normality is with the Bera-Jarque (B-J) test. In addition to look at the mean and the variance, JB also look at skewness and kurtosis. Skewness measures to which extent the distribution is not symmetric about its mean value. Kurtosis measures how fat the tails of the distribution are. There should ideally not be any skewness present in the distribution and kurtosis should be measured at 3. A Normal distribution is symmetric about its mean with two identical tails (Brooks 2014).

The Bera-Jarque test statistic is given by:

$$JB = \frac{n}{6} * (S^2 + \frac{(K-3)^2}{4}) \quad (4.8)$$

4.6 Beta convergence tests periods

I have selected 8 time periods that are interesting to analyze further in order to test for beta-convergence or divergence between the boroughs of Oslo. The time periods are selected because of distinctive reasons:

Two time periods are selected to test for long-term beta convergence:

1987 – 2014 2003-2015

Three periods are chosen because they represent a period with raising housing prices:

2003 – 2007 2009 – 2013 2014 – 2015

Three periods are chosen because they represent a period with declining housing prices:

2007 – 2009 April. 2013 – Dec. 2013 1987-1992

Both my calculated data (1985-2002) and housing data from Eiendomsverdi (2003-2015) have been used. Time periods that starts before 2002 operates with a yearly average, and time periods that starts from 2003 is a cross sectional study of monthly data.

Mathematically the estimation of my regression model of cross section data for the boroughs can be written as follows:

$$\frac{1}{T} \ln \left(\frac{P_{i,T}}{P_{i,0}} \right) = \alpha + \beta \ln (P_{i,0}) + \varepsilon_i \quad (4.8)$$

Where:

Ln P Natural logarithm of the real estate prices.

α Constant level.

β Slope parameter.

ε_i Random component.

i Index indicating the boroughs in the reference period.

0,T Index indicating the time (0 = starting point, T = End point)

The independent variable is log of the housing price in the beginning of the time period. The dependent variable is the growth rate for that period. This is a similar approach that earlier has been used to test for convergence between countries based on GDP (Dvorokova, 2013).

4.7 Test of assumptions

Since my cross-sectional regressions have quite small samples sizes they are not a perfect fit for Breusch-Pagan, White test (Gujarati, 2011), or Bera-Jarque test (Brooks, 2008). In the absence of better options I still use them, but I compliment them with graphical analysis.

In order to test for heteroskedasticity I have used: graphical scatter plot, White test, Breusch-Pagan, and Abridged White test. To test for normal distribution within the error terms I have used the Bera-Jarque test in combination with a graphical approach looking at the normal distribution curve and the Skewness- and kurtosis values.

4.7.1 Spatial autocorrelation

Detecting for autocorrelation in the error terms proved to be the most difficult one, after looking at other papers I started out using Durbin-Watson and Breusch Godfrey, but this approach appeared not to give reliable feedback. In order to completely rule out autocorrelation in the error terms I decided to test for spatial autocorrelation as well. To test for spatial autocorrelation in the error terms, I used the boroughs latitude and longitude coordination's¹³ to set up an inverse distance matrix¹⁴ between the boroughs. Using this combination of tests should make my regression output more robust and BLUE.

¹³ Attached in the appendix

¹⁴ Attached in the appendix

4.8 Test feedback

The summarized outcomes of tests on the error term¹⁵ are shown in table 4.2. The table gives indications of some problems regarding time period April 2013 to December 2013. The White tests are close to the rejecting level of H0. B-P is actually giving feedback on heteroskedasticity present in the model. The output from table 4.2, in combination with a graphical approach, tells that this model is indeed suffering from Heteroskedasticity.

| Period | White | AWT | B-P | B-J | Moran's I | BLUE |
|------------------------|-------|-----|-----|-----|-----------|------|
| 1987-2014 | X | X | X | X | X | X |
| 2003-2015 | X | X | X | X | X | X |
| 2003-2007 | X | X | X | X | X | X |
| 2009-2013 | X | X | X | X | X | X |
| 2014-2015 | X | X | X | X | X | X |
| 2007-2009 | X | X | X | X | X | X |
| 2013-2013 Apr.-Dec. | X* | X* | | X | X | |
| 1987-1992 | X | X | X | X | X | X |

Note: 95% significant level

*Close to discard limit

Figure 4.2: Summary of test in order to make the regressions BLUE

April 2013 – Dec 2013

This was the time period I was most hesitant to use; the reason for the wavering was the models short time period and if it could give any valuable information at all. The argument to use it was that it was the most recent time period with a drop in housing prices and it could back up data from the time period 2007 to 2009. The drop in housing prices form 1987 to 1992 may give historical information, but regarding movements in the markets today is it more uncertain.

¹⁵ Test results are attached in the appendix

4.8.1 Dealing with heteroskedasticity

In order to deal with heteroskedasticity there are several approaches to use: One possibility is to log the data, or in some other way reduce the measure of “size”. This approach has the tendency to “pull in” extreme observations. Another approach is to use standard error estimates that have been modified to account for heteroskedasticity, given by statistical software’s (Brooks 2014). A third option is to modify the model with removing potential outliers or observation that make the form of the regression unfit (Gujarati, 2011).

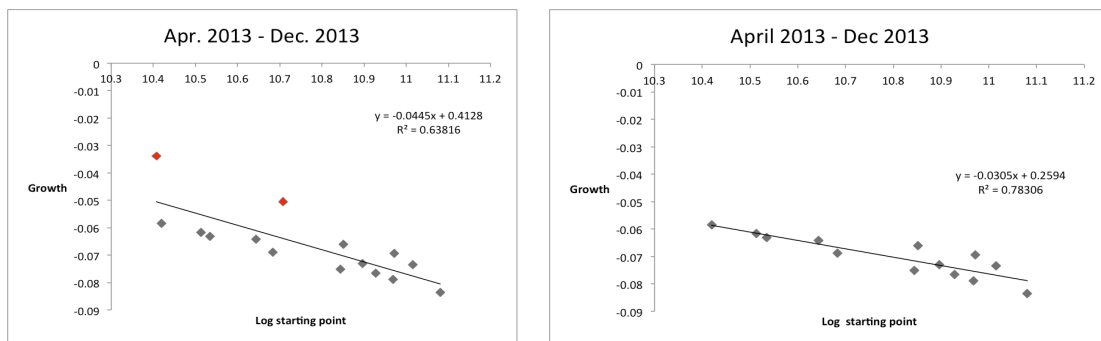


Figure 4.3: Graphical presentation of model fitting in order to deal with heteroskedasticity

The best option in this case was to remove observations that made the model unfit. An interesting observation is that Nordstrand, the borough that is described at geographically on the east side but demographically belong to the west side and its neighbor Søndre Nordstrand that are the two outlandish observations. The observations are market with red on the left graph in figure 4.3. Studying the graph on the right side, the trend line is a better fit.

Both graphs are pointing downwards, indicating convergence. Removing Nordstrand, and Søndre Nordstrand is slowing down the registered speed of convergence, but the trend is still present. Using the modified data, tests are now coming out negative on heteroskedasticity.

| Period | White | AWT | B-P | B-J | Moran's I | BLUE |
|------------------------|-------|-----|-----|-----|-----------|------|
| 2013-2013 Apr.-Dec. | X | X | X | X | X | X* |

Note: 95% significant level
*Modified data

Figure 4.4 Test feedbacks after dealing with heteroskedasticity

5. Results

The overall results are presented both graphically, and with a summary of the regression output¹⁶.

The overall results are:

- It seems to be absolute convergence in time-periods with declining housing prices.
- It seems to be absolute divergence in time-periods with rising housing prices.
- There is no evidence of long-term absolute- convergence or divergence.

¹⁶ Complete regression output is attached in the appendix.

5.1 Long term beta-convergence

The regressions of time-periods 1987-2014 and 2003-2015 show no significant signs of either convergence or divergence. They both have high p-values, which indicate that there is no statistical significant relationship between the initial housing prices and the growth rates for the two time periods. In graph 1987-2014 it looks to be other factors than the initial price that have determined the growth rate over the last 27 years. The speed of growth seems in general to be mainly impartial of initial housing prices. In 2003 to 2015 the observations seems to be scattered further away from the regression line. The regression for overall convergence or divergence is not significant but from the graph there could be signs of conditional- convergence and divergence, dependent on which clusters we focus at. There are clear winners and loser in terms of growth in this period.

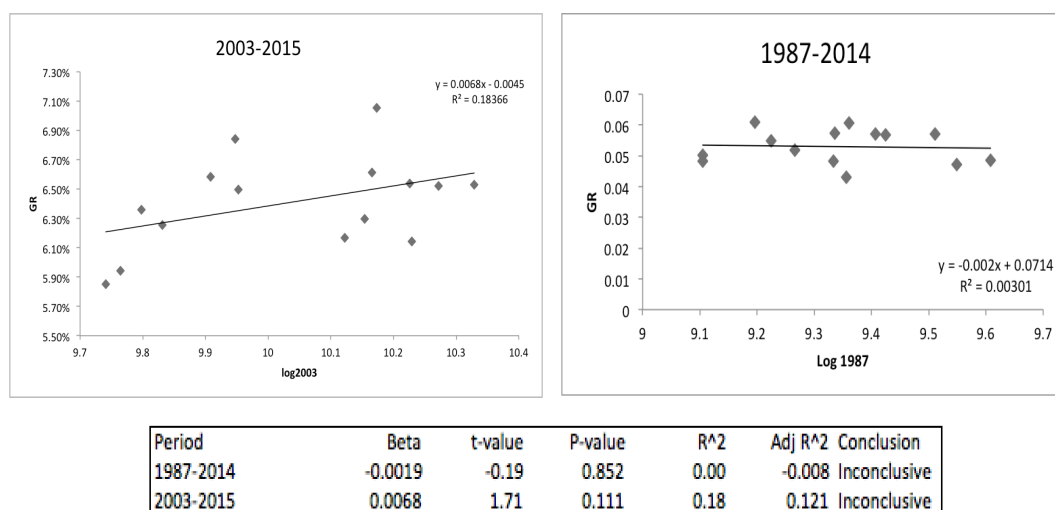


Figure 5.1 Summary regression output, and a graphical presentation, in long-term periods

5.2 Time periods with rising housing prices

All three graphs have an upwards-trending regression line, which indicates overall divergence. From the regression output we can see that 2014-2015 is not statistically significant and the squared R is low. Beta-divergence seems to be present in both the regression 2003-2007 and 2009-2013. The highest t-value and the highest squared R are in the period 2003-2007.

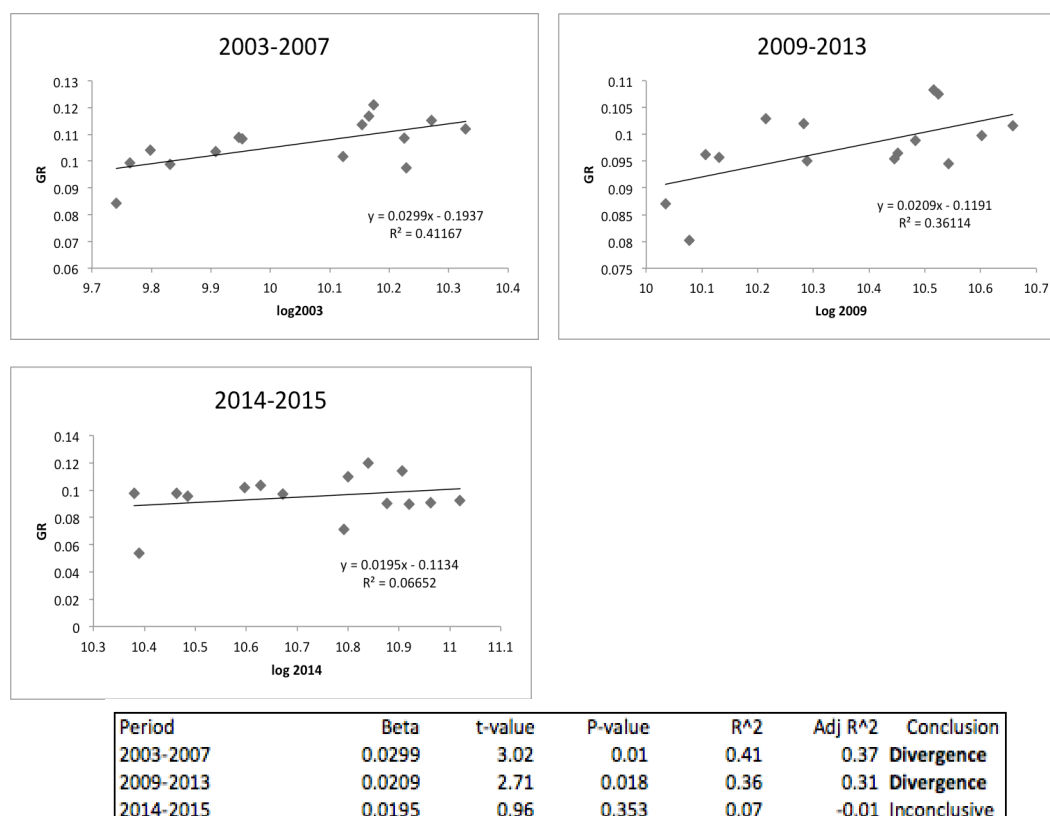


Figure 5.2 Summary regression output, and a graphical presentation, in periods with rising real estate prices

5.3 Time periods with declining housing prices

All three graphs have a downward trending regression line, which should indicate absolute convergence. In regression 1987-1992 the p-value is too high and there is therefore no statistically significant relationship in the model between initial price in 1987 and the growth rate. Both 2007-2009, and April 2013 – December 2013 has evidence of beta-convergence within them. The R squares are high in both, and the p-value is low on a 95% significant level. This indicates that the model is strong for both periods. April 2013 – Dec 2013 was modified to cope with heteroskedasticity problems, Søndre Nordstrand and Nordstrand that was removed would only increase the speed of convergence.

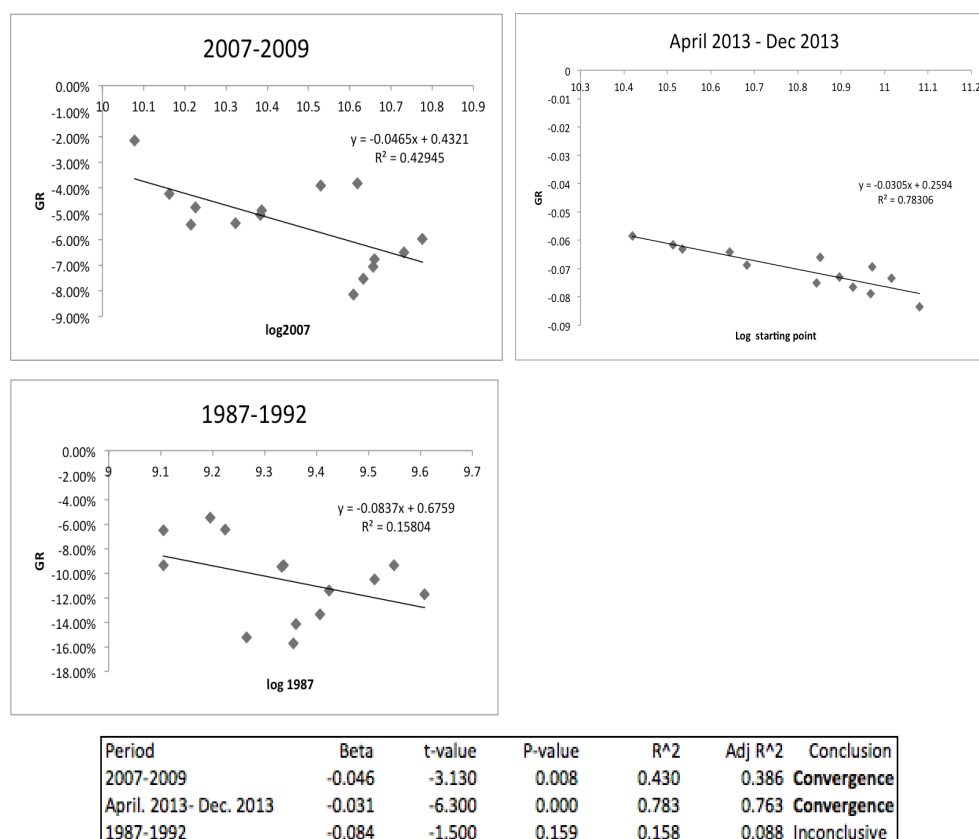


Figure 5.3 Summary regression output, and a graphical presentation, in periods with declining real estate prices

6. Discussion

This chapter looks at the results from the regressions, and with the use of factors presented in chapter two, aims to explain the movement in price between the boroughs and areas. The discussion is presented in the order: periods with rising housing prices, periods with declining housing prices, and the two long-term periods. In the end there is a discussion on convergence groups, main patterns, and boroughs with potential for high future growth. Time periods 1987-1992 and 2014-2015, are excluded from the discussion because of limited and uncertain output from the regression analysis.

6.1 Periods with rising real estate prices

6.1.1 Period 2003-2007

There are indications of absolute divergence in this period. An R^2 of 0.41 and a positive beta of 0.03 are signals that the boroughs overall diverged in this period. The five boroughs with highest growth, are all boroughs from inner west and inner east. Characteristics of the inner boroughs in this period are; high net migration, high debt ratios (SSB, 2015), and large rental markets (Oslo kommune, 2015).

High net migration to the inner boroughs

A growing economy and low interest rates from 2003-2005 appears to have increased the migration towards the center of Oslo, in the beginning of the period (Oslo kommune 2015). The increased migration and future beliefs in growth should have increased the demand of real estates (DN, 2004). Real estate supply is fixed in the short run, while an increase in demand can explain some of the fast growth in real estate prices in the period 2003-2007 within the inner boroughs.

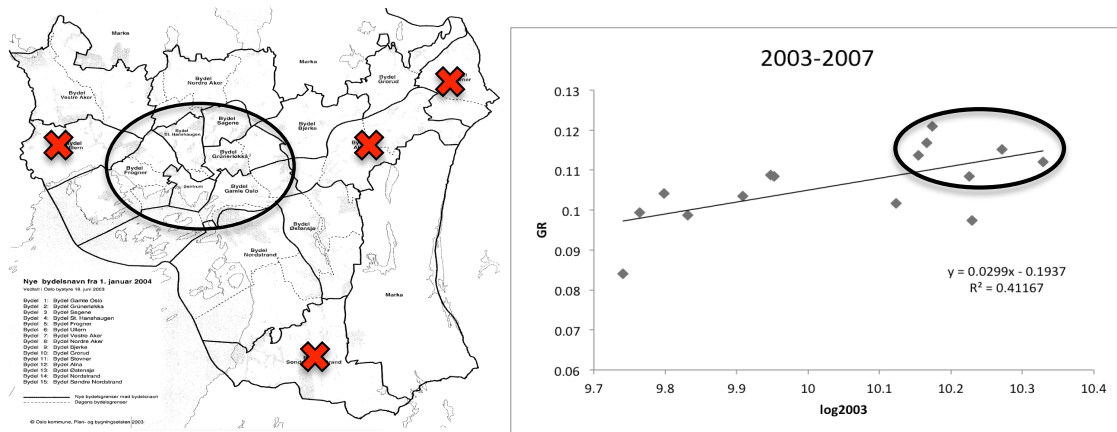


Figure 6.1 Shows areas with the most, and the least price growth in time period 2003-2007. Areas with the least growth are market with X, and areas with the most growth are all within the ring, marking the inner boroughs.

Increased intangible amenities in inner east

The divergence could perhaps also be explained from a spatial equilibrium perspective. The inner east side areas has since 1994 seen a steady flow of investments and new constructions as results of projects, Akerselva Inner East, and the Acting Plan Inner East. As results of these investments the inner east boroughs should have slowly gained more intangible amenities. In order to have a similar utility as the outer boroughs, the housing prices should rise compared to boroughs far away from the investments. Chart 6.1 graphically shows that boroughs with the least growth in real estate prices are located far away from areas affected by the projects.

Spillover effects

A possible spatial spillover effect from the increased demand in real estate in the inner boroughs could be the population growth in Bjerke and Nordre Aker. Bjerke is the neighboring borough of Grünerløkka, and has seen a significant higher net migration than the other outer east side boroughs. Especially Økern¹⁷ has seen tremendous population

¹⁷ Area in Bjerke that is geographically close to Grünerløkka

growth in this period. We see a similar effect on the outer west side with large population growth in Tåsen¹⁸ (Oslo kommune, 2015).

Debt gearing

An important Structural difference between the regions seems to be debt gearing. Debt gearing can vary both in types of households and between regions. The demographic group with the highest debt gearing was young households with young or no kids (Omholt & Strøm, 2014). This is the same demographic group that is highly represented within the inner boroughs (Oslo Kommune, 2015). From my own calculations we saw that the overall debt gearing was highest in the inner east, close followed by the inner west. The two boroughs with the highest debt gearing, Sagene and Grünerløkka, also had the highest growth in real estate prices in this period.

6.2 Period 2009-2013

From 2009 to 2009 the regression analysis shows again clear signs of overall divergence with an R^2 of 0.36 and a positive beta of 0.21. The result builds up under the idea with absolute divergence in times with rising real estate prices. An interesting tendency is that the intense growth of Grünerløkka and Gamle Oslo appears to have slowed down.

Structural changes

There might be some structural changes within the inner east that has influence the growth rates. The projects Akerselva Inner East (1994- 98), and the Acting Program Inner East (1997-2006) have both been carried out. The after-effects might have slowed down and some of the momentum could be gone. This could be part of the reason why Grünerløkka and Gamle Oslo have a slower growth rate in this period compared to the period before the financial crises.

¹⁸ Area in Nordre Aker geographically close to Sagene

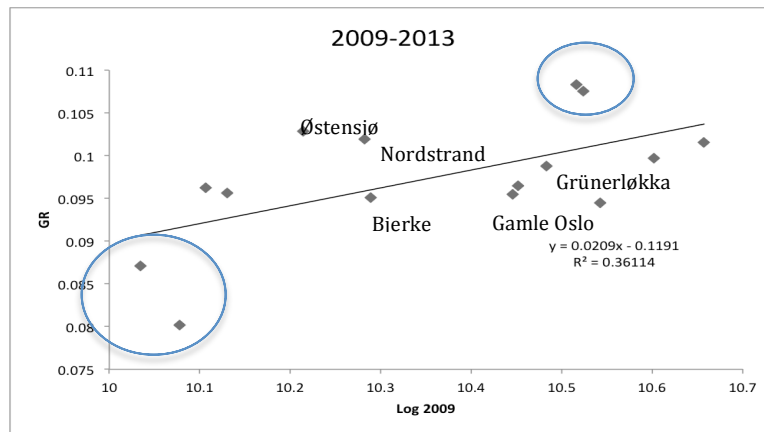


Figure 6.2 Graphical presentation of absolute divergence in time period 2009-2013

Østensjø and Nordstrand

An interesting remark is that Østensjø and Nordstrand seems to converge towards the large convergence group consisting of the inner east and the western boroughs. Low unemployment rates, high education rates, and geographical placement close to nature (Oslo Kommune, 2015) could be to be factors that are pushing real estate prices up in both Østensjø and Nordstrand.

Migration

Migrations statistics discloses that there could be a connection between increased growth in real estate prices and the total net migration to the boroughs Nordstrand and Østensjø. Nordstrand and Østensjø has in this period the highest net migration of all the outer boroughs, and the third and forth highest population growth in total. We also see that some of the potential spatial spillover effects to Bjerke appear to have slowed down. Net migrations are still highest overall to the inner boroughs, but net migrations are not exponential growing from one year to another (Stambøl, 2013). Migration looks to be rather stable throughout the period. The combination of increased migration, and increased real estate prices in Nordstrand and Østensjø strengthens the theory that

migrations are a factor in real estate growth between the boroughs. It also improves the possibility of Oslo's housing market to be efficient; the inter-migration between the boroughs is high with few moving barriers. If people are estimating an area to be underpriced, the movement willingness appears high.

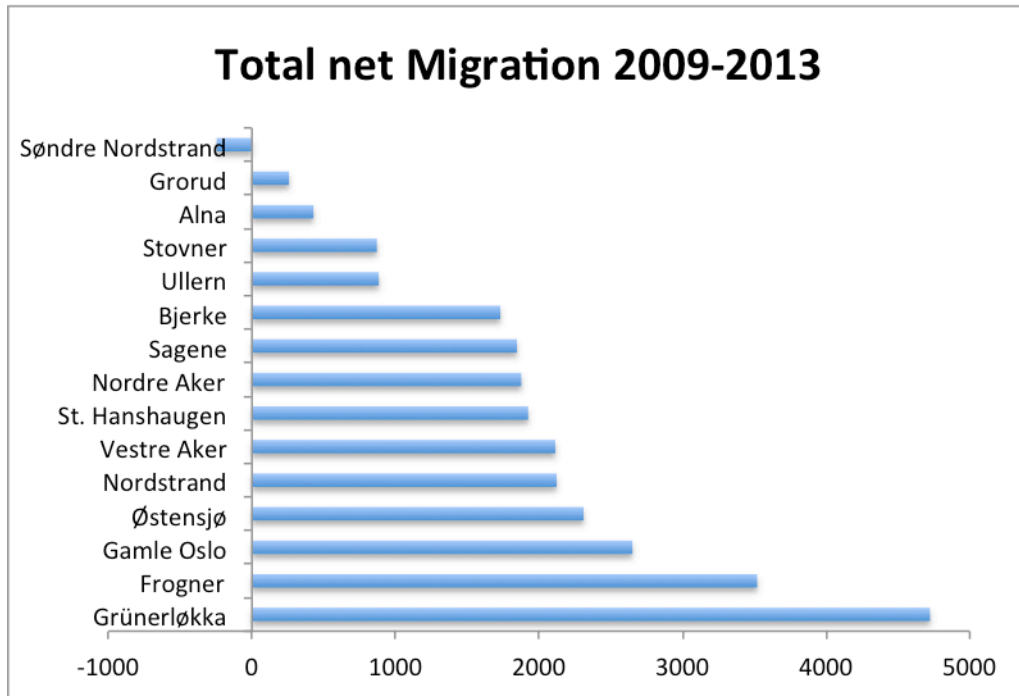


Figure 6.3 total net migrations to Oslo's boroughs 2009-2013 Source: Oslo Kommune

Inconclusive effect of debt gearing

Debt gearing effect seems to be less present in this time period. Several of the high growth areas (Nordstrand, Nordre Aker, and Østensjø) have little or medium debt gearing. The exception is Sagene, which has both the highest growth and the highest debt gearing. A possible rationalization of the link between the high debt gearing and real estate growth before 2007, could be the belief in future growth. The inner boroughs, where the price growth where the highest, was overrepresented with young adults, and most of them had never experienced a real bust in the real estate market. This could have lead to an over belief in future growth, and as a result high debt gearing. After the financial crises 2007-2009, some of the belief in the market might have been reduced,

and other factors could have played a larger part in price movements registered from 2009-2013.

Divergence as a result of extremes

Looking at graph 6.2, the absolute divergence seems to be pushed from four boroughs. Sagene and Nordre Aker¹⁹ have experienced abnormal high growth, and Søndre Nordstrand and Stovner has experienced abnormally minor growth. If we remove these four boroughs we see that the rest of the boroughs seems to be growing without any or little relation to initial real estate prices. This is in consensus with graphs in chapter three, the overall split between east and west, appears to be as visible as ever. But it is a result of outliers, and not a geographical split following Uelandsgate. There are several east side boroughs with similar real estate prices as the west side.

6.3 Periods with declining real estate prices

6.3.1 Period 2007-2009

Period 2007-2009 shows clear signs of absolute convergence in the regression analysis with a high R^2 of 0,43 and a negative beta of -0.046. Period 2007-2009 displays that the outer east side boroughs appear to be more stable in periods with economic detraction.

Debt gearing

Boroughs with high debt-ratios in this period appear to drop the most in terms of real estate prices. High debt gearing seems to be related with excessive growth from 2003-2007 and the largest drops in real estate prices from 2007-2009. As seen above, some of the high debt gearing within the inner boroughs before 2007 could be related to almost speculation from young people without the needs necessary to handle their debt. When migration dropped, and the flow of new byers decreased, the demand appears to have declined quite fast. The financial crises hit Norway modest, and the unemployment rate

¹⁹ Neighboring boroughs

did not increase particularly (Trading economics, 2015). So it does not appear to be a direct result of people losing their job, but more of a result of losing the faith in future growth.

Income little effect

It seems to be little correlation of the short-term changes in income and drop real estate prices. Two boroughs with large drop in income from 2007-2009 were Vestre Aker and Ullern (SSB, 2015), and chart 6.4 demonstrates that they are falling significantly less in terms of real estate prices compared to other boroughs. This confirms that the short-term drop in real estate prices was not mainly caused of people losing their job, or large income setbacks.

Migration

In this period with declining economy, net migration to the inner boroughs dropped significantly from 2008. This effect is not visible to the same degree in the outer boroughs, and this could possibly explain a drop in demand for properties in the inner city in the short run.

With the inner boroughs being harder affected of the immigration factor in this period, this could possibly explain the large drop in real estate prices compared to the outer boroughs, which are less affected of by economic contraction. Having a steady migration flow, which is not largely affected by the economic conditions, appears to make the outer east side boroughs more robust in volatile market conditions (Oslo Kommune, 2015).

Nordstrand

Nordstrand is falling significantly less than the majority the inner boroughs from 2007-2009. The tendency of growing more in economic growth periods, and falling less in economic contraction, could indicate that Nordstrand over time could converge closer towards areas with higher housing prices today. The high growth of Nordstrand could be

a potential spatial spillover effect from the inner east boroughs breaking the east versus west barrier. It appears to almost have been an unbroken law, that west side boroughs had to have the most expensive real estate markets. With the inner east catching up, it could lead the way for other east side areas to gain momentum, and this can be what we are seeing with Nordstrand.

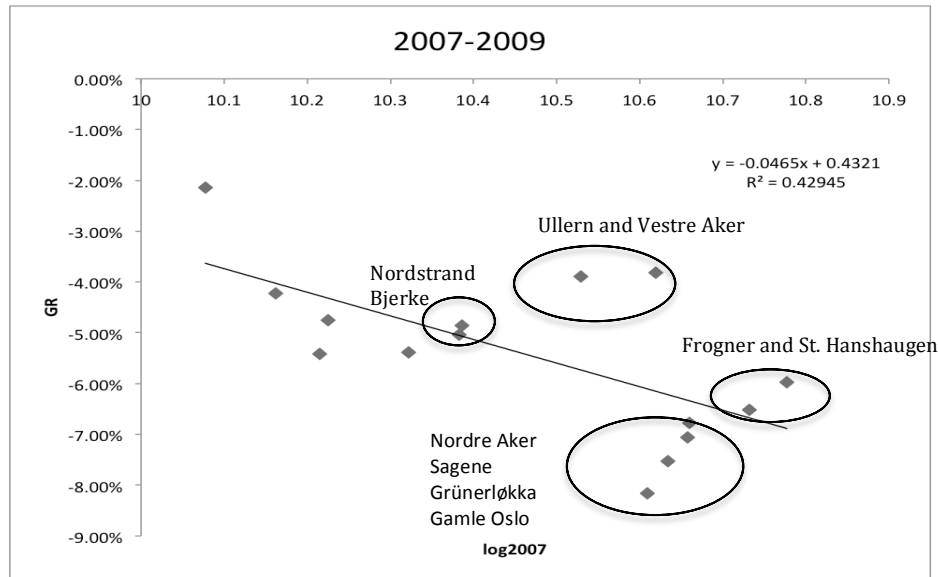


Figure 6.4 Graphical presentation of absolute convergence in time period 2007-2009.

6.3.2 Period April 2013 – December 2013

This period is included because it is the last significant drop in real estate prices in Oslo. It might be too short to actually produce decent output, but it is included as of the information I believe it provides. This period has the strongest R^2 of 0.78, and the regression output is showing clear evidence of absolute convergence with a negative beta of -0.031. The analysis builds up under the theory that the inner boroughs and the west side areas appear to be more volatile in terms of real estate prices. It also gives some insight on Nordstrand, and how this borough is converging quite fast towards the west- and inner boroughs. This is a visible tendency since 2007.

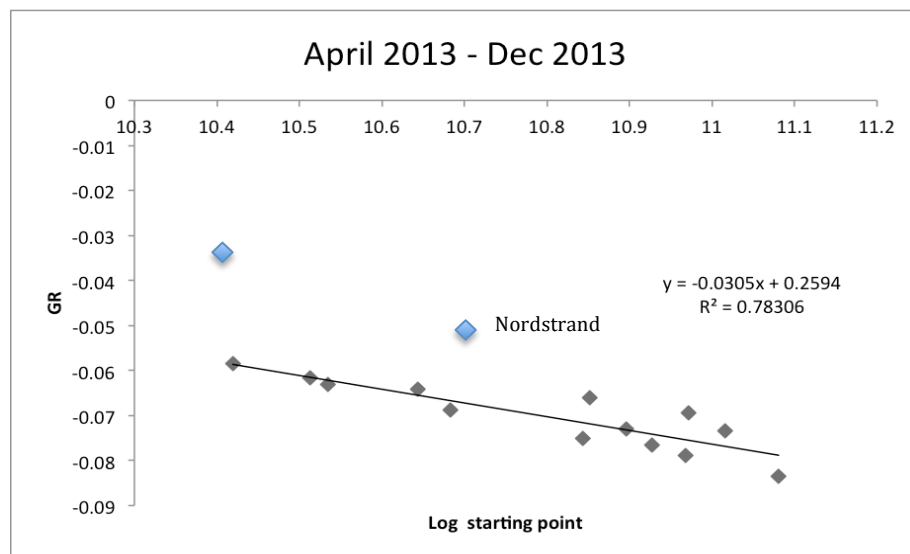


Figure 6.5 Graphical presentation of absolute convergence in time period April 2013 – December 2013.

6.4 Long time periods

The two long-time periods offer valuable insight into Oslo's real estate market and how real estate prices have acted over long time periods through changing economic cycles. Both periods include times with economic expansion and contraction. Despite not providing any statistical significant signs of overall convergence or divergence, there are still interesting patterns and clusters to investigate further.

6.4.1 Period 1987-2014

Inner boroughs highest growth rates

The long time period 1987-2014 indicates no signs of long-term absolute convergence or divergence in Oslo. Looking at other studies, this result is similar to Young and Rous (2012). Their paper concluded that there were no significant evidences of total convergence within the US. Young and Rous (2012) found indications of conditional convergence with convergence groups that converged towards the same steady state. The most noteworthy observation from this period is that the boroughs with the highest growth are Gamle Oslo, St. Hanshaugen, Grünerløkka, Frogner, and Sagene. This indicates that the inner boroughs have had the most growth in the last 27 years. It is also an indication that the inner east side boroughs have converged towards the west side areas.

Initial real estate prices seems to matter little in the long run

Another observation is that initial real estate prices appear not to matter in the long run. Real estate prices in high-priced areas appear to be the most volatile in changing economic cycles. They increase a lot in growing periods, but also drop heavily in periods with declining real estate prices. Over the long haul those two effects seem to somewhat cancel each other out. The long-term price development seems to be impartial of initial real estate prices, and other determinants such as migration, geographical placement and structural differences appear to determine future long-term price growth.

6.4.2 Period 2003 - 2015

Conditional convergence

2003 to 2015 is one of the most interesting time periods to take a closer look at. The regression analysis tells us that there is no significant result of absolute convergence or divergence. Observing the graphical illustration there are several noticeable patterns to look into. The first major observation is that in 2003, the inner east boroughs are in the same price cluster as the west side boroughs. Using my own calculated graph in chapter 3, we can see that the inner east side boroughs appear to have caught up with the outer west side boroughs in the early 2000s.

Grünerløkka and Sagene

Grünerløkka has become the new urban hotspot, and has arguably gone through a gentrification process during this period. Out of all the boroughs in Oslo, Sagene is the one with the highest growth in real estate prices. Sagene is historically important for Oslo as one of the first industrial areas. From the 1600s has there been industry around the part of Akerselva that runs thru the area. The name Sagene also originates from the large head-saws that were powered by the river. With the industrial globalization, these industrial areas in the center of Oslo have now been utilized for modern real estate projects (Oslo kommune, 2015). These parts of the city is close to the city center and the history of the boroughs is making it possible to redefine the areas, and the excessive real estate growth can be a result of this ongoing process.

Gamle Oslo not yet reached its potential

Gamle Oslo has also experienced large amounts of new construction, and migration statistics indicates that all the inner east side boroughs have high net migration in this period. Still Sagene and Grünerløkka have experienced more growth in terms of real estate prices than Gamle Oslo. The explanation could partly be seen in correlation with political decisions and structural differences. Gamle Oslo has slightly higher unemployment rates than Grünerløkka and Sagene. Areas like Grønland, Nedre Tøyen, and Enerhaugen also has lower education levels than overall Oslo. Even with several aid programs, Gamle Oslo still has the most public housing programs, and the largest share of the population on welfare (Oslo Kommune, 2015)

Gamle Oslo is divided with some challenging areas, while other sections are showing positive trends, often in a combination with new constructions (Oslo Kommune, 2015). This indicates that Gamle Oslo has yet to reach its full potential, and it may be possible that it is the next Sagene or Grünerløkka in terms of growth in real estate prices.

Imitations effects

Baumol (1986) was describing the imitations advantages in catching up economies. Lagging economies could look to the market leader and imitate what they were doing, and in that way use less investment and receive similar output. Looking at Oslo we might see a similar effect in terms of new constructions. New areas can imitate already developed areas and use design, and aspects that appear attractive. The overall design of Ensjøbyen²⁰ is a relevant example, as the fast growing area is designed not just to accommodate people but also give the whole area a boost (Oslo Kommune, 2015). To some degree imitation effects could lead to conditional convergence in areas with new construction; this could have been part of the increased growth in both Grünerløkka and Sagene.

²⁰ An area in Gamle Oslo

Attracting capital

Stovner and Søndre Nordstrand from the outer east had the lowest initial housing prices, and lowest growth in real estate prices in this time period. New construction, particular in Stovner, has been extremely low in this time period (Oslo Kommune, 2015). Using Abramovitz (1986) we can perhaps say that Stovner is lacking the ability to attract capital compared with the other boroughs, and hence not have the same convergence potential.

Divergence in outer east

Another pattern is the indications of divergence within the outer east side boroughs. Nordstrand, Bjerke and Østensjø have the highest growth from the outer eastside boroughs. Nordstrand has always been an abnormal east side area, both income and welfare statistics indicates that it is closer to a west side borough. In that sense we can understand the convergence tendencies towards the west side. Østensjø has some of the same characteristics, with higher education rate and fewer unemployed citizens, than the median outer eastern borough. Bjerke have all characteristics of an outer eastside borough, but it is located next to Grünerløkka, and it is possible that we see some spillover effects because of its location. Especially the population growth in Bjerke might have occurred on account of its location, with the highest population growth, in areas close to the boundary with Grünerløkka (Oslo Kommune, 2015).

Outer West

Real estate prices in the outer west side areas Ullern and Vestre Aker have experienced little growth. This could indicate that the growth rates are slowing down and that they are potentially finding their steady state. Real estate prices in Ullern and Vestre Aker are also less volatile in changing economic cycles than the other west side areas. This observation, in a combination with the increased real estate prices in the inner east boroughs, could indicate that the popular areas are switching from center-west towards the inner west and inner east region.

6.5 Convergence groups

Despite evidence of absolute convergence and divergence in the regression analysis, the discussion revealed that different regions also appeared to move in separate convergence groups. Based on long time movement and structural differences it makes sense to split Oslo into three convergence groups: The inner boroughs, the outer west boroughs including Nordstrand, and the outer east boroughs.

| Group 1 | Group 2 | Group 3 |
|----------------|-------------|-------------------|
| St. Hanshaugen | Ullern | Grovdal |
| Frogner | Vestre Aker | Stovner |
| Grünerløkka | Nordre Aker | Alna |
| Sagene | Nordstrand | Bjerke |
| Gamle Oslo | | Østensjø |
| | | Søndre Nordstrand |

Figure 6.6 Table of convergence groups arranged using price movements and structural differences

Volatility in-group one

The overall movements between the regions in Oslo are characterized by volatility within group 1 and more stability within group 2 and 3. Group 1 appears to react the fastest and most to changes in economic cycles.

This could possibly indicate that a ripple effect is present in Oslo's real estate markets. This observation is further backed up by that price differences in the short run can be very large, but this seems to be canceled out over the long run (Meen 1999). We also see that Group 1 has the highest debt gearing. A fundamental difference between the real estate market in Britain and Oslo is the migration factor. In Britain the interregional migration seems to be weak. But in Oslo there are large migrations on a constant level between the boroughs (SSB, 2015). Without any further test, this paper cannot conclude if a ripple effect is present.

6.6 Short term and long term determinants

Volatility in real estate prices over the short run seems strongly affected by migration, and in some time-periods also debt gearing. In the long run new construction and

structural differences seems to be the main determinates for future growth in real estate prices. Boroughs with low unemployment rates, and high education levels, have overall seen high growth rates. The geographical placements of the boroughs appear to be important, real estate prices in Oslo appears to be negatively related with distance to the city center.

6.7 Potential high growth

Gamle Oslo

Gamle Oslo is the area within the inner boroughs that has the lowest real estate prices, and from the discussion part it was evident that it has not yet reached its full potential compared to Grünerløkka and Sagene. In the 1970s Gamle Oslo experienced a version of gentrification within the area of Kampen, young and educated individuals moved in, and raised the quality of the buildings, and the social standings (Høifødt, 2011). It is possible that similar scenarios could happen again. Net migration to Gamle Oslo shows the same trends as the other inner boroughs, and being the area with the most affordable real estate prices of the inner boroughs could attract more migration, and over time increase real estate prices. While an argument against high growth in Gamle Oslo could be some of its structural characteristics. Gamle Oslo had in 2014 7% of its population on some kind social welfare program (Oslo kommune, 2015).

Nordstrand

Nordstrand is the lowest priced borough within its convergence group. Nordstrand has similar characteristics as the outer west side boroughs, but it is geographically on the southeast side. The geographical placement of Nordstrand seems to have kept the real estate prices in the area modest compared to similar structured regions. From 2007 there is a trend that real estate prices in Nordstrand grows significantly more in economic expansion than it drops in economic contractions. The redevelopment of the inner east areas could also indicate that some of the west east side barriers are broken. From 2003-

2007 Nordstrand was the outer borough with the highest growth, and in the time period 2003-2015 with economic growth and contraction, Nordstrand was the second highest growth area of all. The separation between east and west appears to still be significant, and in the last graph in chapter three it is evident the east side overall are not catching up to the west side. But this separation is strong because of extremes, and several of the inner east side boroughs have similar housing prices as west side areas. This indicates that we see conditional convergence for some boroughs from east to west, and several factors could indicate that Nordstrand has this potential.

7. Conclusion

This paper has tested for housing price convergence between the boroughs of Oslo. There is evidence of absolute convergence in times with declining real estate prices, and there is evidence of absolute divergence in times with increasing real estate prices. There is no evidence of long-term absolute convergence or divergence.

Graphs presented in chapter three, indicate that average housing prices on the east side has not overall converged towards average housing prices on the west side. The discussion revealed that this is because of extremes, and in fact have several east side boroughs converged towards west side prices since the 1990s.

Further investigations discovered that it was the inner boroughs that have seen the overall highest price growth since 1987, and these areas also appear to be the most volatile to changes in economic cycles. Migration strongly linked to the overall economy, and high debt gearing, seems to be the main determinants for the short-term volatility in housing prices in these boroughs. In the long run, structural differences between the regions appeared to explain some of the difference in real estate prices. Geographical placement, income, unemployment rates, and education levels appeared to be factors determining the long-term housing price growth. New construction also appears to be strongest in areas with high growth, or areas with potential for high growth. Based on structural differences, and price growth, Oslo real estate market could be broken into three potential convergence groups. Group one consists of the inner boroughs, group two consists of the outer west boroughs and Nordstrand, and group three consists of the outer east boroughs. The two boroughs with the highest potential for future real estate growth based on my discussion, is Gamle Oslo and Nordstrand.

Recommendations for further research

There are several findings in this paper that could or should be investigated in further research. A complimentary research on the housing indexes from 1985-2002 could greatly strengthen their reliability. Time was the main limit in the construction of the housing indexes, and it took months gathering enough observations. For each new observation included, the indexes came out with more consistency. There are to the author's knowledge no other indexes that cover this time period and it should be in the public interest to expand the existing housing price indexes.

The plausible ripple effect is also interesting to investigate further. Ripple effect has been tested for in Britain, Sweden, and overall Norway, but always over large areas. Oslo is interesting because of large price differences in the short run, but relative normal price patterns in the long run. These findings indicate that it could be interesting to test for evidence of a ripple effect being present in Oslo real estate market.

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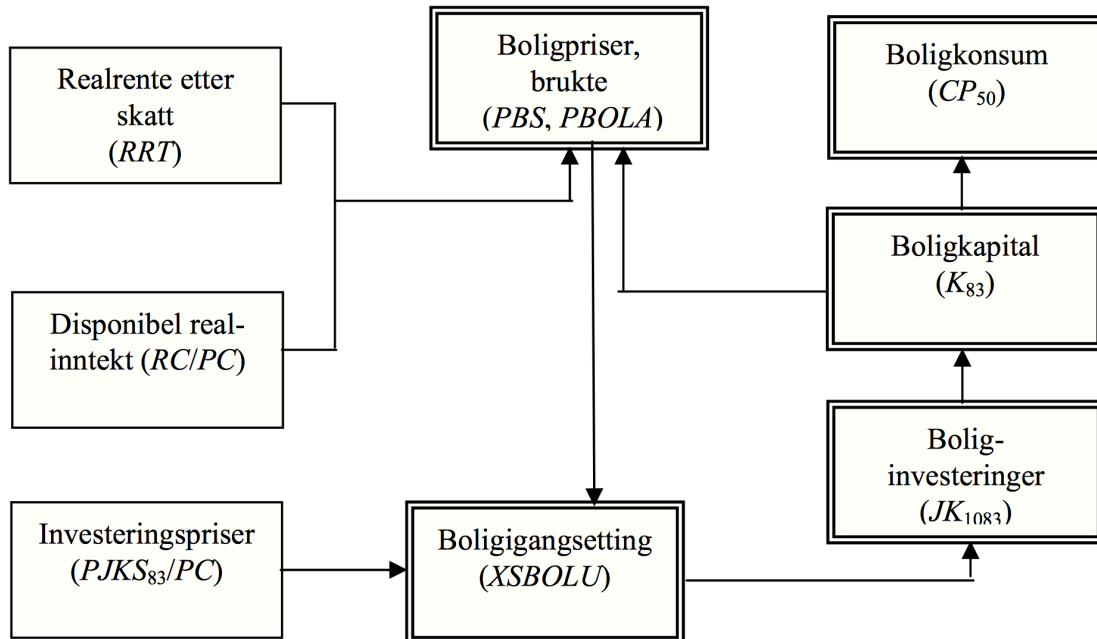
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Appendix

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Jacobsen and Naugs model (2004):**Tabell 1** En modell for boligprisene

$$\begin{aligned}
\Delta \text{boligpris}_t = & 0,12 \Delta \text{inntekt}_t - 3,16 \Delta(\text{RENTE}(1-\tau))_t - 1,47 \Delta(\text{RENTE}(1-\tau))_{t-1} + 0,04 \text{FORV}_t \\
& (1,94) \quad (7,04) \quad (3,27) \quad (3,09) \\
& - 0,12 [\text{boligpris}_{t-1} + 4,47 (\text{RENTE}(1-\tau))_{t-1} + 0,45 \text{ledighet}_t - 1,66 (\text{inntekt} - \text{boligmasse})_{t-1}] \\
& (5,69) \quad (2,54) \quad (3,48) \quad (8,63) \\
& + 0,56 + 0,04 S1 + 0,02 S2 + 0,01 S3. \\
& (3,42) \quad (3,35) \quad (1,80) \quad (0,73)
\end{aligned}$$

Elements in MODAG housing price model**Figur 5.5.1** Boligblokken i MODAG

Net migration Oslo's boroughs. Source (Stambøl, 2013)



1987 -2014

| Source | SS | df | MS | Number of obs | = | 14 |
|----------|------------|----|------------|---------------|---|---------|
| Model | 1.1974e-06 | 1 | 1.1974e-06 | F(1, 12) | = | 0.04 |
| Residual | .000397114 | 12 | .000033093 | Prob > F | = | 0.8523 |
| | | | | R-squared | = | 0.0030 |
| | | | | Adj R-squared | = | -0.0801 |
| Total | .000398312 | 13 | .000030639 | Root MSE | = | .00575 |

| growth | Coef. | Std. Err. | t | P> t | [95% Conf. Interval] |
|--------|-----------|-----------|-------|-------|----------------------|
| ln1987 | -.0019743 | .010379 | -0.19 | 0.852 | -.0245882 .0206396 |
| _cons | .0714353 | .096968 | 0.74 | 0.475 | -.1398397 .2827103 |

White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity

chi2(2) = 0.86
Prob > chi2 = 0.6491

Cameron & Trivedi's decomposition of IM-test

| Source | chi2 | df | p |
|--------------------|------|----|--------|
| Heteroskedasticity | 0.86 | 2 | 0.6491 |
| Skewness | 0.24 | 1 | 0.6233 |
| Kurtosis | 2.61 | 1 | 0.1063 |
| Total | 3.71 | 4 | 0.4460 |

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance
Variables: ln1987

chi2(1) = 0.00
Prob > chi2 = 0.9846

Skewness/Kurtosis tests for Normality

| Variable | Obs | Pr(Skewness) | Pr(Kurtosis) | adj chi2(2) | joint Prob>chi2 |
|-----------|-----|--------------|--------------|-------------|-----------------|
| residuals | 14 | 0.7894 | 0.1995 | 1.97 | 0.3729 |

Measures of global spatial autocorrelation

Weights matrix

Name: bydeler
Type: Distance-based (inverse distance)
Distance band: 0.0 < d <= 3.0
Row-standardized: No

Moran's I

| Variables | I | E(I) | sd(I) | z | p-value* |
|-----------|-------|--------|-------|-------|----------|
| res | 0.206 | -0.077 | 0.174 | 1.623 | 0.052 |

2003-2007

```
. reg growthrate ln2003
```

| Source | SS | df | MS | Number of obs | = | 15 |
|----------|------------|----|------------|---------------|---|--------|
| Model | .000501283 | 1 | .000501283 | F(1, 13) | = | 9.10 |
| Residual | .00071641 | 13 | .000055108 | Prob > F | = | 0.0099 |
| | | | | R-squared | = | 0.4117 |
| | | | | Adj R-squared | = | 0.3664 |
| Total | .001217693 | 14 | .000086978 | Root MSE | = | .00742 |

| growthrate | Coef. | Std. Err. | t | P> t | [95% Conf. Interval] | |
|------------|-----------|-----------|-------|-------|----------------------|----------|
| ln2003 | .0298653 | .0099023 | 3.02 | 0.010 | .0084728 | .0512579 |
| _cons | -.1936533 | .0994465 | -1.95 | 0.073 | -.4084944 | .0211878 |

White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity

```
chi2(2)      =      0.25
Prob > chi2   =      0.8816
```

Cameron & Trivedi's decomposition of IM-test

| Source | chi2 | df | p |
|--------------------|------|----|--------|
| Heteroskedasticity | 0.25 | 2 | 0.8816 |
| Skewness | 3.76 | 1 | 0.0526 |
| Kurtosis | 0.12 | 1 | 0.7293 |
| Total | 4.13 | 4 | 0.3887 |

```
. hettest ln2003
```

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: ln2003

```
chi2(1)      =      0.02
Prob > chi2   =      0.8864
```

Skewness/Kurtosis tests for Normality

| Variable | Obs | Pr(Skewness) | Pr(Kurtosis) | adj chi2(2) | joint Prob>chi2 |
|----------|-----|--------------|--------------|-------------|-----------------|
| res | 15 | 0.1546 | 0.7043 | 2.51 | 0.2850 |

Measures of global spatial autocorrelation

Weights matrix

```
Name: bydeler
Type: Distance-based (inverse distance)
Distance band: 0.0 < d <= 10.0
Row-standardized: No
```

Moran's I

| Variables | I | E(I) | sd(I) | z | p-value* |
|-----------|--------|--------|-------|-------|----------|
| res | -0.070 | -0.071 | 0.161 | 0.011 | 0.496 |

2003-2015

```
. reg growthrate ln2003
```

| Source | SS | df | MS | Number of obs | = | 15 |
|----------|------------|----|------------|---------------|---|--------|
| Model | .000026261 | 1 | .000026261 | F(1, 13) | = | 2.92 |
| Residual | .000116729 | 13 | 8.9791e-06 | Prob > F | = | 0.1110 |
| | | | | R-squared | = | 0.1837 |
| | | | | Adj R-squared | = | 0.1209 |
| Total | .00014299 | 14 | .000010214 | Root MSE | = | .003 |

| growthrate | Coef. | Std. Err. | t | P> t | [95% Conf. Interval] |
|------------|----------|-----------|-------|-------|----------------------|
| ln2003 | .0068357 | .0039971 | 1.71 | 0.111 | -.0017994 .0154709 |
| _cons | -.004505 | .0401418 | -0.11 | 0.912 | -.0912261 .0822162 |

White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity

```
chi2(2)      =      0.99
Prob > chi2   =      0.6097
```

Cameron & Trivedi's decomposition of IM-test

| Source | chi2 | df | p |
|--------------------|------|----|--------|
| Heteroskedasticity | 0.99 | 2 | 0.6097 |
| Skewness | 1.89 | 1 | 0.1688 |
| Kurtosis | 0.56 | 1 | 0.4550 |
| Total | 3.44 | 4 | 0.4868 |

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: ln2003

```
chi2(1)      =      0.02
Prob > chi2   =      0.8922
```

Skewness/Kurtosis tests for Normality

| Variable | Obs | Pr(Skewness) | Pr(Kurtosis) | adj chi2(2) | Prob>chi2 |
|----------|-----|--------------|--------------|-------------|-----------|
| res | 15 | 0.3723 | 0.8697 | 0.90 | 0.6389 |

Weights matrix

```
Name: bydeler
Type: Distance-based (inverse distance)
Distance band: 0.0 < d <= 3.0
Row-standardized: No
```

Moran's I

| Variables | I | E(I) | sd(I) | z | p-value* |
|-----------|--------|--------|-------|-------|----------|
| res | -0.056 | -0.071 | 0.163 | 0.095 | 0.462 |

2007-2009

```
. reg growthrate ln2007
```

| Source | SS | df | MS | Number of obs | = | 15 |
|----------|------------|----|------------|---------------|---|--------|
| Model | .001546543 | 1 | .001546543 | F(1, 13) | = | 9.79 |
| Residual | .00205467 | 13 | .000158052 | Prob > F | = | 0.0080 |
| | | | | R-squared | = | 0.4295 |
| | | | | Adj R-squared | = | 0.3856 |
| Total | .003601212 | 14 | .000257229 | Root MSE | = | .01257 |

| growthrate | Coef. | Std. Err. | t | P> t | [95% Conf. Interval] | |
|------------|-----------|-----------|-------|-------|----------------------|-----------|
| ln2007 | -.0464828 | .0148597 | -3.13 | 0.008 | -.0785852 | -.0143803 |
| _cons | .4321163 | .1555529 | 2.78 | 0.016 | .0960648 | .7681678 |

White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity

```
chi2(2)      =      0.70
Prob > chi2   =      0.7061
```

Cameron & Trivedi's decomposition of IM-test

| Source | chi2 | df | p |
|--------------------|------|----|--------|
| Heteroskedasticity | 0.70 | 2 | 0.7061 |
| Skewness | 1.39 | 1 | 0.2380 |
| Kurtosis | 0.35 | 1 | 0.5562 |
| Total | 2.43 | 4 | 0.6564 |

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: ln2007

```
chi2(1)      =      0.41
Prob > chi2   =      0.5204
```

Skewness/Kurtosis tests for Normality

| Variable | Obs | Pr(Skewness) | Pr(Kurtosis) | adj chi2(2) | joint Prob>chi2 |
|----------|-----|--------------|--------------|-------------|-----------------|
| res | 15 | 0.4146 | 0.9738 | 0.71 | 0.7000 |

Weights matrix

```
Name: bydeler
Type: Distance-based (inverse distance)
Distance band: 0.0 < d <= 1.0
Row-standardized: No
```

Moran's I

| Variables | I | E(I) | sd(I) | z | p-value* |
|-----------|-------|--------|-------|-------|----------|
| res | 0.089 | -0.071 | 0.163 | 0.984 | 0.162 |

1987-1992

| Source | SS | df | MS | Number of obs | = | 14 |
|----------|------------|----|------------|---------------|---|--------|
| Model | .002150846 | 1 | .002150846 | F(1, 12) | = | 2.25 |
| Residual | .011458274 | 12 | .000954856 | Prob > F | = | 0.1592 |
| | | | | R-squared | = | 0.1580 |
| | | | | Adj R-squared | = | 0.0879 |
| Total | .013609119 | 13 | .001046855 | Root MSE | = | .0309 |

| growthrate | Coef. | Std. Err. | t | P> t | [95% Conf. Interval] |
|------------|-----------|-----------|-------|-------|----------------------|
| ln1987 | -.0836746 | .0557517 | -1.50 | 0.159 | -.205147 .0377979 |
| _cons | .6759352 | .520871 | 1.30 | 0.219 | -.4589452 1.810816 |

White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity

chi2(2) = 2.22
Prob > chi2 = 0.3299

Cameron & Trivedi's decomposition of IM-test

| Source | chi2 | df | p |
|--------------------|------|----|--------|
| Heteroskedasticity | 2.22 | 2 | 0.3299 |
| Skewness | 2.52 | 1 | 0.1122 |
| Kurtosis | 0.94 | 1 | 0.3331 |
| Total | 5.68 | 4 | 0.2245 |

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: ln1987

chi2(1) = 0.26
Prob > chi2 = 0.6079

Skewness/Kurtosis tests for Normality

| Variable | Obs | Pr(Skewness) | Pr(Kurtosis) | adj chi2(2) | joint Prob>chi2 |
|----------|-----|--------------|--------------|-------------|-----------------|
| res | 14 | 0.2488 | 0.6273 | 1.79 | 0.4088 |

Measures of global spatial autocorrelation

Weights matrix

Name: bydeler
Type: Distance-based (inverse distance)
Distance band: 0.0 < d <= 3.0
Row-standardized: No

Moran's I

| Variables | I | E(I) | sd(I) | z | p-value* |
|-----------|--------|--------|-------|-------|----------|
| res | -0.058 | -0.077 | 0.172 | 0.112 | 0.455 |

2009-2013

```
. reg growthrate ln2009
```

| Source | SS | df | MS | Number of obs | = | 15 |
|----------|------------|----|------------|---------------|---|--------|
| Model | .000260988 | 1 | .000260988 | F(1, 13) | = | 7.35 |
| Residual | .00046169 | 13 | .000035515 | Prob > F | = | 0.0178 |
| | | | | R-squared | = | 0.3611 |
| | | | | Adj R-squared | = | 0.3120 |
| Total | .000722678 | 14 | .00005162 | Root MSE | = | .00596 |

| growthrate | Coef. | Std. Err. | t | P> t | [95% Conf. Interval] |
|------------|-----------|-----------|-------|-------|----------------------|
| ln2009 | .0209068 | .0077123 | 2.71 | 0.018 | .0042455 .0375681 |
| _cons | -.1191116 | .0798913 | -1.49 | 0.160 | -.2917062 .0534831 |

White:2 against Ha: unrestricted heteroskedasticity

```
chi2(2)      =      1.22
Prob > chi2   =      0.5445
```

Cameron & Trivedi's decomposition of IM-test

| Source | chi2 | df | p |
|--------------------|------|----|--------|
| Heteroskedasticity | 1.22 | 2 | 0.5445 |
| Skewness | 2.82 | 1 | 0.0931 |
| Kurtosis | 1.02 | 1 | 0.3115 |
| Total | 5.06 | 4 | 0.2811 |

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

```
Ho: Constant variance
Variables: ln2009
```

```
chi2(1)      =      0.74
Prob > chi2   =      0.3912
```

Skewness/Kurtosis tests for Normality

| Variable | Obs | Pr(Skewness) | Pr(Kurtosis) | adj joint chi2(2) | Prob>chi2 |
|----------|-----|--------------|--------------|-------------------|-----------|
| res | 15 | 0.7997 | 0.6737 | 0.24 | 0.8862 |

Measures of global spatial autocorrelation

Weights matrix

```
Name: bydeler
Type: Distance-based (inverse distance)
Distance band: 0.0 < d <= 1.0
Row-standardized: No
```

Moran's I

| Variables | I | E(I) | sd(I) | z | p-value* |
|-----------|--------|--------|-------|--------|----------|
| res | -0.102 | -0.071 | 0.164 | -0.187 | 0.426 |

Jan - April 2013

```
. reg growthrate ln april
```

| Source | SS | df | MS | Number of obs | = | 15 |
|----------|------------|----|------------|---------------|---|--------|
| Model | .00137222 | 1 | .00137222 | F(1, 13) | = | 22.93 |
| Residual | .000778072 | 13 | .000059852 | Prob > F | = | 0.0004 |
| | | | | R-squared | = | 0.6382 |
| | | | | Adj R-squared | = | 0.6103 |
| Total | .002150291 | 14 | .000153592 | Root MSE | = | .00774 |

| growthrate | Coef. | Std. Err. | t | P> t | [95% Conf. Interval] | |
|------------|-----------|-----------|-------|-------|----------------------|-----------|
| ln april | -.0445158 | .0092969 | -4.79 | 0.000 | -.0646006 | -.0244309 |
| _cons | .41278 | .1000942 | 4.12 | 0.001 | .1965396 | .6290204 |

White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity

```
chi2(2)      =      5.20
Prob > chi2   =      0.0742
```

Cameron & Trivedi's decomposition of IM-test

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: ln april

```
chi2(1)      =      4.61
Prob > chi2   =      0.0317
```

| Source | chi2 | df | p |
|--------------------|-------|----|--------|
| Heteroskedasticity | 5.20 | 2 | 0.0742 |
| Skewness | 9.10 | 1 | 0.0026 |
| Kurtosis | 0.00 | 1 | 0.9733 |
| Total | 14.30 | 4 | 0.0064 |

Measures of global spatial autocorrelation

Weights matrix

```
Name: bydeler
Type: Distance-based (inverse distance)
Distance band: 0.0 < d <= 1.0
Row-standardized: No
```

Moran's I

| Variables | I | E(I) | sd(I) | z | p-value* |
|-----------|--------|--------|-------|-------|----------|
| residuals | -0.006 | -0.071 | 0.160 | 0.411 | 0.341 |

Skewness/Kurtosis tests for Normality

| Variable | Obs | Pr(Skewness) | Pr(Kurtosis) | adj chi2(2) | joint Prob>chi2 |
|-----------|-----|--------------|--------------|-------------|-----------------|
| residuals | 15 | 0.0430 | 0.4753 | 4.69 | 0.0960 |

2014-2015

| Source | SS | df | MS | Number of obs | = | 15 |
|----------|------------|----|------------|---------------|---|---------|
| Model | .0002447 | 1 | .0002447 | F(1, 13) | = | 0.93 |
| Residual | .003433963 | 13 | .000264151 | Prob > F | = | 0.3534 |
| | | | | R-squared | = | 0.0665 |
| | | | | Adj R-squared | = | -0.0053 |
| Total | .003678663 | 14 | .000262762 | Root MSE | = | .01625 |

| growthrate | Coef. | Std. Err. | t | P> t | [95% Conf. Interval] |
|------------|-----------|-----------|-------|-------|----------------------|
| ln2014 | .0194628 | .0202216 | 0.96 | 0.353 | -.0242232 .0631489 |
| _cons | -.1134104 | .2167222 | -0.52 | 0.610 | -.5816101 .3547894 |

White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity

chi2(2) = 1.10
Prob > chi2 = 0.5778

Cameron & Trivedi's decomposition of IM-test

| Source | chi2 | df | p |
|--------------------|------|----|--------|
| Heteroskedasticity | 1.10 | 2 | 0.5778 |
| Skewness | 8.60 | 1 | 0.0034 |
| Kurtosis | 0.03 | 1 | 0.8661 |
| Total | 9.72 | 4 | 0.0454 |

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: ln2014

chi2(1) = 0.73
Prob > chi2 = 0.3939

Skewness/Kurtosis tests for Normality

| Variable | Obs | Pr(Skewness) | Pr(Kurtosis) | adj chi2(2) | Prob>chi2 |
|----------|-----|--------------|--------------|-------------|-----------|
| res | 15 | 0.1270 | 0.5699 | 3.10 | 0.2127 |

Weights matrix

Name: bydeler
Type: Distance-based (inverse distance)
Distance band: 0.0 < d <= 3.0
Row-standardized: No

Moran's I

| Variables | I | E(I) | sd(I) | z | p-value* |
|-----------|--------|--------|-------|--------|----------|
| res | -0.161 | -0.071 | 0.160 | -0.560 | 0.288 |

Update 2013

```
. reg growthrate lnapril
```

| Source | SS | df | MS | Number of obs | = | 13 |
|----------|------------|----|------------|---------------|---|--------|
| Model | .000511103 | 1 | .000511103 | F(1, 11) | = | 39.70 |
| Residual | .000141598 | 11 | .000012873 | Prob > F | = | 0.0001 |
| | | | | R-squared | = | 0.7831 |
| | | | | Adj R-squared | = | 0.7633 |
| Total | .000652701 | 12 | .000054392 | Root MSE | = | .00359 |

| growthrate | Coef. | Std. Err. | t | P> t | [95% Conf. Interval] |
|------------|-----------|-----------|-------|-------|----------------------|
| lnapril | -.0305194 | .0048434 | -6.30 | 0.000 | -.0411797 -.019859 |
| _cons | .2593574 | .0522992 | 4.96 | 0.000 | .1442476 .3744672 |

```
. estat imtest, white
```

White's test for Ho: homoskedasticity
against Ha: unrestricted heteroskedasticity

```
chi2(2)      =      4.76
Prob > chi2   =      0.0926
```

Cameron & Trivedi's decomposition of IM-test

| Source | chi2 | df | p |
|--------------------|------|----|--------|
| Heteroskedasticity | 4.76 | 2 | 0.0926 |
| Skewness | 2.51 | 1 | 0.1134 |
| Kurtosis | 0.64 | 1 | 0.4235 |
| Total | 7.91 | 4 | 0.0951 |

```
. hettest lnapril
```

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: lnapril

```
chi2(1)      =      2.96
Prob > chi2   =      0.0853
```

Skewness/Kurtosis tests for Normality

| Variable | Obs | Pr(Skewness) | Pr(Kurtosis) | adj chi2(2) | Prob>chi2 |
|----------|-----|--------------|--------------|-------------|-----------|
| res | 13 | 0.3040 | 0.7806 | 1.27 | 0.5293 |

Weights matrix

```
Name: bydeler
Type: Distance-based (inverse distance)
Distance band: 0.0 < d <= 3.0
Row-standardized: No
```

Moran's I

| Variables | I | E(I) | sd(I) | z | p-value* |
|-----------|--------|--------|-------|-------|----------|
| res | -0.055 | -0.083 | 0.191 | 0.148 | 0.441 |

Moran's I Matrix

Inverse distance weights matrix bydeler

Dimension: 15x15
 Distance band: 0 < d ≤ 3
 Friction parameter: 1
 Minimum distance: 0.0
 1st quartile distance: 0.1
 Median distance: 0.1
 3rd quartile distance: 0.1
 Maximum distance: 0.3
 Largest minimum distance: 0.06
 Smallest maximum distance: 0.15

matrix list bydeler

symmetric bydeler[15,15]

```

      0      0      3      0      0      0      0
SWMDist 0
No 34.12961 0
No 24.709966 70.629891 0
No 21.948305 59.219472 59.10608 0
No 13.283558 19.419338 18.713311 27.137929 0
No 7.8064546 9.7256725 9.8681996 11.548497 18.904087 0
No 16.130199 30.209961 35.102517 60.846408 34.638696 13.70999 0
No 35.569883 355.71512 59.278088 57.159415 19.704618 9.7536294 29.490627
No 22.836947 18.632604 18.873652 14.664547 9.5469671 6.4818286 12.274672
No 8.7423698 7.6998944 7.7746972 6.9274808 5.5247603 4.3512073 6.3739013
No 6.6183028 5.9293087 5.9505998 5.4483828 4.5451389 3.7127233 5.091512
No 10.5988 8.7041183 8.5626471 7.6425837 6.0139295 4.5990481 6.8880128
No 16.829786 11.433932 10.480586 9.5902041 7.4418671 5.3398416 8.2947043
No 34.25987 17.919211 14.578501 14.278466 10.855714 6.9329829 11.629806
No 11.143214 8.5222887 7.6961005 7.6176592 6.711638 5.0369082 6.8071983

      0      0      0      0      0      0      0
No 0
No 18.179113 0
No 7.628802 13.111463 0
No 5.8924378 8.6693374 25.17199 0
No 8.6556765 15.531763 32.954343 17.213438 0
No 11.515774 17.091611 12.157436 9.1246313 18.833965 0
No 18.566769 15.535711 8.1709915 6.4489927 10.310742 20.356487 0
No 8.666637 8.8780219 7.0796521 6.1773407 9.0114645 16.223076 16.250889

      0
No 0

```

| Bydel | Lat | Lon |
|-------------|-----------|-----------|
| Gamle Oslo | 59.906472 | 10.78142 |
| Grünerløkk | 59.923868 | 10.757842 |
| Sagene | 59.937894 | 10.755916 |
| St. Hansha | 59.928752 | 10.741678 |
| Frogner | 59.916739 | 10.706842 |
| Ullern | 59.927707 | 10.655093 |
| Vestre Aker | 59.936965 | 10.727443 |
| Nordre Ake | 59.92109 | 10.757405 |
| Bjerke | 59.94062 | 10.808829 |
| Grorud | 59.959671 | 10.882681 |
| Stovner | 59.960853 | 10.92239 |
| Alna | 59.931082 | 10.872503 |
| Østensjø | 59.890241 | 10.838578 |
| Nordstrand | 59.87883 | 10.790797 |
| Søndre Nor | 59.82957 | 10.827677 |