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Master thesis

House prices following Covid-19: A possible shift in demand?

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Abstract

In this thesis, we study the house price growth in 2020 for different dwelling types and municipalities and compare it with its growth in 2015. The two years had one thing in common: both experienced a drop in the policy rate. We look at Oslo, and municipalities just outside Oslo, to see if there was a change in the geographical distribution in house price growth. We analyze how house prices have developed using a quantitative approach by studying the housing market between 2014 and 2021. Our research argues that there is an increased demand for detached houses in 2020 compared to 2015. Additionally, we discover that people have not moved out of Oslo, as analysts predicted, following the outbreak of Covid-19.

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1 Introduction

Was there a significant change in the geographical distribution of house price changes in 2020 compared to 2015? To answer this question, we will exploit a dataset containing all housing transactions in a selected set of municipalities between 2014 and 2021. To further develop our analysis, we will consider parameters such as dwelling size, centrality index, and property type. We have chosen to view specifically the following ten municipalities: Oslo, Drammen, Fredrikstad, Frogn, Indre Østfold, Kongsvinger, Moss, Ringerike, Tønsberg, and Ullensaker.

2 Motivation

The question is engaging because the housing market affects extensive parts of the Norwegian population - according to Statistics Norway, as many as 81.9% of Norway's population own their own home (SSB, 2022). During the Covid-19 pandemic, teleworking alternatives expanded significantly, making the physical distance from the workplace less relevant. This led to a more prominent interest in additional space, resulting in a possible shift in demand during the pandemic in 2020. There has been a rise in housing prices in both periods, making it fascinating to examine the parameters that directly affect housing prices, such as dwelling size, commute time, and property type. Because the Covid-19 pandemic occurred so recently, there is limited research on the subject. For this reason, we believe additional study on the topic is beneficial.

The growth rate of Norwegian property prices has accelerated substantially during the previous decade. According to Statistics Norway, the price per square meter climbed by 74 percent in Oslo and 48 percent nationwide between 2014 and 2021 (SSB, 2022).

In both 2015 and 2020, we saw significant interest rate reductions. In 2015, the key policy rate was lowered by 0,5 percent to 0,75 percent. In 2020, a few weeks after the outbreak of the covid pandemic, the policy rate in Norway was lowered to a record low of 0 percent. As a result, from December 2014 to March 2016 (from the interest rate decline began until it was 0,75 percent), house prices in Norway and

Oslo rose by 7,48% and 13,48%, respectively. Following the interest rate reduction in March 2020, house prices increased by 12,52% and 15,62%, respectively.

When the pandemic came in March 2020, it was common practice to stay home. Children were homeschooled, and adults had home offices. As a result, it is possible that more individuals feel the want to leave the city now that "home ground" has taken on a greater significance in daily life. Not having to commute to Oslo every day, only 2-3 times a week, could contribute to where people want to settle. We also presume that several jobs are located in Oslo, supported by data from Statistics Norway, which confirms that in 2020, 179.079 people commuted to Oslo (SSB, 2022).

3 Literature review

We have compared different studies directed by some of the leading researchers within this field, including Erling Røed Larsen, who has studied the real estate market for decades. This section of the thesis will review additional research around housing prices and their price fluctuations due to key policy rates. At this point, we will also explain the theoretical background for the thesis.

***Table 1**: Literature review*

Author	Year	Title	Published	Method	Key Findings
Lin, C.-C., & Tsai, I.-C.	2021	The special effect of interest rate cuts on housing prices	Journal of Business Economics and Management	Theoretical models and empirical research	Governments that adopt low interest rates to revitalize the economy provide significant results.
James M. McGibany & Farrokh Nourzad	2010	Do lower mortgage rates mean higher housing prices?	Applied Economics	Advanced nonstructural estimation methods	Results show a long-run relationship between mortgage rates and housing prices. However, contrary to previous research, there is nearly no short-run relationship.

Erling Røed Larsen	2018	Can monetary policy revive the housing market in a crisis? Evidence from high-resolution data on Norwegian transactions	Journal of Housing Economics	Hedonic time dummy price index	Evidence suggests a unique role between the housing market and monetary policy.
William Miles	2014	The Housing Bubble: How Much Blame Does the Fed Really Deserve?	The Journal of Real Estate Research	Using mortgage rate and the federal funds rate as determinants of housing variables.	The long-term rate has an independent and maybe more significant impact on housing prices than the federal funds rate.

The literature we have chosen to compare our research constitutes different methods of evaluating which grade the key policy rate affects housing prices. Considering that the Covid-19 pandemic has recently ended, there is limited research on the topic. However, several earlier studies analyze past pandemics' impact on residential housing. In addition, various pieces of literature investigate the impact monetary policy has had on housing prices, which is highly relevant for our research question.

A recent study by Erling Røed Larsen from December 2018 suggests a significant link between monetary policy and the housing market recovery after the 2008 financial crisis. By studying a Norwegian high-resolution housing transaction data set, Larsen constructs a hedonic time dummy price index and tracks the changes over short periods to observe critical junctures. Larsen also compares the price differences in 2008 with previous years to be able to control seasonal effects. The result shows significant changes in the house price index shortly after the implementation of monetary policy.

In research performed by Miles (2014), he examines the federal funds rate (FFR) and the mortgage rate's impact on the housing market. He performs estimations on house prices and residential investment and includes both the FFR and the 30-year mortgage rate as monetary policy measures. He estimates regression models over different sample periods to see how the relationship has evolved. Finally, Miles performs formal Andrews-Quandt endogenous structural break tests on the models to gain more evidence on the nature of the shifting connections. The estimations reveal "that long-term interest rates have a larger impact on house prices than the

FFR, and that the impact of the FFR has fallen into irrelevance in recent years" (Miles, 2014, p. 56). Given the significance of housing to the economy, the search for culprits is understandable, as lowering the volatility of house values and activity would be desired. While many have pointed the finger at Fed policies, the research's findings imply that long-term interest rates significantly influence house prices more than the FFR and that the FFR's impact has faded in recent years. Similarly, while the FFR still has some predictive power in residential investment, the mortgage rate's predictive power is larger than in the past.

A study done by Wong, Hui, and Seabrooke in 2003, investigated the role interest rates had on housing prices from expectation perspectives. The principal findings were that housing prices have a high negative correlation with interest rates, meaning that when interest rates dropped, housing prices went up. They also noticed periods where interest rates declined while housing prices also had a dip. This was stated to be mainly because of low hope-led price expectations. Therefore, the results were that interest rates do not Granger-cause housing prices, as one specific time series was not valuable in forecasting another. The study implied that low interest rates do not necessarily lead to higher housing prices. It also stated that even though interest rates could be a good factor in predicting housing prices, it alone does not hold. Worse, interest rate swings may periodically provide erroneous evidence concerning the direction and extent of housing price movements beyond sensible boundaries.

It is important to mention that this study was done in the Hong Kong housing market. Hong Kong may have other meaningful macroeconomic factors than interest rates, that impact the housing market. It is also critical to mention that this study was done almost 20 years ago, in 2003, and several conditions may have changed since the start of the 21. Century.

4 Data

To dig into our research question, we have received a valuable dataset containing second-hand housing sales for Oslo and smaller cities outside Oslo in 2014-2021, obtained and owned by Eiendomsverdi AS. The data includes sale date, municipality, price, incl. joint debt, size, housing type, ownership, and year of construction for the mentioned municipalities and time period. We also gathered

historical data on interest rates, income, GDP, and unemployment from 2014 to 2021 from Statistics Norway.

4.1 Factors

To understand how house prices develop, we look at several essential factors. Many factors influence house prices and they are not easily determined. Researchers have long tried to predict housing prices, with and without success; it is simply too complex. The real estate market is intricately linked with general economic cycles (Wang, 2003). Grum and Govekar (2016) have revealed that among macroeconomic factors related to real estate prices key factors are gross domestic product (GDP), unemployment, share index, country's current account, demographic factors, household income, interest rate, industrial production, and consumption of households. In our analysis, we include inflation, unemployment, interest rate, GDP, and income to adjust for general price growth. Data on these elements is provided by Statistics Norway (SSB, 2022).

4.1.1 Short-term factors:

Short-term factors that may explain some of the changes in house prices:

Interest rates:

Higher interest rates make it more expensive to get a loan-financed home purchase and vice versa. This indicates that interest rates significantly impact house prices. According to a model created by the national housing center Housing Lab, a reduction in interest rates of 1 percentage point will increase house prices by an average of 13.8 percent, given other factors unchanged (Housing Lab, 2020). In addition, studies show that a rise in interest rates of one percentage point leads to a fall in house prices of about 10 percent, given other factors unchanged. Therefore, we conclude that interest rates have a vital impact on the housing market.

Income:

Income is strongly correlated with debt and is a crucial variable concerning how much loan one can receive from the bank. This leads to the logical assumption; a bank can grant a larger loan the greater the income, increasing the available capital.

Income data was collected from Statistics Norway. The statistics include each municipality's average monthly after-tax income per household. Income statistics for each area in Oslo was obtained from the Oslo Municipality's official statistical database.

Unemployment:

In times of rising unemployment, people may be apprehensive about the future. People may be unsure whether they will retain their jobs, and there will be general uncertainty about the future and investment in new housing. As a result, a share of demand disappears, which is essential for the short-term price level.

GDP:

Since income must be earned to purchase a home, GDP cycles and housing price cycles frequently coincide. For example, according to studies in Asia, Europe, and the United States, median housing prices correlate with 60 to 95 percent GDP per capita (Asia Green Real Estate, 2017). When GDP growth is high, housing price growth is also generally high, especially in the long run.

4.1.2 Long-term factors

We include population growth and housing preferences, which we see as the most critical long term factors.

Population growth:

Population growth must be followed up with increased housing development, so prices do not run away from us. An imbalance in supply and demand may explain some of the house price growth in the long run. This is particularly problematic in Oslo, where the housing development does not correlate with population growth.

Housing preferences:

In 2015, we saw no apparent change in where people wanted to live. However, developments since the pandemic indicate increased relocation and increased relocation preferences from the expensive Oslo-market to cheaper residential areas.

Accordingly, we regard home offices as an alluring incentive for people to move from expensive cities to more affordable areas.

4.1.3 Centrality Index

In 2017, SSB presented a centrality index for each municipality (Statistisk sentralbyrå, 2022). Until 2017, the index was only based on the municipality's location concerning towns and the size of these towns. The municipalities that served as "regional centers" and the municipalities surrounding them had the highest centrality levels. There were four significant centrality levels at the time, ranging from 0 to 3. Since 2018, a new definition for centrality has been implemented, focusing on closeness to workplaces and service functions rather than towns. The centrality ranges from 0 (only theoretically possible as no municipalities in Norway have no access to workplaces or service functions) to 1000. These values are divided into six categories, 1 through 6. The most central municipality, Oslo, will permanently be assigned a value of 1000, while the least central municipality will be assigned a value of 300.

We only have one municipality from our chosen municipalities in category 1, Oslo. In category 2 we have Drammen, Ullensaker, Moss, Frogn, Tønsberg, Fredrikstad, listed from highest to lowest centrality index. Further, in category 3, we have Indre Østfold, Ringerike, and Kongsvinger.

4.2 Descriptive statistics

Our dataset contains 222.074 housing sales over eight years – giving us an extensive number of transactions to show relevant results. Therefore, we consider our data will give us enough substance to support an accurate conclusion.

We find the data robust as they include accurate sales prices for specific areas in and outside Oslo. We know some biased estimates might weaken the validity of future outcomes – if not considered. However, our analysis will not focus on the direct relationship between monetary policy and home prices, but others of the aspects of fluctuation in residential housing prices. Hence, we do not think this will undermine our results.

Ahead of our analysis, we observe that some data lack key variables; thus, they are omitted. We remove all properties that had "zero" as price incl. joint debt, properties with "zero" size, in addition to several apartments sold in Oslo under NOK 800.000. These Oslo apartments were significantly large, and it did not make sense to include these in our analysis as the data is likely incorrect. It is reasonable to assume that no apartments sold in Oslo, larger than 100 square meters, cost less than NOK 800.000, as this is so far from the average square meter price. Further, we eliminate every property under 10 square meters. We consider all apartments under 10 square meters as invalid data and assume these "apartments" to be parking spots, storage areas, et cetera. We remove all apartments with the form of ownership of "obligasjonsleilighet". This is because an "obligasjonsleilighet" is a rental home where the tenant gives the owner a loan to be allowed to rent the apartment. In an "obligasjonsleilighet", you own nothing but the right to rent your home.

Accordingly, we exclude a total of 1.970 outcomes from our dataset, equal to around one percent of our total dataset, which is a small insignificant eradication. This leaves us with a total of 220.102 observations. In theory, removing input from our dataset could result in a risk of omitted variable bias. However, we believe this is improbable in this case, as the variables removed are likely to be invalid. Thus, strengthening our results.

4.3 Summary statistics

Since our data set includes various observations and variables, we will present the data using summary statistics. This gives us an overview of the data set's most essential features. Oslo is split into five smaller areas based on the inner and outer city, providing a detailed insight into housing prices in Oslo.

***Figure 1**: Districts of Oslo divided into broader areas in accordance with www.oslo.kommune.no*

Inner East	Inner West	Outer East	Outer West	Outer South
Gamle Oslo	St. Hanshaugen	Bjerke	Ullern	Østensjø
Grünerløkka	Frogner	Grorud	Vestre Aker	Nordstrand
Sagene		Stovner	Nordre Aker	Søndre Nordstrand
Sentrum		Alna		

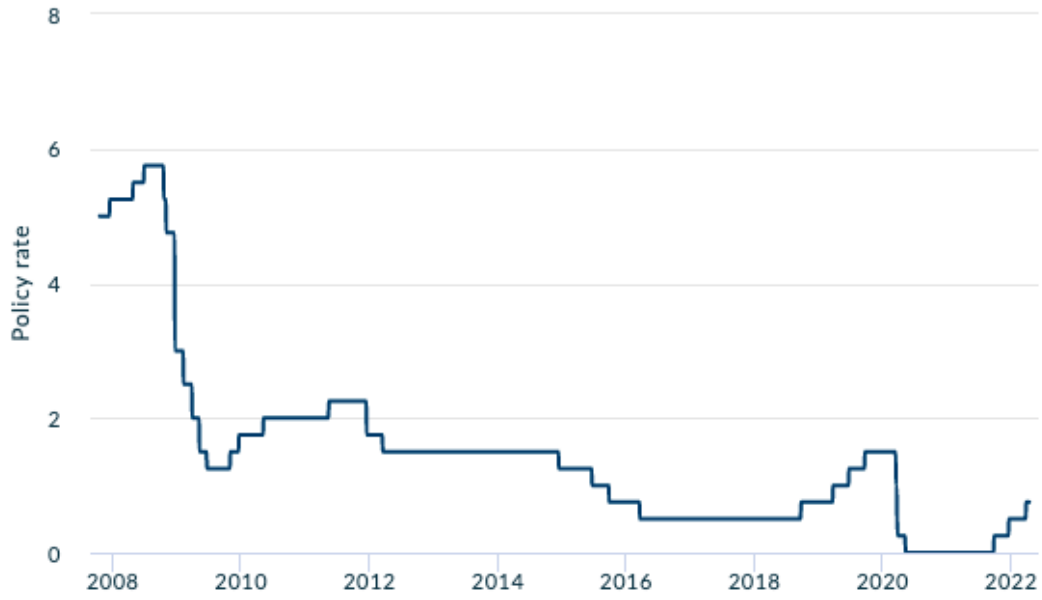
***Table 2**: Summary statistics for Oslo based on housing type, year, and area.*

2014-2021								Price/m2
OSLO	**Obsevations**	**Variable**	**Average**	**Median**	**Minimum**	**Maximum**	**Std. dev.**	**Price change**
Detached house	5 939	**Sales price**	11 000 000	10 100 000	1 520 000	71 100 000	5 529 895	50 228
		Size (sqm)	219	206	23	970	81	
Semi-detached hou	4 516	**Sales price**	8 898 343	8 350 000	1 900 000	40 000 000	3 890 210	53 188
		Size (sqm)	167	157	47	699	65	
Terraced house	5 968	**Sales price**	6 536 087	5 898 431	1 983 000	93 000 000	3 051 731	50 001
		Size (sqm)	131	125	47	1 141	35	
Apartment	138 032	**Sales price**	4 339 932	3 775 000	820 000	67 500 000	2 130 313	65 931
		Size (sqm)	66	63	13	747	27	
2014	18 323	**Sales price**	3 500 671	2 850 000	820 000	38 000 000	1 982 675	45 463
		Size (sqm)	77	66	14	772	48	
2015	19 771	**Sales price**	3 915 133	3 200 000	971 000	28 700 000	2 164 723	50 394
		Size (sqm)	78	66	13	744	49	*11%*
2016	18 136	**Sales price**	4 520 329	3 739 730	1 153 595	45 500 000	2 430 976	58 671
		Size (sqm)	77	66	13			*16,4%*
2017	17 678	**Sales price**	4 853 321	3 962 000	1 234 000	55 500 000	2 685 838	63 203
		Size (sqm)	77	66	13	970	48	7,7%
2018	18 645	**Sales price**	4 896 407	3 962 000	1 100 000	48 000 000	2 755 486	63 458
		Size (sqm)	77	66	14	814	47	*0,4%*
2019	20 075	**Sales price**	5 174 499	4 163 879	1 258 000	71 100 000	3 055 560	66 485
		Size (sqm)	78	66	13	890	47	*4,8%*
2020	20 778	**Sales price**	5 429 702	4 404 683	1 355 606	68 000 000	3 106 113	70 281
		Size (sqm)	77	66	13	890	47	*5,7%*
2021	21 049	**Sales price**	5 993 395	4 822 715	1 413 577	93 000 000	3 542 547	78 154
		Size (sqm)	77	66	13	1 141	49	*11,2%*
Inner East	54 819	**Sales price**	4 184 036	3 840 000	841 278	42 000 000	1 610 665	72 276
		Size (sqm)	58	55	13	478	21	
Inner West	27 585	**Sales price**	5 730 133	4 919 212	1 100 000	93 000 000	3 334 757	79 442
		Size (sqm)	72	65	13	1 141	41	
Outer East	26 398	**Sales price**	3 602 990	3 219 000	995 640	19 900 000	1 551 014	43 982
		Size (sqm)	82	72	15	658	41	
Outer West	20 645	**Sales price**	7 047 344	5 800 000	820 000	71 100 000	4 324 043	63 820
		Size (sqm)	110	87	14	970	74	
Outer South	25 008	**Sales price**	4 616 001	3 657 047	946 000	55 500 000	2 799 364	49 634
		Size (sqm)	93	72	17	747	55	

Table 2 presents summary statistics for Oslo by dwelling type, year, and the sample shown in Figure 1. We observe from the statistics that apartments make up most of the dwelling types in Oslo. Apartments also have the lowest mean- and average-price and size, but the highest price per square meter. This is consistent with our expectations and the typical characteristics of the price-size relationship. The Inner East is the area with the most transactions during the period, while the Inner West has the most expensive dwellings per square meter. Both in 2015 and 2021, dwelling prices rose roughly 11%. This is the most extensive price change except for an increase of 16.4% in 2016. This is noteworthy because the policy rate was reduced in late 2014 and 2020. In December 2014, Norges Bank reduced the policy rate by 0.25 percentage points to 1.25 (Norges Bank, 2018). The interest rate was reduced further in 2015 and was kept unchanged at 0.5 percent from 2016 until a gradual increase from September 2018. When Covid-19 hit Norway in March 2020, Norges Bank's primary monetary policy reaction was a 0.50-percentage point drop in policy rates on March 13, 2020, another 0.75 percentage point reduction on

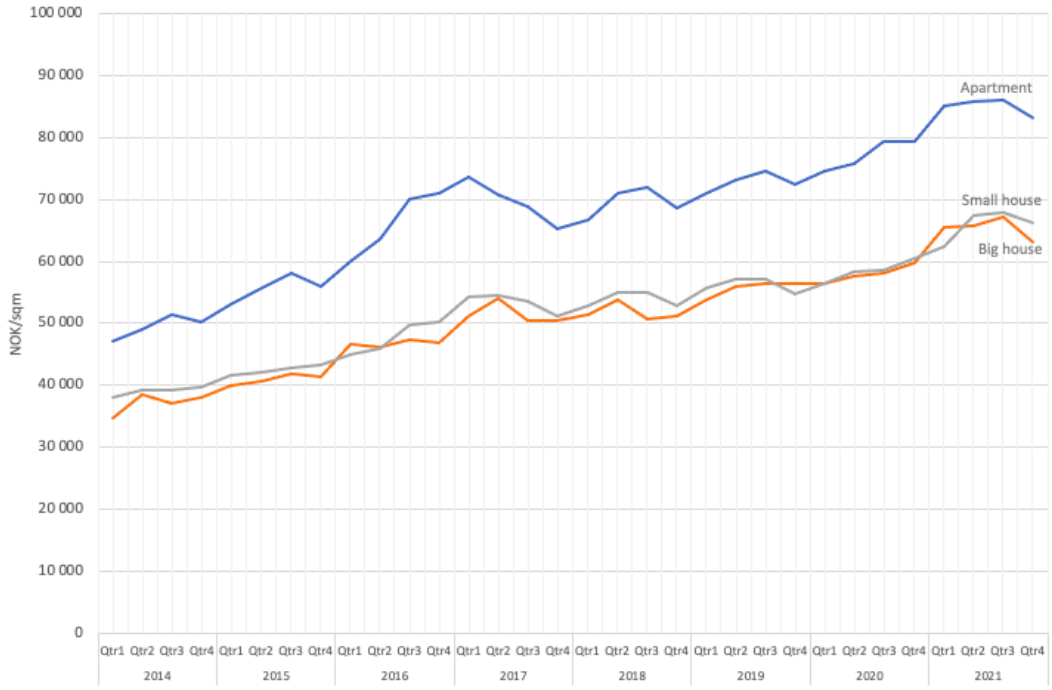
March 20, and a final reduction to zero on May 7, 2020. (Norges Bank, 2020). Figure 2 illustrates the historical change in Norway's policy rate.

***Figure 2**: Changes in Norway's policy rate from 2008 to 2022. From Norges Bank, 2022,* https://www.norges-bank.no/en/topics/Monetary-policy/Policy-rate/



Our calculations indicate that the reduction in the policy rate in 2020 affected the housing prices in Oslo less than in 2015/2016. The increase in housing prices in 2016 was 16.4% compared to 11.2% in 2021 in Oslo.

Figure 3: House price trends in Oslo based on housing type from 2014 to 2021



From Figure 3, we see different dwelling types in Oslo have followed a similar growth pattern. All housing types had a strong increase in 2016, followed by a decline in 2017.

***Table 3**: Summary statistics for each municipality*

Municipality	Obs.	Variable	Average	Median	Minimum	Maximum	Std. dev.
Oslo	154 455	**Sales price**	4 813 515	3 949 998	820 000	93 000 000	2 881 000
		Size (sqm)	77	66	13	1 141	48
Drammen	16 465	**Sales price**	3 346 979	2 971 888	432 181	18 900 000	1 547 856
		Size (sqm)	113	91	14	813	67
Fredrikstad	10 963	**Sales price**	3 022 562	2 700 000	261 000	17 500 000	1 390 002
		Size (sqm)	125	108	22	725	69
Frogn	2 130	**Sales price**	5 074 635	4 500 000	959 693	22 000 000	2 565 822
		Size (sqm)	127	112	21	513	71
Indre Østfold	5 841	**Sales price**	2 702 970	2 520 000	529 234	9 600 000	1 073 387
		Size (sqm)	138	120	21	674	75
Kongsvinger	2 594	**Sales price**	2 091 792	1 875 005	240 000	9 300 000	982 654
		Size (sqm)	123	113	22	591	62
Moss	8 297	**Sales price**	3 234 561	2 800 000	810 818	19 300 000	1 577 491
		Size (sqm)	114	94	26	672	66
Ringerike	3 824	**Sales price**	2 720 392	2 500 000	409 000	12 700 000	1 112 531
		Size (sqm)	133	113	23	591	74
Tønsberg	9 465	**Sales price**	3 298 368	2 860 000	450 000	29 000 000	1 726 241
		Size (sqm)	121	100	15	1 036	74
Ullensaker	6 068	**Sales price**	3 670 890	3 300 000	1 020 000	12 800 000	1 496 320
		Size (sqm)	112	97	20	757	67

According to Table 3, Frogn has the highest average- and median price, while Kongsvinger has the lowest. Appendix 4 shows that Fredrikstad has the strongest linear relationship in average square meter price from 2014 to 2021. From 2015 to 2016, the square meter price in Drammen, Frogn, Indre Østfold, Ringerike, and Ullensaker increased substantially.

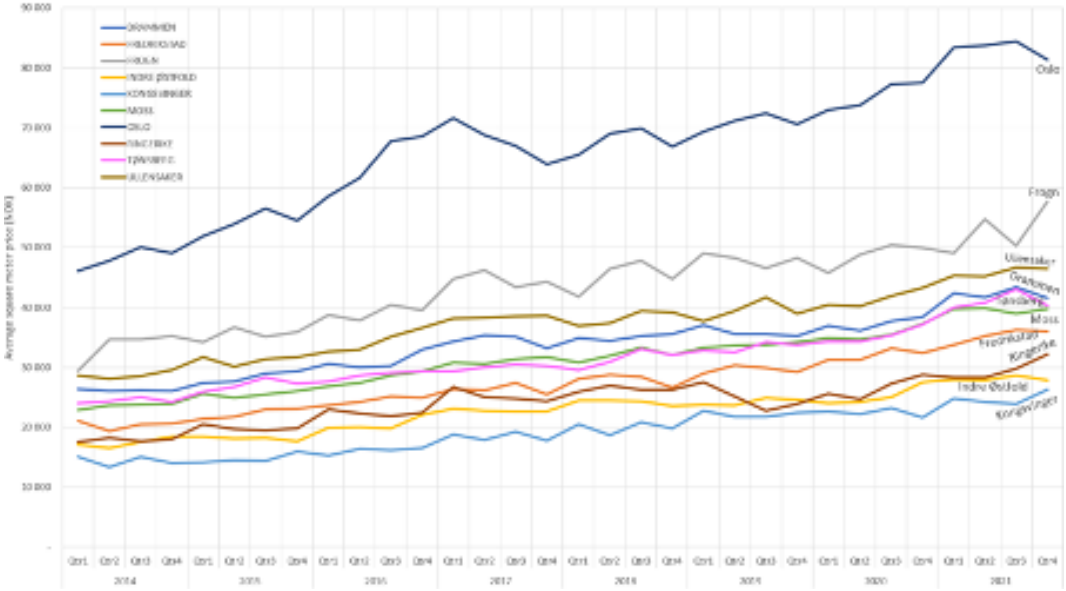
***Table 4**: Summary statistics for the entire data set from 2014-2021 based on year*

Year	Obs.	Average	Median	Minimum	Maximum	Std. dev.	Sqm. price	Price change
2014-2021	6 068	3 670 890	3 300 000	1 020 000	12 800 000	1 496 320	32 776	61,0%
2014	630	2 839 859	2 600 000	1 020 000	8 900 000	1 085 290	24 911	
2015	615	3 093 815	2 753 821	1 137 811	10 500 000	1 250 434	26 903	8,0%
2016	612	3 468 408	3 200 000	1 201 148	11 000 000	1 261 913	29 645	10,2%
2017	777	3 736 152	3 274 529	1 550 646	10 600 000	1 466 787	33 359	12,5%
2018	811	3 758 619	3 370 000	1 672 682	11 000 000	1 457 598	32 970	-1,2%
2019	865	3 828 027	3 415 000	1 214 000	10 500 000	1 504 626	34 179	3,7%
2020	888	3 902 413	3 500 000	1 620 000	12 700 000	1 516 416	36 133	5,7%
2021	870	4 290 426	3 822 446	1 135 626	12 800 000	1 677 856	40 097	11,0%

Table 4 summarizes the entire data set yearly. The transaction value of dwellings sold, ranges from 0.24 to 93 million, with a mean of 4.3 million and a median of 3.6 million. The overall price change for all cities was at its lowest in 2018 with an increase of 0.89%. From Appendix 4, we see that Ullensaker, Outer East, and Outer South of Oslo had a decrease in dwelling prices this year. A reason for this may be due to the government's new mortgage regulations governing bank lending

activities and consumer equity requirements, which went into effect in January 2017 (Iversen, 2017).

***Figure 4**: House price trends entire data set*



We note from Figure 4 a higher square meter price in Oslo than in the other municipalities. Ringerike, Indre Østfold, and Kongsvinger have the lowest. The square meter price is continuously growing, and the price gap between Oslo and the other cities has expanded, implying that Oslo has faster growth in price than the others. Frogn has followed a similar growth pattern as Oslo. The fact that Frogn is the municipality closest to Oslo may account for some similarities in housing prices. However, during the third quarter of 2021, when Oslo was experiencing a decline in housing prices, the prices in Frogn increased substantially. This might result from the pandemic and home office, as Oslo saw record-high emigration in 2020, up 37% from 2019. (Lundegaard et al., 2022). Drammen had an increase in housing prices of 8.24% in 2015 and 10.53% in 2021. With a travel time of around 40 minutes, Drammen is one of the most popular commuter cities in Oslo (Finn, 2020). The price shift in 2020 compared to 2015 indicates that Drammen had a more robust demand for housing in 2020, which may be attributed to covid restrictions.

Further, we conducted regression studies with policy rate as the dependent variable to estimate coefficients for different policy rate levels. This will help us comprehend how different municipalities are impacted by policy rates. From Appendix 5, we observe how the policy rate level affects the price per square meter

in the different municipalities. As expected, Oslo is most affected when facing a one percentage point increase in the policy rate. For instance, in Oslo, when the policy rate is zero percent, the average square meter price is approximately NOK 80.000, compared to NOK 65.000 if the policy rate increases one percent. Additionally, we discover that for all municipalities, a policy rate change from zero percent to one percent has a greater impact on pricing than a move from one percent to two percent.

5 Methodology

5.2 Excel model

We use Excel to calculate house price growth for each municipality for three-, six- and twelve-month periods. In our model, we use small houses as a common term for semi-detached houses and terraced houses, while big houses are detached houses. In addition, we divide apartments into three categories; less than 46 square meters, between 46 and 85 square meters, and larger than 85 square meters. When analyzing the results of our Excel models, we must consider some concerns. Firstly, some municipalities have few sales, especially in the three and six-month intervals, so these results are not necessarily credible. With this in mind, we have chosen to use simple models because different parameters may be subject to over-adaptation. We also remove outliers from the dataset. To avoid sampling bias, our primary focus will be on the twelve-month periods from March 19, 2015, to March 19, 2016, and from March 12, 2020, to March 12, 2021.

5.3 Correlation

We find the correlation to the statistical measure that tells us about the association between variables (Statistics How To, 2022). This describes how one variable behaves if there are changes in the other variable. Both Pearson and Spearman correlation coefficients are used for measuring correlation, but the difference lies in the type of analysis we want. We use a Pearson correlation test to measure the strength and direction of linear covariation between two continuous variables (Statistics Solutions, 2022). On the other hand, we use a Spearman correlation to evaluate the monotonic relationship.

In our case, we prefer to use the Pearson correlation. From this test, we obtain three outputs: r, R^2, and a p-value. r refers to the Pearson correlation coefficient, which tells us the correlation's direction and strength. r is between -1 and 1 and has no units of measure. The absolute value of r is how strongly the two variables correlate. However, we must interpret the r value in the context of the scientific question. For example, a positive correlation of 0.1 might be weak in one research, while it is a strong correlation in another. Further, R^2 refers to the coefficient of the determination and has an absolute value between 0 and 1. R^2 is the proportion of the variation in the dependent variable that is predictable from the independent variable(s) (Wikipedia, 2022). The third main output from the Pearson correlation test is the P-value, and we perform a two-tailed analysis and create a null and alternative hypothesis. This is to determine if the variables are statistically significant.

To implement a Pearson correlation test, some assumptions must hold. The data must satisfy the following assumptions (Tip Top Bio, 2021). If one of the following assumptions is violated, then we should perform a different correlation test, as the test will likely give false or imprecise results:

1. Random sample
2. Variables are continuous data
3. Data contains paired samples
4. Independence of observations
5. Variables are (approximately) normally distributed
6. A linear association exists
7. Absence of outliers x

We test assumptions of correlation by using a Shapiro-Wilk test. We check if a continuous variable follows a normal distribution (Wikipedia, 2022). The null hypothesis states the variables are normally distributed, while the alternative hypothesis states the variables are not normally distributed.

5.4 Regression discontinuity design

An increasingly widespread application of the regression discontinuity design (RDD) uses time as the running variable, with a treatment date as the threshold (Hausman et al., 2018). RDD is a quasi-experimental design that has grown in

popularity in recent years in social science and econometric research. We want to look at the effect of reduction in policy rate using a regression discontinuity design on the different municipalities by looking at a treated and a non-treated group based on a cut-off point. To check if the policy rate has impacted housing prices, we use the data before the reduction as the control group and the data after the reduction as the treated group.

RDD was first introduced in the evaluation literature by Thistlewaite and Campbell in 1960. Goldberger did the earliest research on RDD in economics in 1972, showing that bias arises when non-equivalent groups vary in an incompletely observed pretest score. However, that bias does not exist when treatment selection is based only on an observed pretest score, as in RDD (Cook, 2008). However, the approach did not attract much attention in economics literature until the past decades (Imbens & Lemieux, 2007).

In a study by Zuckerman et al. (2005), RDD was performed in medical research to assess the usage of medications. The study compared treated and non-treated groups, with the regression line moving continuously through the cut-off point if the treatment had no effect. However, if the treatment had an impact, the line would shift at the cut-off point.

Similar research is done in the USA by Bhutta & Ringo (2017) on the effect of interest rates on home buying using regression discontinuity design. They found that a 50-basis point cut in interest rate led to an immediate 14 percent increase in home buying among the Federal Housing Administration-reliant population. Given the similarities between this research article and our theory, we believe it is appropriate to apply RDD to assess the impact of a lower interest rate on housing prices in 2015 and 2020.

If the properties were sold on or after the date of the reduction in the policy rate, they would be subject to the new macroprudential regulation. On the other hand, if the properties were sold before the reduction or cut-off, they would not be treated. Formally, a simple RDD is as follows:

(1) $$Y = \beta_0 + \beta_1 D + \beta_2 X + u, \qquad D = \begin{cases} 0 \; if \; X < c \\ 1 \; if \; X \geq c \end{cases}$$

Where D is the treatment variable, X is the running variable that determines the treatment, and D is a dummy variable for whether the running variable exceeds the cut-off point, c.

Our models are constructed using; macro factors to eliminate general price growth, variables to differentiate house-specific features, dummies for the municipalities, dummies for 2015 and 2020 when the interest rate was reduced, and interaction terms to isolate the effects of the reduction on each municipality. Macro factors used are inflation, income, GDP, and unemployment. The dummy variables capturing the policy rate reductions are 0 before 2015 and 1 after.

Stock and Watson (2015, p. 496) distinguish two RDD methods: fuzzy and sharp. The treatment variable estimates the treatment in sharp RDD. When using fuzzy RDD, the cut-off point only increases the probability of treatment, but does not completely determine treatment. In our RDD, we use 2015 and 2020 as cut-off points as we anticipate that the shift in house prices will occur over a more extended period than the precisely the two dates with a decline in interest rate. The delay is due to market adaptability, and according to Mihm (2022), property prices can be slow to respond to changes in interest rates. Therefore, we developed two RDD models which applied the same slopes on both sides of the cut-off, one for 2015 and the other for 2020, see equation 2.

(2) $$\ln(\text{Square meter price}) = \beta_0 + \beta_1 D + \beta_2 (YrSold - 2015) + u$$
$$\ln(\text{Square meter price}) = \beta_0 + \beta_1 D + \beta_2 (YrSold - 2020) + u$$

We regress the variable square meter price logarithm, where D is the dummy variable. D indicates whether a transaction is below or above the cut-off, and is the continuous assignment variable that determines the treatment. We subtracted the cut-off from each transaction year, to regress the square meter price on the threshold dummy and transaction year in our data set.

(3) H_0: *The reduction in policy rate did not have a significant effect on house prices*
H_A: *The reduction in policy rate did have a significant effect on house prices*

The null hypothesis states that there is no discontinuity at the cut-off point as shown in equation 3. This means that the reduction in the key policy rate and the strict measures following the Covid-19 pandemic did not affect housing prices. The alternative hypothesis states that there exists discontinuity at the cut-off point. We reject the null hypothesis if the coefficient is statistically significant at a 5% significance level:

(4) $$Reject\ H_0\ if\ p - value < 0{,}05$$

5.3.1 Limitations regression discontinuity design

An econometric problem in estimating treatment effects is selection bias, which arises from the fact that the treated group differs from the non-treated group, for reasons other than treatment status. These effects might include, for example, a new rail line, freshly built or existing flats, or simply a general market tendency for certain municipalities. These impacts are difficult to regulate since some may be unmeasurable, such as a general trend, while others are difficult to define. Another limitation with these regressions is the scarcity of data from 2014 to 2015 and 2020 to 2021. This might have made the regression lines imprecise, resulting in an incorrect or imprecise interpretation of the treatment effect before 2015 and after 2020. Although the statistical regressions give essential information on whether there has been a change in housing prices, the amount of statistical significance does not correspond to the extent of the treatment effect.

6 Results

6.1 Results Excel model

In this section, we present the results of our excel model for each municipality separately; the results are shown in Appendix 6.

6.1.1 Drammen

Property prices in Drammen increased by 10.53 percent between March 2020 and March 2021, compared to 8.24 percent between 2015 and 2016. The most considerable disparity in price rise between 2015/2016 and 2020/2021 is for large properties, which grew by 18.62 percent in the first three months after the lockdown in March 2020, compared to 4.27 percent in March 2015. However, we only have

166 and 193 transactions on large houses for the three months in 2015 and 2020, respectively, making these growth projections inadequate. Big house prices rose by 13.33% in 2015 and 9.56% in 2020, while small house prices rose 16.81% in 2015 and 3.27% in 2020. As Drammen is the municipality with the most extensive centrality index (916), we expected to find a higher price growth for detached houses in 2020. On the other hand, we saw a significant increase in large apartment prices of 12.98% in 2020, while it grew only 4.68% in 2015. Due to the pandemic's restrictions, this suggests a rise in the demand for larger apartments.

6.1.2 Fredrikstad

Fredrikstad has a centrality index of 872 and is in category 2 on the centrality scale. We notice a significant increase in house prices from March 19, 2015, to March 19, 2016, by 17.01%. We also note that apartments have mainly contributed to the increase in value, and detached houses have had a negative return of 1.07%. Small houses also contributed to growth, with an increase of 16.08%. Further, we perceive that large apartments have increased by 18.62%. On the other hand, from March 12, 2020, detached houses have contributed to growth, with a house price increase of 10.45%. We note that large apartments have increased by as much as 28.35%, and the total house price change was -5.41% one year after the fall in interest rates in 2020. Notably, small houses fell 9.57% in 2020, compared to an increase of 16.08% in 2015.

6.1.3 Frogn

Another municipality with the same centrality category as Fredrikstad is Frogn, with a centrality index of 903. Here we see a slightly contrasting pattern, with a total increase in 2015 of 1.11%. The moderate growth comes mainly from large houses and medium-sized apartments. We see a more considerable increase in 2020 with a substantial total growth of 11.08%, where apartments and detached houses increased by 26.79% and 21.77%, respectively. It is remarkable to note the substantial increase in detached houses after only three months in 2020, of 54.08%. This may be a result of few homes sold in this period, but it is nevertheless interesting to note as there was a decrease in the same period in 2015 of 1.21%. Prices on small houses decreased in both 2015 and 2020 for time periods of six months and twelve months.

6.1.4 Indre Østfold

Indre Østfold is one of the municipalities with the most prominent house price growth. We noticed a substantial increase in 2015 of 20.96%. Here we see that especially small apartments contribute to the increase by 59.97%. Again, this may be due to fewer dwellings sold during the period; nevertheless, it is abnormal. In 2020, we also saw a substantial increase, and housing prices rose by 45.05% from March 12, 2020, to March 12, 2021. Additionally, detached houses contributed the most to the increase of 47.67%. Indre Østfold has a centrality index of 860 and is thus classified in category 3, the lowest category of our chosen municipalities. According to Appendix 8, commuting time to Oslo takes between 55 and 100 minutes (by car or public transportation). We also see that large apartments lost 40.34% of their value. As the home becomes a more significant part of everyday life with Covid measures and home office, we assume it provides a greater incentive to move to a detached house. We note an increase in small houses in both time periods, by 11.81% in 2015 and 22.80% in 2020. Comparing small and large apartments, we see an increase in 2015 of 59.97% and 26.15%, respectively, compared to a decrease in 2020 of 10.09% and 40.34%. This is according to our hypothesis and strengthens it.

6.1.5 Kongsvinger

Kongsvinger has a centrality index of 793 and is in category 3 - the municipality with the lowest centrality index in this thesis. In Kongsvinger, house prices have increased relatively equal in 2015 and 2020, 9.27% against 7.36%. What we find interesting are the significant differences in price changes in small apartments. We do not have enough data for time periods of three and six months in 2020; therefore, they are omitted. For twelve months in 2015, small apartments increased by 43.24%, while they decreased by 27.53% in 2020. People want extra space and thus want a more prominent place to live, for example, larger apartments or detached houses. If we look at detached houses, we detect an upswing in both periods, 55.29% in 2015 and a staggering 220.63% in 2020. Again, this supports our theory that detached houses have become more lucrative in 2020 versus 2015. Evidently, people want extra space and thus choose detached houses over apartments in this municipality. It can also stem from people moving from expensive cities like Oslo to be able to afford to buy a detached house.

6.1.6 Moss

With a centrality index of 903, Moss is also in category 2. Moss's house price decreased from March 19, 2015, to March 19, 2016, by 1.39%. In 2020, on the other hand, prices increased by 13.81%. We notice the same pattern here, as in many other municipalities in 2020, a decrease in small apartments and an increase in large apartments and detached houses. We detect that small houses have had an inverse correlation - a decrease in 2015 of 15.35% and an increase of 11.16% in 2020. As Moss is located by Oslofjorden, it may have attracted buyers looking for a new home and potential cottage buyers. Cottages by the sea have attracted interest as regulations have made it hard to increase supply in these areas. According to Hytteavisen, from 2015-2018, the most expensive sea cabins are, on average, one million NOK more expensive than mountain cabins in popular areas (Hytteavisen, 2019).

6.1.7 Ringerike

Ringerike's housing prices increased by 8.90% in 2015 and 12.80% in 2020. The greatest price growth in 2020 was 25.53% for big houses, but we saw an equal increase in 2015 of 25.79%. Small houses rose in 2015 by 9.93% and 23.89% in 2020. Apartments had a similar price shift in 2015 and 2020, with –13.32% and –11.40%, respectively. We notice a remarkable decline of 15.62% for small apartments in 2020 and a rise of 25.79% in 2015. Nevertheless, Ringerike only has 88 sales of apartments under 46 square meters, which makes these results weak. Large apartments grew 12.54% in 2020, compared to a decrease of 1.37% in 2015. This significant discrepancy in large apartments' price growth confirms our belief that individuals seek larger homes, needing more space.

6.1.8 Tønsberg

We find Tønsberg in category 2 with a centrality index of 877. We see a price decline in 2015 simultaneously as we see a relatively significant decline in detached houses in particular in the same year, down 11.36%. We notice all housing types have had a decline in this period. On the other hand, small apartments have increased by 8.92%. In 2020, we saw a total increase of 7.84%, and detached houses primarily contributed to the price increase. Large apartments plummeted and are down 29.15% a year from the fall in interest rates in 2020. Tønsberg is also a

popular place to have a sea cabin, which may explain the increase in detached houses in 2020. Again, this supports our hypothesis - a decline in apartment prices and a rise in detached house prices.

6.1.9 Ullensaker

The data on Ullensaker shows large fluctuations in the first three months of both 2015 and 2020. In 2015, we witnessed a total house price decline of 20.58%, and detached house prices fell 30.89%. In 2020, on the other hand, detached house prices rose by 34.36%, and large apartments also rose by 36.29%. In the long term, we see a decline in detached houses in 2015 of 18.10% and an increase in 2020 of 36.47%. With a high price index of 915, it is natural to assume that individuals from Oslo have moved to Ullensaker to be able to afford a detached house. According to Appendix 8, Ullensaker is only 30 minutes from Oslo by car, making it a swift commute.

6.1.10 Inner East

For Inner East of Oslo, we observe a minor difference in price change by apartment size between 2015 and 2020. The total price growth was slightly lower in 2020, at 9,48%, while it was 14,31% in 2015, and the smallest apartments increased by 15,27% in 2015 and 9,98% in 2020. Large apartments had the highest rise in prices in 2020 with 17,59%. However, large apartments also saw a considerable increase in 2015 of 15,03%. The Inner East is the district in Oslo with the fewest disparities between 2015 and 2020. We do not evaluate detached house price increases since there were barely any transactions of this housing type in the Inner East from 2014 to 2021.

6.1.11 Inner West

In the Inner West, prices increased 12.20% during Covid-19, against 6.46% in 2015. The rise is primarily due to a significant increase in both small and large-sized apartments in 2020. Detached houses account for a considerably small share of the housing stock in this area. It is worth noting that Inner- and Outer West are the only areas in Oslo with a more significant total price increase in 2020 compared to 2015.

6.1.12 Outer East

The Outer East had a slight difference in price change between 2015 and 2020, with an increase of 8.79% and 7.08%, respectively. Price increase for medium and large apartments in Oslo's Outer East was significantly reduced from 2015 to 2020. On the other hand, house prices, particularly large ones, surged in 2020 by 37.50%, compared to a 25.89% gain in 2015. This supports our belief that the pandemic increased the demand for large houses.

6.1.13 Outer South

The Outer South has the most detached house transactions; hence we anticipated a more considerable price increase following the Covid-19 pandemic. However, we discovered that the price rise for both large houses and apartments in the Outer South rose significantly more in 2015 compared to 2020, with an increase of 28.46% in 2015 and a 2.13% in 2020. The growth for large apartments was 20.49% in 2015 and 9.64% in 2020. This is unexpected but is presumably a result of the area's characteristics. The districts in Outer East, Søndre Nordstrand, Østensjø, and Nordstrand are the city districts that have had the lowest price increases over the last five years (Lorvik, 2020).

6.1.14 Outer West

Outer West had a slight growth of 1.31% in 2015 and an increase of 10.68% in 2020. Looking at apartments by size, we find considerable differences in price changes – the price has been highest for the smallest apartments, which increased by 24.44% in 2020. The price fall for large apartments of 0.43% during the three first months of lockdown was followed by a relatively substantial rise of 7.29% over the next twelve months. Compared to 2015, the rise in detached houses was 2.81%, compared to 22.14% in 2020. For 2020, the rise in prices was highest for detached houses and lowest for apartments. The findings indicate that the Covid-19 pandemic may have led to a shift in demand toward detached houses, and there has been a preference for detached houses over large apartments.

6.1.15 Oslo

Looking at the estimations for all areas in Oslo, the price growth for 2015 was 11.18%, while it was 12.46% in 2020. Price growth for apartments over 85 square meters increased by around 11 percentage points from 10.42% in 2015 to 21.76% in 2020. For all dwelling types, the price growth was significantly higher in 2020 than in 2015.

6.1.16 Summary

We detect that most results point in the same direction. In centrality category 1, Oslo, we see a strong and stable price increase in 2015 and 2020, mainly due to apartment sales. In the municipalities in centrality category 2, we also see a general price increase in 2015 and 2020. We see that dwelling type «apartments» in the municipalities on the outskirts of Oslo are becoming less attractive and that people want more space. We see a different pattern for detached homes in 2020, especially in centrality category 3, where they become more attractive.

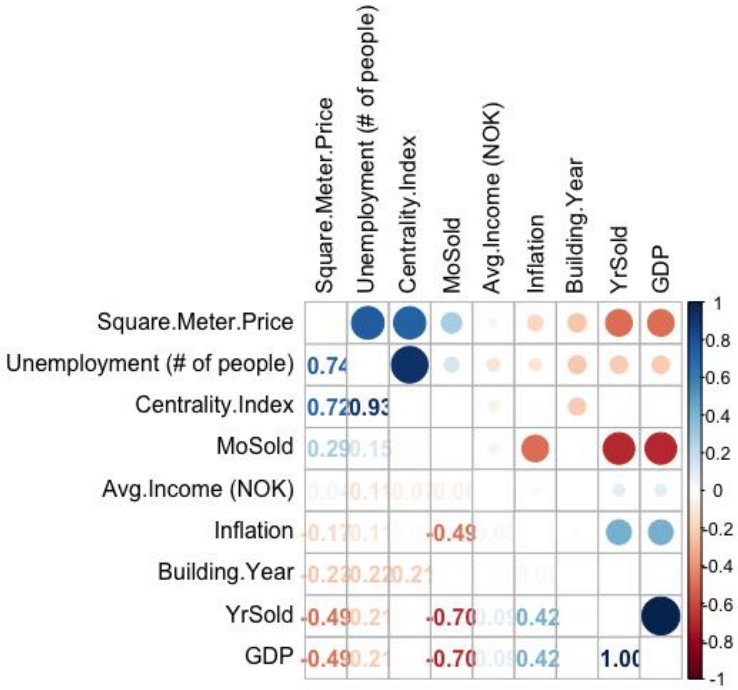
From our data set, we perceive a high house price growth both in 2015 and 2020. From our Excel models, we observe that seven out of ten municipalities had a house price decline during the first three months after the interest rate fell on March 19, 2015. This could be related to the fact that there were few homes sold in the period, and these are overestimated in our analysis. We prevent overfitting by eliminating outliers, utilizing simple models, and integrating various methods. We observe an increase in detached homes and small homes in five of the ten municipalities. During the first six months, we spot an increase in half of the municipalities we have included in our thesis. The increase is primarily due to good apartment sales as only four out of ten municipalities had an increase in small and big houses. We have chosen to focus on the twelve months after the interest rate cut to get the best possible analysis. This period includes multiple interest rate cuts in addition to being a more extended period; thus, the outcomes will be more dependable. We notice an increase in seven out of ten selected municipalities, with the most significant increase in Indre Østfold of 20.96%. We also note that six out of ten municipalities have an increase in terraced houses and detached houses and that most of the data come from apartment sales in the capital, Oslo. We detect that

apartments, terraced houses, and detached houses increased similarly by 11.26%, 13.75%, and 12.42%, respectively.

In 2020, we see slightly different results, although there was a substantial increase in house prices here as well. Nine out of ten municipalities increased in the first three months after March 12, 2020. As mentioned earlier, this may be due to significant fluctuations due to a few home sales and a sharp fall in interest rates. We notice increased prices for detached houses in all municipalities. After six months, we see an increase in house prices in seven out of ten municipalities, in addition to perceiving an increase in small- and detached houses in all municipalities. In our most useful calculations, after twelve months, there are similar developments. House prices increased in nine out of ten selected municipalities, only Fredrikstad, ending in a change of -5.41%. During this period, detached houses have risen in value in all municipalities. We note solid price increases for detached houses in Frogn, Ringerike, Ullensaker, Indre Østfold, and Kongsvinger of 21.77%, 25.53%, 36.47%, 47.67%, and 220.63%, respectively, in these twelve months. Another notable finding is that analysts predicted that people would move out of Oslo. However, our results indicate that this is not the case since housing prices grew significantly more in 2020 than in 2015 for all dwelling types.

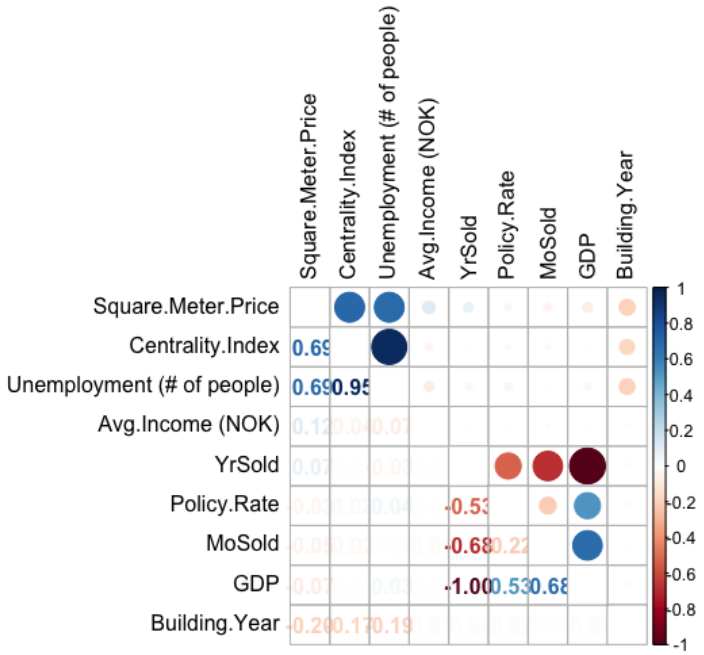
6.2 Results correlation matrix

Figure 5*: Results from the correlation matrix for 2015*



We examine several factors in the correlation matrix. As anticipated, from Figure 5, we notice a relatively high correlation between price per square meter and centrality index, of 0.72. This suggests that the higher the centrality index, the higher the price per square meter. This corresponds with prior research where we notice that the municipalities closest to Oslo have the highest price per square meter. This reflects the strength of the relationship between the price per square meter and the municipality.

***Figure 6**: Results from the correlation matrix for 2020*



Further, from Figure 6, we notice a correlation of 0.69 between price per square meter and centrality index in 2020. We acknowledge that the correlation between price per square meter and centrality went down from 2015 to 2020. This implies that centrality has less impact on the price per square, which is aligned with our hypothesis. We determine this is due to a rise in house prices in municipalities outside Oslo. Important to note that a correlation of 0.69 is still high, but interestingly it is lower than in 2015. In contrast to 2020, where the price increase was more evenly distributed throughout many municipalities, we observe a more concentrated increase in central Oslo in 2015.

6.3 Results regression discontinuity design

***Table 5**: Results from RDD analyses of reduction in the key policy rate in 2015 and 2020*

	OSLO 2015		DRAMMEN 2015		FREDRIKSTAD 2015		FROGN 2015		INDRE ØSTFOLD 2015	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Intercept	10,800	0,000	10,166	0,000	9,923	0,000	10,436	0,000	9,754	0,000
Treatment effect	0,109	0,000	0,046	0,000	0,033	0,000	0,046	0,069	0,027	0,168
YrSold-2015	0,058	0,000	0,058	0,000	0,073	0,000	0,059	0,000	0,065	0,000
	OSLO 2020		**DRAMMEN 2020**		**FREDRIKSTAD 2020**		**FROGN 2020**		**INDRE ØSTFOLD 2020**	
Intercept	11,244	0,000	10,527	0,000	10,332	0,000	10,829	0,000	10,150	0,000
Treshold	-0,056	0,000	-0,036	0,000	-0,014	0,248	-0,081	0,001	-0,066	0,000
YrSold-2020	0,075	0,000	0,067	0,000	0,078	0,000	0,074	0,000	0,077	0,000
	KONGSVINGER 2015		**MOSS 2015**		**RINGERIKE 2015**		**TØNSBERG 2015**		**ULLENSAKER 2015**	
Intercept	9,583	0,000	10,091	0,000	9,583	0,000	10,094	0,000	10,272	0,000
Treatment effect	-0,038	0,234	0,035	0,007	-0,038	0,234	0,022	0,158	0,059	0,000
YrSold-2015	0,084	0,000	0,066	0,000	0,084	0,000	0,062	0,000	0,056	0,000
	KONGSVINGER 2020		**MOSS 2020**		**RINGERIKE 2020**		**TØNSBERG 2020**		**ULLENSAKER 2020**	
Intercept	10,006	0,000	10,477	0,000	10,006	0,000	10,410	0,000	10,638	0,000
Treatment effect	-0,067	0,021	-0,031	0,010	-0,067	0,021	0,030	0,031	-0,034	0,016
YrSold-2020	0,091	0,000	0,073	0,000	0,091	0,000	0,060	0,000	0,007	0,000

Table 5 shows results from ten different regression discontinuity designs with cut-offs in 2015 and 2020. Square meter price is the dependent variable with a logarithmic specification. The running variable is the year of sale.

The coefficient estimates of interest are the dummy estimates (treatment effect) which measure the average treatment effect. We apply p-values to determine statistical significance and whether to reject the null hypothesis. One beneficial advantage of regression discontinuity designs is that the findings can easily be graphically presented; see results in Appendix 7. In addition, the use of RDD plots supplements the previous RDD analysis and provides transparency to the results (Cattaneo et al., 2019).

Based on the 2015 regression discontinuity data, we retain the null hypothesis for Kongsvinger, Ringerike, Tønsberg, Frogn, and Indre Østfold, meaning there is no discontinuity in the regression before and after 2015. The result indicates that the reduction in policy rate did not affect housing prices in these municipalities in 2015.

Except for Fredrikstad, all derived p-values for the predicted treatment effect are statistically significant at a 5% significance level for the 2020 outcomes, meaning structural breaks exist in the different regressions.

It is worth noting that the regression findings show continuity in five of the municipalities in 2015 but only one in 2020. This is expected since we anticipated that a drop in the key policy rate combined with remote work would result in more significant price growth in housing prices compared to when there only was a policy

rate decline in 2015. However, looking at the estimated treatment effect coefficient, we notice that Oslo had a coefficient value of 0.109 in 2015 and –0.056 in 2020. The positive variable implies that housing prices in Oslo are rising, while the negative coefficient indicates a negative impact on housing prices. All municipalities, except for Tønsberg, had a negative treatment effect coefficient value in 2020. On the other hand, it was almost positive for all regressions in 2015. We find this surprising, as we predicted the opposite. The RDD analysis results are ambiguous, yielding mixed outcomes. We hypothesized that reducing key policy rates and Covid restrictions would lead to higher price growth in 2020, but we did not find evidence supporting this in our RDD results.

7 Conclusion

The question we asked in this thesis has been:

Was there a significant change in the geographical distribution of house price changes in 2020 compared to 2015?

To address this question, our primary model is done in Excel, where we calculate house price growth for each municipality for three-, six-, and twelve-month periods from 2015 and 2020. This model indicates a high house price growth in 2015 and 2020 for most of the municipalities. We detect a significant increase in dwelling prices in Oslo, especially for apartments, which is unexpected. We anticipated more individuals leaving the capital due to constraints and a general demand for bigger homes. Dwelling type «apartments» in the municipalities on the outskirts of Oslo are becoming less attractive, indicating that people want extra space. When Covid-19 hit in March 2020, there were different speculations about how housing prices would evolve after several restrictions were introduced. The house price rise was moderate during the first shutdown period but quickly accelerated. Like in 2015, prices grew substantially. Our data suggests that Covid-19 may have altered housing preferences, increasing the demand for bigger houses and residences in places further from the city center.

Further, we determine the most significant variables in relation to the centrality index. We have constructed two correlation matrices: one for 2015 and one for 2020. This is done with a Pearson correlation test, examining the correlation between the centrality index and price per square meter. Results from our

correlation matrix justify that the price per square meter correlates higher to the centrality index in 2015 than in 2020. Proving centrality was a more crucial factor in 2015, enhancing our theory.

Lastly, we conduct regression discontinuity designs to support the results from the main model. We made two regressions for each municipality, one for 2015 and one for 2020. This is to determine whether there were any discontinuities when the interest rate fell at the two cut-off points. From our RDD results, all municipalities, except for Tønsberg, have a higher price growth in 2015 compared to 2020.

Our results from the Excel model and regression discontinuity design are ambiguous and yield mixed outcomes. However, there are limitations to the RDD results regarding the scarcity of data from 2014 to 2015 and 2020 to 2021. As a result, the regression lines may become imprecise, resulting in an inconsistent interpretation of the interest rate impacts before 2015 and after 2020. Thus, we believe the Excel model is the most reliable, as we discover no limitations in our price growth projections.

We conclude that our results show a significant change in the geographical distributions of house price changes in 2020 compared to 2015. While the increase in housing prices was more concentrated in central Oslo in 2015, it was more widely dispersed over numerous municipalities in 2020. From our results, we witness people are willing to substitute location with size, during and after the pandemic in 2020 – a shift in the demand.

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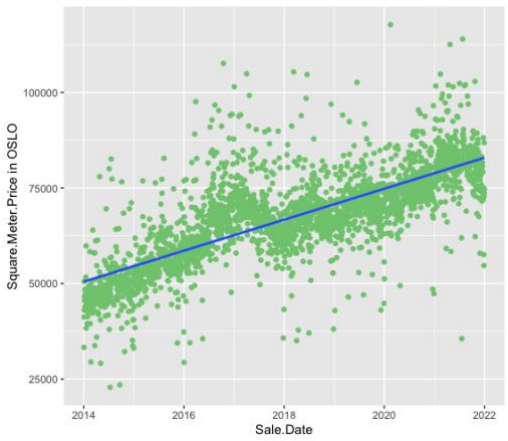
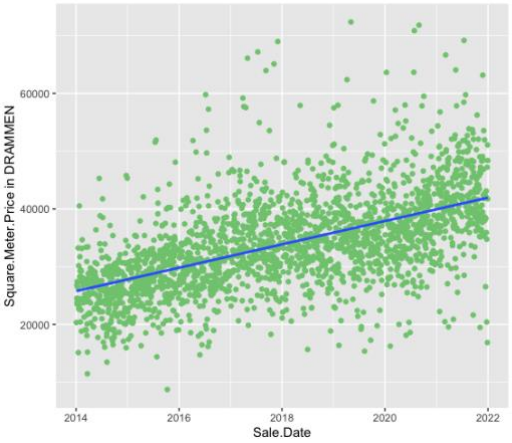
9 Appendix

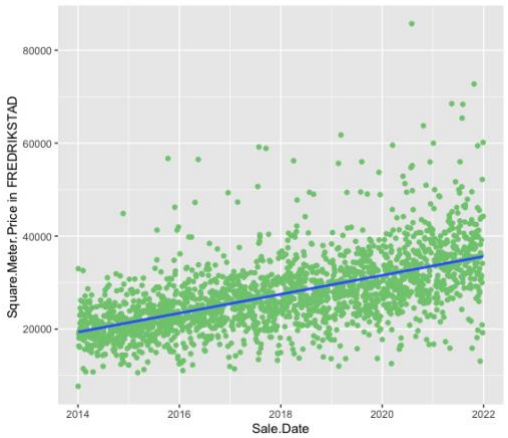
***Appendix 1**: Scatter plot of square meter price*



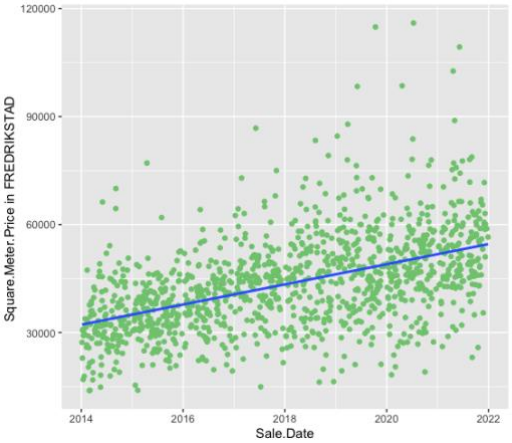
Oslo



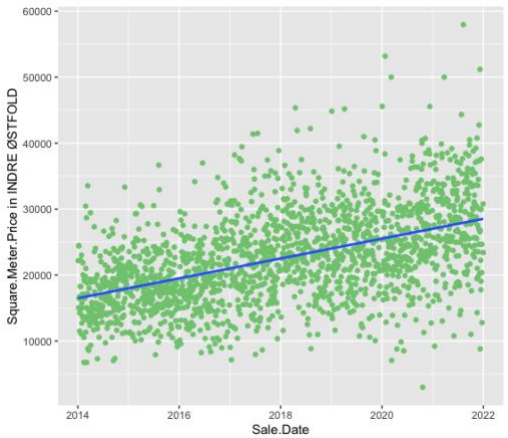
Drammen



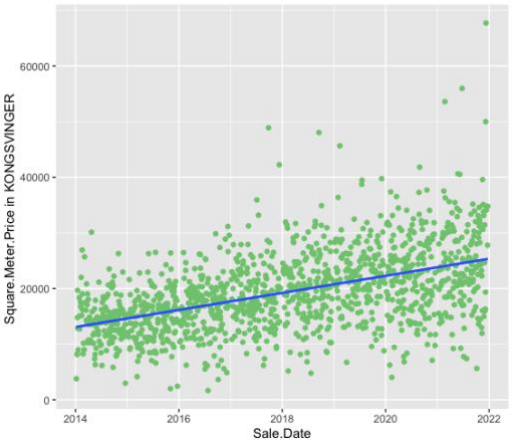
Fredrikstad



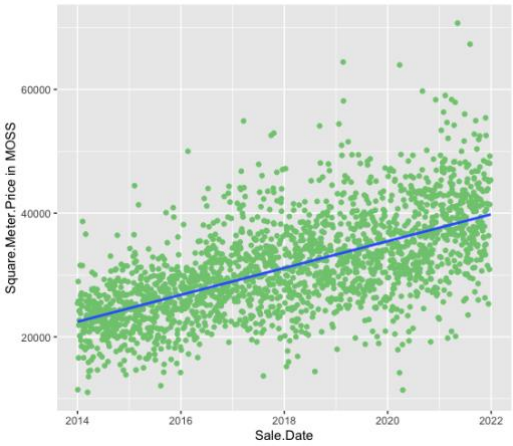
Frogn



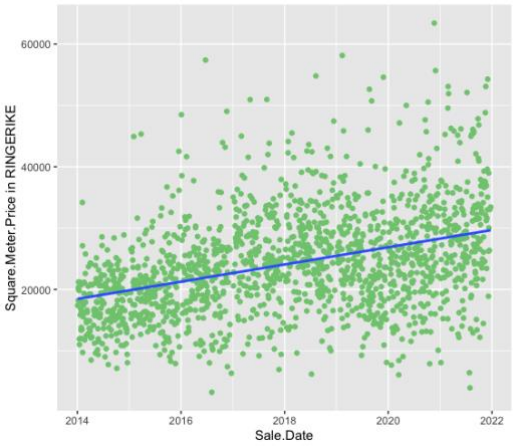
Indre Østfold



Kongsvinger



Moss



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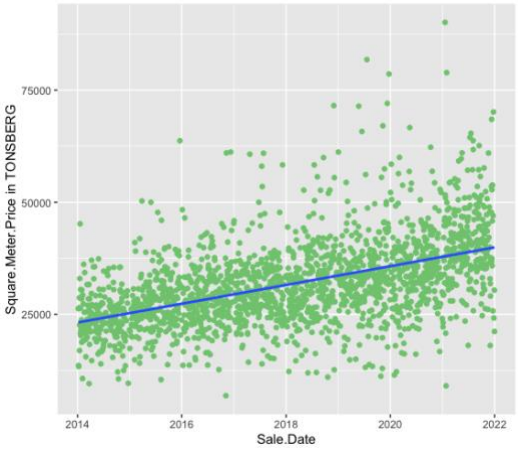
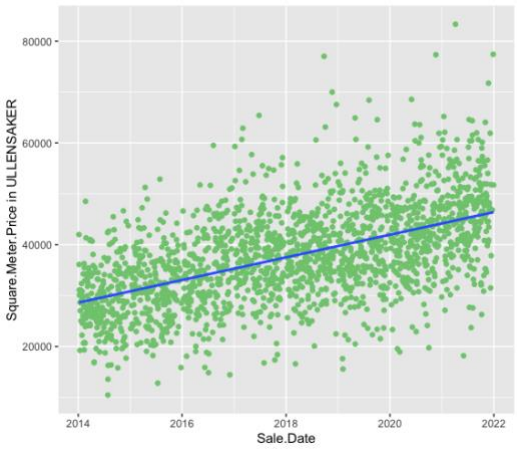
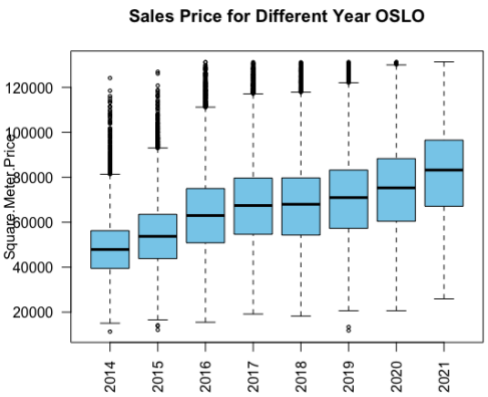


Tønsberg

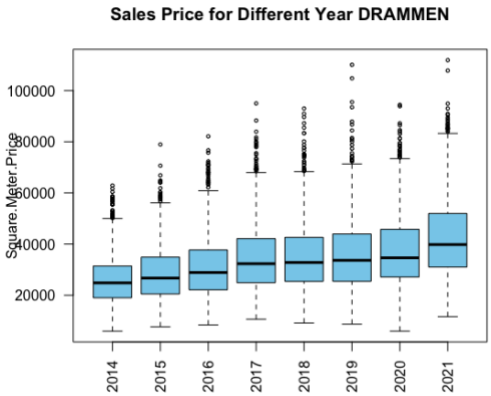


Ullensaker

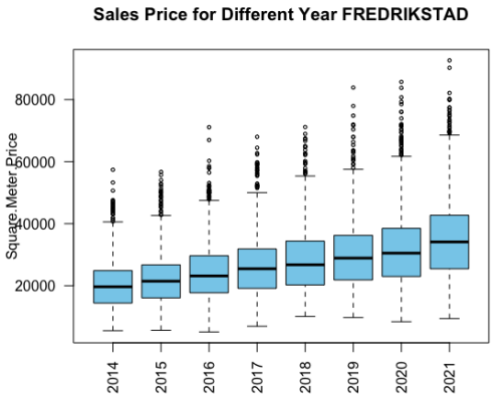
***Appendix 2**: Square meter price for different years*



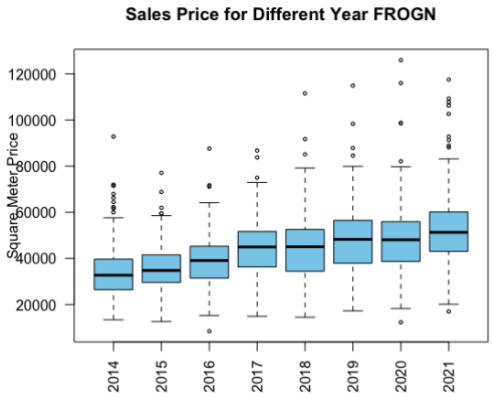
Oslo



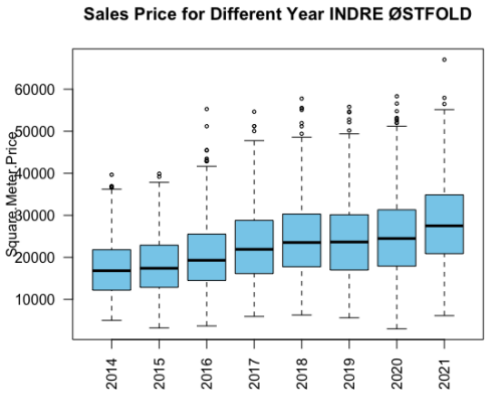
Drammen



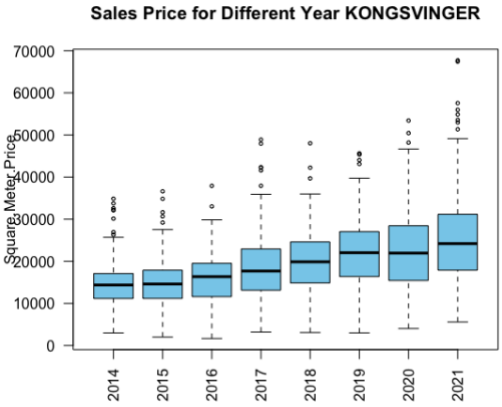
Fredrikstad



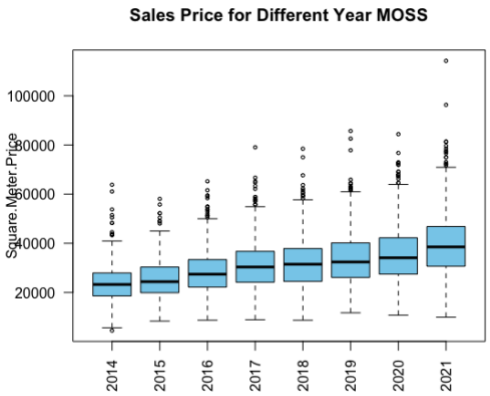
Frogn



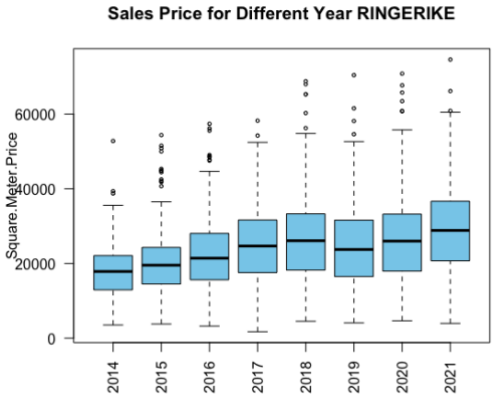
Indre Østfold



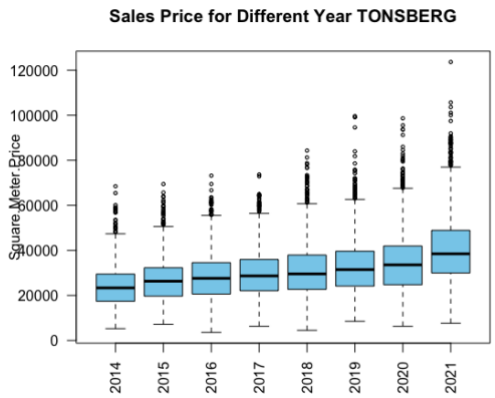
Kongsvinger

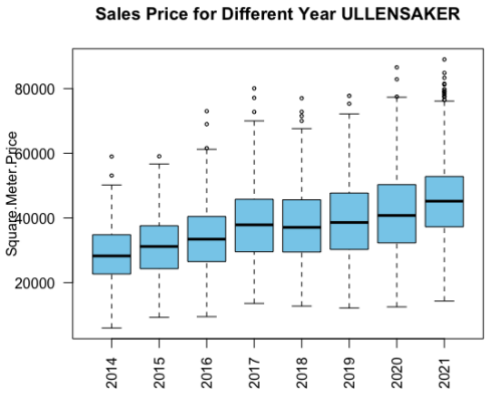


Moss



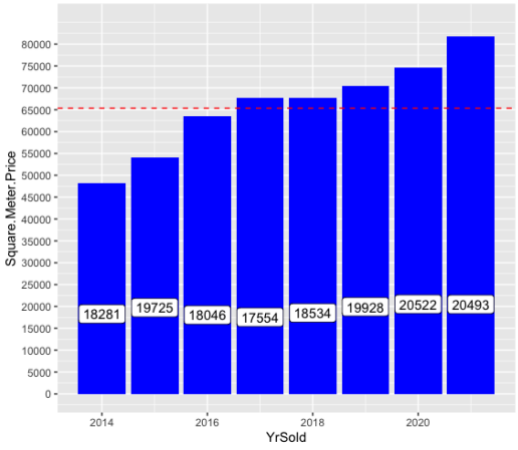
Ringerike

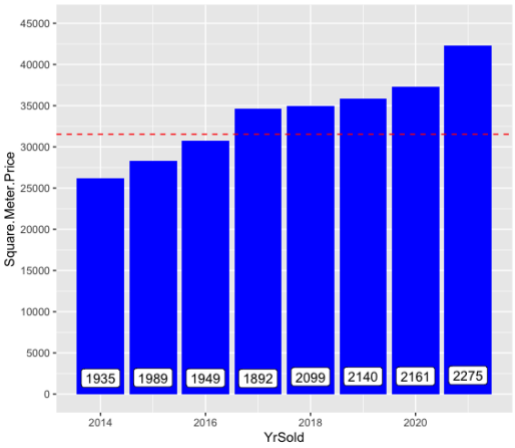




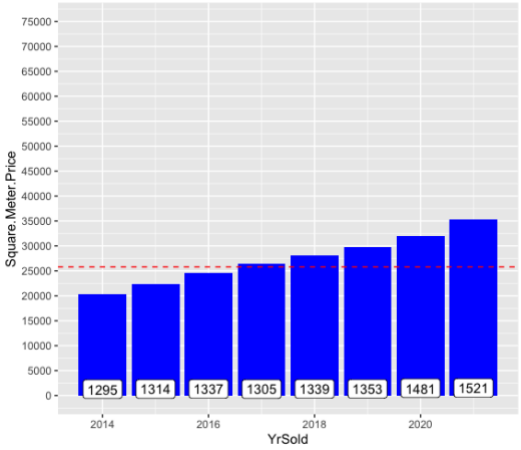
Tønsberg *Ullensaker*

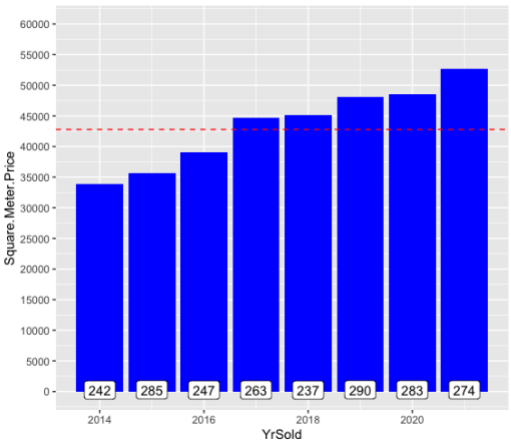
***Appendix 3**: Square meter price for 2014 to 2021 with the number of transactions per year. The dashed line is the median price for all years.*



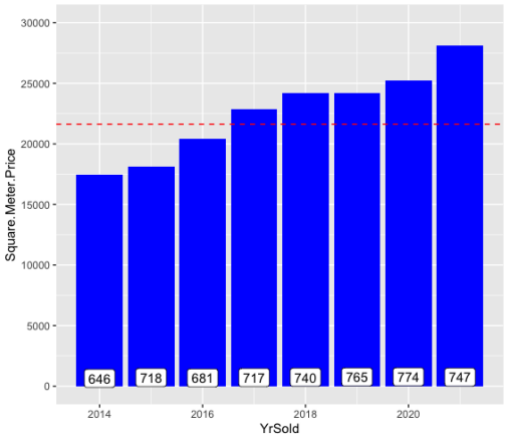


Oslo *Drammen*

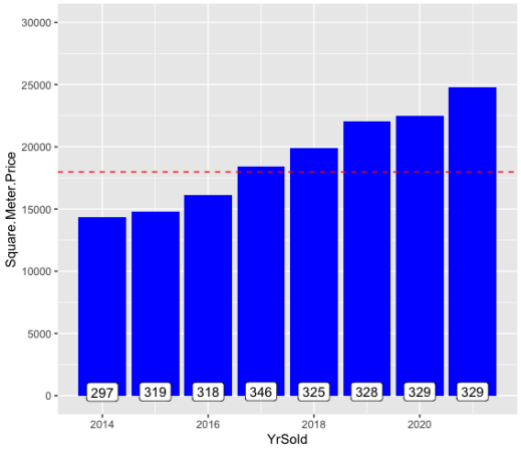




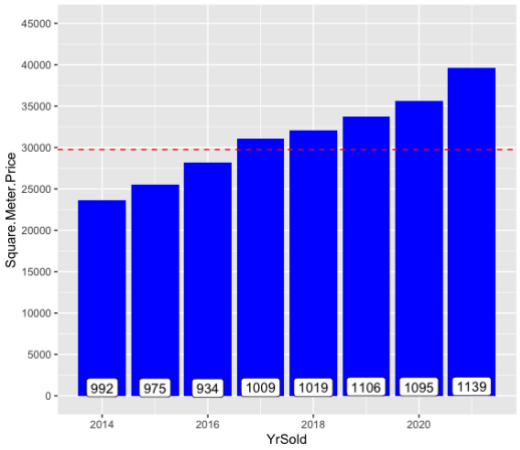
Fredrikstad *Frogn*



Indre Østfold



Kongsvinger



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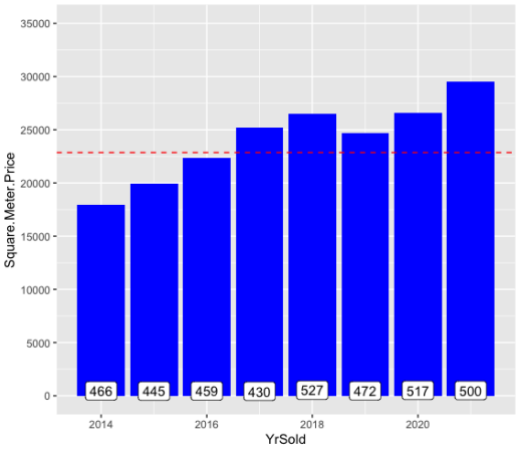

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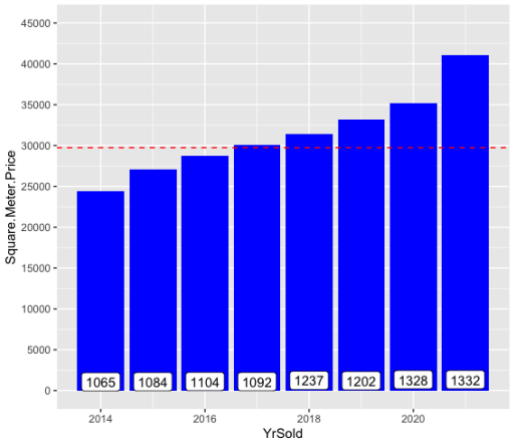
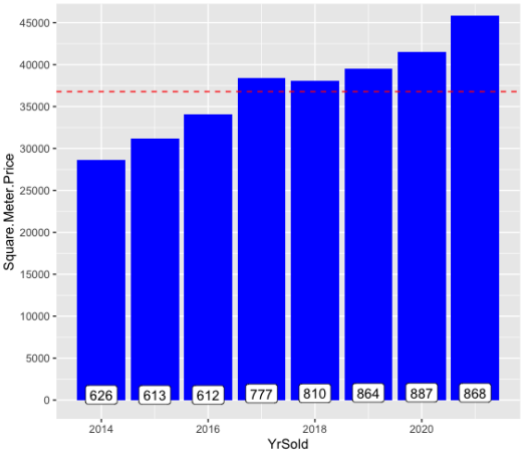
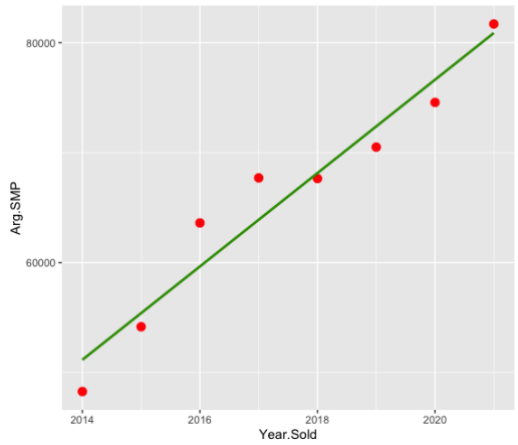


Tønsberg

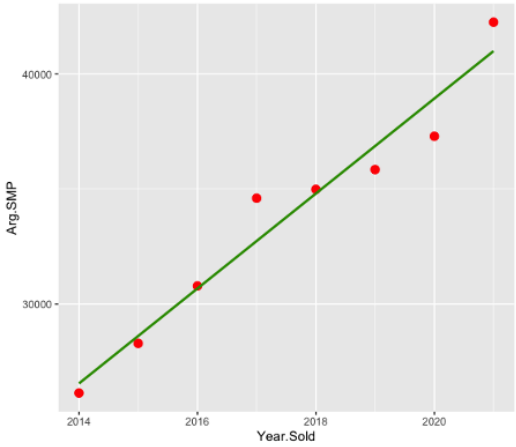


Ullensaker

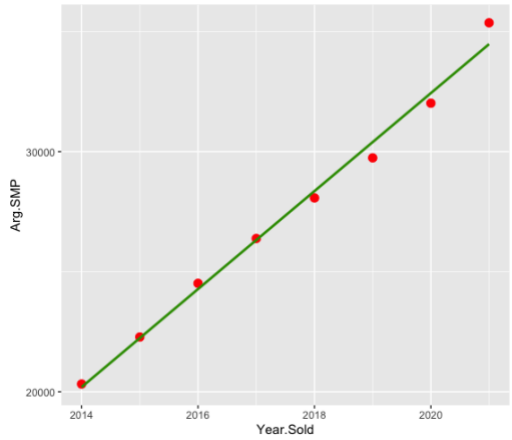
***Appendix 4**: Regressions for average square meter price*



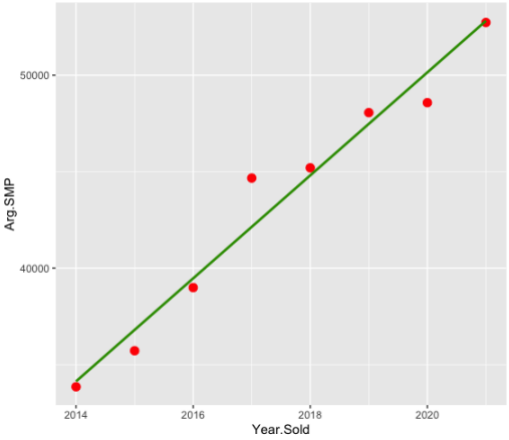
Oslo



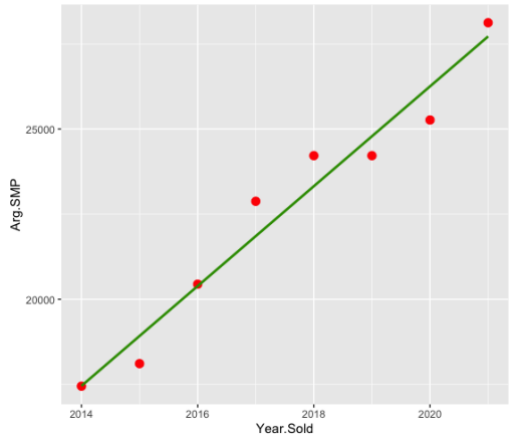
Drammen



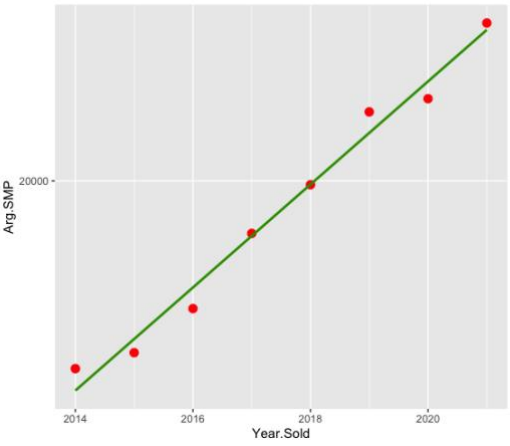
Fredrikstad



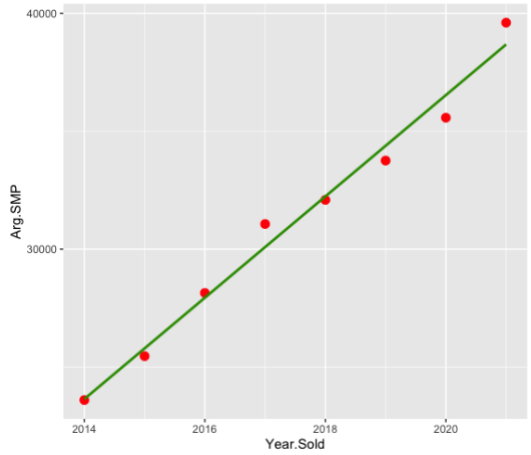
Frogn



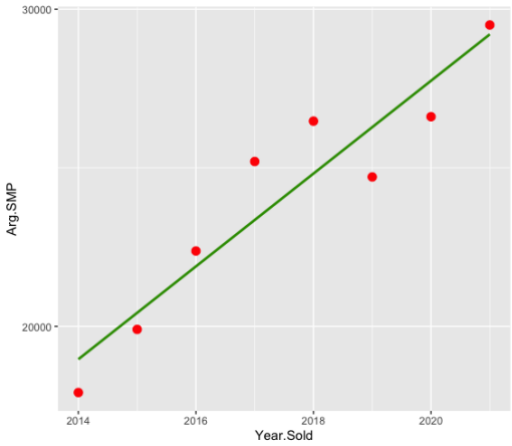
Indre Østfold



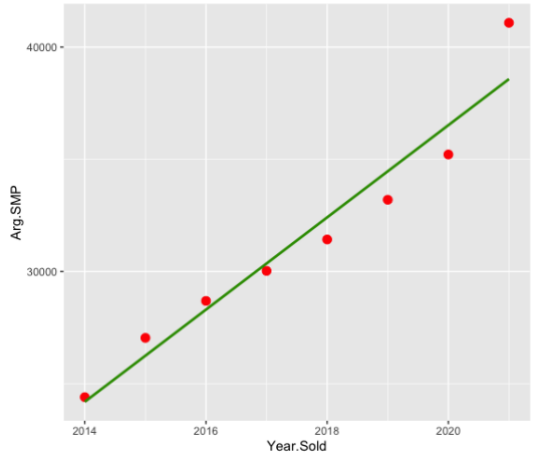
Kongsvinger



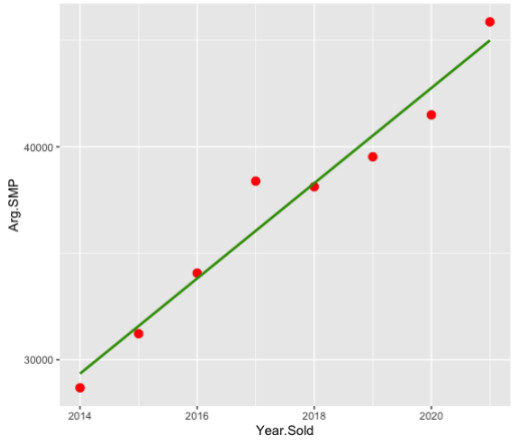
Moss



Ringerike



Tønsberg



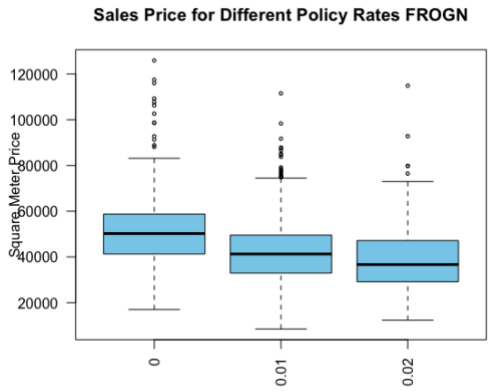
Ullensaker

***Appendix 5**: Square meter sales price for different policy rates*

Oslo

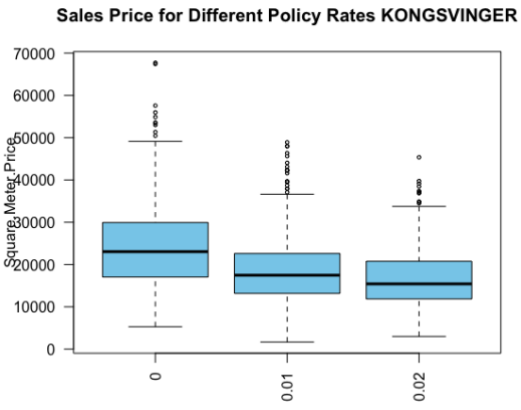
Drammen

Fredrikstad

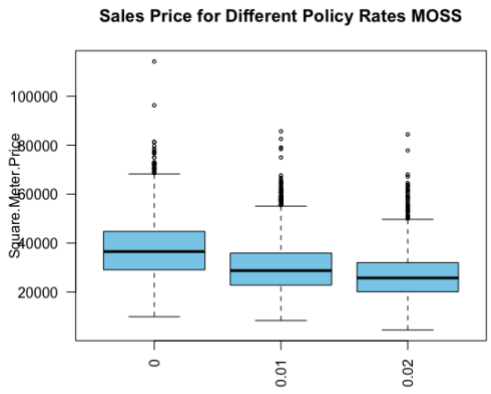


Frogn

Indre Østfold

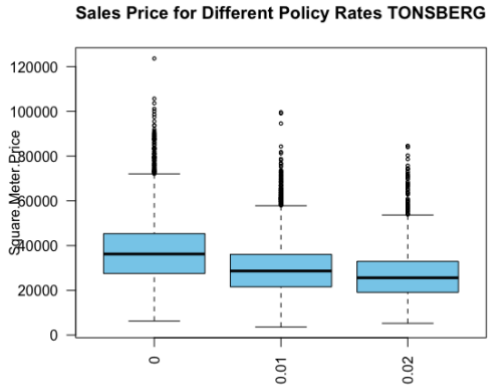


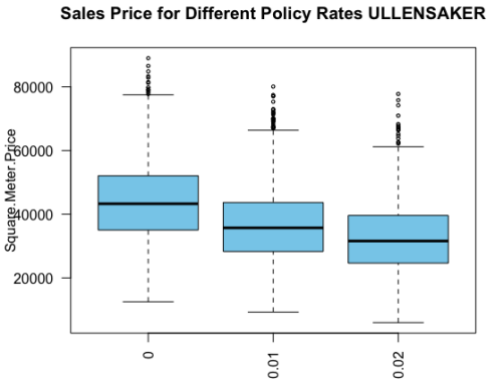
Kongsvinger



Moss

Ringerike





Tønsberg *Ullensaker*

***Appendix 6**: Results from the Excel model*

Oslo		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		5,01%	8,85%	11,18%	7,85%	8,77%	12,46%
Property Type	Apartment	5,16%	9,61%	11,26%	7,51%	9,40%	12,04%
	Small House	3,50%	7,30%	13,75%	20,11%	20,03%	17,02%
	Big House	18,64%	14,16%	12,42%	18,21%	0,86%	15,27%
Apartment Size	0-45 sqm	2,87%	6,76%	11,33%	7,79%	11,59%	16,27%
	46-85 sqm	5,51%	10,66%	14,22%	5,81%	9,09%	15,61%
	86+ sqm	5,17%	9,98%	10,42%	20,56%	21,61%	21,76%

Oslo - Inner East		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		2,00%	3,94%	14,31%	4,02%	6,17%	9,43%
Property Type	Apartment	1,81%	3,85%	14,14%	4,06%	6,33%	9,48%
	Small House	31,86%	40,15%	34,47%	-4,89%	9,02%	-2,91%
	Big House	11,46%	-25,84%	-5,28%	55,00%	64,60%	42,39%
Apartment Size	0-45 sqm	3,79%	6,63%	15,27%	4,76%	6,45%	9,98%
	46-85 sqm	3,02%	4,45%	14,11%	6,02%	9,39%	14,20%
	86+ sqm	1,72%	-4,89%	15,03%	5,40%	14,19%	17,59%

Oslo - Inner West		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		4,06%	3,41%	6,46%	3,94%	5,11%	12,20%
Property Type	Apartment	4,39%	3,70%	7,08%	4,15%	5,10%	12,31%
	Small House	84,00%	40,80%	-4,54%	1,55%	7,18%	3,04%
	Big House	-14,52%	-7,19%	-5,43%	-31,67%	5,69%	-11,73%
Apartment Size	0-45 sqm	6,61%	5,25%	4,37%	8,34%	14,59%	16,44%
	46-85 sqm	1,26%	2,67%	10,13%	3,12%	4,77%	10,46%
	86+ sqm	6,89%	7,69%	11,01%	8,72%	7,38%	18,06%

Oslo - Outer East		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		-0,09%	1,33%	8,79%	2,31%	4,04%	7,08%
Property Type	Apartment	-0,34%	2,84%	7,66%	1,28%	5,44%	5,78%
	Small House	1,06%	-3,77%	8,84%	20,81%	12,09%	10,33%
	Big House	-1,13%	15,98%	25,89%	26,03%	41,70%	37,50%
Apartment Size	0-45 sqm	3,54%	1,17%	8,39%	5,69%	22,00%	12,67%
	46-85 sqm	-1,24%	4,25%	14,56%	-0,22%	0,03%	5,61%
	86+ sqm	14,94%	6,70%	20,67%	2,31%	24,07%	10,05%

Oslo - Outer South		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		-0,30%	1,92%	13,01%	1,69%	0,93%	8,53%
Property Type	Apartment	-1,37%	3,09%	12,72%	0,21%	2,02%	8,61%
	Small House	9,07%	6,49%	17,95%	13,32%	-2,69%	9,81%
	Big House	15,43%	8,41%	28,46%	3,19%	-5,13%	2,13%
Apartment Size	0-45 sqm	-8,83%	-5,89%	12,14%	7,26%	12,26%	20,24%
	46-85 sqm	0,61%	4,02%	14,12%	2,10%	3,54%	12,60%
	86+ sqm	2,99%	2,69%	20,49%	5,94%	5,38%	9,64%

Oslo - Outer West		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		0,21%	0,61%	1,31%	0,01%	2,73%	10,68%
Property Type	Apartment	1,62%	2,93%	2,02%	0,55%	3,08%	8,86%
	Small House	-0,08%	-7,32%	-3,58%	0,69%	3,52%	12,39%
	Big House	2,08%	8,85%	2,81%	9,38%	9,43%	22,14%
Apartment Size	0-45 sqm	5,27%	0,57%	3,19%	6,14%	15,30%	24,44%
	46-85 sqm	3,00%	4,12%	6,31%	1,39%	1,59%	9,00%
	86+ sqm	1,88%	3,95%	-0,02%	-0,43%	3,39%	7,29%

Drammen		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		-9,96%	2,83%	8,24%	1,35%	1,19%	10,53%
Property Type	Apartment	-6,26%	-3,14%	4,39%	4,15%	1,32%	14,37%
	Small House	9,21%	13,44%	16,81%	6,65%	4,36%	3,27%
	Big House	4,27%	12,84%	13,33%	18,62%	6,22%	9,56%
Apartment Size	0-45 sqm	-15,05%	13,97%	15,22%	23,58%	7,35%	23,25%
	46-85 sqm	-1,93%	-0,76%	2,41%	1,78%	2,77%	9,89%
	86+ sqm	-14,06%	-15,72%	4,68%	-1,41%	5,31%	12,98%

Fredrikstad		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		1,54%	3,53%	17,01%	0,58%	-1,46%	-5,41%
Property Type	Apartment	10,55%	9,06%	27,29%	11,39%	6,16%	2,50%
	Small House	2,18%	-6,52%	16,08%	-7,57%	-8,05%	-9,57%
	Big House	0,37%	9,33%	-1,07%	25,02%	16,50%	10,45%
Apartment Size	0-45 sqm	13,15%	52,52%	4,07%	-33,32%	-28,68%	-5,46%
	46-85 sqm	13,29%	16,08%	13,81%	17,01%	7,27%	-1,17%
	86+ sqm	5,35%	21,37%	18,62%	42,34%	35,86%	28,35%

Frogn		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		-5,78%	0,69%	1,11%	24,99%	14,38%	11,08%
Property Type	Apartment	3,63%	-4,88%	0,73%	16,49%	24,71%	26,79%
	Small House	1,48%	-27,97%	-6,77%	21,08%	-0,59%	-2,74%
	Big House	-1,21%	-10,28%	2,09%	54,08%	30,45%	21,77%
Apartment Size	0-45 sqm	-27,76%	-1,44%	-9,93%	4,71%	3,16%	-0,93%
	46-85 sqm	12,78%	13,55%	20,95%	8,66%	22,78%	7,25%
	86+ sqm	4,64%	-17,35%	-8,12%	12,15%	24,76%	10,05%

Indre Østfold		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		-7,42%	-0,89%	20,96%	13,86%	17,11%	45,05%
Property Type	Apartment	-7,64%	2,62%	31,50%	11,18%	14,81%	27,87%
	Small House	-8,14%	-18,04%	11,81%	21,41%	8,90%	22,80%
	Big House	-9,29%	1,43%	1,82%	13,70%	29,36%	47,67%
Apartment Size	0-45 sqm	-	59,06%	59,97%	51,40%	-32,58%	-10,09%
	46-85 sqm	-13,61%	-16,67%	11,74%	24,79%	22,78%	19,27%
	86+ sqm	-18,67%	14,05%	26,15%	-47,85%	-36,32%	-40,34%

Kongsvinger		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		-2,39%	-12,54%	9,27%	-5,92%	-6,42%	7,36%
Property Type	Apartment	22,67%	16,41%	6,63%	5,02%	2,66%	3,22%
	Small House	-26,72%	-9,62%	10,20%	-10,60%	-37,26%	-0,27%
	Big House	6,50%	4,82%	55,29%	183,79%	147,05%	220,63%
Apartment Size	0-45 sqm	43,16%	35,09%	43,24%	-	-	-27,53%
	46-85 sqm	7,80%	-5,51%	0,91%	10,34%	5,53%	19,77%
	86+ sqm	4,82%	152,19%	7,74%	24,38%	-22,32%	8,92%

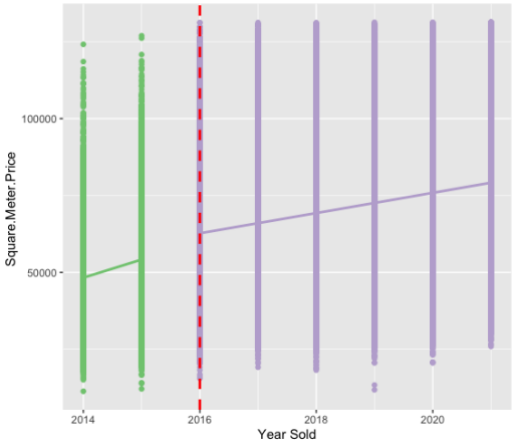
Moss		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		-7,47%	-5,67%	-1,39%	6,32%	3,57%	13,81%
Property Type	Apartment	0,49%	7,99%	4,74%	3,09%	-4,51%	-0,61%
	Small House	-9,95%	-19,79%	-15,35%	4,64%	18,97%	11,16%
	Big House	-14,03%	-15,74%	-5,71%	23,60%	10,89%	22,47%
Apartment Size	0-45 sqm	1,09%	16,56%	23,50%	-0,24%	-13,01%	-3,65%
	46-85 sqm	-1,48%	0,04%	4,83%	2,05%	0,16%	1,41%
	86+ sqm	-20,09%	15,55%	-0,04%	42,59%	3,68%	16,84%

Ringerike		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		7,30%	-7,69%	8,90%	2,35%	10,50%	12,80%
Property Type	Apartment	-1,14%	-21,79%	-13,32%	-14,68%	9,79%	-11,40%
	Small House	-12,07%	27,13%	9,93%	5,59%	-3,69%	23,89%
	Big House	6,95%	-1,07%	25,79%	2,22%	8,76%	25,53%
Apartment Size	0-45 sqm	4,28%	-12,74%	21,58%	-5,56%	21,85%	-15,62%
	46-85 sqm	-1,42%	9,44%	-2,70%	-8,21%	14,00%	-4,39%
	86+ sqm	-3,42%	-11,40%	-1,37%	13,11%	27,73%	12,54%

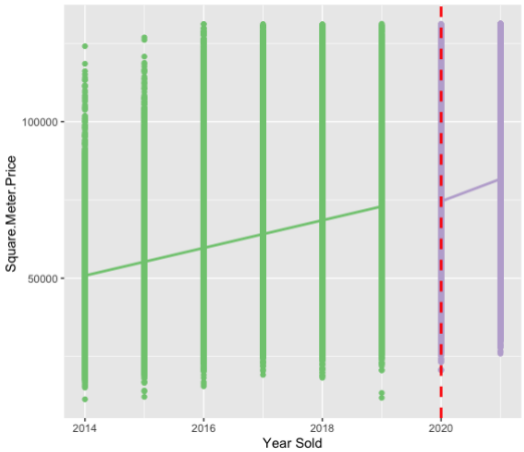
Tønsberg		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		-12,07%	2,71%	-5,64%	1,29%	7,93%	7,84%
Property Type	Apartment	-16,81%	2,19%	-1,87%	-0,48%	-4,10%	-3,40%
	Small House	-5,02%	5,39%	-2,53%	-3,86%	2,47%	-2,57%
	Big House	6,43%	-16,49%	-11,36%	5,56%	2,09%	8,00%
Apartment Size	0-45 sqm	-2,17%	8,50%	8,92%	6,47%	-9,16%	-5,60%
	46-85 sqm	-14,32%	3,28%	-5,15%	0,44%	0,62%	3,89%
	86+ sqm	-30,61%	0,37%	0,21%	-20,26%	-13,77%	-29,15%

Ullensaker		2015			2020		
		3M	6M	12M	3M	6M	12M
Total		-20,58%	-14,61%	-7,32%	7,06%	-0,18%	2,22%
Property Type	Apartment	-3,11%	4,70%	2,36%	5,24%	10,56%	4,59%
	Small House	1,14%	-5,91%	-3,13%	4,46%	-12,04%	-15,69%
	Big House	-30,89%	-20,22%	-18,10%	34,36%	14,61%	36,47%
Apartment Size	0-45 sqm	2,80%	-1,89%	0,39%	12,09%	23,62%	-7,78%
	46-85 sqm	1,40%	6,65%	0,90%	8,85%	6,22%	14,72%
	86+ sqm	11,39%	19,12%	32,36%	36,29%	13,07%	15,43%

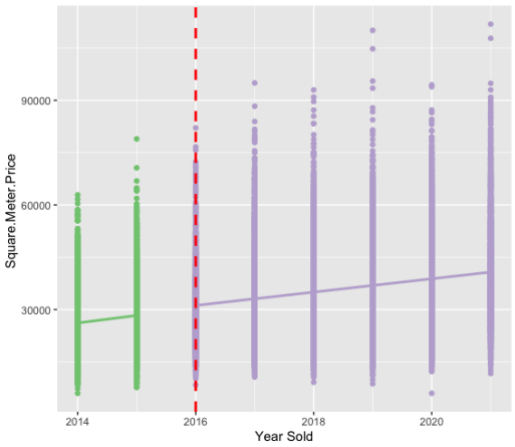
***Appendix 7**: Graphical representations for regression discontinuity design results*



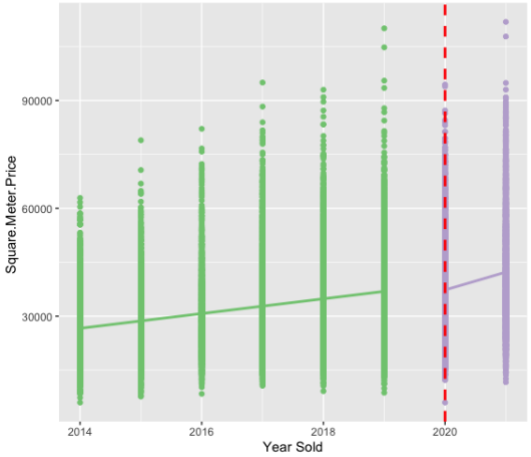
Oslo 2015



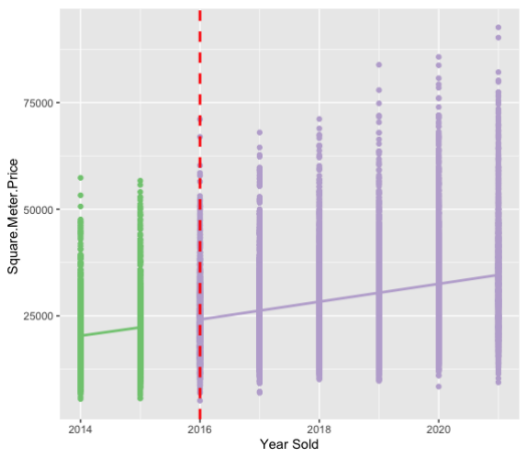
Oslo 2020



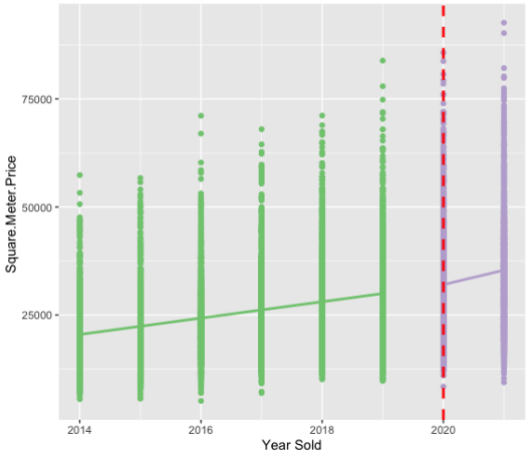
Drammen 2015



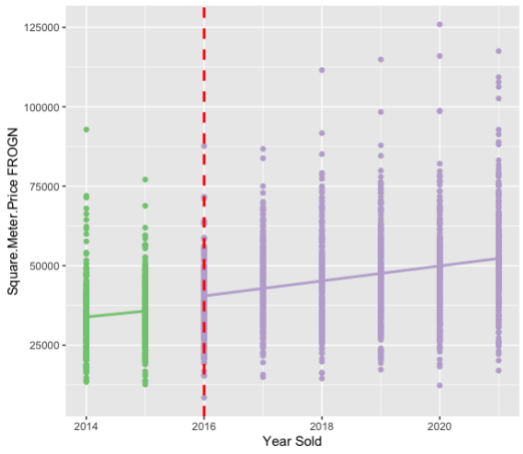
Drammen 2020



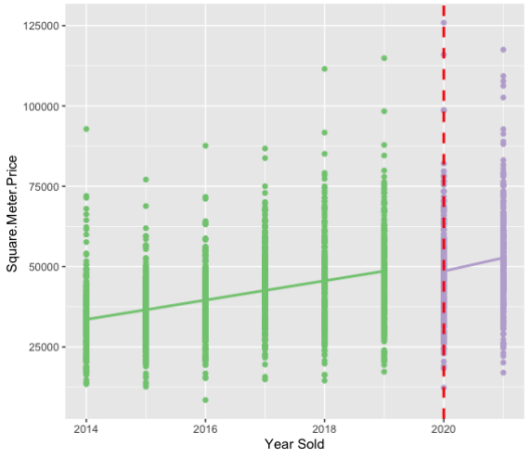
Fredrikstad 2015



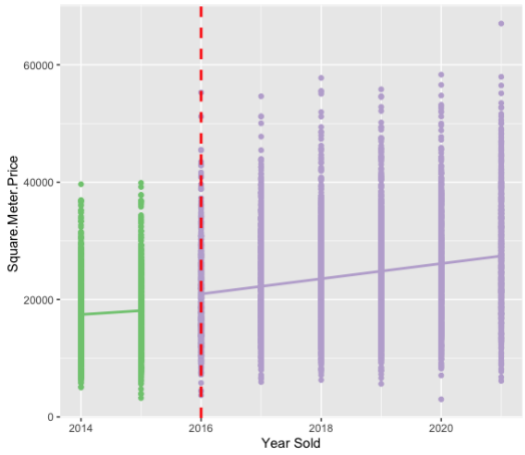
Fredrikstad 2020



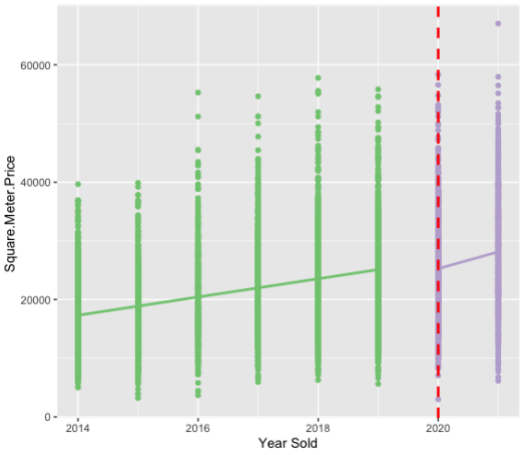
Frogn 2015



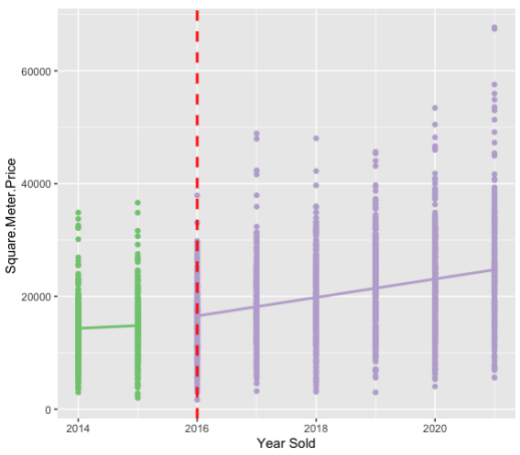
Frogn 2020



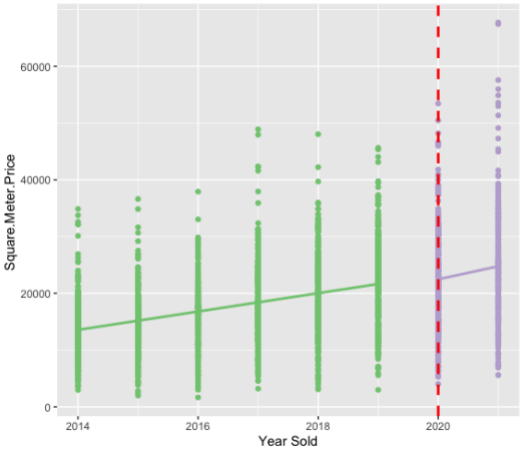
Indre Østfold 2015



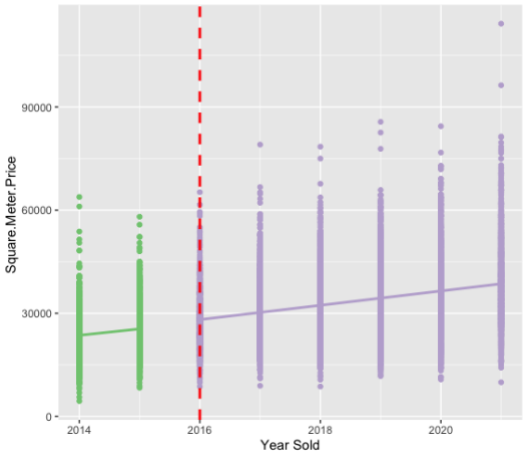
Indre Østfold 2020



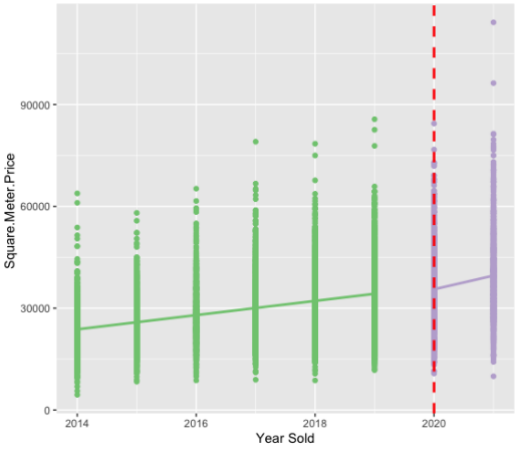
Kongsvinger 2015



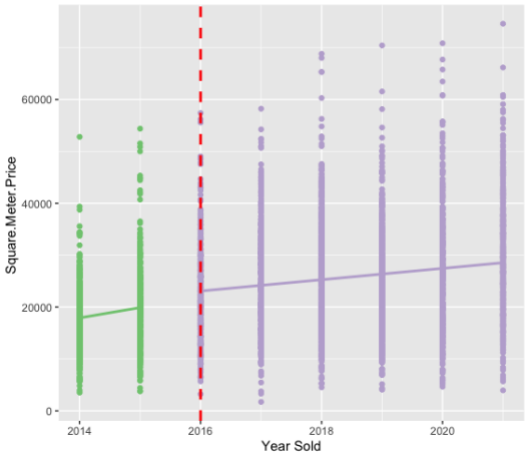
Kongsvinger 2020



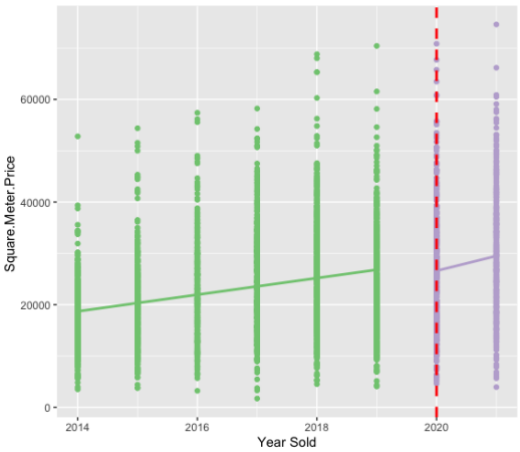
Moss 2015



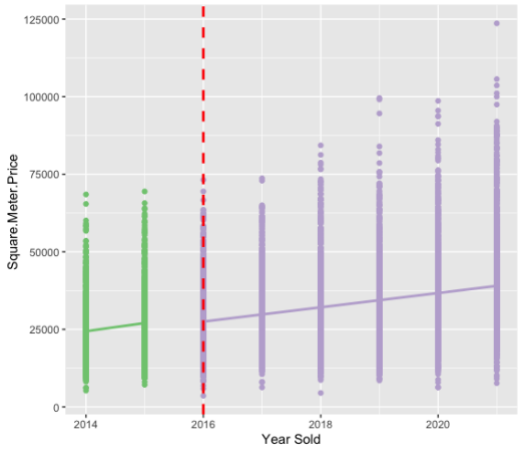
Moss 2020



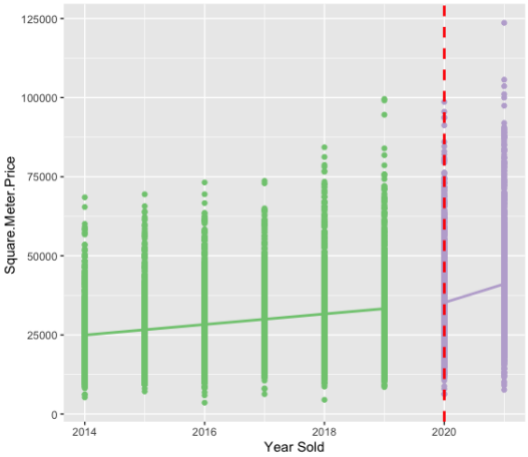
Ringerike 2015



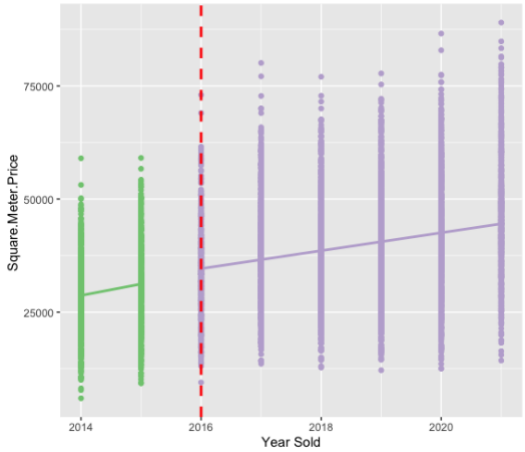
Ringerike 2020



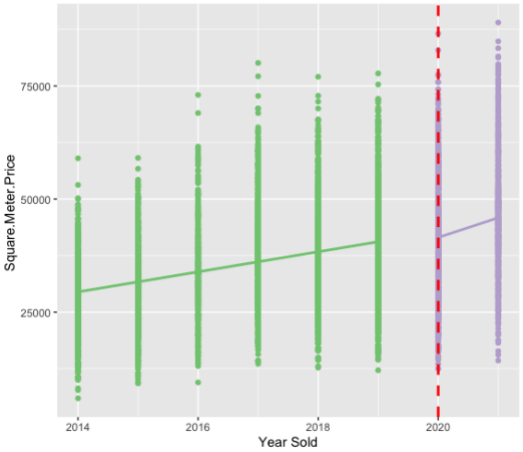
Tønsberg 2015



Tønsberg 2020



Ullensaker 2015



Ullensaker 2020

***Appendix 8**: Commute time to Oslo by public transport and car from Google Maps*

	Drammen	Fredrikstad	Frogn	Indre Østfold	Kongsvinger	Moss	Ringerike	Tønsberg	Ullensaker
Public transport	40 min	75 min	60 min	100 min	90 min	90 min	120 min	90 min	60 min
Car	40 min	75 min	35 min	55 min	90 min	70 min	105 min	75 min	30 min