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Investigating the Yield Rate of Office Real Estate in Oslo

A Vector Error Correction Approach

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This thesis is written as part of our masters degree in Financial Economics at the Norwegian School of Economics, and marks the end of our time at this institution. Writing this thesis has been highly educational, but also challenging at times. We knew early on we wanted to write about the real estate market, and ended up choosing the commercial office market, as this topic is, to our knowledge, less explored and perhaps specially relevant due to the effect of the pandemic. We hope that our thesis can contribute further to professional and academic research.

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Abstract

The yield rate of office real estate is little researched, yet it is an important figure for measuring rate of return. In this thesis, the drivers of the yield rate of office real estate in Oslo, Norway, has been investigated through the use of several relevant factors.

Using the Johansen framework for cointegration to determine the existence of long term relationships, we construct a vector error correction model to analyse the effects of both real estate factors and macroeconomic factors. This enables the possibility of investigating both short term and long term drivers. We asses the effect of monetary supply, real rate, consumer expectation and office supply on yield, based on Nowaks (2021) model for the yield office rate in Warsaw, Poland. We also construct an alternative model, using gdp, real rate and office supply.

Both models suggest a return to a long term equilibrium yield. The findings establish a connection of the real rate, consumer expectations, M2 and office supply to long run yield. In the short term, M2, consumer expectation and real rate are significant in explaining movements in the yield rate. The results do not indicate any significant effect due to the growth in GDP. We also find evidence of structural breaks in the yield rate, both from 2015, and from Q1 2020. Overall, our findings are in line with similar research conducted in other cities.

Keywords – Office, Yield, VECM

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1 Introduction

Commercial real estate has in later times been a popular and lucrative investment asset for institutional investors. Although there is some research internationally, there has been a lack of research into the drivers of the yield rate in Oslo, Norway. The lack of research gives uncertainty to the risk factors this asset class is exposed to. Regarding commercial real estate, the office segment is the one where the most previous analysis has been conducted, improving the availability of historical data. Therefore, we wish to investigate the following problem:

> *What are the macroeconomic drivers of the yield rate of office real estate in Oslo, Norway?*

This is, to the extent of our research, the first attempt to investigate the yield rate of offices in Oslo.

For the analysis, we will construct a dataset containing historical yields of office real estate in Oslo, office market variables, and macroeconomic variables. The data set is constructed from quarterly data. The initial reasonability of the model is ensured through investigating stationarity. Then the model is constructed by investigating cointegration through the Johansen test and estimating a vector error correction model (VECM). Finally, the validity of the results is tested.

A common issue of real estate research is the availability of data. Contracts regarding both rental and transactions are often confidential, hampering analysis. We solved this through getting access to yield data from Malling & Co and rental contract data from Arealstatistikk.

The main body of research into commercial real estate concerns investigating U.S. and U.K. markets. Hendershott et al. (2002); Hendershott and MacGregor (2005) introduced the adaptation of VECM to real estate. Nowak (2021) used the VECM to look at the yield rate of offices in Warsaw, Poland, which will be a main inspiration. A factor we include, which is not commonly used, is a measure of future expectation, inspired by the Jacobsen and Naug (2005) modelling of Norwegian house prices.

Based on previous research we have established two models. These models incorporate variables from the office market and macroeconomic factors. In our analysis, we uncover a long-term relationship between the yield rate of office real estate, money supply, consumer expectation and the real rate. There is also evidence that office yield has a trend reverting to an equilibrium. In the short term, the lags of the yield, future expectation and real rate are significant. We also find evidence supporting two structural breaks in the yield, in 2015 and 2020.

The rest of the thesis is structured as follows. Chapter 2 will give a brief overview of the market for office real estate in Oslo and walk through some potentially key drivers from the investor perspective. Chapter 3 will review and summarize a wide range of relevant literature in relation to general real estate, as well as commercial real estate. Both international and Norwegian literature will be reviewed. Chapter 4 will present our chosen methodology used to evaluate our hypothesis. Both the required methodology for building our model, as well as the tests for the validity of the model are included here. In chapter 5, the data used in the analysis will be introduced. Following, in chapter 6, the suitability of the variables will be evaluated regarding stationarity and the potential for spurious relationships. Chapter 7 to 10 present the results of the analysis for the chosen models, regarding both the long run and short run effects, as well as an investigation into the validity of the models will be presented. Chapter 11 contains our conclusion, as well as any identified weaknesses and potential for further research.

2 The Norwegian Market for Office Property

This section will first give a definition of yield. Then, a summary of historical events that have affected the commercial property market the last decades will be presented. Next, we are going to cover some important determinants on office yield. Lastly, advantages and risks regarding office investments will be presented.

2.1 Yield

Yield in the context of this thesis is net rental yield. Net rental yield is determined by the gross rental income I from the property, subtracted by the ordinary operating costs C, and divided by property value V

$$y = \frac{I - C}{V} \tag{2.1}$$

We also distinguish between normal and prime yield[1]. The normal yield used in this thesis is the average net rental yield in Lysaker and Helsfyr. Prime yield is the average net rental yield of the most expensive properties in the central business district of Oslo.

2.2 Historical View

To get a comprehensive picture of how the office yield has developed through the years, we will look at its development the last few decades.

At the start of 2000, the economy was coming off a period of low unemployment, strong wage growth and several new top office rentals were registered. Prime yield was 7.5 % and normal yield 8.75 %. In this period, the policy rate in Norway was 5.5 %. Then a recession internationally caused by the "dot-com" crisis hit the economy. This contributed to the interest rate level in Norway becoming relatively high, which in turn led to the strengthening of NOK (Benedictow, 2005). As the currency strengthened, Norwegian goods became more expensive on the world market. As the "dot-com" crisis was happening, the Norwegian industry was hit very hard and the unemployment and office vacancy rate increased significantly. Consequently, the policy rate was lowered from 7 % in 2001 to 1.75 % in 2004. Prime and normal office yield declined consistently until 2007, reaching a

[1] See appendix A1 for full definitions

bottom of 5 % and 6,25 %, respectively. The developments of yields since 2005 can be seen in Figure 2.1[2].

Right before the financial crisis in 2008 the economy had recovered from the "dot-com" event, seeing increasing demand and employment levels (Benedictow, 2005). Simultaneously the office market was seeing new heights through record-setting rents. Office yields were growing steady from 2007 until 2009. However, as the financial crisis hit the Norwegian economy, the policy rate drastically fell from 5.2 % to 1.25 %, together with decreasing office yields. By mid-2010 the economy had stabilized along with the interest rate and yield. Expectations of increasing demand led to stable growth until reaching a peak in 2015, with record-setting transaction volumes in the real estate rental market. In 2015, the office market became affected by a decline in oil prices, especially from oil-related businesses. Consequently, vacancy rates grew, and employment declined. From 2016, the policy rate has been consistently below 1.5 %, driving GDP growth and low yield levels.

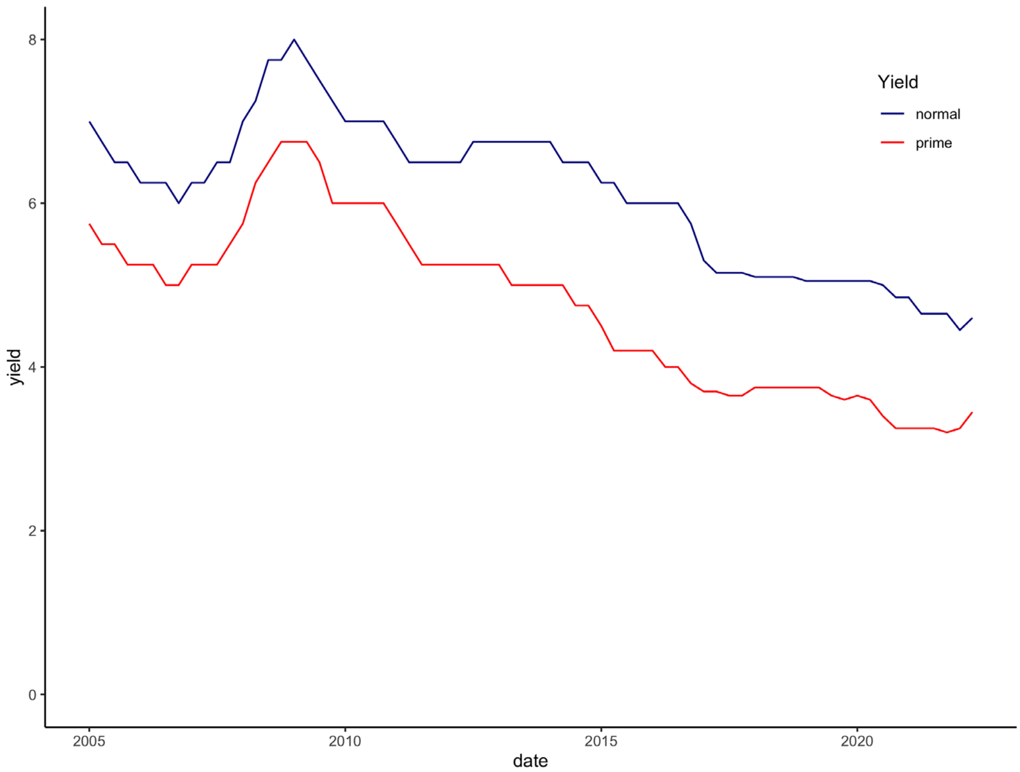

Figure 2.1: Historical development of yields

[2]Data provided from Malling & Co, see Chapter 5.1-2 for description

2.3 Determinants of Office Yield

Yield is used as a term of the relationship between rental income and property value. This gives an expression of the direct return of a property (Mortensen, 2022). The term is also used in pricing of a property ($rental\ income/yield = price$) and must be seen in context of the risk that the investment entails. Yield makes it easier to compare the price of a property with other properties in the same risk group. The yield term assumes no tax, perpetual rental income, static risk of the property and no loan costs. Therefore, it is vital to note that yield only shows a simplified reality, and property investments should look more in detail at the expected income and costs.

Yield is generally said to be affected by three elements, namely relevant substitutes, expectation of growth and risk (Mortensen, 2022).

2.3.1 Alternative Investment Classes

For commercial real estate, the alternative investment opportunities such as bonds, stocks and other investment instruments will affect how much investors are willing to pay for the cash flow from the property (Mortensen, 2022). The yield that is required from investors is naturally affected by what they can alternatively invest their capital in. The real rate is often regarded as the most relevant substitute when predicting yield (Sigmund Aas, personal communication, 17.11.2022). For instance, an increase in real interest rate will cause the yield requirement for property investors to increase, as the risk-adjusted return outside of commercial real estate has increased. Conversely, the yield requirement will decrease if alternative returns decline.

2.3.2 Expectation of Growth

Investors' expectations of future rental income are one of the most vital factors that influence yield (Sigmund Aas, personal communication, 17.11.2022). For instance, if investors speculate on higher rental income in the future, the willingness to pay increase due to expectations of increased rent from the property. The same principle can be applied to development property where the rental income may be low at the start of the investment. In such instances, it is normal to calculate a "market yield" in which a future market rent is used as opposed to the current rental income.

2.3.3 Risk

Risk is important in any investment analysis. Assuming that the market is well-functioning, an investor is willing to pay more for less risky investments (Mortensen, 2022). To compensate for risk, an investor will demand higher yield compared to a property that is considered to have low risk. For this reason, prime yield has historically been lower than normal yield. There is less idiosyncratic risk associated with offering office spaces in expensive and sought after areas compared to less attractive areas. The systematic risk will typically be lower in times with high activity in the economy where GDP and employment levels are high and demand for offices increases.

2.4 Financial Benefits of Investing in Office Real Estate

The last 20 years office yield has given high returns. Within this period, prime office has ranged from 7.5 % to 3.2 %, while normal office has ranged from 8.75 % to 4.6 %, gaining higher returns compared to investments such as stock dividends. While residential properties are normally held on short leases, commercial property leases usually are between 3 and 10 years, providing predictable income over a long time period (FNRP, 2020). Numbers from Oslo have the same indications, as seen in Figure 2.2, showing that newly signed contracts on average are approximately 4-5 years[3]. In addition, office real estate investments provide a security advantage. There is a stable demand for most commercial real estate properties, indicating a stable income source. In office real estate, one also has the opportunity to hedge risk by having a high number of tenants. Having many tenants will equate to less idiosyncratic risk since each tenant only makes up a percentage of the property's income. Consequently, potential vacancies will not cause a substantial income loss. The systematic risk, however, will remain. Furthermore, as most lease contracts are adjusted for increases in CPI, it offers a desired hedge against inflation (Ødegaard, 2022).

[3] Data from Arealstatistikk, Oslo average

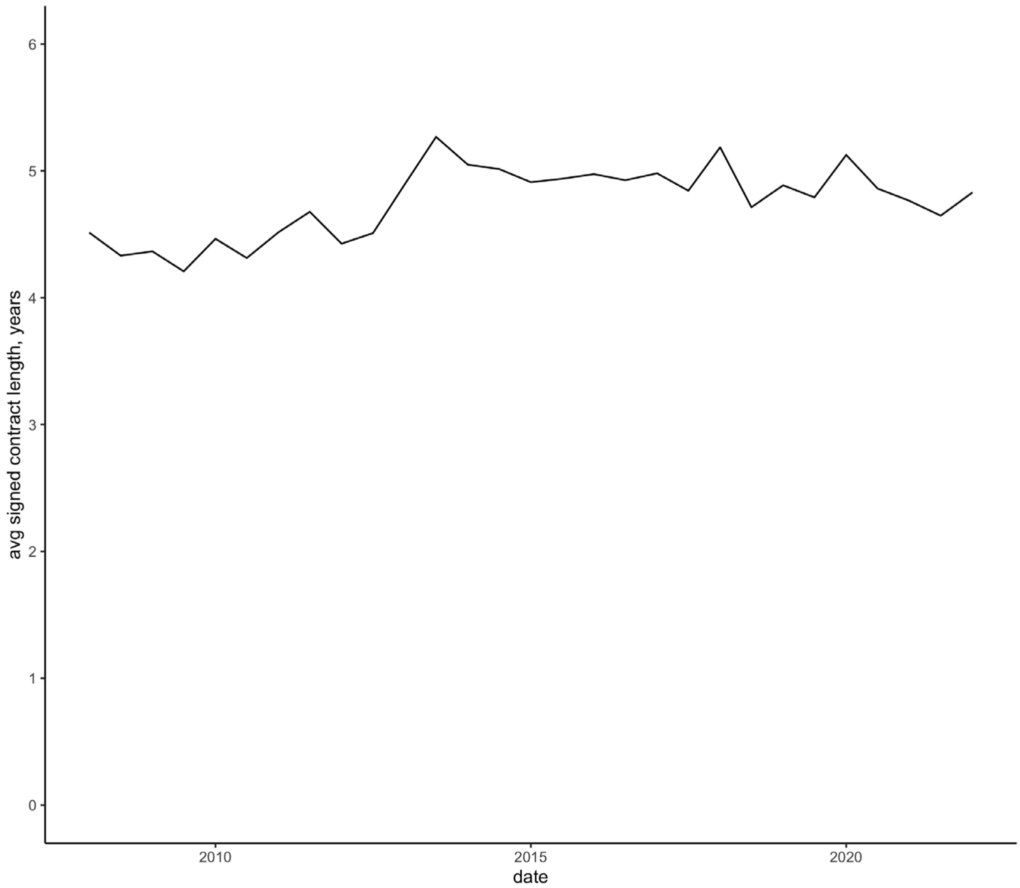

Figure 2.2: Average contract length of office rent, Oslo, years

2.5 Risks Associated with Office Real Estate

In relation to longer lease terms, office investments require a long horizon. The capital invested in the property will take a long time to pay off and generate profits, making the payback time long. Thus, the ability to rebalance the portfolio in the case of other investment opportunities occuring is limited, especially compared to the market liquidity of stocks and bonds. Additionally, leased property includes a risk that tenants will not be able to make timely lease payments (FNRP, 2020). Late payments can cause overall liquidity issues for the property owner, and the situation will be more critical if tenants go out of business. The risk of losing payments will be higher during recessions where unemployment rates are rising. Vacancy rates will also increase, and finding new tenants is challenging, which results in lower property valuation. The office market is also exposed to risks regarding local and federal tax rates and banking regulations. For instance, an increase in tax rate does not only affect the owner's taxable income, but also the tenants.

Changes in banking regulations could make it more expensive to borrow and finance new projects.

3 Literature Review

In our research, we have researched existing literature related to our main topic, the yield rate of office real estate in Oslo. First, there will be a review of relevant, international literature, then literature relevant for the Norwegian market for real estate. Lastly, a summary of the literature and a formulation and reasoning of the chosen models will follow.

A fundamental piece of literature for our research is an article by Nowak (2021) looking at the yield rate of the office market in Warsaw, Poland. He found that the yield rate was in both long run and short term determined by monetary supply (M2) and the exchange rate of Polish Zloty and Euro. The vacancy and interest rate seemed to have an effect in the long term. The models also introduced dummy variables to check for any effects due to the global financial crisis of 2008-2009 or the COVID-pandemic. These dummy variables did not have any statistically significant effect, although due to the recency of the pandemic it is hard to tell. He did, however, find evidence of structural breaks in the yield rate in 2010 and 2015.

Differing views have been put forward in relation to the significance of the effect of local market office indicators on the yield rate of office real estate. Sivitanidou and Sivitanides (1999), looked at several large US cities, and found a larger effect by local indicators than the impact of the national capital market. However, D'Argensio and Laurin (2018), by investigating a panel of 52 countries from 2002 to 2006, found opposite results, where the yield of government bonds were the main determinants. Local indicators also had an effect, but to a lesser extent. The work done by Sivitanides et al. (2003) discovered an influence by both interest rates and systematic market fundamentals on the yield rate of real estate assets.

Investigating the gap between government bond and real estate yields in the UK, US and Australia, Jones et al. (2015) found that this relationship is not stable. They found that especially the global financial crisis of 2008 affected this gap enough to establish a structural break. The Government bond yields became very low, while the yield on commercial real estate kept its level to a greater extent.

Balemi et al. (2021) argued the likelihood that the COVID-pandemic would affect the future of the office market. They focus on the potential of increased use of remote working, especially in cities with poorer public infrastructure. This would potentially lead to a lower demand for office space. On the other hand, space requirements related to social distancing rules may have a positive impact on the demand.

Hendershott et al. (2002) were, to the extent of our knowledge and research, the first to apply an ECM model to commercial real estate, to explain rent adjustments. Hendershott and MacGregor (2005) were then the first to apply the ECM approach in the study of the office and retail yield rates. Looking at the UK, they discovered, among other findings, a clear connection to the capital market. Peyton (2009) used ECM to determine relationships between yield rate of commercial real estate and four groups of factors: macroeconomic and interest rate fundamentals, credit risk pricing, investor risk aversion and commercial real estate performance. Findings indicated that in the short term, commercial real estate pricing was predicted by macroeconomic, financial market and real estate fundamental factors. Kohlert (2010), applying the ECM framework to the UK market for commercial real estate, used the variables GDP, total investment, and unemployment to explain the total return. Bruneau and Cherfouh (2018) used the ECM approach. They stated that risk-free interest rate, expected rental growth and money supply were the main factors influencing office yields.

There is, to the extent of our knowledge, a lack of research into the Norwegian Real Estate market. There has been more research into housing, and less into commercial real estate. Therefore, much of our basis will lie on foreign research, and apply this to Oslo. However, a summary of relevant research on Norway follows.

A much-cited paper by Jacobsen and Naug (2005) attempts to model the market for Norwegian housing prices. This research discovered that the main explanatory factors were interest rates, housing construction, household income and unemployment. They also included a variable attempting to consider the expectation of households of both their personal economy and the Norwegian economy, which had a positive relation on housing prices. Robstad (2018) researched the effect of monetary policy on, amongst other variables, housing prices. He found a large effect on the prices of residential real estate and argued that this is due to a low refinancing rate in Norway. This effect was also found by Roed Larsen (2018). Investigating the effect monetary policy had on the upswing of housing prices after the financial crisis of 2008-2009, he argues that monetary policy was a significant contributor to the recovery of these prices.

Regarding housing prices in Oslo, Krakstad and Oust (2015) found an overpricing of 35 % compared to their estimated equilibrium price. They found this using ratios of price-rent, price-construction cost and price-wage. Although not suggesting a bubble, they state an expectation for the housing prices to fall in order to return to a long-term equilibrium given by the ratios.

Looking at the drivers for sustainability in commercial real estate in the US, UK and Norway, Collins et al. (2018) found that company policies of sustainability have been a more significant driver of sustainable office spaces, rather than cost. This has changed the market for development of offices.

Much of the previously conducted research on commercial real estate in Norway is done by master theses. However, many of these mainly focus on the rent prices, and not the yield rate. Hvesser and Høvik (2017) found a positive effect of long rates and new build office area and a negative effect of unemployment on office rents. Utheim and Torgersen (2020) found a negative effect of the COVID-pandemic on the office rent in Oslo.

Regarding previous research, it seems that both market effects and macroeconomic effects seem to be factors determining the yield rate of commercial real estate, including office spaces. Investigating a structural break due to the COVID-pandemic is also deemed necessary, as well as the one found in 2015 by Nowak (2021). On basis of the previous research, the following models have been formulated, investigating the possible factors explaining the yield rate in Oslo:

Model 1: Vacancy rate, M2, Interest rate, Consumer expectations

Model 2: Interest rate, GDP, vacancy rate

The reasoning for the models is as follows. For Model 1, we base it mainly on the model described by Nowak (2021). The modification we add is the consumer expectation factor, inspired by Jacobsen and Naug (2005), as the future expectation of the economy is believed to play into valuations of real estate. For Model 2, the desire to investigate more traditional macroeconomic factors, GDP and the consumer price index was chosen. To account for market factors, the vacancy rate is included, as it should reflect a lot of market fundamentals related to the supply and demand of rental space.

In addition, we will include dummy variables for structural breaks in 2015 and 2020.

4 Methodology

The purpose of this section is to describe time-series techniques used to find the significance of our chosen independent variables on office yield. The thesis presents the method and theory necessary to examine this relationship.

4.1 Time Series Models

A simple time series analysis is based on an ordinary least-squared (OLS) regression. An OLS regression can be formulated as follows:

$$y = \beta_0 + \beta_1 x + \epsilon \tag{4.1}$$

The Gauss Markov theorem states that if 6 specific assumptions are met, the OLS estimate for the regression coefficients is the best linear unbiased estimate (BLUE) possible (Wooldrige, 2016, p. 89). BLUE estimator means that there are no other linear estimators that give a lower sample variance. Only assumption 1-4 are necessary for a consistent and unbiased model.

More specifically, the requirements are the following:

1. Linearity in parameters
2. Zero conditional mean
3. No perfect multicollinearity
4. Normality
5. Homoscedasticity
6. No autocorrelation

When studying an object over time it is essential to apply the principles of time-series analysis.

$$y_t = \beta_0 + \beta_1 x_t + \epsilon_t \tag{4.2}$$

Here, the dependent variable y at time t is regressed upon the independent variable x, also, at time t. The error term ϵ_t has a mean of 0, and a variance of σ^2. The mean and variance should not vary over time and should stay constant.

An important aspect of time series analysis is the fact that events in the past can affect the future, but the future cannot affect the past (Wooldrige, 2016, p. 313). Therefore, proper ordering of the variables and their respective effects need to be considered.

Important considerations for a time series are how the underlying assumptions evolve over time. The principle of stationarity will be discussed later, in Chapter 4.9.

4.2 Linearity

Linearity means that no parameter should be an exponent, nor divided or multiplied by another parameter. For example, if an equation of the model includes two explanatory variables that are multiplied. A violation of this could lead the model to predict the data poorly (Mueller, 2017).

4.3 Normality

An assumption in statistical analysis is the assumption of a normally distributed error term.

The error term ϵ_i is independent of x_i, meaning

$$E(\epsilon|x_1, ..., x_k) = E(\epsilon) = 0 \tag{4.3}$$

and

$$Var(\epsilon) = \sigma^2 \tag{4.4}$$

As graphical analysis of the error term can be difficult, a formal test for normality is required for more conclusive evidence of normality (Razali and Wah, 2011). As they found, the Shaprio-Wilk test is the most powerful when testing normality. When testing for multivariate normality, such as for a VECM, the Jarque-Bera test by Urzua (1996) has been found to be efficient.

4.4 Serial Correlation

Serial correlation is when the error terms are correlated across time. This is a violation to the OLS assumption which requires zero covariance between error terms (Wooldrige, 2016, p. 339). Correlation between error terms may entail an over- or underestimation of the variance of the residuals. This could affect the test statistic as the standard error becomes biased and could lead to a wrong conclusion about the significance of the variable (Wooldrige, 2016, p. 373). Serial correlation occurs from omitting an important variable, functional misspecification, or a measurement error in the independent variable. Serial correlation often causes an understatement of the significance of a variable, which in turn often leads the model to believe that the variables are more significant than what is true.

It is possible to detect serial correlation through a graphic assessment. There are three possible types of scenarios when looking visually at the error terms across time. Either an error of a given sign is followed by an error of the the same sign, or an error of a given sign is followed by an error of the opposite sign. The former is called positive serial correlation, while the latter is known as negative serial correlation. If no pattern exists, there is no serial correlation. Realistically, it is challenging to see graphically whether serial correlation is present or not. Therefore, more formal tests are necessary.

4.4.1 Formal Tests for Serial Correlation

In the following paragraphs, formal tests for serial correlation will be introduced. Two common tests for testing serial correlation are the Durbin-Watson (DW) test and the Breusch-Godfrey (BG) test.

4.4.1.1 Durbin-Watson

The DW test only checks whether there is autocorrelation at lag 1 and is sufficient if autocorrelations beyond order 1 are ruled out (Wooldrige, 2016, p. 378). Hence, the null and alternative hypothesis are:

$$H_0 : No\ first - order\ serial\ correlationexists$$

$$H_1 : First - order\ serial\ correlation\ exists$$

The test statistic is expressed by the following equation:

$$d = \frac{\sum_{t=2}^{n}(\hat{u} - \hat{u}_{t-1})^2}{\sum_{t=1}^{n}\hat{u}_t^2} \tag{4.5}$$

The test statistic requires that the OLS assumptions are fulfilled, and it returns numbers ranging from 0 to 4. A test statistic above 2 indicates negative autocorrelation, while a number below 2 suggests positive autocorrelation. A test result between 1,5 and 2,5 is generally regarded as no autocorrelation.

4.4.1.2 Breusch-Godfrey

While the DW test only tests autocorrelations from the previous period, the BG test looks at all autocorrelations up to lag h. In contrast to Durbin-Watson, The Breusch-Godfrey test does not require strictly exogenous independent variables (Wooldrige, 2016, p. 381). It will provide an alternative test if the independent variable correlates with the error term from the previous period. The general hypothesis can be expressed as:

$$H_0 : No\ serial\ correlation\ of\ any\ order\ up\ to\ p\ exists$$
$$H_1 : The\ error\ term\ follows\ an\ AR(p)\ or MA(p)\ process$$

The test statistic is:

$$LM = (n-p)R_{\hat{u}}^2 \tag{4.6}$$

The test statistic is based on the chi-squared distribution. The null hypothesis of is rejected if the test statistic exceeds the chi-squared critical value.

4.5 Homoscedasticity

A key assumption in linear regression is the assumption of homoscedasticity, where the variance of the error-term ϵ remains constant among the independent variables (Wooldrige, 2016, p. 243). The model can be said to be suffering from heteroscedasticity when the variance of the error-term changes. When a model is suffering from heteroscedasticity, the results of t-tests and F-tests will be susceptible to a wrong estimate of the variance of the population. Both graphical analysis of the residuals, as well as formal tests, can be used to uncover heteroscedasticity.

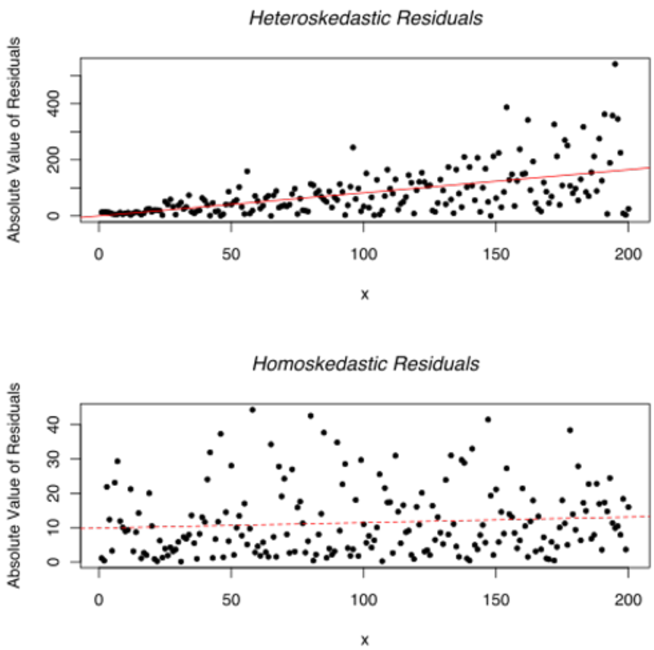

Figure 4.1: Heteroscedastic and Homoscedastic Residuals

4.5.1 Formal Tests

There are multiple ways to test for homoscedasticity. Different tests have unique methods of testing whether the variance of the error term remains constant over time. In this paper, we are going to use the common Breusch-Pagan (BP) test. The BP tests for homoscedasticity in linear regression models.

The first step of the test is to estimate the unknown parameters in the regression shown below. The next step is to estimate the squared residual on the independent variable as seen in equation x

$$y_t = \beta_0 + \beta_1 x_1 + \epsilon \tag{4.7}$$

$$\hat{u}_t^2 = \delta_0 + \delta_1 x_t 1 + ... + \delta_k x_t k + v \tag{4.8}$$

Next, the test statistic for the BP is calculated. This can be done through a F-statistic or a Lagrange multiplier. The F-statistic is the method of choice in our case, and it is calculated from the following expression:

$$\frac{R^2_{\hat{u}^2}/k}{((1 - R^2_{\hat{u}^2})/(n - k - 1))} \tag{4.9}$$

The F-distribution is used to find the rejection value. The null hypothesis of homoscedasticity present is rejected if the p-value is small, which then indicates heteroscedasticity.

4.6 No Perfect Multicollinearity

Multicollinearity occurs when there is a correlation between two or more independent variables. One typically distinguishes between perfect and strong correlations among the variables (Wooldrige, 2016, p. 83). Strong multicollinearity is when the independent variables are strongly correlated. Consequently, the precision of the coefficient's estimates will suffer due to higher variance among the coefficients. However, detecting perfect multicollinearity is more critical. Luckily in our case, this is not an issue as R will not continue its estimates if this is the case.

4.7 Zero Conditional Mean

This assumption refers to the condition that no independent variables should correlate with the error term for all time periods (Wooldrige, 2016, p. 92). Equation 4.10 formalizes this. It is important to have zero conditional mean since the sample parameter will not be equal to the population parameter.

$$E(u_t|X) = 0 \tag{4.10}$$

Zero conditional mean occurs for three reasons. Firstly, a violation of the assumption can be because of an omitted variable bias. If the model fails to include an important variable, the results attribute the effects of the missing variables to those that were included. Hence, the significance of the missing variables transfers to the included ones. Furthermore, a violation of zero conditional mean could stem from reverse causality. This occurs when you think that X affects Y, but it is the opposite. Lastly, measurement errors will lead to a violation of the condition. For instance, if one variable has a measure error, the model will likely not pick up a relationship at all.

4.8 Stationarity

Stationarity is required for time series analysis, as there is a need for the assumption that variables are stable over time (Wooldrige, 2016). This is to avoid spurious relationships, where two time series correlate due to a similar trend or through random walk. In theory, strict stationarity is required, and is defined by (Wooldrige, 2016, p. 345) as:

> A stationary time series process is one whose probability distributions are stable over time in the following sense: If we take any collection of random variables in the sequence and then shift that sequence ahead h time periods, the joint probability distribution must remain unchanged

This strict interpretation of stationarity is somewhat restrictive, and in practice a weaker form is often deemed as sufficient. This weaker form is viewed as the time series having a constant mean and variance over time

Non-stationarity is common amongst many economic measures, as they typically contain trends, cycles or random walks, and combinations of these. Including economic measures affected by these non-stationary issues in a statistical model will tend to wrongly estimate the future mean and variance of the model, due to changing mean or variance over time.

Most trends tend to be either deterministic or stochastic. The main difference between these types of trends is the effect of shocks. Deterministic trends revert towards the mean, and the effect of the shock on the time series vanishes with time. Due to this nature of deterministic trends, the trend can be estimated, and the variable de-trended. This enables a deterministic trend to be included as stationary, if an appropriate time trend is included (Wooldrige, 2016, p. 348). As a stochastic trend is conversely permanently altered by the shock. This implies that the trend does not revert to the mean. This makes prediction of future values difficult, as there is no long-term trend. However, a stochastic trend can be transformed to a stationary process through differencing.

A stochastic time series is said to be integrated of order n, denoted by $I(d)$, with the d being the unit root of the series and indicates how many times the time series needs to be differenced before the time series becomes stationary.

There are several ways to test for unit roots in a time series, most commonly used are the Augmented Dickey-Fuller test (ADF) and Phillips-Perron test (PP). These are both based on the first-order autoregressive process:

$$y_t = \phi y_{t-1} + \epsilon_t \tag{4.11}$$

where ϕ is the autoregressive parameter, and is the parameter evaluated by these tests. The test can be formulated as:

$$H_0: \ \phi = 1 \tag{4.12}$$

$$H_1: \ |\phi| < 1 \tag{4.13}$$

The null-hypothesis suggests a random-walk process. Should the absolute value of the autoregressive parameter ϕ be more than 1, the process would be an explosive time series, and not a unit root time series.

4.9 Cointegration

Non-stationary can be solved by differencing variables until they become stationary. However, differencing variables could limit the scope of the questions that we can answer. A regression with first-differenced variables will show how a variable reacts when another changes, i.e., the regression will show the short-run relationship between the variables. But differencing might be an issue as it could ignore a potential long-run relationship. If we have two variables that converge to an equilibrium in the long run, the changes in the variables would be zero after having converged to equilibrium. Therefore, using a first-difference equation, all terms would equal zero, and the long-run relationship will not be modeled. Here, the cointegration process could be applied.

Variables are cointegrated if a linear combination of them produces a stationary time series. If you have two variables, both unit roots, that revert toward each other in the long run, we have a cointegration process (Wooldrige, 2016, p. 580). Even though they periodically deviate, they eventually revert to the long-term stochastic trend. For instance, the distance between them remains constant or keeps increasing. Consequently, if two variables are cointegrated, we can predict the trend, and cointegration is preferred over differencing.

Cointegration captures both short and long-term relationships, while dealing with spurious regression. A cointegration relationship can be exemplified by three variables x, y and z all integrated of order one. The variables are said to be cointegrated if there exists a linear combination of $ax + by + cz$ that is stationary (Wooldrige, 2016, p. 580).

There are many ways to test for cointegration. In this paper, we are using the Johansen test, which is less restrictive than Engle and Granger, another common test. This is because the Johansen test allows for multiple variables and cointegration relationships (Gerald, 2015, p.2).

$$H_0 : \ number \ of \ cointegrating \ vectors \ <= r \tag{4.14}$$

$$H_1 : \ number \ of \ cointegrating \ vectors \ > r \tag{4.15}$$

r stands for the number of cointegrated vectors. The null hypothesis is rejected if there are more cointegrated vectors than r. For instance, if $r = 1$ it tests for one cointegrated vector against the alternative of more than one vector. If rejected, i.e., there are more than one cointegrated relationship, the Johansen test continues to the next rank until the maximum number of vectors are determined.

4.10 Error Correction Model

Error correction model is a dynamic model that estimates both the long and short-run effects, by assuming a long-run stochastic trend in the included independent variables. The ECM model can be shown with an independent variable x and a dependent variable y integrated in the same order (Wooldrige, 2016, p. 585). If no cointegration relationship exists, the first difference estimator can still find short run effects, but not long run relationships. To derive ECM, we begin with looking at a first difference equation shown below:

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta y_t + \gamma_0 \Delta x_t + \gamma_1 \Delta x_{t-1} + \epsilon_t \tag{4.16}$$

If parameter β cointegrates x and y, the following error correction model term can be included in the equation above as a stationary variable:

$$\delta(y_{t-1} - \beta x_{t-1}) \tag{4.17}$$

Where equation 4.18 describes the deviation between the dependent variable and equilibrium from the last period:

$$y_{t-1} - \beta x_{t-1} \tag{4.18}$$

The error correction term uses the last observation to adjust a deviation, as the variables can only react to a deviation after a deviation has occurred. The term adjusts the dependent variable towards the equilibrium. δ tells us the speed of the deviation[4]. For the ECM to revert to the long-run equilibrium, δ needs to be less than 0. A positive error correction term implies that the process is not converging in the long run. if y_{t-1} and βx_{t-1} are not equal, the model deviated from the long-run equilibrium in the last period.

The ECM model can be expressed as:

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta y_t + \gamma_0 \Delta x_t + \gamma_1 \Delta x_{t-1} + \delta(y_{t-1} - \beta x_{t-1}) + \epsilon_t \tag{4.19}$$

The differenced independent variables are included to express the short-run relationships.

The ECM model estimates the long run coefficients on the following, general expression:

$$1 \times y - \beta_1 x_1 = 0 \tag{4.20}$$

To find the long-run effect of the independent variables, we must solve for the dependent variable

$$y = \beta_1 x_1 \tag{4.21}$$

In practice, this equates to switching the signs of the coefficients of the independent variables after calculating the model when interpreting their effect on the dependent variable.

[4] See Appendix A2 for calculation of adjustment speed

4.11 Vector Error Correction Model

As we aim to examine several variables in this study, we need to use a vector error correction model (VECM). The ECM is only a single equation model, while the VECM can be applied to multiple equation models as an extension to a Vector Autoregression Model (VAR) where cointegration is present (Winarno et al., 2021, p. 3). The VECM adds an additional error correction term to the VAR, which allows for interpretation of short-run effects. VAR assumes that each variable is dependent on the past values of all the variables in the model. Hence, a first-differenced VAR is a system where the differenced variables are dependent on past differences of all variables.

A VECM can be expressed as follows:

$$\Delta y_t = \Pi y_{t-1} + \sum_{h=1}^{l} \Gamma_h \Delta y_{t-h} + \Phi d_t + \epsilon_t \tag{4.22}$$

Here a $n \times n$ matrix is the $\Pi = \alpha\beta'$ and α and β are $n \times r$ full rank matrices (Koop et al., 2007). Hence, the Πy_{t-1} represent the error-correction term of the model. The d_t term represents deterministic trends. The r is the number of cointegration relationships among the variables and ϵ_t is a normal mean zero error with a positive covariance matrix x. An important assumption of the VECM is that to measure the number of cointegration relationships, the variables need to be in the same order of integration.

Akaite Information Criteria (AIC), Bayesian Information Criteria (BIC), Final Prediction Error (FPE) and Hannan Quinn Information Criteria (HC) are helpful measures to determine the appropriate amount of lag, which is important in the VECM. These information criteria are measures of how well the model fits the data and include a penalty for adding more variables to the model. The 4 different information criteria in this thesis have different forms of penalty and can favor different models. Therefore, we have included all 4 to get an overall assessment.

The performance of the model might suffer when choosing an insufficient number of lags. A potential underfit could lead to an oversimplified model and potentially losing valuable insight, while overfitting might result in a great fit with the variables but limited ability in generalizing the results. In addition, an overfitting may result in the Johansen test overestimating the number of cointegration relationships.

4.12 Granger Causality

Statistical models, such as the ones previously mentioned, mainly determine correlation. However, correlation does not have any economic significance in and of itself, as correlation may be random. Therefore, in any econometric analysis the question of causality must be investigated.

True causality is hard to establish. In econometrics, the Granger causality test can be used to determine causality. This is done through testing whether X has predictive traits for Y (Granger, 1969). If this relation is found, the variable X is said to Granger cause the variable Y.

The concept of Granger causality rests upon two assumptions (Eichler, 2012):

1. The cause must precede the effect in time
2. There exists unique information in the cause that could not be found otherwise

A common breach of the first assumption is when expectations of future values of Y affect today's values of X. For instance, expectations of high CPI in the future can cause interest rates to be raised today.

5 Data Description

In this section, the variables for the analysis will be presented. The main aim of the analysis is to investigate the effect of macroeconomic factors on the yield rate of office real estate in Oslo. To avoid omitted variable bias, real estate factors have also been included. Therefore, this part is separated in real estate factors and macroeconomic factors

5.1 Commercial Real Estate Factors

Although the main topic at hand is macroeconomic factors, real estate specific factors do contribute to the determination of yield rate, as found by existing literature on the topic. Therefore, it is regarded as relevant to include some of these factors in the analysis, to reduce the effect of spurious relationships between these and the macroeconomic factors.

The main variable of interest is the yield rate, which is an indicator of rate of return. The explanatory commercial real estate factors have been identified as the vacancy rate and new office space.

5.1.1 Yield of Office Real Estate

The data for yield in office real estate has been gathered from Malling & Co. Malling & Co is a Norwegian firm, based in Oslo, and delivering administration, brokerage, and consulting services towards commercial real estate (Malling, 2022a).

The data is based on Malling & Co's Investor Yield and Sentiment Report, where a select group of respondents in the Norwegian commercial real estate market are inquired about yield and sentiment for prime and normal in the office, retail, and logistics segments (Malling, 2022b, p. 8). They estimate the current yield based on a set criterion[5]. Then an average of these estimates are given as the final yield number.

The yield is separated into two different segments, namely prime and normal[6]. Prime yield is based on the net rental yield of the best properties in the central business district of Oslo, while normal yield is based on an average of net rental yield in Lysaker and Helsfyr.

[5]See Appendix A1 for criterion, and difference in prime and normal
[6]See footnote 5

Malling & Co have monthly yield data from January 2000 until October 2022, provide a wide period for data analysis

A weakness in the data is that the yield numbers are subject to estimation errors. However, Malling & Co has long experience in the field, and the yield estimates reflect this experience.

Another weakness is that yields have been rounded to the nearest 0,05 %, introducing some degree of measurement error. The market for commercial real estate also suffers from low turnover, lowering the precision of property price estimates.

5.1.2 Vacancy Rate

The vacancy rate of offices is defined as the percentage of available office units that are unoccupied or available within 3 months for a given quarter (Akershus Eiendom, 2022).

The vacancy is a good measure of the saturation of the market. As noted by Kołodziejczyk and Osiichuk (2021), an increase in the vacancy rate tends to lower rents in the office market.

5.1.3 New Office Space

The data is gathered by Statistisk Sentralbyrå (SSB), the national statistical institute of Norway, using the Norwegian Cadastre. This data is based on quarterly data of approved, started and finished square meters of office space in Oslo.

The definitions of the types of categories (Statistisk Sentralbyrå, 2022e):

- **Approved:**
  A building that has been granted general permission is defined as approved. This implies that there has been given permission for preparative work, but not a full start-up of construction works
- **Started:**
  A building that has been granted a project start-up permission is regarded as started. Here, the construction can be fully started.
- **Finished:**
  A building regarded as finished is a building that has been given a certificate of

completion or provisional permission to use.

There are some potential sources of errors in this data. The Norwegian Cadastre contains data sent in by Norwegian municipalities. Therefore, it is naturally prone to errors in registration, especially as some municipalities register on behalf of smaller municipalities. However, it is likely that Oslo tracks this themselves. A restriction conducted in this thesis is to only include the growth in new office space in Oslo, and not considering any growth in neighboring municipalities. To the extent of our research, we have not found any previous research addressing this issue, and as our data for the yield on office real estate is restricted to this area, the data on new office area is as well. Another weakness is that new office space does not take into account any potential removal of existing office spaces. Therefore, it does not give a complete picture of the change of available supply.

5.2 Macroeconomic Factors

Macroeconomic factors have an effect on yield, which is evident from Chapters 2 and 3. Therefore, we include the macro variables that are deemed to be relevant to explain the yield rate.

5.2.1 Consumer Price Index

The Consumer Price Index (CPI) is a measure for the change in consumer prices and is a common measure for adjusting for inflation across time frames. The Norwegian CPI is developed by SSB and published monthly.

The Norwegian CPI is derived from actual prices offered to consumers (Statistisk Sentralbyrå, 2022f). These prices include any taxes, fees and subsidies which may affect the offered prices. Any discounts or offers are therefore reflected in the prices which the CPI is based on.

SSB also publishes the consumer price index adjusted for changes in taxes and fees, and withholding energy goods (CPI-JAE), also regarded as the core-inflation[7]. Here, the prices are still based on observed prices as in the normal CPI, but any changes in taxes and fees are adjusted to a baseline. Energy goods are removed from the calculation. Otherwise,

[7]See Appendix A3 for what is included in adjustment

this index is calculated in the same way as the regular CPI.

The choice between these two measures for CPI fell on CPI-JAE. This is due to CPI-JAE being regarded as a better measure of the underlying inflation in the economy. Also, many of the taxes and fees that are adjusted are not relevant for the yield of real-estate and would give a skewed picture of the relevant inflation.

5.2.2 Gross Domestic Product

The gross domestic product (GDP) of a country is a measure of the aggregated value created in a country.

To ensure a similar data structure to the dependent variable of yield, a transformation of the GDP into a 12-month growth figure was done.

The data SSB publishes is collected from several different sources (Statistisk Sentralbyrå, 2022g). However, there is regulated and standardized reporting in place, which should ensure the trustworthiness of the figures. The GDP is audited, including the numbers from each quarter, and older GDP figures will therefore be more accurate.

5.2.3 Interest Rate

The interest rate is a significant macroeconomic factor regarding real estate. The real estate industry naturally consists of tangible assets that can serve as proper collateral. Therefore, there is significant debt financing of real-estate. Debt financed industries will be more affected by the interest rate.

There are several considerations to take when choosing the correct interest rate for the analysis. A common method for establishing an appropriate interest rate is to find government bonds at a similar duration as the project. However, research suggests a somewhat low liquidity in the Norwegian government bond market (Hein, 2003; Evjen et al., 2017). This introduces the potential of mispricing and an incorrect estimation of the long term rate. Therefore, using the interest rate of the Norwegian Central Bank is the chosen interest rate.

The interest rate of the Norwegian Central Bank is sourced from Statistisk Sentralbyrå (2022c), which gathers the data at the end of every month.

As mentioned in Chapter 2.3, a common industry indicator is the real rate, which is the interest rate adjusted for inflation. Therefore, this rate will also be investigated further. To find the real rate, the following calculation has been done:

$$r_{real} = \frac{r_CB - cpi}{1 + cpi}$$

$$r_{real} = Real\ rate$$

$$r_{CB} = Rate\ of\ central\ bank$$

$$cpi = Rate\ of\ inflation$$

5.2.4 Norwegian Consumer Confidence Index

The Norwegian Consumer Confidence Index (CCI) seeks to track the confidence of Norwegian households in both Norway's and their own, personal economy. It is constructed using a survey, conducted by Kantar TNS on behalf of FinansNorge (2022)[8]. The index is published quarterly and was first published in 1992. This will be used as a proxy for confidence in the future of the economy.

The main indicator is derived from the average difference between the percentage of optimistic and pessimistic answers (FinansNorge, 2022). The indicator is also adjusted for trend and seasonal variations, according to the recommendations of the Norwegian Central Bank, and other central actors in the Norwegian financial markets. This seasonal adjustment will imply some larger degree of uncertainty to the numbers at the end of the time series, as these observations can only be adjusted using past observations.

5.2.5 Electricity Prices

The type of electricity price that have been used for the analysis is 1-year fixed price contracts. The data has been gathered by SSB, having sourced the spot prices from the electricity marketplace Nord Pool (Statistisk Sentralbyrå, 2022h). The price is measured in øre/kwh, and excludes any fees and taxes, and any grid tariffs.

The data is the combination of two different time series, the first one from the first quarter

[8]See Appendix A4 for survey questions

of 1999 until the last quarter of 2011, and the second one from the first quarter of 2012 until the second quarter of 2022 (Statistisk Sentralbyrå, 2022a,b). The first time-series measures the price at the last date of the quarter, while the second one measures the average price of the quarter. This might induce a difference in volatility across the combined time-series.

A weakness with the data is that the prices are not exclusively from the price region which Oslo is located in. However, as the price tends to be similar in southern Norway, and most of the electricity being consumed there, this should not cause large errors. The fact that the measurement period for the prices is not equal across the whole period is also a weakness.

5.2.6 Population

Population is collected from SSB every quarter (Statistisk Sentralbyrå, 2022d). The population is based on how many that are registered with an address in Oslo municipality in the Norwegian Population Register.

As some are registered in Oslo, but live in different cities (and vice versa), this number may not be exact. As the number used is the increase in population, this should not be grounds for any significant error.

6 Stationarity

In the following section we will go through the possibility of unit root presence in our variables. Stationarity is important to avoid spurious and meaningless results. We will assess each variable separately, going through the process of stationarity through the Augmented Dickey-Fuller test, to differencing the variables to determine which order of integration they are[9]. This is necessary since the model requires that each variable is integrated in the same order. Below, each figure will show the variable at levels to the left and first difference to the right.

6.1 Normal Yield

The trend element seems to be negative when looking at levels in Figure 6.1 below. This is also confirmed by the ADF test, which does not reject the null hypothesis of non-stationarity. By visually inspecting the differenced time series, it is apparent that the trend element is less evident and the variance more consistent. Normal yield is verified by the ADF test to be stationary after first differencing as it rejects the null hypothesis, and thus integrated of order 1 (1).

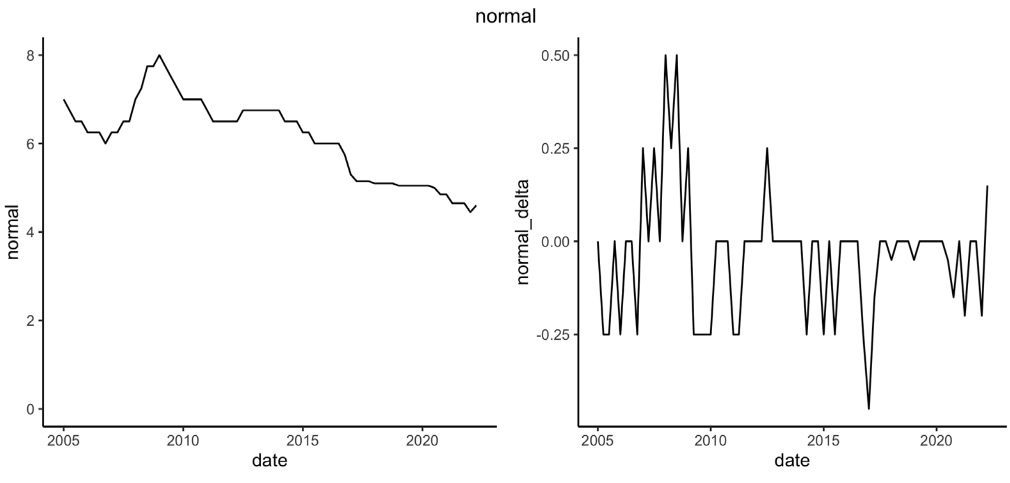

Figure 6.1: Normal Yield

[9]See Appendix A5 for full results

6.2 Prime Yield

Looking at Figure 6.2, prime yield clearly trends downwards with some inconsistencies in variance. Stationarity is rejected by the ADF test, which means we must difference prime yield to try to get the variable stationary. Looking at the differenced values, the trend appears flatter, but still an uneven variance. The test does not reject the null hypothesis of non-stationarity after differencing. Prime yield is, therefore, not integrated of order 1. This is unexpected as the time series seems to be following almost the same pattern as normal yield, suggesting that there should be no integration differences between them.

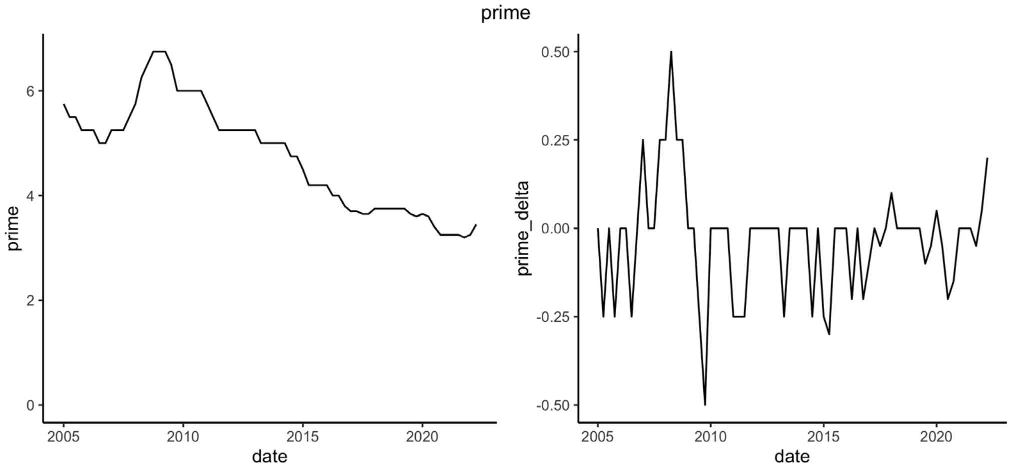

Figure 6.2: Prime Yield

6.3 CPI-JAE

Looking at Figure 6.3, the variable does not appear to be stationary at levels. This is intuitive as the price level has risen over time. When applying the ADF test, we cannot reject the null hypothesis of non-stationarity going by the test results in appendix 4. However, the ADF test confirms stationarity after differencing. Accordingly, CPI-JAE is integrated of order 1 (1).

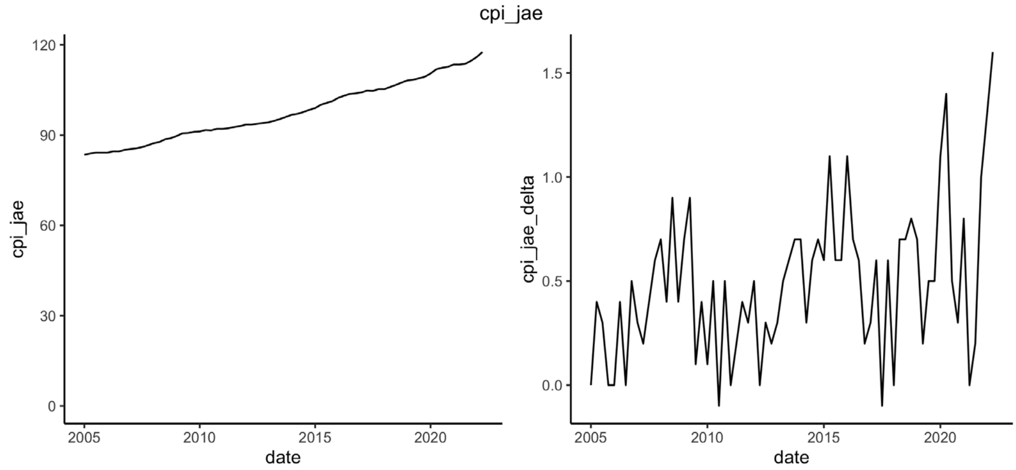

Figure 6.3: CPI-JAE

6.4 GDP

Looking at Figure 6.4, we infer that GDP has increased significantly since 2005, though the pace has differed. We expect GDP to be non-stationary as changes in GDP are permanent. For example, new inventions that automate production processes are likely to last. For that reason, it is reasonable to assume that GDP trends upwards. This is confirmed when looking at the test statistic from the ADF test, showing that we cannot reject non-stationarity. Though, seeing the differenced GDP timeseries to the right, the upwards trend has been flattened out. This is consistent with the ADF test statistic after differencing, in which the null hypothesis is rejected. Hence, GDP is integrated of order 1.

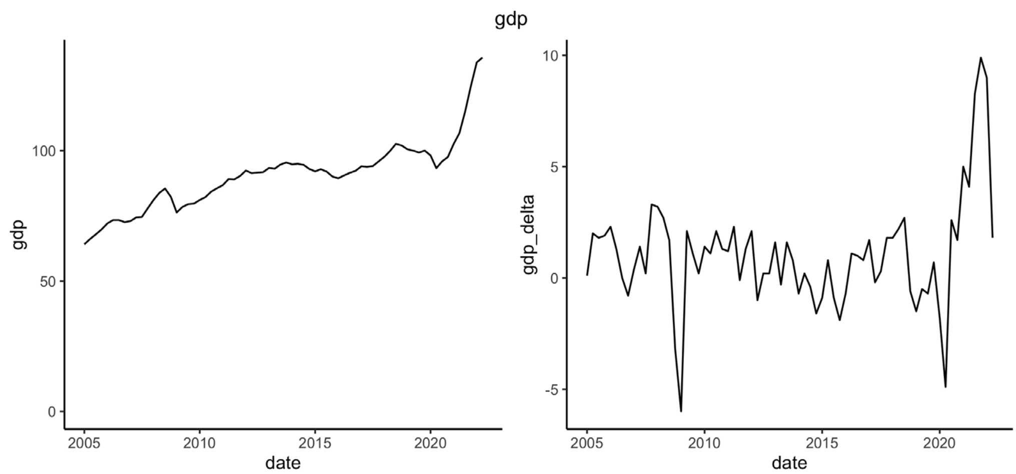

Figure 6.4: GDP

6.5 Real Interest rate

In the Figure 6.5 to the left the variance seems to be somewhat inconsistent, while the mean value appears to follow a negative trend through time. The test statistic from the ADF test indicates that the variable is not stationary at levels. Consequently, further differencing is needed to avoid spurious results. After differencing the ADF test rejects the null hypothesis of non-stationarity, confirming stationarity. From the figure to the right, this appears correct as the mean value has stabilized and the variance looks constant. This suggests that the variable is integrated of order one (1).

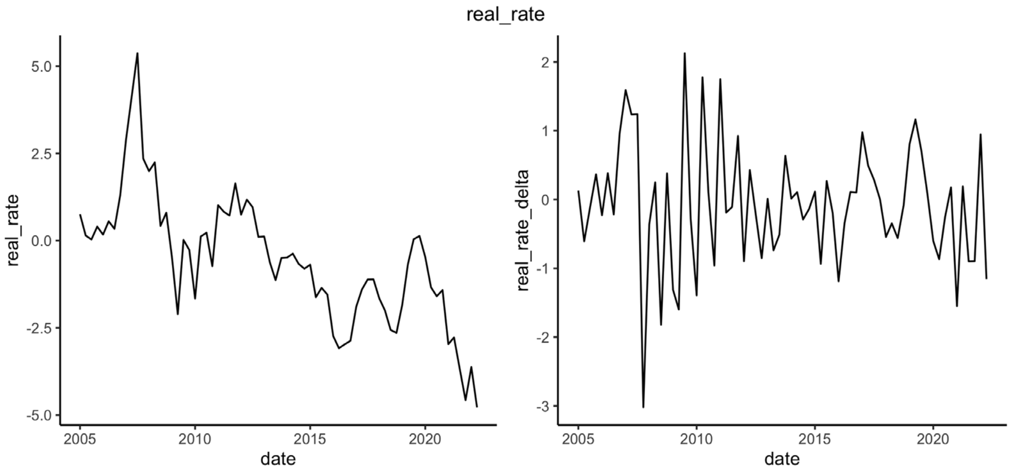

Figure 6.5: Real Rate

6.6 Electricity Price

Figure 6.6 displays the electricity price of 1-year contracts from 2005-2022. It does look like the mean value remains fairly constant, but with inconsistencies in variance. The ADF test confirms stationarity at levels. Hence, the variable is integrated of order 0.

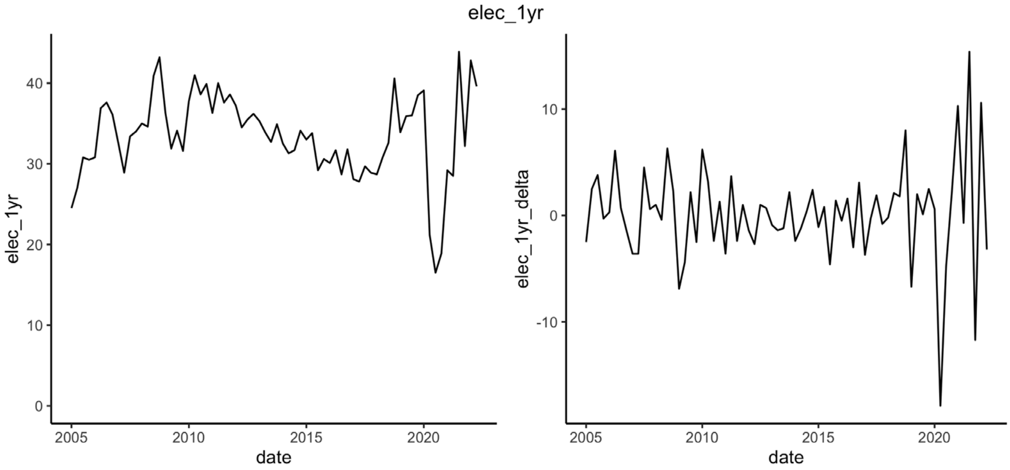

Figure 6.6: Electricity 1-year Contracts

6.7 Office Started

Figure 6.7 shows the number of office projects that have started since the beginning of the year 2005 until today. The ADF test does not confirm stationarity at levels, which means differencing is needed. Based on the test statistic we can reject non-stationarity after first-differencing the variable. We also notice that the variance seems more constant after differencing the variable. Therefore, the "office started" is integrated of first order (1).

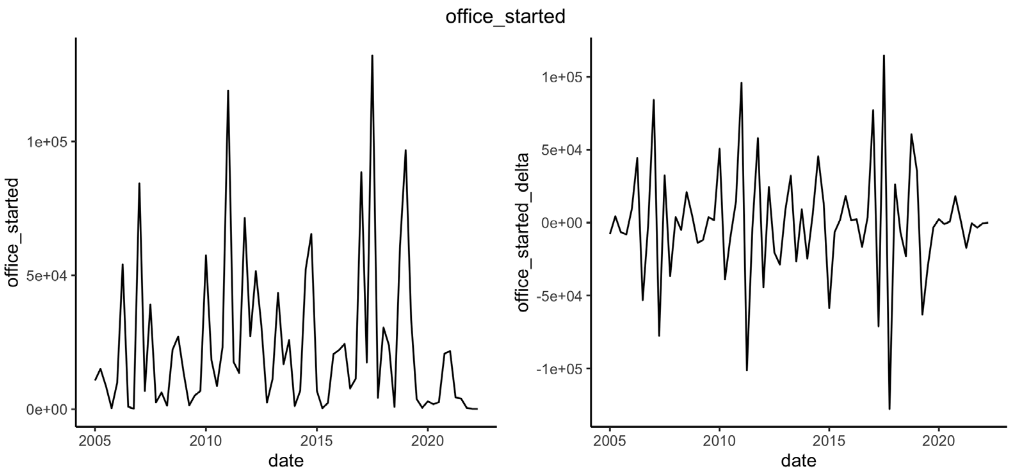

Figure 6.7: Office Area Started

6.8 Office Completed

By looking visually at Figure 6.8 below, it appears that the variance is not consistent across the whole period, with relatively high values around year 2015. The trend seems to be slightly positive as well. This is confirmed by the ADF test, as it does not reject the null hypothesis of non-stationarity. Nonetheless, after differencing the variable, the test statistic verifies stationarity. Subsequently, the variable is integrated of first order (1).

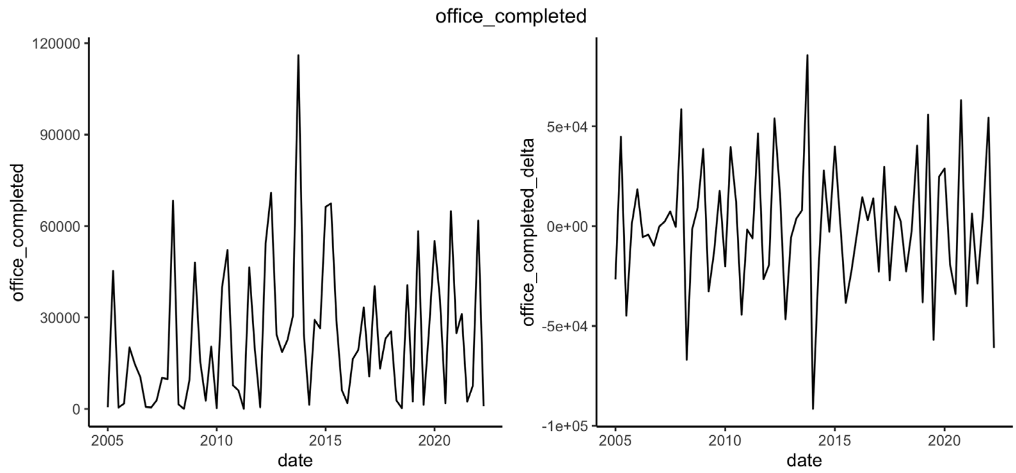

Figure 6.8: Office Completed

6.9 Consumer Expectation

Figure 6.9 highlights the consumer expectations in the last few decades. We infer an apparent downwards trend with inconsistent variance. The ADF test results confirm a random walk with drift at levels. Visually, the differenced time series shows a more stable mean value, which also corresponds to the ADF test that rejects the null hypothesis after differencing. Thus, consumer expectation is first order of integration.

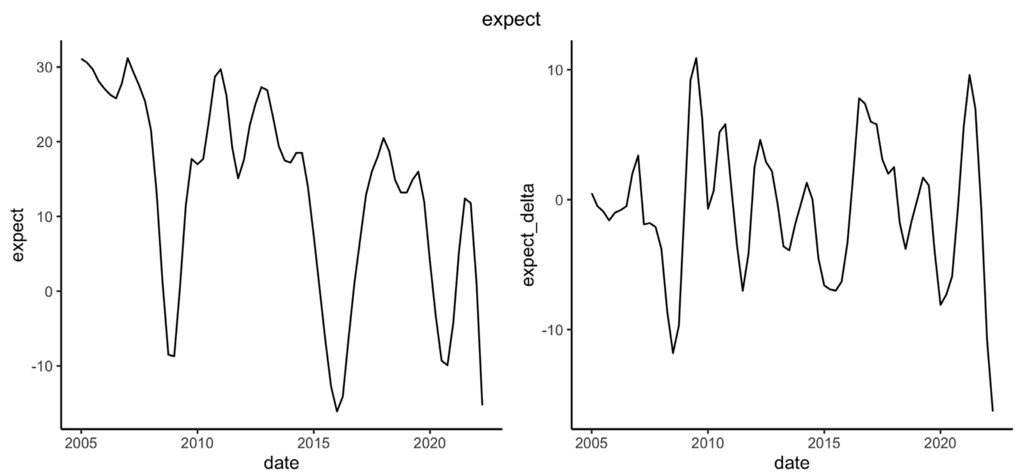

Figure 6.9: Consumer Expectation

6.10 Population

We expect the population variable to be non-stationary at levels, as it is known that Norway has experienced a growing population the last decades. We also see from Figure 6.10 that the variance is quite stable, which seems reasonable as there are no obvious reasons why the population should increase faster in some time periods. The ADF test cannot reject presence of unit root in the variable. After differencing the data, the ADF strongly confirms stationarity within the variable. Hence, the variable is also first order integrated.

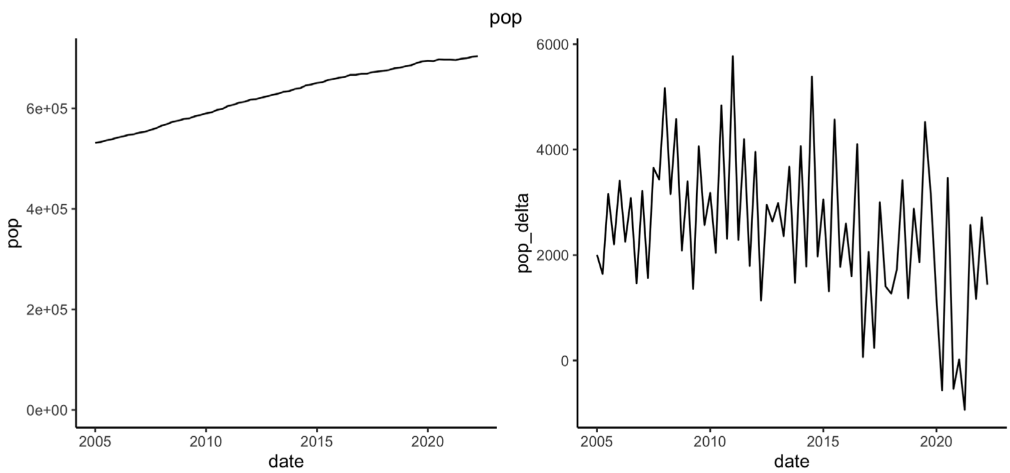

Figure 6.10: Population

6.11 M2

In Figure 6.11, we observe some relatively high values around 2006 followed by a significant decline the year after. After this time period the variance and mean value seem to stabilize until 2020, where we notice considerable increases in value. The ADF test confirms non-stationarity at levels. Therefore, we difference the variable. From the figure below, it appears that M2 is stationary after differencing. The new ADF test statistic also verifies stationarity of first order.

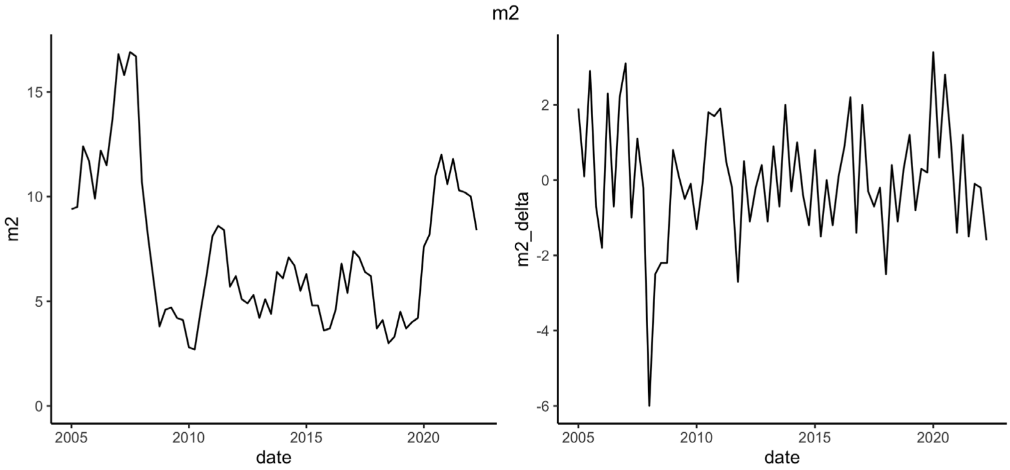

Figure 6.11: M2

6.12 Vacancy

From Figure 6.12 illustrating the levels time series, it does appear to be somewhat of a negative trend from year 2005 until 2008 in the vacancy, with major irregularities in variance. Afterwards, the mean and variance look to stabilize. The ADF test rejects the null hypothesis at levels, which means no differencing is needed for the variable. Thus, vacancy is integrated of order 0.

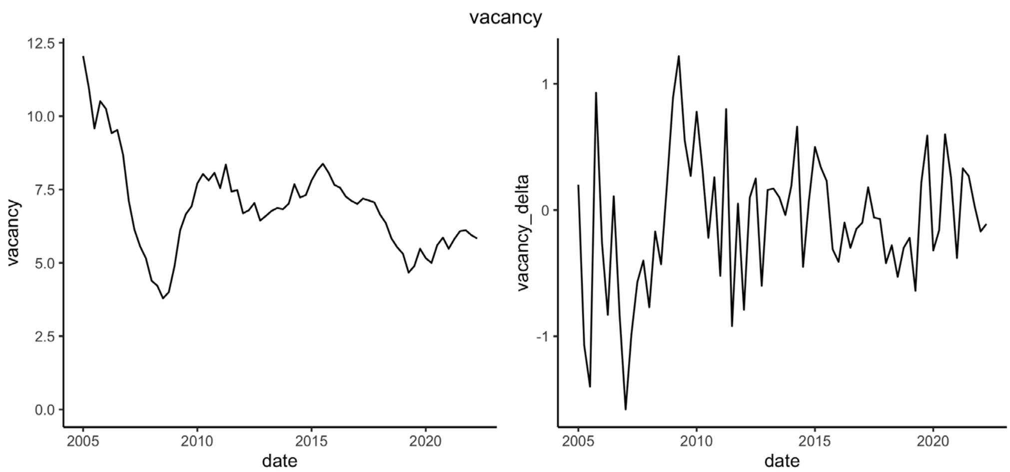

Figure 6.12: Vacancy

7 Constructing the VECM Model

This section of our thesis is dedicated to deriving the VECM. First, the treatment of unit root processes in the included variables will be discussed. Then, the determination of the number of lags will be evaluated. The number of lags is used in both the Johansen cointegration test and the VECM. Furthermore, we will discuss the results from the Johansen test which tests the number of cointegration relationships between the variables. Lastly, the results from the VECM will be compared to relevant theory and literature.

7.1 Unit Root Processes

The VECM requires presence of cointegration between the included variables. To properly measure cointegration between variables, they need to be in the same order of integration. Based on our assessment from Chapter 6, prime yield, electricity price and vacancy are not integrated of order one. Therefore, they are excluded from further investigation. This is necessary to get a precise estimate of the number of cointegrating relationships in the model. Consequently, we will only analyse normal yield going forward.

As the initial specification for Model 1 and Model 2, as formulated in Chapter 3, include the vacancy rate, there is a need to alter the models. The replacement in Model 1 will be new office area started, and in Model 2 it will be replaced by new office area completed.

7.2 Number of Lags

We use four criteria to find the optimal number of lags. It is critical to find the right number of lags since including too many could lead to an overfitting of the VECM. Based on this, we will limit the model to five lags to make the model easier to interpret. The VECM could give lag structures longer than five, but as mentioned, this could increase the complexity of the VECM. However, we are particularly attentive when we investigate autocorrelation in the residuals after the model estimation. Autocorrelation in the residuals will indicate that we have a misspecified model, and that it may be necessary to include more lags. We calculate the optimal number of lags based on an overall assessment of four informational criteria, namely the Final Prediction Error (FPE), Akaite Information

Criteria (AIC), Hannan Quinn Information Criteria (HC) and Bayesian Information Criteria (BIC). The lag structure that minimizes the score of the criteria is the preferred one. Setting maximum lag structure to five, the results from the information criteria show a majority choosing five lags[10]. Hence, this is the optimal structure. We are, however, aware that the information criteria could have suggested a longer lag structure had we not restricted it to five. Nevertheless, we consider the risk of using an oversimplified model as opposed to an over-complex model as more tolerable.

7.3 Cointegration

To determine the right amount of cointegration relationships in our model, we apply the Johansen test. This test is preferred over the also common Engle-Granger test as it allows more than 1 cointegration relationship to exist. The test reports the Max-Eigen statistics. We choose five lags as discussed above. In Table 1 the results of the Johansen test are displayed.

The first null hypothesis of zero cointegration relationships is rejected on a 1 % level. This indicates that there is at least one cointegration relationship among the variables. Furthermore, the test also rejects the second null hypothesis of maximum one cointegrated vector against the hypothesis of more than 1 cointegration vector. Testing for maximum two cointegration vectors, the test does not reject the null hypothesis. Hence, we accept the null hypothesis of maximum two cointegration vectors.

Table 7.1: Cointegration Model 1

Rank	Fisher test Max eigenvalue	10 pct	5 pct	1 pct
r<=0	63.43	31.66	34.40	39.79
r<=1	36.41	25.56	28.14	33.24
r<=2	20.07	19.77	22.00	26.81
r<=3	7.92	13.75	15.67	20.20

[10] See Appendix A6 for full results

7.4 Model 1

Table 7.2 contains the complete results from the estimation[11]. We evaluate the results for the differenced short-term effects, the error correction term and long-term effects. The results are interpreted as changes to net yield in the event of change in one variable at a time, ceteris paribus.

As can be seen, the R^2 number is 0.750, which is quite high. However, as there is a quite high ratio of explanatory variables to the amount of observations, there exists a risk of overfitting.

[11]The cajorls()-function in R outputs $K-1$ lags, therefore the selection of 5 lags results in 4 lags in the model

Table 7.2: VECM Results of Model 1

Long Run Effects	Coefficients	Standard Error	t-value	p-value
yield	1			
office	0.00002***	0.000006	5.793	0.000
M2	0.0689***	0.0129	5.309	0.000
real_rate	−0.3869***	0.0501	−7.715	0.000
expect	0.0236***	0.0048	4.894	0.000
Short Run Effects	Coefficients	Standard Error	t-value	p-value
ECT1	−0.3363***	0.0591	-5.686	0.000
ECT2	$-2.834e-06$	1.924e-06	-1.473	0.148
d_2015	−0.3633***	0.0664	-5.470	0.000
covid	−0.2204***	0.0788	-2.798	0.008
Δyield.L1	−0.4825***	0.1312	-3.677	0.001
Δoffice.L1	$-3.830e-07$	5.261e-07	-0.728	0.471
ΔM2.L1	−0.0109	0.0123	-0.890	0.379
Δreal_rate.L1	0.0339	0.0207	1.636	0.110
Δexpect.L1	−0.0280***	0.0077	-3.650	0.001
Δyield.L2	−0.1836	0.1350	-1.360	0.181
Δoffice.L2	$-1.654e-07$	8.369e-07	-0.198	0.844
ΔM2.L2	−0.0387***	0.0123	-3.135	0.003
Δreal_rate.L2	0.0419*	0.0220	1.905	0.064
Δexpect.L2	0.0283**	0.0125	2.261	0.029
Δyield.L3	−0.4088***	0.1256	2.705	0.002
Δoffice.L3	$-2.728e-07$	1.233e-06	-0.221	0.826
ΔM2.L3	−0.0380***	0.0119	-3.178	0.003
Δreal_rate.L3	0.0925***	0.0229	4.034	0.000
Δexpect.L3	−0.0381***	0.0129	-2.961	0.005
Δyield.L4	−0.3724**	0.1288	-2.892	0.006
Δoffice.L4	$-1.827e-06$	1.621e-06	-1.127	0.266
ΔM2.L4	−0.0101	0.0119	-0.843	0.404
Δreal_rate.L4	−0.1484***	0.0255	5.821	0.000
Δexpect.L4	0.0079	0.0077	1.020	0.314
Dependent variable	$\Delta yield$			
Observations	65			
R^2	0.7503			
Adjusted R^2	0.6041			
Residual Std. Error	0.1064 (df = 41)			
F Statistic	5.133*** (df = 24; 41)			
Note:	*p<0.1; **p<0.05; ***p<0.01			

7.4.1 Short Run Effects

Looking at Table 2, we infer significant negative short run effects from previous yield levels in all four lags. Hence, increases in yield are associated with decreasing yield in the following periods. This suggests the existence of negative autocorrelation in the change of the yield rate, lasting several quarters.

The real rate seems to have a short run effect on yield given that the model reports three significant lags. The coefficients indicate that increases in real rate are later followed by a change in yield in the same direction. The first lag, however, is insignificant, implying that yield is not affected by changes in real rate a quarter prior. These findings match both the market belief of Chapter 2, through the substitute principle, and the findings of D'Argensio and Laurin (2008), and Siviantides et. al (2003). The historical view in Chapter 2.1 illustrates the co-variance between yield and policy rate, of which our real rate is based on. We saw that in time periods when policy rate was set high, for example right before the financial crisis hit, yield was relatively high. In the last two years, policy rate has been consistently low, which is also reflected in yield levels.

The VECM outlines significant short run effects on yield caused by changes in consumer expectation. In general, the effect of the expectation factor is negative, although there are some conflicting effects in the lags. Changes in consumer expectation a year prior do not significantly influence yield today. The consumer expectation factor relates to household positivity in both personal economy and the economy as a whole. Therefore, a negative influence can suggest that a positive outlook drives the risk of investment down, lowering the required yield rate. This finding is in accordance to Jacobsen and Naug (2005). They found the expectation factor to correlate positively with housing prices. Transferring this finding to offices, increases in real estate prices will lower yield.

We have included two dummy variables to reflect the influence of structural breaches in 2015 and 2020. The variables are taking 1 starting in the first quarter of 2015 and 1 starting in the second quarter of 2020, respectively. The variable for 2015 is negative and significant, which indicates that yield is significantly lower after 2015. This is in accordance to the finding of Nowak (2021). The covid factor is also negative and significant. Hence, yield is significantly lower after the second quarter of 2020. This is an interesting finding, as intuitively the pandemic should come with an expectation of lower demand for office areas due to more people working from home. The reduced demand should increase the risk of office real estate, which in turn increases yield. However, due to the length of lease contracts, the effects of covid-19 are probably not yet seen. Low interest rates and record-high transaction volumes the last two years are more reasonable explanatory factors for lower yield levels from the second quarter of 2020 (Nestaas, 2021).

7.4.2 Error Correction Term

As the error correction term is negative and significant, it entails that the model exhibits a long-run relationship. There is a reverting trend back to the long-run equilibrium after short-term deviations. The coefficient value indicates that the adjustment speed back to equilibrium is 6.8 years[12].

7.4.3 Long Run Effects

The VEC model suggests that M2, real rate, new office area started and consumer expectation have a long run relationship with long run yield. Changes in consumer expectation, new office area started and M2 decrease yield in the long run, while the real rate has a positive long run relationship. These findings fall in line with previous research. The effects also correspond to the short run effects, validating the sign of the coefficients. The negative influence of office space started on the yield may be due to the willingness to start an expensive project involves a positive outlook on the return on investment.

7.5 Granger Causality

To be able to measure if our included independent variables have a predictive causal relationship with yield, one must discuss whether the Granger causality assumptions are fulfilled. We assume that the causal relationship persists for several periods as we have a dynamic model. Another assumption is that future values of yield cannot affect present values of the independent variables. We do not find any apparent reasons as to why our included variables would violate this assumption.

Based on the p-values in table 7.3, it seems that real rate is effective in predicting office

[12] See Appendix A2 for equation

yield. M2 is also relevant in forecasting on a 10 % significant level. Consequently, these two variables have a predictive causal relationship with yield, which makes it more likely that a true causality relationship also exists.

Table 7.3: Granger Causality Model 1

X-effect	F-statistic	P-value
Office_started	0.0978	0.755
M2	3.4058	0.069
Real_rate	19.107	0.000
consumer_expectation	1.036	0.313

Note: *p<0.1; **p<0.05; ***p<0.01

8 Validity of VECM Model

In this part of the thesis, we will evaluate the assumptions for VECM. A violation of the assumptions could cause biased and inconsistent results. We will emphasize the assumptions regarding serial correlation, homoscedasticity and normality. The results from the validity tests can be seen in table 8.1.

Table 8.1: Validity tests Model 1

Test	Statistic value	P-value
Breusch-Pagan Test (homoscedasticity)	4.6725	0.323
Shapiro-Wilk (normality)	0.95603	0.015
Jarque-Bera (normality)	50.961	0.000
ARCH	750	1
Breusch-Godfrey	7.2298	0.124
Note:	*p<0.1; **p<0.05; ***p<0.01	

8.1 Normality

Normality in the residuals is necessary for the efficiency of the estimation. Looking graphically at the residuals in Figure 8.1, they seem to be normally distributed, although we do observe a tendency towards a skewness. The plotted residuals should ideally be represented across a straight line. Generally, significant deviations from the straight line indicate instances of non-normality. In our case, it appears that we could have issues with normality, especially at the tail ends, as there are some residuals that deviate significantly from the line.

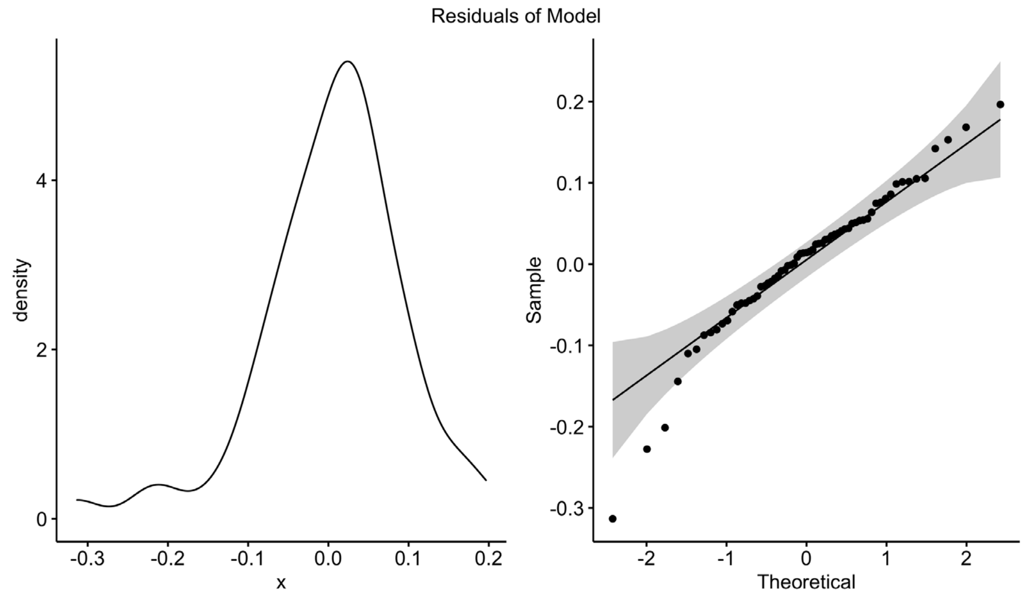

Figure 8.1: Residuals

To substantiate this, we test for normality using the Jarque-Bera test. The p-value of the test suggest a rejection of the null hypothesis of normality in the residuals. In isolation this means the efficiency of the VECM will be negatively affected. On the contrary, according to Chang et al. (2006), test results are usually reliable for any nonnormal distributions if the sample size exceeds 30. Therefore, for moderate to large sample sizes, non-normality of residuals should not affect the inference procedures (LaMorte, 2016). Given that our VECM has a sample size of 65, the nonnormality reported in the Jarque-Bera test is not troublesome.

8.2 Homoscedasticity

Violation of homoscedasticity will cause potentially misestimated standard errors from the regression. To test for this, we use the Breusch-Pagan test. If the null hypothesis gets rejected, there is presence of heteroscedasticity. The test statistic outlines a p-value of 77 %, indicating no violation of homoscedasticity in our model.

8.3 Serial Correlation

A serial correlation assessment is essential in order to know whether the significance of the coefficients can be trusted. By examining the residual plot in Figure 17, there are no clear indicators of autocorrelation. The observations seem randomly spread with no obvious patterns, although there are some rare cases of positive and negative serial correlation. We apply the Breusch-Godfrey test to formally test for autocorrelation. The p-value for the Breusch-Godfrey test with four lags is reported to be 12 %. Subsequently, the null hypothesis of no autocorrelation cannot be rejected, indicating that our chosen model is fulfilling the serial correlation assumption.

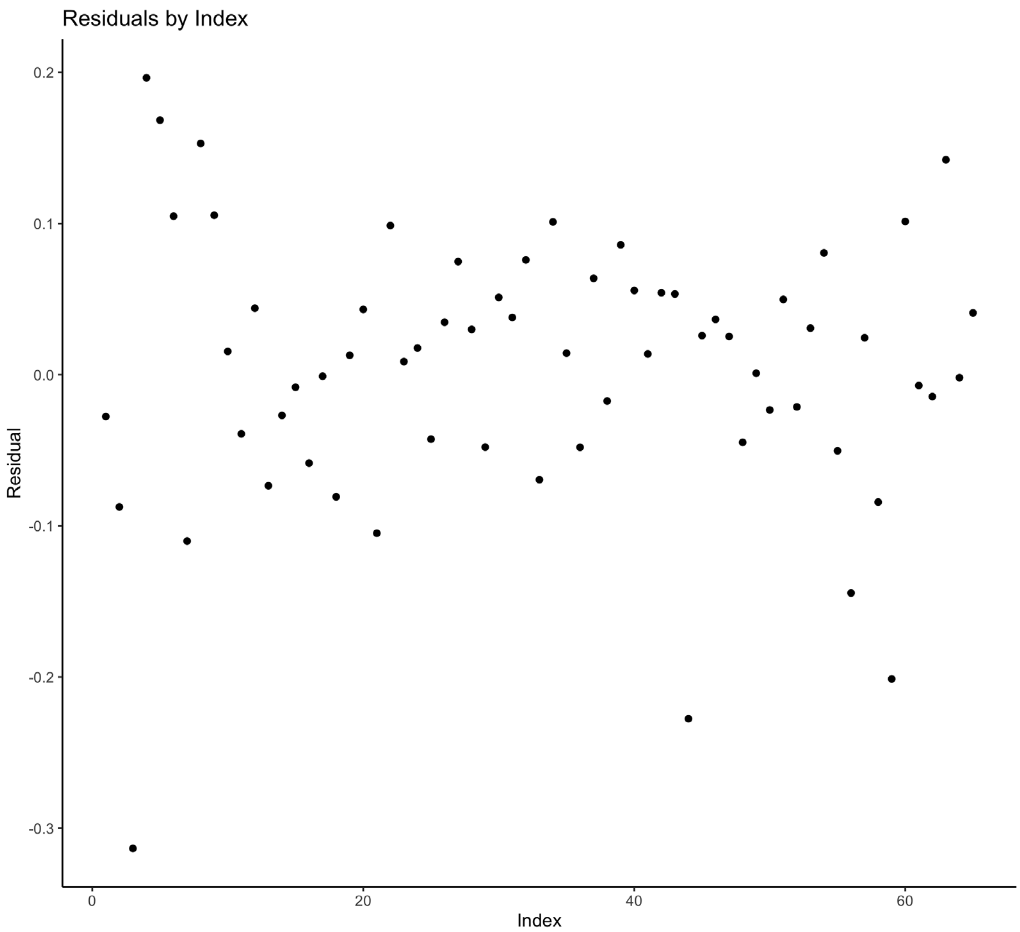

Figure 8.2: Residuals

8.4 Goodness of Fit

To assess a potential overfitting issue in the VECM, we run the model with three lags as opposed to five lags[13]. This will reduce the number of explanatory variables in relation to the number of observations. The multiple R^2 is now reduced to 0.613. However, this number will naturally decrease as we have included less explanatory variables. The adjusted R^2 is 0.511, which is lower than the original model, indicating that the additional

[13]See Appendix A7.1 for full results

lags in the original model have a significant explanatory effect on yield. The significant short run effects are aligned with the initial VECM, but reports less effects. The long run effects of office area started and M2 contradict the results of the first VECM, in that they have a positive relationship with long run yield. These findings are less aligned to economic theory, as well as the findings of Chapters 2 and 3.

In the more parsimonious model, the Adjusted R^2 is lower, and has some illogical long run effects. This leads us to suggest that the original model is better at explaining the effects, although the risk of overfitting exists.

9 Constructing an Alternative VECM Model

The main difference in this model is the inclusion of GDP as a factor, and exclusion of M2 and the expectation factor. As with our first model, we exclude prime yield, vacancy and electricity price. We test for the optimal number of lags using the informational criteria and find four lags as optimal[14]. Then, we run the Johansen test for cointegration. Lastly, the results and validity of the alternative VECM will be discussed. The discussion will be based on the output in table 9.2.

9.1 Cointegration

Applying four lags into the Johansen test, we get that two cointegration vectors exist among the variables. Looking at table 9.1, the test statistic exceeds the critical value for r<=0. Therefore, we reject the null hypothesis of no cointegration relationships. This procedure continues until r<=2, where we cannot reject the null hypothesis of more than two cointegration relationships. For this reason, we assume two cointegrated vectors.

Table 9.1: Cointegration Model 2

Rank	Fisher test Max eigenvalue	10 pct	5 pct	1 pct
r<=0	41.60	25.56	28.14	33.24
r<=1	31.43	19.77	22.00	26.81
r<=2	13.86	13.75	15.67	20.20
r<=3	6.12	7.52	9.24	12.97

9.2 Model 2

Table 9.2 presents the results of Model 2. The main things of note in comparison to Model 1 is the clear decrease in significant lags, as well as the lower Adjusted R^2 figure, at 0.493 compared to 0.604 of Model 2.

[14]See Appendix A6 for full results

Table 9.2: Model 2

Long Run Effects	Coefficients	Standard Error	t-value	p-value
yield	1			
office	$-2.423e-05^{**}$	$9.465e-06$	−2.560	0.017
gdp	0.0274	0.0261	1.050	0.288
real_rate	-1.114^{***}	0.1275	−8.735	0.000
Short Run Effects	Coefficients	Standard Error	t-value	p-value
ECT1	-0.0904^{***}	0.0231	−3.906	0.000
ECT2	$1.447e-06$	$1.464e-06$	−0.989	0.328
d_2015	0.0275	0.0419	0.656	0.515
covid	-0.1166^{**}	0.0578	−2.028	0.048
Δyield.L1	-0.2415^{*}	0.1378	−1.753	0.086
Δoffice.L1	$6.844e-07$	$6.656e-07$	1.028	0.309
Δgdp.L1	−0.0019	0.0065	−0.306	0.761
Δreal_rate.L1	0.0246	0.0208	1.179	0.244
Δyield.L2	0.2520^{**}	0.1147	2.198	0.033
Δoffice.L2	$3.799e-08$	$9.509e-07$	0.040	0.968
Δgdp.L2	0.0114^{*}	0.0065	1.735	0.089
Δreal_rate.L2	0.0356^{*}	0.0196	1.910	0.088
Δyield.L3	−0.1325	0.1169	−1.133	0.263
Δoffice.L3	$-1.328e-07$	$1.192e-06$	−0.111	0.912
Δgdp.L3	0.0062	0.0062	1.006	0.319
Δreal_rate.L3	0.0687^{***}	0.0214	3.206	0.002
Dependent variable	$\Delta yield$			
Observations	66			
R^2	0.616			
Adjusted R^2	0.493			
Residual Std. Error	0.1215 (df = 50)			
F Statistic	5.005^{***} (df = 16; 50)			
Note:	*p<0.1; **p<0.05; ***p<0.01			

9.2.1 Short Run Effects

In the alternative model, yield is significant at lag 1 and 2. However, the effect is not consistent, being positive at lag 2 and negative at lag 1. Changes in yield more than 2 quarters prior do not influence yield today. GDP is significant at lag 2, with the effect being positive. As in Model 1, the real rate is positively correlated, being significant at lag 2 and 3. With only two lags being significant at 5 % or less, this weakens the explanatory power of the model.

9.2.2 Error Correction Term

The error correction term is highly significant and negative, implying that there exists a long run equilibrium. However, this equilibrium transpires slowly over time, adjusting to short run effects. More precisely, the VECM adjusts to the long run equilibrium over the next 2.9 years[15].

9.2.3 Long Run Effects

Our suggested model argues two long run relationships, with GDP not being significant. Both office completed and the real rate are significant. GDP appears to decrease yield in the long run, while real rate increases long run yield. This is consistent with the market overview in Chapter 2. Finally, the dummy variable for covid-19 comes out significant, and negative, while 2015 comes out insignificant.

The positive effect on the yield of completed office space is contrary to intuition. The influx of available area will drive rent prices down, lowering yield.

9.3 Granger Causality

All independent variables are tested for Granger causality, summarized in table 9.3. Only the real rate is significant at 1 % level. Hence, it appears that real rate has a predictive causal relationship with yield. GDP is significant at 10 % level. This is interesting, given the lack of explanatory power the variable had in Model 2. We believe that our variables do not violate the assumptions of Granger causality.

Table 9.3: Granger Causality Model 2

X-effect	F-statistic	P-value
office_completed	0.010	0.919
GDP	3.026	0.087
real_rate	19.107	0.000

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

[15]See Appendix A2 for equation

10 Validity of the Alternative Model

Table 10.1: Validity tests Model 1

Test	Statistic value	P-value
Breusch-Pagan Test (homoscedasticity)	2.4133	0.4912
Shapiro-Wilk (normality)	0.91695	0.0002
Jarque-Bera (normality)	19.854	0.0109
ARCH	510	1
Breusch-Godfrey	12.827	0.01215
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$	

In table 10.1, model 2 fails the both the Jarque test for normality and the Shapiro-Wilks test. However, for sample sizes over 30 normality should not be an issue. Looking at the residuals in Figure 10.1, this assumption seems reasonable.

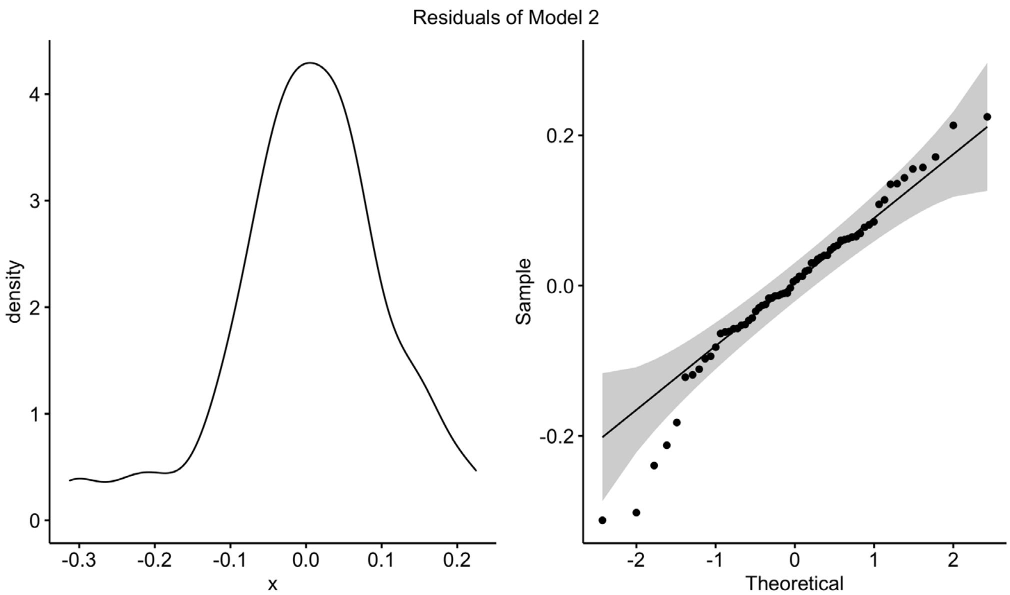

Figure 10.1: Residual plots of Model 2

Regarding homoscedasticity, the result of the Breush-Pagan test does not reject the null hypothesis. Therefore, we can continue to assume a similar variance across the data and have no reason to discredit the validity of the standard errors.

Using the Breush-Godfrey test for serial correlation, the null hypothesis of no serial correlation is rejected. The test was done on three lags. Visually inspecting the residuals, as shown in Figure 10.2, there seems to be no apparent pattern that signals serial correlation. Although serial correlation does not seem to be apparent visually, the test statistics suggest otherwise. Subsequently, the conclusions drawn from the short and long run coefficients lose credibility.

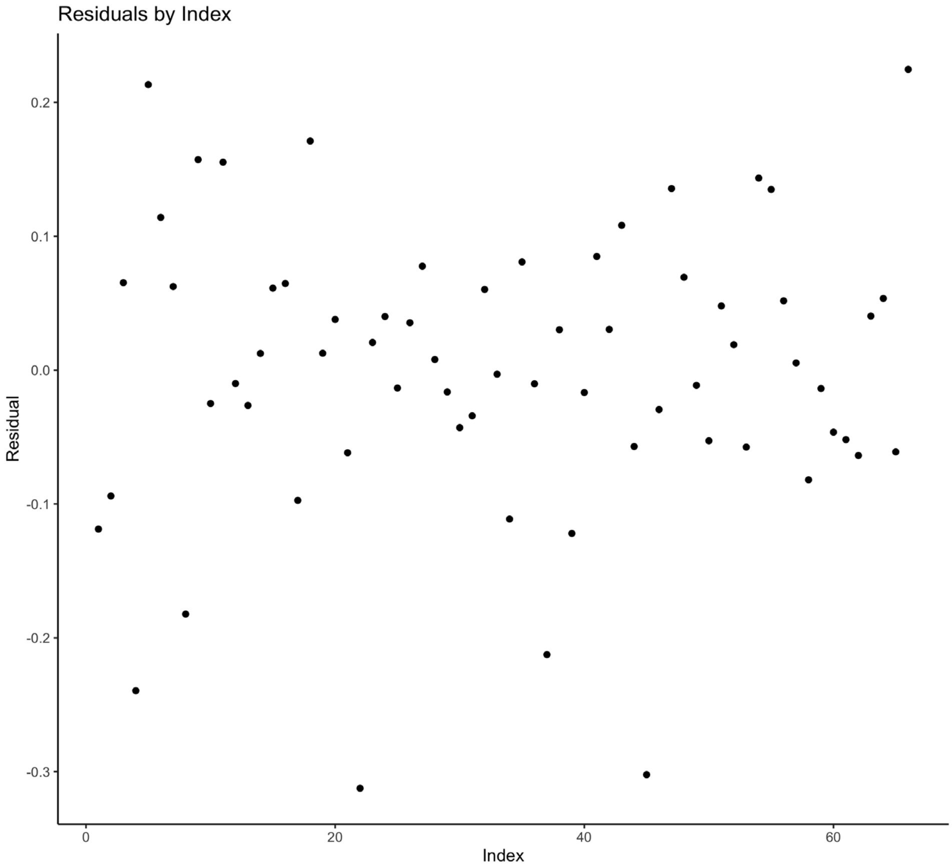

Figure 10.2: Residuals by index

11 Conclusion

This thesis set out to investigate some dynamics of the market for office real estate in Oslo. The findings of Nowak (2021) were used as a basis for the thesis. Thereby a dataset consisting of yields and relevant variables from Q1 2005 until Q3 2022 was constructed.

The analysis had the goal of answering the following question: "What are the macroeconomic drivers of the yield rate of office real estate in Oslo, Norway?".

The thesis followed a framework for vector error correction models, using the Johansen test for cointegration, to gather information on both long term and short-term effects of the tested explanatory variables. The design of the models was established after testing for stationarity, which required some altering of the models, especially in relation to vacancies.

The findings indicate a positive long and short term effect on yield by changes in the real rate. We found M2 and consumer expectation to have both negative short and long run effects. Past values of yield also have a negative effect in the short run. Additionally, the number of offices started have a negative long run relationship with yield, while offices completed positively impacts yield in the long term.

The findings do not differ significantly from previous research. The effect of M2 found by Nowak (2021) is confirmed. The significance of the added variable of consumer expectations is interesting, although a variable showing investor sentiment may perhaps uncover a more causal effect. The significance of the structural break in 2015 by Nowak is also found in this data. Interestingly, in this thesis, a significance is found related to the time period following the covid-pandemic, although the findings are opposite to the expected effects of covid and office usage. Most likely, other effects, such as lowered rates and increases in disposable income are the underlying factors.

There are several points in this thesis that may provide grounds for further research. As mentioned in Chapter 5.1.3, using the total supply of the office area in Oslo may provide a better view of the supply side. As mentioned in Chapter 2, the long-term nature of office leasing contracts implies some degree of inertia in terms of the prices. Therefore, re-investigating the effects of the COVID-pandemic may provide some interesting insights.

Also, applying this model to other cities in both Norway and Scandinavia to investigate whether there is a difference in the effects of these markets might be an interesting subject.

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Appendix

A1 Yield Definitions

Table A1.1: Prime Oslo Office (CBD/City Centre)

Type	Office - Not protected building
Size m2	12 000
Floors	8 - flexible floorplans
Standard	Great standard
Location	Vestbanetomten
Owner cost	Normalised owner costs
Parking	150 places
Tenant	Government actor or solid private A credit rating
Rental prices	Top market rate without VAT compensation
Rental period	15 years

Table A1.2: Normal Oslo Office (Helsfyr/Lysaker)

Type	Office - Not protected building
Size m2	12 000
Floors	8 - flexible floorplans
Standard	Good standard
Location	<5 minutes walk from public transport hub
Owner cost	Normalised owner costs
Parking	150 places
Tenant	4 solid private A credit rating
Rental prices	Normal market rate without VAT compensation
Rental period	8 years

A2 Error Correction Adjustment Speed

The following is the equation for calculation the adjustment speed of the error correction term

$$\frac{-\frac{1}{n}}{\ln(1+\delta)} \tag{.1}$$

Where n is the number of periods per year, and δ is the error correction term

A3 Taxes and Fees exempt in CPI-JAE

The following taxes and fees are excluded

1. Value Added Tax
2. Alcohol Tax
3. Tobacco Tax
4. Petrol Tax
5. Diesel Tax
6. Tax on electric power
7. Taxes on mineral products
8. Chocolate tax
9. Taxes on alcohol-free products
10. Sugar tax
11. Packaging tax
12. Aeroplane-, passenger and security tax
13. One-off registration tax for cars, weight based
14. One-off registration tax for cars, stroke volume
15. One-off registration tax for cars, engine power

The following energy costs are excluded

- Electricity, including power grid fees
- Fuel, liquid and solid
- Heat energy
- Petrol

A4 Consumer Confidence Index

The following questions are asked when computing the Conusmer Confidence Index

1. Would you say that the economy in your household is better or worse than for one year ago, or is there no difference?
2. Do you believe that the economy in your household will get better or worse in one year, or will there be no difference?
3. If we look at the economic situation for the whole of Norway, would you say that the economy is better or worse than for one year ago, or is there no difference?
4. Do you believe that the economic situation in Norway will get better or worse n one year, or will there be no difference?
5. Do you believe that now is a good time for the population in general to buy larger household appliances or do you believe that the timing is poor?

A5 Results of Augmented Dickey Fuller-test

	Variable	stat	p-value	sig
1	cpi_jae	-0.044	0.99	
2	nibor	-3.475	0.051	*
3	elec_1yr	-3.637	0.037	**
4	elec_spot	-1.733	0.684	
5	office_approved	-3.251	0.087	*
6	office_started	-3.018	0.161	
7	office_completed	-2.823	0.241	
8	expect	-2.712	0.286	
9	pop	-0.515	0.979	
10	m2	-1.943	0.599	
11	vacancy	-4.604	0.01	***
12	cpi	-2.092	0.538	
13	real_rate	-3.139	0.112	
14	prime	-2.589	0.336	
15	normal	-2.878	0.218	
16	gdp_12m	-1.058	0.922	
17	cpi_jae_delta	-3.293	0.08	*
18	gdp_12m_delta	-3.915	0.019	**
19	elec_1yr_delta	-4.21	0.01	***
20	elec_spot_delta	-2.065	0.549	
21	office_approved_delta	-5.217	0.01	***
22	office_started_delta	-6.333	0.01	***
23	office_completed_delta	-6.865	0.01	***
24	expect_delta	-3.268	0.084	*
25	pop_delta	-3.727	0.029	**
26	normal_delta	-3.566	0.043	**
27	prime_delta	-2.936	0.195	
28	m2_delta	-4.143	0.01	***
29	vacancy_delta	-2.834	0.236	
30	real_rate_delta	-3.626	0.038	**

**=p<0.1, **=p<0.05, ***=p<0.01*
adf.test() function in R-software (tseries package) does not give p-values less than 0.01, so any p values at 0.01 are potentially lower

A6 Results of Information Criteria Testing

Table A6.1: Lag Selection Model 1

	1	2	3	4	5
AIC(n)	20.85	19.92	19.43	19.17	**18.84**
HQ(n)	21.25	20.65	**20.48**	20.55	20.55
SC(n)	21.85	**21.76**	22.10	22.68	23.19
FPE(n)	1137990217.15	456550127.99	288503051.91	238261569.41	**192429916.95**

Lower is better, bolded is selected

Table A6.2: Lag Selection Model 2

	1	2	3	4	5
AIC(n)	18.78	18.67	18.62	**18.49**	18.51
HQ(n)	**19.05**	19.15	19.31	19.38	19.62
SC(n)	**19.45**	19.88	20.36	20.76	21.32
FPE(n)	143581675.13	129553687.17	125228137.79	**112271140.33**	119943761.49

Lower is better, bolded is selected

A7 VECM with Fewer Lags

Table A7.1: Model 1 with 2 lags

Long Run Effects	Coefficients	Standard Error	t-value	p-value
yield	1			
office	-0.00003^{***}	0.000003	-8.946	0.000
M2	-0.0587^{***}	0.0199	-2.956	0.006
real_rate	-0.1994^{***}	0.0637	-3.132	0.004
expect	0.0537^{***}	0.0073	7.404	0.000
Short Run Effects	Coefficients	Standard Error	t-value	p-value
ECT1	-0.2687^{***}	0.0468	-5.743	0.000
ECT2	$9.361e-06$	1.145e-06	0.817	0.417
d_2015	-0.3913^{***}	0.0612	-6.394	0.000
covid	-0.1777^{**}	0.0678	-2.621	0.011
Δyield.L1	-0.3080^{**}	0.1169	-2.635	0.011
Δoffice.L1	$-1.310e-07$	5.501e-07	-0.238	0.813
ΔM2.L1	-0.0065	0.0112	-0.577	0.567
Δreal_rate.L1	0.0120	0.0186	0.643	0.523
Δexpect.L1	-0.0196^{***}	0.0048	-4.061	0.000
Δyield.L2	-0.0943	0.1164	-0.810	0.421
Δoffice.L2	$6.789e-07$	8.421e-07	0.806	0.424
ΔM2.L2	-0.0301^{***}	0.0105	-2.865	0.006
Δreal_rate.L2	0.0115	0.0197	0.583	0.563
Δexpect.L2	0.0025	0.0047	0.524	0.602
Dependent variable	$\Delta yield$			
Observations	67			
R^2	0.613			
Adjusted R^2	0.511			
Residual Std. Error	0.1183 (df = 53)			
F Statistic	6.006^{***} (df = 14; 53)			
Note:	*p<0.1; **p<0.05; ***p<0.01			

A8 Data Sources

Table A8.1: Data Sources

Data	Source(s)
Yield	Malling & Co
Rent Contract Data	Arealstatistikk
Vacancy Rate	Akershus Eiendom
New Office Space	SSB (Table 05887: Byggeareal)
CPI, CPI-JAE	SSB (Table 06444: KPI og KPI-JAE)
GDP	SSB (Table 09190: Makroøkonomiske hovedstørrelser)
Policy Rate	SSB (Table 09381: Renter i banker og kredittforetak)
CCI	Finans Norge/TNS Gallup
Electricity	SSB (Table 05103 & 09364: Elektrisitetspriser)
Population	SSB (Table 01222: Befolkning)