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The Intertwining of Sectoral Stock Market Volatility and Macroeconomic Fundamentals

A study of Sweden's sectoral indices

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Abstract

The stock market has come to play a larger role in many people's lives as years pass and its accessibility has come to be exponentially easier for many. Investment in publicly listed companies has become a foundation of saving and a way of managing wealth for the general public. Even though the stock market permeates many of our daily lives and is heavily monitored and regulated, there is still uncertainty on how and what factors pave the way for changes on the stock market. One factor, often brought up in literature, is the effect of fundamental macroeconomics on the volatility on the stock market. The purpose of this thesis is to explore and delve deeper into the stock market volatility, specifically, discrepancies between sectors and the explanatory power of changes in fundamental macroeconomic variables.

To study the explanatory power of fundamental macroeconomics for the volatility of the sectoral indices, a heterogeneous autoregressive model of the realized volatility, HAR-RV, is used. We run the regressions on 11 sectoral indices, classified by the GICS, as well as OMX All-Share together with both lagged indices and 4 different macroeconomic variables as explanatory variables, inflation, industrial production, short- and long term interest rate.

The result of the thesis shows that there exists discrepancies between how the sectoral volatility can be explained by changes in fundamental macroeconomics, and what variables carry the most explanatory power. We also find evidence of a consistent significant relationship between volatility and long-term interest rates. Furthermore, sectors that are more sensitive to the business cycle are generally more responsive to changes in the IPI. We find low evidence of a relationship between both inflation and short-term interest rates to sectoral volatility, with the exception of a few outliers.

Keywords: HAR-RV, Stock Sectors, Realized Volatility

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1 Introduction

The stock market has a long history of being closely studied by the academia, professional- and retail investors, and policy makers. The financial market permeates many people's day-to-day lives, either directly or indirectly, and movements in the stock market heavily influences the economic environment as well as the general public. The stock market is a complicated entity and understanding the driving forces of both returns and volatility has puzzled researchers to this day. The market for shares is closely related to the real economy. At a fundamental level, the price of a share, and hence the movement of prices, depends on the present value of future cash flows. The size of cash flows and discount rates et cetera are clearly dependent on the state of the economy.

There has been an extensive amount of research studying and analyzing the relationship between both fundamental macroeconomic conditions and stock returns as well return volatility. Nonetheless, there is no consensus amongst the literature to what extent macroeconomic factors are a significant determinant of both returns and return volatility. There are many elements to consider such as time frame, choice of data and model, as all of these significantly impact the relationship. One branch of the research focuses on the connectedness between returns and macroeconomic fundamentals. Fama (1981) finds that returns are positively related to capital expenditure and output and negatively related to inflation. Chen, Roll and Ross (1986) find that the yield curve and growth rate in the industrial production index significantly explain stock returns. In the other branch that focuses on return volatility and macroeconomic volatility, Schwert (1989) uses a VAR-model and finds weak evidence of a consistent relationship. Abbas, McMillan and Wang (2018) uses a two-step approach by firstly estimating the volatility of variables using both GARCH and E-GARCH. Then they estimate the relationship using a VAR-model and find that industrial production growth volatility and oil price volatility influences return volatility.

This thesis aims to relate the volatility of Sweden's sectoral indices with changes in fundamental macroeconomics as an explanatory factor. The purpose is to see if there are any discrepancies between the dependence of different sectors' volatility to macroeconomic fundamentals, as well as how each index relates to real economic variables at an individual level. To the best of our knowledge, there has not been extensive research relating macroeconomic variables to volatility at a sectoral level, both on individual sectors and how they differ. This thesis fills the gap in previous literature by separating the stock market into sectoral volatility, analyzing the explanatory strength of macroeconomic variables on individual sectors and comparing the sectors to each other.

To investigate our research question we have our foundation in the HAR-RV model, developed by Corsi (2009). The advantage of this specific approach is its simplicity, the structure of the model is simple but it still exhibits the properties of volatility such as fat tails and long memory. Thus, this model easily allows for extensions, as in our case, and enables us to interpret the results in a simple way. However, we have modified the initial model to include explanatory variables, which is our chosen fundamental macroeconomics: inflation, industrial production index, and short- and long term interest rate. The sectoral indices are chosen in accordance with the Global Industry Classification Standard. The selected indices are Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care, Financials, Technology, Telecom, Utilities and Real Estate, with the addition of OMX All-Share, which will serve as a proxy for the stock market as a whole.

Our results show that there are clear discrepancies between the different sectors and how well changes in macroeconomic fundamentals explain volatility. We find that changes in the long-term yield on 10 year government bonds significantly explain volatility for all sectors to a varying degree, while changes in short-term rates are insignificant in most cases. Furthermore we find a negative relationship between the growth rate in the IPI and realized volatility for sectors that are more closely related to the general state of the economy, The inflation rate is insignificant in all cases except for the Utilities sector.

A greater understanding of the relationship between the sectors and real economic variables, as well as an understanding of the discrepancies between the stock sectors on how they are explained by changes in macroeconomic variables will be beneficial to both investors and policy makers. For investors, it can serve as a tool while analyzing optimal asset allocation, given the state of the economy, and provide evidence of what sector will exhibit a greater or lower volatility given a change in the fundamental real economy. It is also of interest for policymakers to determine what sectors are volatile, and hence more risky with respect to current and expected underlying macroeconomic conditions. By understanding the different relationships between fundamental macroeconomics and sectoral indices, it will allow policymakers, to some extent, be able to foresee turnouts of changes in these variables.

The remainder of this thesis is constructed by the following structure: In section 2, we will analyze previous research on the topic and study different approaches, as well as their advantages and disadvantages. Section 3 presents the research framework and development of our hypotheses as well as the essential elements required to answer these. Section 4 will present and explore the considered data set and its properties. The model used to answer our research question is presented and discussed in section 5. Section 6 analyzes the results and how it answers the hypotheses and how further research on this topic can be improved. Finally, section 7 concludes the thesis.

2 Previous Research

This section analyzes previous literature on the stock market and its relation to fundamental macroeconomics. The first section studies the relation of the macroeconomy with the stock market returns, the second with the stock market volatility, and the last section discusses different macroeconomic variables included by the different researchers.

2.1 Stock Market Returns and the Macroeconomy

Stock market volatility and its linkage to macroeconomic state variables and the real economy have been extensively examined in the literature. Early contributors began analyzing the effect that real economy variables had on the returns of stocks. Fama and Schwert (1977) finds that common stock returns are negatively related to expected inflation and possibly the unexpected inflation. Fama (1981) analyzed stock returns and its relationship with the real economy. The author finds that real stock returns are positively related to measures of activity such as capital expenditure and average real rate of return on capital and output. Following this, he further finds consistent evidence of negative relation between inflation rates and stock returns.

Geske and Roll (1983) examine the negative relation of stock returns to expected- and unexpected inflation, short-term interest rates and contemporaneous changes to short-term interest rates. The authors present an economic reasoning for the negative relation between inflation and stock returns through a causal chain of events. Random exogenous shocks to real activity, signalled through the stock market, induce changes in corporate tax income (through reduced corporate earnings and higher unemployment). This, in turn, changes the government deficit, government debt and consequently the monetization of the debt. Rational investors anticipate these events and adjust prices and interest rates accordingly.

Chen, Roll and Ross (1986) paper looked at systematic economic state variables' effect on stock returns and asset pricing. The macroeconomic variables chosen were variables which are sources of asset risk. The authors find variables that are significant in explaining expected stock returns, specifically growth in industrial production, changes in the yield curve (measured as the spread between 10-year and 1-month Treasury bill rates) and changes in expected inflation among others. The authors conclude that stock returns are priced in accordance to their exposure to these systematic variables. For additional reading on early contributions to the relation between stock returns and the macroeconomy see e.g. Schwert (1990), Pearce and Roley (1983), Kaul (1987), Fama (1990), and Fama and French (1989).

2.2 Stock Market Volatility and the Macroeconomy

As can be deduced from above, plenty of research has been conducted on the relationship between returns and the macroeconomy. In another branch of research, the literature shifts its focus from relating stock market returns to the macroeconomy to analyzing volatility on stock markets and its relation to the real economy, both to the volatility of the variables and to their state levels using a plethora of methods. A question that early researchers were puzzled by is why volatility on the stock market changes across time, i.e why stock returns exhibit a heteroscedastic trend. This topic is of interest since significant changes in volatility across time have important negative effects on risk-averse investors as well as capital investments, consumption and other variables related to the economic cycle (Schwert, 1989).

Officer (1977) finds, amongst other things, that volatility on the stock markets are significantly higher during the 1929-1939 Great Depression and relates this change to the volatility of macroeconomic variables. An alternative explanation for the time varying volatility of stock returns is presented by Black (1976) and Christie (1982), they argue that financial leverage partly explains the phenomenon. Schwert (1989) uses a VAR-model to relate the volatility of stock returns to the volatility of macroeconomic variables and finds weak evidence of macroeconomic volatility as a predictor of stock market volatility, however, unsurprisingly, the author finds a stronger effect in the opposite direction. Volatility in financial markets helps predict volatility in macroeconomic variables. This result should come as no surprise since pricing of stocks and other financial instruments incorporates new economic information instantaneously.

In contrast to this result, Liljeblom and Stenius (1997) consider a Finnish dataset and find that conditional volatility in inflation, industrial production and money supply is related to the conditional volatility of stock returns. In more recent years Engle, Ghysels and Sohn (2013) revisited the relation between stock market volatility and macroeconomic activity using a new set of models that separates the analysis into a short-run and a long-run component. Specifically the authors introduce a GARCH-MIDAS to be able to model the stock market using daily data and macroeconomic variables that are sampled monthly and quarterly. Their results point to that including economic activity in volatility models yields better results in terms of forecasting in the long horizon. They also find that real economic activity plays an important role in the short-term as well.

Diebold and Yilmaz (2008) examines the cross-sectional relationship between stock return volatility and the volatility of economic fundamentals. Using a sample of 46 countries they find evidence of Granger causality between GDP-volatility and return volatility. Specifically that GDP-volatility Granger causes return volatility while there is no indication of an opposite result.

Abbas, McMillan and Wang (2018) uses a two-step approach to assess the relationship between return volatility and macroeconomic variables. Firstly, a GARCH and E-GARCH specification is used to model the conditional volatility of stock returns and macroeconomic fundamentals. Next, the authors estimate a multivariate VAR to analyze the interrelation. The dataset considered consists of the G-7 countries. The results point to a low volatility transmission from real economy factors to return volatility at a country level but the overall transmission is highly significant. The most significant factors influencing volatility according to the authors are industrial production growth volatility and oil price volatility

Common methods used to model the volatility in financial assets are models belonging to the GARCH-family. Popular methods include GARCH, E-GARCH and the more recent innovation, GARCH-MIDAS which allows for data with different frequencies. An alternative model to study financial volatility, the HAR-RV, as opposed to the regularly used GARCH-models is presented by Corsi (2009). The model the author presents captures the heteroscedastic behaviour and long-run memory of financial time series data. Andersen, Bollerslev, Diebold and Labys (2003) proves that the model exhibits stronger volatility forecasting ability, in terms of out-of-sample forecasting, in contrast to the GARCH model.

2.3 Macroeconomic Variables

There is a lot of evidence from previous research that macroeconomic variables have an impact on the common stock market, where the magnitude of the effect varies between variables and at what point in time the effects are stronger. In this subchapter, we will analyze the previous researcher's inclusion and exclusion of certain fundamental macroeconomic variables.

Previous researchers include several different macroeconomic variables when studying its explanatory power of stock market volatility, and both the amount and what variables are used change, depending on the author. In a study written by Morelli (2002), he studies the conditional stock market volatility and conditional macroeconomic volatility in the United Kingdom. Morelli (2002) considers five different macroeconomic variables in his study, which are as follows: industrial production, money supply (broad money), real retail sales, Deutsche mark/Pound sterling exchange rate and inflation. The argument underlying the choice of macroeconomic variables is that the ones chosen have been shown to influence security returns. Following this, Morelli mentions that if variables can give information regarding the volatility of expected cash flows, then they can possibly explain why conditional stock market volatility changes over time.

As mentioned above, Fama (1981) studies the relationship between stock returns and inflation. He considers two types of expected inflation, one which is based on the decomposition of interest rates into expected inflation and expected real returns. The second method he uses for expected inflation is based on money demand theory and the quantity theory of money. He finds a negative correlation between the two variables.

The different variables included in Schwert's study (1989), presented in chapter 2, are: Producer power index, inflation rates, industrial production growth, high and medium quality yield measures of long-term corporate bond returns, short-term interest rate, and monetary base growth rate, among a few others, see Schwert (1989). In Schwert's study, he find that stock market volatility did in fact increase with financial leverage, however, it could only explain a smaller part of the stock market volatility. Furthermore, Schwert also finds evidence of correlation between interest rate and corporate bond volatility to stock return volatility. Finally, Schwert explains that the above mentioned factors could only explain the stock market volatility over time to a small extent.

Another interesting paper to consider is Diebold and Yilmaz (2008), where they investigate the links between stock market volatility and macroeconomic volatility, motivated by financial economic theory. In their paper they make use of real GDP as well as real personal consumption expenditures for several different countries. The volatility of the fundamental macroeconomic variables are measured in two different ways. Firstly, they calculate the standard deviation of GDP and consumption growth, secondly they use the residuals from an AR(3) process to fit GDP and consumption growth. By doing this, they have both unconditional fundamental volatility, from the first named method, and conditional volatility from the latter. Their findings include, among others, a clear positive relationship between volatility in stock return and GDP, and the same finding holds when exchanging consumption for GDP.

From the few above mentioned studies we can conclude that there is no blueprint for the amount of macroeconomic variables used, or what the variables should depict. However, we can find some resemblance between the researchers such as Fama (1981), Morelli (2002) and Schwert (1989), where they all have the inclusion of inflation. Furthermore, another common thread we are able to deduce while studying previous research is the inclusion of the industrial production index, money growth, interest rates and exchange rates, among a few others. An important key factor brought up in Morellis study (2002) is that variables that are informative on the volatility of expected cash flows for companies can be useful in order to explain changes in stock market volatility.

3 Research Framework

This chapter will dig deeper into existing research and literature while analyzing the content, relevant methods and approaches used in order to study the relationship between the stock market and fundamental macroeconomics. Furthermore, we will also discuss a division into sectoral indices and relevant macroeconomic variables. From the information gathered, together with our own intuition, we will form an opinion about the outcome and construct our hypotheses, depending on which index is considered.

3.1 Model Selection

Previous literature has considered several different approaches to model volatility of stock returns. In the literature, a popular approach to model the return volatility of financial assets such as stocks, bonds and indices is to apply a model from the GARCH-family. Many papers that relate macroeconomic volatility to stock market volatility consider a GARCH specification to model the volatility in both the macroeconomic variables and stock returns. However, in this paper we are not modelling the volatility in macroeconomic variables since we're analyzing to what extent the change and growth rate in macroeconomic variables can explain volatility in different sectors of the Swedish stock market. We consider a different approach in order to capture this effect. We consider a version of the heterogeneous autoregressive model of the realized volatility, or HAR-RV, developed by Corsi (2009). The structure of the model is fairly simple and it lacks long-memory component, but despite this the HAR-RV captures the effect exhibited by financial assets such as long-memory, fat tails and self similarity in a parsimonious and manageable way (Corsi, Mittnik, Pigorsch and Pigorsch, 2008). As mentioned before, the model of realized volatility also exhibits stronger volatility forecasting ability, in terms of out-of-sample forecasting, in contrast to the GARCH model, which was shown by Andersen, Bollerslev, Diebold and Labys (2003).

In his original paper, Corsi (2004) does not include exogenous variables but he mentions that due to its simplicity the model can easily be extended to include economically significant variables, which is something we will include when using this model. On top of this, due to the model's simplicity in structure and implementation, a meaningful economic interpretation can be made and communicated with ease.

By having the addition of exogenous variables in Corsis HAR-RV model, we will be able to analyze how a change or growth in different fundamental macroeconomics are able to explain the sectoral indices realized volatility in Sweden, and thereby formulate an answer to our below presented hypotheses. In chapter 5 we will delve deeper into the HAR-RV, its specification and the version we apply in this thesis.

3.2 Division of the Swedish Stock Market

In this thesis, we want to dissect the stock market and unlike a majority of previous research, study on a sectoral level rather than the stock market as a whole. Because of this, we have to make a decision on how we divide and choose what sectoral indices to study. The choice of the Swedish stock indices is made in accordance with the Global Industry Classification Standard. This classification standard is developed by MSCI together with S&P Dow Jones Indices, with the intention that the sectioning of indices could serve globally and be reliable in the sense that it should correctly reflect the industries in the equity investment universe (MSCI 2020). The GICS divides the stock market into 11 different sectors, which in turn has 24 industry groups, 69 industries and 158 sub-divisions. However, this thesis will only account for the 11 sectors, which are: Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Healthcare, Financials, Information Technology, Communications Services, Utilities and Real Estate with the addition of OMX All-Share, which serve as a proxy for the Swedish stock market. For more information, see MSCI (2020) provided in the reference list.

3.3 Choice of Fundamental Macroeconomic Variables

Looking at the stock market at an aggregate level, the state of the economy clearly influences the intrinsic value of a share and consequently the volatility. Fundamental macroeconomic data such as the interest rate, GDP and the inflation does not affect the stock market directly, instead it provides information on the volatility of future cash flows and future discount rates which in turn may explain the volatility exhibited by different sectors and why there are discrepancies between them. With this information in mind, together with the often used fundamental macroeconomic variables provided in previous research, we have landed in using the Swedish short- and long-term interest rates (3 months and 10 years), inflation and the industrial production index. In the below sub-chapters, 3.3.1-3.3.3 we will discuss how and why we believe that these specific variables will serve as good explanatory variables.

3.3.1 Interest Rates

Both long-term and short-term government bond yields have been proven to influence the price and hence the return of stocks, see e.g. Fama and Schwert (1977). Changes in government bond yields influence the nominal interest rates and thus the discount rate. If the discount rate changes, so does the value of future cash flows. However changes in interest rates also have an effect on the actual future cash flows, so there is uncertainty if this offsets or augments the effect due to a change in interest rates. Certain sectors on the stock market have more consistent and large cash flows than others and are thus more prone to be affected by changes in interest rates. To put into context, industries such as consumer staples exhibit consistent cash flows whereas there is greater inconsistency in cash flows for firms in the health care sector due to patents, R&D etc. Thus changes in interest rates have larger effects on sectors with consistency in cash flows compared to sectors that do not.

Another aspect of interest rates and its effect on the share price besides the effect on the discount rate relates to the capital structure and how it differs between sectors. A reduction in nominal interest rates leads to cheaper borrowing which in turn is a great incentive for firms to expand, on the contrary, higher nominal interest rates increases the cost of debt and thus reduces earnings. Sectors with larger debt levels are expected to be affected by interest rates to a larger extent, that is the volatility in these sectors can be explained to a larger extent by changes in the interest rates. However, some sectors, such as Real Estate and Financials, dependency on interest rates are more intricate than the capital structure.

A final important note is that our dataset ranges from January 2000 until March 2021 and during this time, Sweden's central bank, Riksbanken, has continuously lowered the repo rate which in turn influences the yield on government bonds. In other words our dataset only encompasses a low interest rate environment, this in turn may affect the validity of our results. Ideally we would have preferred a larger dataset in order to identify a long-run relationship independent of cycles.

3.3.2 Industrial Production Index

The Industrial Production Index is a common proxy for GDP and the real economy and, as previously mentioned, has continuously been shown to influence the return volatility of the stock market, see e.g. Chen, Roll and Ross (1986). Consider the simple present value model mentioned earlier, when the real economy changes, corporate revenue, cash flows and the discount rate changes. Hence the price of a stock changes during significant recessions and consequently stock market volatility. Nevertheless, separating the stock market into different sectors, intuitively, there exists discrepancies between the different sectors. Since some sectors are more closely related to the state of the economy than others, the effect of changes in the IPI on volatility is expected to differentiate among sectors. For example, a sector that is considered non-cyclical is Consumer Staples, it refers to firms which sell and produce essential goods which are in high demand independently of the state of the economy. In contrast to Consumer Discretionary which are non-essential goods to consumers that are higher in demand when their disposable income is sufficiently high, or when the general income level is high in the economy.

3.3.3 Inflation

Inflation is of high interest to businesses, policymakers, central bankers as well as investors. Rising inflation affects input prices, corporate profits and consumer spending amongst others. As with interest rates, inflation rate affects the stock market indirectly both through expected- and unexpected parts of inflation and the different sectors are likely to be affected differently. The discrepancies arise due to a number of factors such as free-market prices versus regulated prices, consumption goods versus raw materials and goods versus services etc. Inflation also impacts the nominal interest rate, which in turn relates to the discount rate and the overall interest rate environment in the economy. Albulescu, Aubin and Goyeau (2017) uses data from the Dow Jones indices and concludes that there exists a long-run negative relationship between inflation, its uncertainty and stock returns. They also find evidence that inflation uncertainty negatively impacts stock returns in the short run. Furthermore, they find that a cointegrating relationship can be deduced between inflation and three sectoral indices, namely consumer goods, telecommunications and utilities. A general consensus is that all equities perform worse in high inflationary periods as well as rising inflation, however some are more prone than others.

3.4 Sectoral Hypotheses

As stated above, it can be difficult to draw final conclusions regarding the hypotheses of the explanatory strength of the fundamental macroeconomic variables. In some cases, e.g. the interest rate, we can have contradicting effects which results in a question of which effect is dominating. In other cases, it can be difficult to anticipate the effect of macroeconomics on a specific sector. Furthermore, some indices are more prone to larger changes in volatility, with regards to changes in fundamental macroeconomics, than others. With this in mind, together with previous research and our own intuition, we have come to the following hypotheses regarding the different sectors:

Utilities

The utilities sector is characterized as very capital intensive due to the necessity of large amounts of investments in infrastructure therefore it is very sensitive to interest rate hikes and cuts. The sensitivity with respect to the business cycle is minimal due to the constant demand of utilities from society. Utilities are traditionally a fairly good inflation hedge due to its constant payments of dividends and consistent cash flows, but there is another aspect to it. If input prices increase, due to the regulatory characterization, firms in the utilities sector struggle to raise the prices to consumers. This effect may lead to a strong connection between inflation and returns. With this in mind we hypothesize that changes in the interest rates will impact the volatility of the utility index while inflation will have a moderate effect and finally the growth rate of the IPI will have a minimal impact.

Real Estate

It should come as no surprise that the interest rate has a major effect on real estate stock as the current interest rate environment determines the rate at which firms can borrow to finance the building of houses, offices etc. Low interest rates are very beneficial while high interest rates can be detrimental. The real estate's relation to the business cycle is also significant, during recessions and economically difficult times the income level is lower and housing prices tend to drop while the opposite is true during booms and stable economic conditions. Inflation is also expected to have an impact on returns in the real estate markets as it affects the nominal interest rate. Following this, we believe that all three macroeconomic variables impact the volatility in the real estate sector.

Consumer Discretionary

The effect of the GDP growth rate, proxied by growth rate in IPI, can easily be deduced from the definition of consumer discretionary. The term classifies firms that produce and sell goods and services that are considered non-essential by consumers. In other words consumers demand these products if their income allows them to. Hence, a significant determinant of cash flows for firms is the current income level. The interest rate also impacts the discount rate of these cash flows and should hence provide information on the volatility of returns. During higher inflation it stands to reason that if prices of luxurious and non-essential goods rise significantly the demand for them should decrease as well, therefore inflation is expected to influence the volatility of returns in the consumer discretionary sector.

Consumer Staples

Consumer staples exhibit the opposite effect with respect to inflation compared to consumer discretionary. It tends to perform better, due to the essential nature of the goods being sold. If input prices rise, firms can in turn easily raise their prices to consumers which will continue to purchase their goods. As the cash flows are consistent and large, the discount rate is important for valuation purposes, hence the interest rate is hypothesized to be a significant determinant of volatility. The growth rate in IPI is theorized to have a small effect on return volatility as the sector is very non-cyclical.

Basic Resources

Basic resources are firms which operate in discovery, development, and processing of raw materials such as mining, forestry products etc. In this sector, numerous firms supply materials to the construction and real estate industries and are hence very sensitive to the aggregate demand in the economy. This sector is cyclical in nature. Firms operating in this sector use a lot of debt to finance their input goods, machineries and other infrastructure. Companies that own natural resources such as forests, mines, etc, are sensitive to the interest rate since the present value of assets (and their cash flows) changes with respect to the discount rate. Because of this and the leverage, changes in the interest rate are hypothesized to significantly explain the return volatility. The inflation rate and its impact is difficult to ascertain. On one hand, firms can easily adjust their prices in order to sustain revenue but on the other hand inflation impacts the interest rate which in turn affects interest payments, discount rate etc.

Energy

Energy firms tend to carry a significant amount of cash and low debt on their balance sheet. They also generate significant cash flows and due to this are sensitive to the interest rate through the discount rate. Energy stocks are very pro-cyclical, due to the fact that demand for energy, and hence revenue, follows the business cycle. Therefore the IPI is expected to be a significant explanatory factor for the volatility. The sensitivity to inflation should be minimal, as firms are allowed to freely adjust their prices due to inflation.

Financials

Financials is a cyclical sector, when the economic activity increases their revenue and profits increase as well. Firms such as banks generate cash flows from increasing business activities through fees, interest rate margins, etc. Financials are also sensitive to the interest rate, banks want a higher interest rate level in the economy as interest rate margins increase. Inflation, in our opinion, is hypothesized to have a minimal impact besides the effect on nominal interest rates.

Healthcare

The healthcare sector is counter-cyclical, the demand for healthcare is constant across both booms and busts, therefore the sensitivity to the IPI is expected to be minimal. As other sectors, interest rates also impact the healthcare industry, some firms that for example produce pharmaceutical drugs are capital intensive while others such as elderly care are less sensitive. This sector should be quite insensitive to inflation as they can easily raise prices as input prices increase.

Industrials

Firms in this sector are very capital intensive and generate significant cash flows, therefore the interest rate is hypothesized to be a significant determinant of return volatility. Industrials are highly dependent on the aggregate demand in the economy and is traditionally a cyclical sector. The industrial production index is self-evidently an important aspect of this industry. Rising inflation poses little threat to revenue since firms can easily raise output prices.

Telecom

The telecommunications sector has traditionally been seen as a defensive sector, meaning that it tends to be fairly stable across time, but the sector has seen an increase in communication services corporations in recent years which are more cyclical in nature. Hence there is evidence of a sensitivity with respect to the growth rate in IPI. Fluctuating interest rates is a significant risk factor for telecommunication firms, they usually participate in large M&A deals and undertake investments in infrastructure. Inflation, especially higher inflation, is of risk to firms in this industry since it negatively affects margins and cash flows. Another aspect of inflation is that firms in this sector can push the change in input prices to the consumers and hence disregard fluctuations in inflation.

Technology

The valuation of tech firms puts heavy weight on future cash flows, hence interest changes, specifically rising interest rates, impacts the discount rate and consequently the present value of future cash flows and valuation. There are also plenty of growth stocks in this sector which benefit heavily from low interest rates. The tech sector is not hypothesized to be impacted by the IPI. One reason is due to our dataset, the dot-com bubble in sweden burst in early 2000 and this decline is separated from the fundamental real economy. Hence our results may be skewed based on this metric. Rising inflation also impacts growth stocks which are heavily represented in the technology sector.

4 Data

In this chapter we present, dissect and analyze the characteristic properties of the collected data set. First, we briefly argue for our division into sectoral indices and choice of fundamental macroeconomic variables. Continuing, we analyze the time frame and magnitude of our data set. Furthermore, we discuss a few characteristic properties of the collected data set. Finally, we conclude the chapter with a short summation of our findings.

4.1 Choice of Data

To our knowledge there is no extensive research on the relationship between stock market volatility of specific countries' sectoral indices and macroeconomic variables, we have made the conclusion to analyze 12 different indices on the Swedish stock market, including OMX All-Share. All data of the Swedish stock indices and the fundamental macroeconomic variables have been collected from Datastream. The 12 sectors are determined based on the GICS, the global industry classification standard, developed by MSCI and Standard & Poor's (MSCI, 2020), with the addition of OMX All-Share. The chosen stock indices are: Basic Resources, Consumer Discretionary, Consumer Staples, Utilities, Energy, Financials, Health Care, Industrials, Real Estate, Technology, Telecom and OMX All-Share. Basic Resources and Telecom are added instead of the Materials and Communications sector since a Swedish Materials- and Communications index does not exist in the database. Consumer Discretionary, Consumer Staples and Utilities are created by the FTSE group and the other 9 are created by Nasdaq.

As stated in the sub-chapter 2.3, even though the existing literature uses several different macroeconomic variables and are differentiated on the amount of variables used to study the relationship, there are still some recurring variables within these. With this taken into account, together with the above statement from Morelli, regarding relevant macroeconomic variables, we have chosen four different Swedish fundamental macroeconomic variables. The macroeconomic variables chosen for our study are: industrial production index (computed as the logarithmic growth rate of the IPI), inflation (calculated as the log growth rate of the CPI), the yield on both 3-month and 10-year government bonds. We believe that these three different macroeconomic variables are informative of the volatility of the expected cash flow, and changes in these could impact the different constituents in the sectoral indices, independent of which sector they are classified in. Of course, some sectors are more dependent on certain variables than others.

4.2 Description of Data

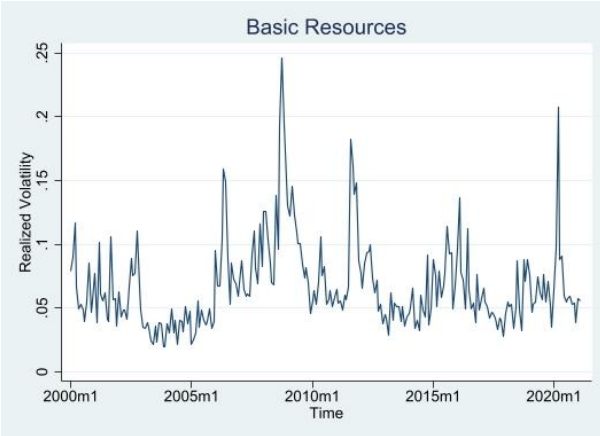
The different indices were chosen in order to try and capture all the different industries represented on the Swedish stock market. The data of the different stock indices is gathered on a daily basis ranging from 1st of January 2000 to 1st of March 2021, resulting in 5521 observations per index, excluding Energy which were not recorded until 2nd of January 2003. However, with the purpose to answer our hypothesis we transform the Swedish stock indices into monthly realized volatility, finally resulting in 254 individual observations per index.

Together with these indices we also consider different macroeconomic variables, namely CPI, industrial production index, short-term (3 months) and long-term (10 years) government bond yields. The time frame of the macroeconomic variables is composed on a monthly basis ranging from January 2000 to March 2021. The inflation rate is measured by computing the log growth rate of the CPI, we transform the industrial production index in the same way. We also choose to take the first difference of the yield on both 10 year and 3 month government bonds. For both the Swedish stock indices and the macroeconomic variables.

Below, we continue the discussion about the data set and perform different descriptive tests to study the development of the index, stationarity and more.

4.3 Descriptive Statistics

When working with financial time series, and data in general, it is important to understand your data and what type of properties it exhibits. Below we will briefly discuss the characteristics of our data set, how it affects the application of our chosen model, and if it could lead to any potentially faulty or skewed results.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Realized Volatility
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.05
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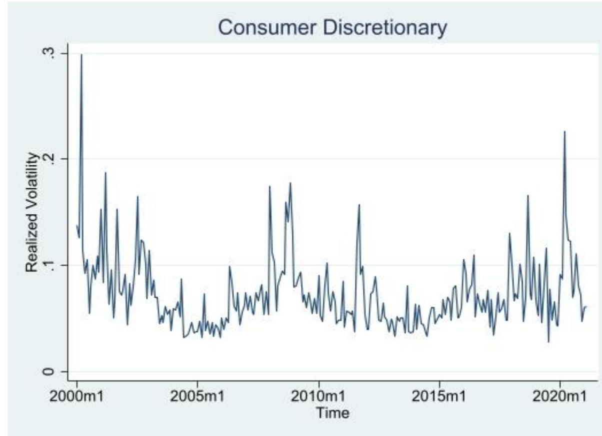
2000m1
2005m1
2010m1
2015m1
2020m1
Time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Realized Volatility
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2000m1
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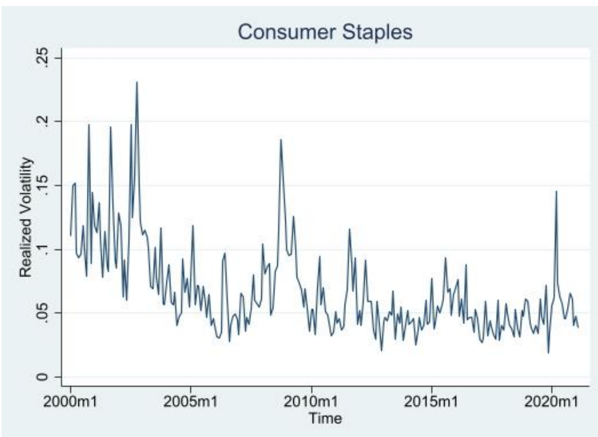
2010m1
2015m1
2020m1
Time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Realized Volatility
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2000m1
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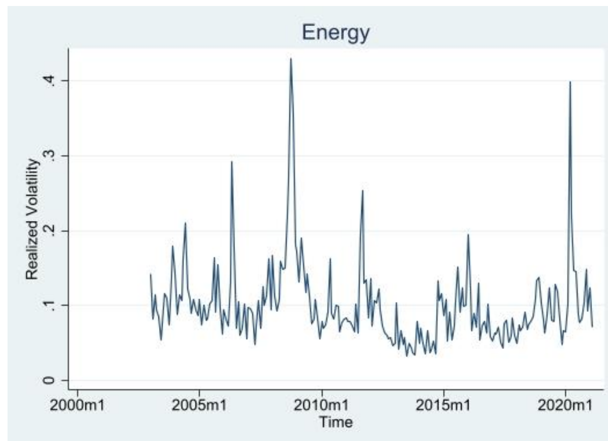
2010m1
2015m1
2020m1
Time


Energy
Realized Volatility
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.1
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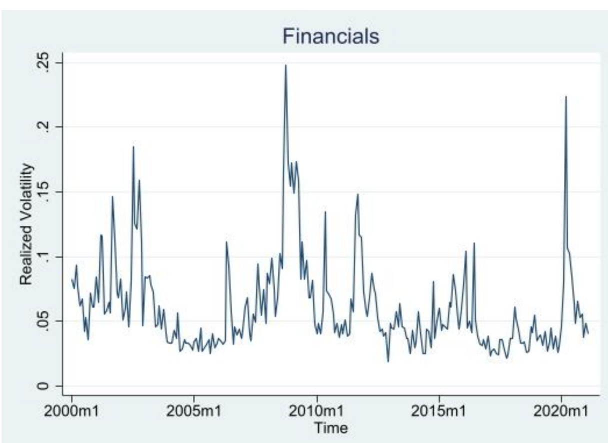
.4
2000m1
2005m1
2010m1
2015m1
2020m1
Time


Financials
Realized Volatility
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.05
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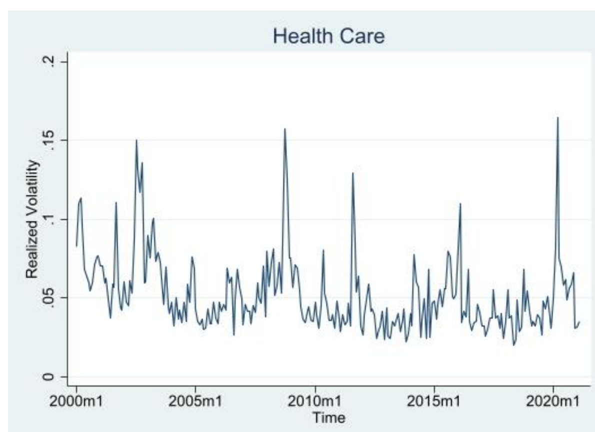
.15
.2
.25
2000m1
2005m1
2010m1
2015m1
2020m1
Time


Health Care
Realized Volatility
0
.05
.1
.15
.2
2000m1
2005m1
2010m1
2015m1
2020m1
Time

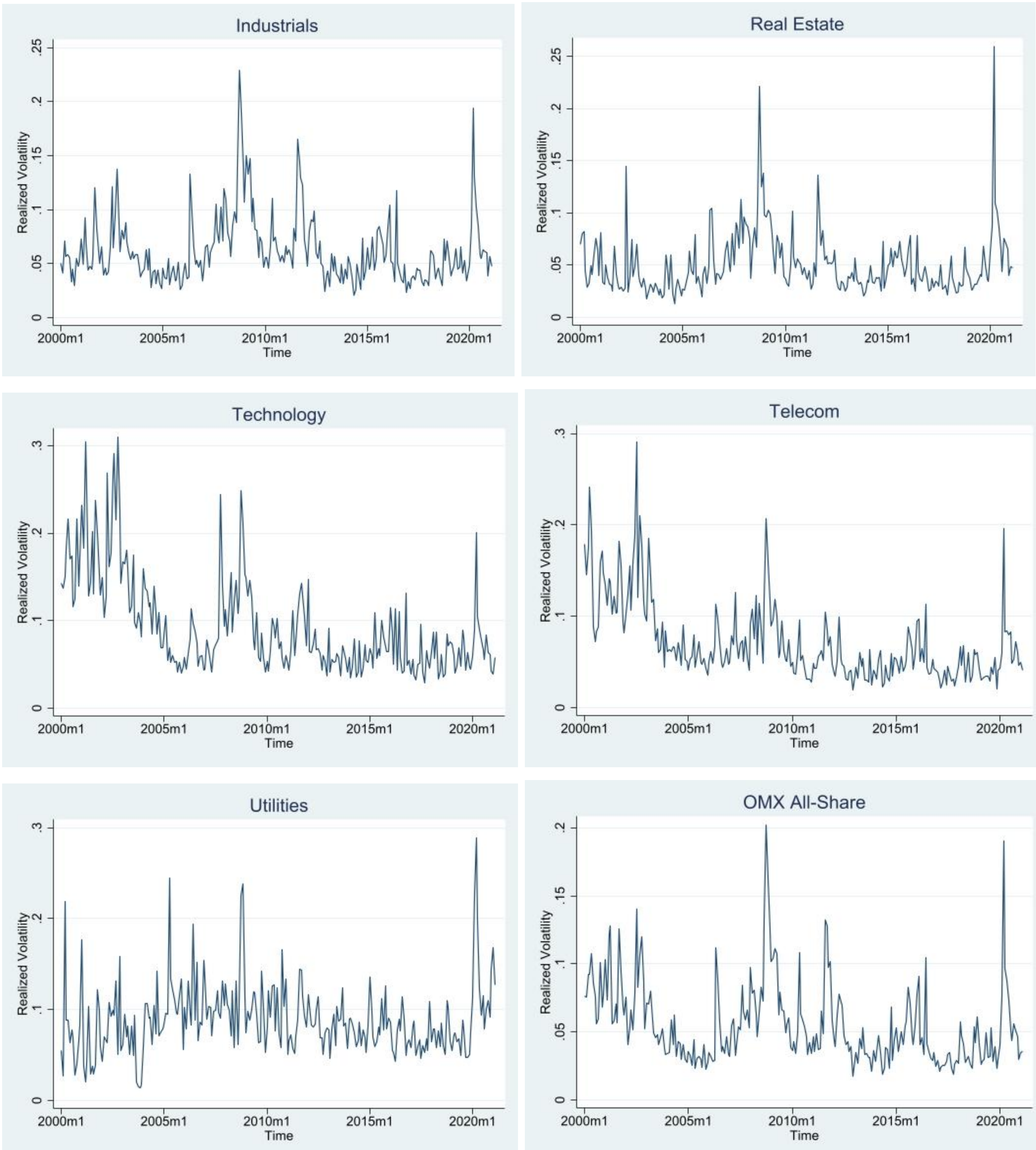


Figure 1. Monthly realized volatility of the considered Swedish stock indices

The graphs presented above represent the realized volatility of the chosen sectoral indices. When studying any type of volatility, it is interesting to study if the data exhibit any possible volatility clusterings. In a research conducted by Mandelbrot (1963), he explains that in financial time series, it is often the case that “large changes tend to be followed by large changes, of either sign” and explains that small changes follow this “rule” as well. From a brief optical inspection of the above realized volatility, we can clearly see that our data exhibit volatility clusterings. A consistent observation of volatility clustering from all the indices considered is during the financial crises in 2007-2008, which one might anticipate. This was then followed by a somewhat more stable period, up until the COVID-19 pandemic, which again led to a large-scale volatility clustering. Another interesting observation from the sectoral volatilities of the sectors is the large changes in the early 2000s for both Technology and Telecom. The clusterings can potentially be an aftermath created by the dot-com bubble in the late 1990s and early 2000s.

For the development of the sectoral indices, see appendix Figure A1. When studying these, we can clearly see an upwards sloping trend amongst several indices. However, there is one index that differentiate from the above statement, Technology. Technology exhibits a rapid growth in the early 2000s, while shortly after April 2002 experienced a dramatic change and cascaded to its lowest value of 277 SEK. The index in question remained somewhat stable afterwards, but has again developed an upwards trend.

Furthermore, from appendix Figure A1, we can also observe structural breaks throughout the time period considered, especially around the financial crisis of 2007-2008. Having structural breaks in the data considered could potentially lead to a faulty result. If such an issue exists it could result in failure in forecasting. However, in this thesis we will not study the fundamental macroeconomic variables ability to forecast the sectoral indices, but instead its explanatory ability.

Table 2. Descriptive statistics on the returns of the twelve analyzed indices.

	Average	*Std.Dev*	*Kurtosis*	*Skewness*
OMXAllShare	0.0002	0.0137	5.0219	-0.1907
Basic Resources	0.0002	0.0165	4.6528	-0.1085
Energy	0.0006	0.0252	8.5381	-0.3238
Financials	0.0002	0.0155	6.4328	-0.1126
Health Care	0.0003	0.0126	4.6851	-0.2480
Industrials	0.0003	0.0152	4.2814	-0.1052
Real Estate	0.0005	0.0128	11.4331	-0.3443
Telecom	-0.0001	0.0182	7.7419	0.1188
Technology	-0.0002	0.0239	8.1055	-0.5056
Consumer Discretionary	0.0001	0.0176	12.9391	-0.5577
Consumer Staples	0.0002	0.0166	5.9092	-0.0250
Utilities	0.0000	0.0212	6.8330	0.4190

The table above presents descriptive statistics of the selected sectoral indices. From left to the right it presents the average return, the standard deviation, kurtosis and lastly the indices skewness

The table above presents a few descriptive statistics on the returns of the twelve analyzed indices. As can be seen from Table 2, the average return across the indices are fairly similar with regards to sign and size, however two sectors, Telecom and Technology, demonstrate negative average return during the analyzed time horizon. This occurrence can be attributed to the dot-com bubble that struck Sweden's tech industry in the early 2000s and by looking at Figure A1 in the appendix the two sectors declined rapidly during this time frame. The kurtosis, which is not excess kurtosis, is also fairly similar with two outliers, Real Estate and Consumer Discretionary. By comparing the kurtosis to the normal distribution, which has a kurtosis of 3, all indices are considered leptokurtic, i.e. more concentrated around the mean, to a varying degree. Ten of the twelve considered indices have a negative skewness, this implies that the left tail of the distribution is longer while the mass of the distribution is to the right. In other words, the data exhibits more positive returns than negative but the negative returns have a wider span. The opposite effect is displayed by Utilities and Telecom.

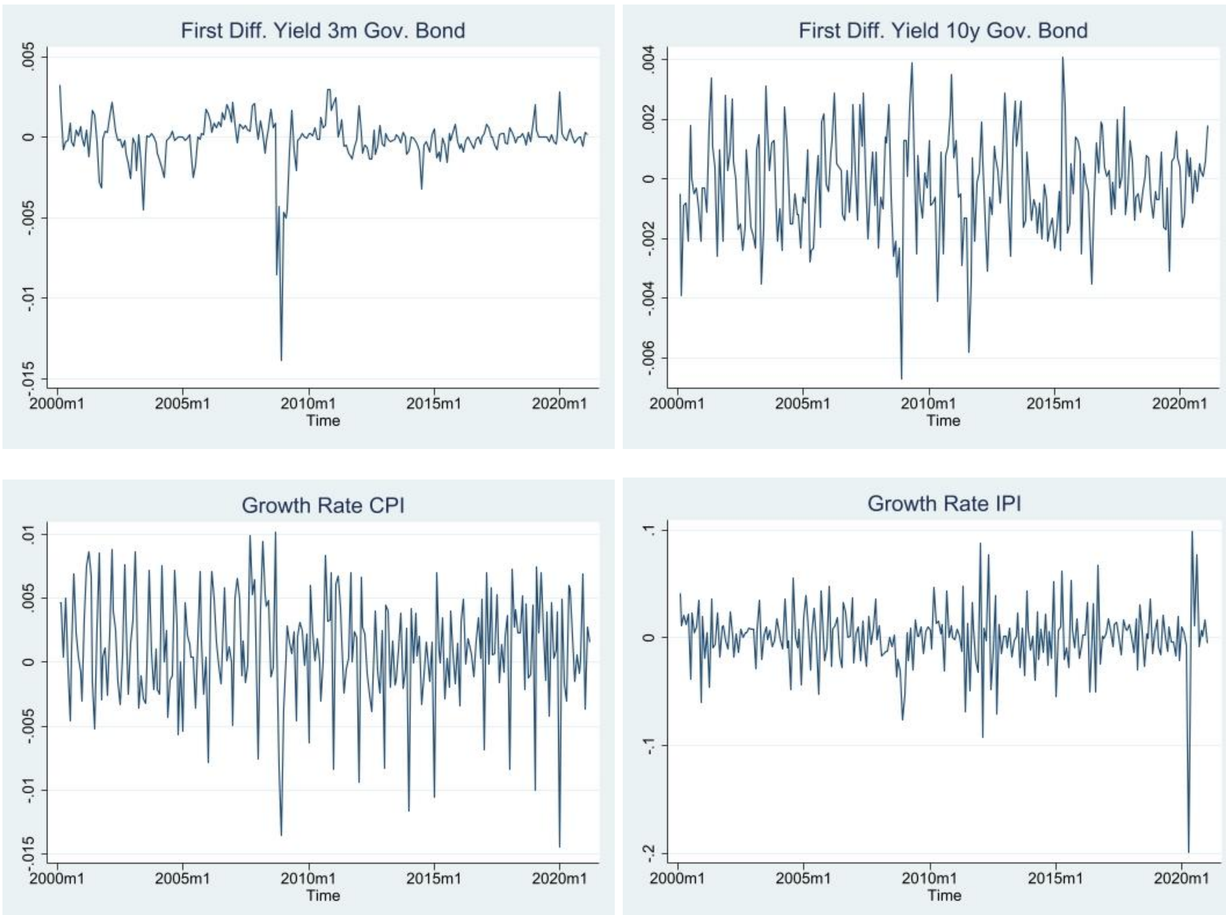


Figure 2. Time Series plots of the macroeconomic variables.

Figure 2 above presents time series plots of the four macroeconomic variables considered in this thesis. The first difference of the yield on 3 month government bonds exhibit fairly steady changes across the time frame with one exception, a massive cut in response to the financial crisis in 2008-2009. The long-term yield has seen a fairly similar pattern albeit a less dramatic cut in 2008-2009. Most of the yield changes in both instruments have been reductions, but the mean is hovering around the zero-mark. The growth rate in the CPI shows both increases and decreases, two major declines are seen during the 2008-2009 financial crisis as well as the COVID-19 pandemic in early 2020. Finally, the growth rate in the industrial production index has moved both upwards and downwards. The financial crisis and the COVID-19 pandemic have clearly impacted the IPI as can be seen in the figure. Both periods resulted in declines, especially the COVID-19 period in early 2020, however the IPI bounced back quickly and significantly.

Augmented Dickey-Fuller Test

To test the data for any potential unit roots we make use of the Dickey-Fuller test constructed by David Dickey and Wayne Fuller (1976), namely the Augmented Dickey-Fuller test. The test considers the null hypothesis that a unit root is present in the data, while the alternative hypothesis points to a variable generated by a stationary process. When performing the Augmented Dickey-Fuller test for the indices, we perform it on the stock indices reconstructed as their realized volatility. The result of the ADF-test considering the 11 indices, as well as the OMX All-Share index showed, with great statistical significance, that the variables do not exhibit a unit root with a P-value close to zero, indicating stationarity. The null hypothesis was able to be rejected at the 1% confidence level for all the above mentioned indices. The full report of our test statistic can be found in the appendix, Table A1. When analyzing the stationarity characteristics of the fundamental macroeconomic variables, once again we could not find any evidence of non-stationarity, which can be seen from Table A2 in the appendix.

Even though we would like to analyze a longer period of time, we were limited by the sectoral indices not being dated further back than January 2000. To study and answer the above presented hypotheses, we will analyze the whole sample as one time period. Given the low amount of observations, a potential drawback could be encountered such as low statistical significance, as well as misleading results.

4.4 Summary of Descriptive Statistics

To summarize our findings regarding the characteristics of our collected data set. The data of both the macroeconomic variables and the stock indices roughly stretches over a 21 year period with a total of 254 observations with the exception of a few variables, after transforming the Swedish stock indices to monthly realized volatility. Generally we can observe a positive trend in all stock indices, except telecom and technology. Furthermore, we found evidence of both structural breaks and volatility clusterings. Both volatility clusterings and structural breaks could be distinguished to certain events in the world, such as the dot-com bubble and the financial crisis in 2008 as well as the COVID-19 pandemic. After transformation, all indices exhibited stationarity, as suggested by the Augmented Dickey-Fuller test. However, when using our chosen model to study the relationship of the Swedish sectoral volatility and changes in the fundamental macroeconomic variables, stationarity is not a requirement when performing the tests. Finally, we also find leptokurtic properties of the indices, as well as mainly negative skewness.

5 Methodology

In this chapter we present our model of choice, and a step-by-step approach of its application in order to study the explanatory power of fundamental macroeconomic variables on the different sectoral indices realized volatility on the Swedish stock market.

In order to answer the mentioned hypotheses one may take different routes. Throughout this research we consider several different approaches and models which might fit, as well as their advantages and disadvantages, before landing in the below presented model.

To capture the effect of volatility clustering and heteroskedasticity, effects exhibited by financial assets, we consider a version of the HAR-RV model introduced by Corsi (2009). In order to obtain the monthly realized volatility we start from daily prices for the 12 different indices considered in this thesis. We calculate daily log returns for the different indices by computing the first difference of the logarithm of the price as follows:

(1) $$r_t = ln(P_t) - ln(P_{t-1})$$

Following this we compute the daily realized variance, $Realized\,Variance_t^{(d)}$, by squaring the daily returns. Finally to obtain the monthly realized volatility, $RV_t^{(m)}$ we compute the square root of the monthly realized variance (which is the sum of the daily realized variance for the trading days belonging to each respective month) as follows:

(2) $$RV_t^{(m)} = \sqrt{\sum_{t=1}^{n} Realized\,Variance_t^{(d)}}$$

Here, n denotes the number of trading days in each respective month. Since the number of trading days is not constant across the different months the value of n varies.

This is done for each respective index for the entire sample period ranging from January 2000 to March 2021. In order to control for the long-run volatility when running the models we include the lagged 3-month realized volatility, the lagged 6-month realized volatility and the lagged 12-month realized volatility. For example, the 3-month realized volatility is computed as the average of the previous three months 1-month realized volatility. Similar to how Corsi (2009) calculates the weekly realized volatility from the previous daily realized volatility. The 6-month and 12-month realized volatility is defined analogously.

Following this we fit the following simple time series model using OLS and Newey-West standard errors in order to control for heteroskedasticity and autocorrelation in the error terms (Newey and West, 1987):

(3)

$$RV_t^{(m)} = c + \beta_{3m}RV_t^{(3m)} + \beta_{6m}RV_t^{(6m)} + \beta_{12m}RV_t^{(12m)} + \beta_{ipi}ipi_t + \beta_{\pi}\pi_t + \beta_{10y}\Delta yield(10y)_t + \beta_{3m}\Delta yield(3m)_t + \varepsilon_t$$

Where ipi_t, is the growth rate of the swedish industrial production index at time t.π_t is monthly inflation, measured as the growth rate of the CPI. $\Delta yield(10y)_t$ is the first difference of the yield on 10 year government bonds and $\Delta yield(3m)_t$ is the first difference of the yield on 3 month government bonds. c is a constant and ε_t is an error term. Since the macroeconomic variables are not lagged we assume exogeneity when fitting the model with OLS. We do not include lags of the macroeconomic factors since we're considering their explanatory power of realized volatility and not predictive power. This means that the coefficients can be interpreted as to what extent each variable can explain the existing realized volatility.

We also run an additional version of the HAR-RV model, specifically one that controls for one lag of the realized volatility in addition to the previous model presented in equation (3). This version is also fitted using OLS and Newey-West standard errors. The reasoning behind running this model is to analyze to what extent the current realized volatility can be explained by the previous period.

(4)

$$RV_t^{(m)} = c + \beta_{1m}RV_{t-1} + \beta_{3m}RV_t^{(3m)} + \beta_{6m}RV_t^{(6m)} + \beta_{12m}RV_t^{(12m)} + \beta_{ipi}ipi_t + \beta_{\pi}\pi_t + \beta_{10y}\Delta yield(10y)_t + \beta_{3m}\Delta yield(3$$

The Newey-West standard error lag truncation, m, is selected to be 5 by the following formula, which is a common method in the literature:

(5) $$m = 0.75 \times T^{1/3}$$

Where T denotes the number of observations.

The results from this methodology will allow us to conclude the explanatory power of the independent variables, on top of this we will easily be able to distinguish any discrepancies of the independent variables' explanatory power of sectoral realized volatility.

6 Results

This section, with its foundation in the methodology and data presented in the thesis, will present the results of the regressions. The first section presents the results of the HAR-RV model, both with the inclusion and exclusion of a one period lagged realized volatility. The following section analyzes and presents the sector-by-sector results. The final section discusses the findings of the thesis, as well as discusses its limitations and improvements for further research.

6.1 Regression Results

Table 3. Regression results from running the HAR-RV based on equation (3)

	$RV^{(3M)}$	$RV^{(6M)}$	$RV^{(12M)}$	ipi	π	$\Delta yield(10y)$	$\Delta yield(3m)$	c
OMX AllShare	0.5809***	0.0373	0.0787	-0.0802**	0.4225	-3.9302***	-1.6694	0.0145***
	(0.1240)	(0.2048)	(0.1654)	(0.0383)	(0.3390)	(1.0890)	(1.2553)	(0.0045)
Basic Resources	0.6407***	0.0616	0.0584	-0.0642	0.1543	-5.0426***	0.4892	0.0150***
	(0.1641)	(0.2350)	(0.1801)	(0.0436)	(0.4234)	(1.5418)	(1.2652)	(0.0054)
Energy	0.5358***	-0.0280	0.1106	-0.0818	0.2429	-5.6351**	-1.5898	0.0366***
	(0.1318)	(0.1910)	(0.1857)	(0.1250)	(0.8153)	(2.2897)	(2.8316)	(0.0112)
Financials	0.6660***	0.0560	-0.0248	-0.0982**	0.5588	-3.8121***	-2.6368**	0.0165***
	(0.1353)	(0.2299)	(0.1544)	(0.0405)	(0.4326)	(1.2854)	(1.5113)	(0.0047)
Health Care	0.4957***	0.1489	-0.0151	-0.0687**	0.1512	-2.8671***	-0.3851	0.0180***
	(0.1872)	(0.2419)	(0.1856)	(0.0306)	(0.2599)	(1.0063)	(1.3162)	(0.0048)
Industrials	0.5705***	0.0516	0.0540	-0.0893	0.3222	-4.0288***	-2.0868	0.0189***
	(0.1373)	(0.2407)	(0.1736)	(0.0567)	(0.3490)	(1.1787)	(1.3856)	(0.0052)
Real Estate	0.5195***	0.0513	0.1170	-0.1028**	0.2406	-2.6665**	-1.4792	0.0148***
	(0.0908)	(0.2010)	(0.2114)	(0.0410)	(0.3381)	(1.1585)	(1.6857)	(0.0041)
Telecom	0.4079**	0.2466	0.1730	-0.0975***	0.5739	-3.1561***	-0.7338	0.0093*
	(0.1691)	(0.2768)	(0.1919)	(0.0353)	(0.3697)	(0.9857)	(1.8799)	(0.0052)
Technology	0.7059***	0.0199	0.1454	0.0126	0.2171	-2.8851*	-0.7470	0.0096
	(0.1954)	(0.2682)	(0.1717)	(0.0803)	(0.4807)	(1.4723)	(2.1057)	(0.0062)
Consumer Discretionary	0.4832***	-0.0389	0.2845	-0.0892**	-0.1658	-3.6106***	0.6544	0.0185***
	(0.1563)	(0.2603)	(0.2258)	(0.0453)	(0.5175)	(1.2770)	(1.325)	(0.0069)
Consumer Staples	0.5312**	0.0198	0.2563	-0.0494	-0.1336	-2.6529**	-1.3457	0.0111**
	(0.2234)	(0.2910)	(0.2031)	(0.0351)	(0.3462)	(1.1256)	(1.4032)	(0.0050)
Utilities	0.3026	-0.1187	0.4669**	-0.1207*	-0.7567*	-3.3205**	0.6848	0.0322***
	(0.1977)	(0.2041)	(0.2229)	(0.0732)	(0.4426)	(1.4171)	(2.2933)	(0.0101)

The table above presents the results of the HAR-RV model which is fitted with OLS and Newey-West Standard Errors used with bandwidth selected to 5. Standard errors are reported in parenthesis. *, ** and *** indicate significance at the 10%-, 5%- and 1% level respectively.

Table 3 presents the result from running the HAR-RV model (without controlling for the one period lagged realized volatility) on the 12 indices. The OMX All-Share index is used for comparison with the sectoral indices in order to see how the sectoral indices differ with respect to the stock market as a whole. One important thing to note is that the OMX All-Share is not evenly represented by the different sectors, some sectors have a much larger weight compared to others. Because of this, the OMX All-Share is somewhat biased. Initially there is clear evidence of a semi long-run connectectedness of the realized volatility. In all indices except Utilities the coefficient controlling for the average volatility across the previous 3 months is highly significant. Furthermore, the effect differs between indices with the largest coefficient belonging to the Technology index and the smallest, amongst the significant, is associated with Telecom. When considering longer time horizons such as the average 6-month and 12-month volatility the significance of the coefficient drops substantially. This indicates that, in the long run, previous volatility is not an important explanatory factor for current volatility. This is not surprising since market conditions are constantly evolving and looking back 6 months and 12 months is irrelevant for today's volatility. Furthermore, that the 3-month average volatility is significant should come as no surprise since clustering and heteroscedasticity amongst return volatility has been proven time and time again, at least when considering a shorter time frame. For the Utilities sector the 3-month average volatility is relevant but not statistically proven and the 12-month average volatility is significant at a five percent level, this gives evidence of the importance of both semi long-run and long-run volatility in explaining current volatility. A crucial note revolves around the constituents, specifically that index is composed of two firms. The utilities sector in Sweden is mainly state-owned and hence few public firms are active in this industry. Consequently our results may be skewed to an extent.

Table 4. Regression results from running the HAR-RV model based on equation (4).

	RV_{t-1}	$RV^{(3M)}$	$RV^{(6M)}$	$RV^{(12M)}$	ipi	π	$\Delta yield(10y)$	$\Delta yield(3m)$	c
OMX AllShare	0.4834***	0.0245	0.1865	0.0520	-0.0335	0.3836	-3.4443***	-1.2569	0.0121***
	(0.0994)	(0.1424)	(0.1645)	(0.1316)	(0.0445)	(0.3180)	(1.0093)	(1.0100)	(0.0037)
Basic Resources	0.4959***	0.0683	0.1940	0.0453	-0.0059	0.0802	-4.4579***	0.6869	0.0124***
	(0.1031)	(0.1482)	(0.1835)	(0.1439)	(0.0599)	(0.4169)	(1.3778)	(1.0804)	(0.0046)
Energy	0.5512***	-0.0742	0.1235	0.0823	0.0992	0.1989	-4.6326**	-1.7739	0.0303***
	(0.1161)	(0.1241)	(0.1515)	(0.1461)	(0.0899)	(0.7440)	(2.3230)	(2.3710)	(0.0098)
Financials	0.4615***	0.1218	0.1993	-0.0414	-0.0440	0.4688	-3.3010**	-2.1595	0.0141***
	(0.0747)	(0.1345)	(0.1913)	(0.1260)	(0.0473)	(0.4042)	(1.1784)	(1.2963)	(0.0040)
Health Care	0.4000***	0.0416	0.2479	-0.0228	-0.0360	0.1217	-2.3814**	-0.4405	0.0162***
	(0.0999)	(0.1648)	(0.1961)	(0.1528)	(0.0469)	(0.2682)	(0.9619)	(1.1380)	(0.0043)
Industrials	0.4764***	0.0296	0.1778	0.0440	-0.0399	0.2480	-3.4558***	-1.6175	0.0159***
	(0.1013)	(0.1451)	(0.1869)	(0.1406)	(0.0424)	(0.3549)	(1.0627)	(1.1874)	(0.0045)
Real Estate	0.2257**	0.2637*	0.1121	0.1027	-0.0679	0.2272	-2.457**	-1.5248	0.0140***
	(0.1006)	(0.1391)	(0.1946)	(0.1957)	(0.0510)	(0.3338)	(1.1110)	(1.6972)	(0.0037)
Telecom	0.2766***	0.1291	0.2424	0.1928	-0.0761*	0.6245	-2.8377***	-0.7151	0.0085**
	(0.1044)	(0.2242)	(0.2437)	(0.1717)	(0.0438)	(0.3897)	(0.9549)	(1.6830)	(0.0047)
Technology	0.2215***	0.4408**	0.0857	0.1311	0.0405	0.1051	-2.4487*	-0.7940	0.0092
	(0.0638)	(0.1971)	(0.2475)	(0.1602)	(0.0793)	(0.4578)	(1.4225)	(2.0149)	(0.0058)
Consumer Discretionary	0.1817**	0.2740	0.0067	0.2857	-0.0675*	-0.1721	-3.5388***	0.7695	0.0172***
	(0.0916)	(0.1692)	(0.2464)	(0.2172)	(0.0402)	(0.5195)	(1.2530)	(1.2172)	(0.0066)
Consumer Staples	0.2888***	0.2189	0.0748	0.2390	-0.0276	-0.1327	-2.2327**	-1.2874	0.0103**
	(0.0816)	(0.2316)	(0.2671)	(0.1842)	(0.0369)	(0.3613)	(1.0263)	(1.2709)	(0.0045)
Utilities	0.3529**	-0.0706	-0.0260	0.4183*	-0.0709	-0.5767	-2.7576**	0.6334	0.0299***
	(0.1500)	(0.1504)	(0.1748)	(0.2137)	(0.0559)	(0.4187)	(1.2409)	(2.0997)	(0.0086)

The model is fitted with OLS and Newey-West Standard Errors are used with bandwidth selected to 5. Standard errors are reported in parenthesis. *, ** and *** indicate significance at the 10%-, 5%- and 1% level respectively.

Table 4 presents the regression results from running the model presented in equation (4), this version includes the one period lagged realized volatility of the index as an explanatory variable, in order to control for the previous periods volatility. In comparison with excluding the one period lagged volatility, as done in Table 3, we exhibit less statistical significance, where almost all variables have an insignificant explanatory power on sectoral volatility, except the one period lagged volatility and the long-term interest rate. The reasoning behind the skewed results when including a one period lag, could be explained by the effect of the fundamental macroeconomic variables entering twice, once as the variable itself, and the other via the lagged volatility. The reasoning for this phenomenon can be connected to the efficient market hypothesis. Specifically that the market incorporates all available information at the current time when determining the price of a share. Included in this information are expectations about the future, such as how the IPI will develop, the interest rate will fluctuate and inflationary changes. The change from month to month is typically non-drastic and small, because of this the changes get anticipated and priced in at one lag.

Another explanation of the difference in statistical significance between the two models can be attributed to omitted-variable bias. The lagged realized volatility is correlated with the independent variables and by excluding the lagged volatility the estimators become biased. Thus, it results in the model incorporating the effect of the lagged volatility to the other variables that are included. However as can be seen by Table 3, the effect might be entirely captured by the lagged 3-month volatility as it is highly significant whereas it was not in the model presented in Table 4.

Because of the above mentioned complications with the inclusion of a one period lagged realized volatility, we base our discussion on the results presented in Table 3. It is difficult to pinpoint the exact causation of the difference in statistical significance so the results discussed should not be taken as an absolute but it gives an indication of the relationship.

IPI

As can bee seen from Table 3, the growth rate in the IPI is significant for 7 out of the 12 indices considered in this dataset. If we begin by looking at the OMX All-Share, the negative sign of the coefficient indicates that there is a negative correlation between the growth rate in the industrial production index and the volatility. In other words, when there is an increase in the IPI the volatility exhibited tends to be lower. This result is quite economically intuitive as the IPI acts as a proxy for the real economy and when the real economy performs better, the volatility of stock returns is lower. Another aspect at play here is the asymmetrical effect between negative- and positive returns and volatility. Previous research has proven that volatility is higher following negative returns compared to positive returns, and when the economy is strengthening, returns are positive and consequently this leads to lower volatility. All indices except Technology have a negative coefficient for the IPI, however the size of the coefficient varies between indices. It is significant for the following indices: Utilities at a ten percent level, Financials, Health Care, Real Estate and Consumer Discretionary at a five percent level and finally Telecom at a one percent level. The coefficient is insignificant for Basic Resources, Energy, Industrials and Consumer Staples.

Inflation

The monthly inflation rate, measured as the growth rate in the CPI, is insignificant in explaining return volatility in all indices except Utilities. The coefficient is positive, meaning that there is a positive relationship between volatility and inflation, if inflation increases the mean return volatility tends to increase during that month as well. The positive relation is exhibited by the following indices: OMX All-Share, Basic Resources, Energy, Financials, Health Care, Industrials, Real Estate, Telecom and Technology. However this effect can not be statistically proven. Three indices have a negative coefficient and relationship, specifically that when inflation increases the mean of the return volatility tends to be lower. The three indices are: Consumer Discretionary, Consumer Staples and Utilities. Generally, rising inflation has a negative impact on stock returns as it puts downward pressure on margins and earnings, increases cost of debt and increases input costs. Judging from our result it is hard to argue for a consistent relationship between the inflation rate and volatility. An important note is that the inflation rate during our dataset, ranging from 2000 - 2021, has been fairly stable and consistent. But as history tells us this has not always been the case. Therefore our dataset fails to capture high inflationary periods as well as massive spikes, up and down. The low inflationary period throughout our dataset has possibly resulted in the small and insignificant effect of inflation on volatility.

Interest rates

As can be seen from Table 3, there is clear evidence of a fairly consistent negative relation between the first difference on the yield of a government debt instrument and the return volatility. For the 10 year bond, the coefficient is highly significant for all considered indices. Specifically it is significant at the ten percent level for Technology. At the five percent level for Energy, Real Estate, Consumer Staples and Utilities. Finally at the one percent level there are seven indices: OMX All-Share, Basic Resources, Financials, Health Care, Industrials, Telecom and Consumer Discretionary. The negative relationship implies that given a decrease in the yield (compared to the previous month), i.e. a negative sign on the first difference, the mean of the return volatility tends to be higher, and vice versa given an increase in the yield. This result is somewhat unintuitive. Generally when interest rates decrease, the present value (and size) of future cash flows are expected to increase through a reduction in the discount rate and the lowering of interest payments. This in turn increases returns and as previously stated should reduce volatility (due to positive returns having a smaller effect on volatility compared to negative returns). However, throughout our dataset the interest rate has continuously been lowered due to the continuous reduction in the repo rate by the Swedish Riksbank. This has led to most observations of the yield changes being negative which consequently impact the relation to return volatility. This limits the robustness of our results as we only analyze a time period in which the interest rate environment is low and decreasing.

6.2 Sector-by-Sector results

From the above presented result we have been able to find several statistical significant effects of fundamental macroeconomic variables explaining volatility in Sweden's sectoral index returns. Below we will present the results sector by sector.

Utilities

As mentioned before, the average realized volatility over 12 months is significant while the average across 3 months is insignificant in explaining the volatility of the Utilities index. This is an opposite result compared to the other sectors, and gives an indication of a long-run volatility connectedness. The growth rate in the IPI is significant at a five percent level, on top of this the coefficient is the most negative of all indices. In other words, the IPI explains a lower volatility to a larger extent in the Utilities sector compared to the rest of the dataset. This contradicts our hypothesized effect. We also find a significant negative relationship between inflationary changes and volatility, the hypothesized effect of Utilities inflationary hedge may be dominating. Long-term interest rate changes are also a significant determinant of volatility in line with the other sectors. The composition of the index is important for this sector, there are not many publicly traded firms operating in the Utilities sector, specifically there are only two constituents in the index. Hence this may skew our results.

Real Estate

The 3-month average volatility, the growth rate in the IPI and the long-term yield changes are significant factors explaining the volatility in this sector. This confirms our predicted result with the exception of the insignificant effect of inflation rate. The real estate sector is heavily dependent on the state of the economy and the interest rate environment through heavy debt payments, and consequently our result is economically intuitive.

Consumer Discretionary

As earlier predicted, the IPI and the interest rate, specifically the 10 year yield, explains the volatility of this sector. It is highly sensitive to the business cycle as previously mentioned and the negative coefficient of the IPI indicates that volatility tends to be lower when the IPI is increasing. Controlling for the 3-month realized volatility is significant while the other time horizons are not. Similar to a majority of the other indices the sector is sensitive to long-term interest rate changes. Inflation is negatively related to the volatility but insignificant, which is a somewhat spurious result.

Consumer Staples

The only significant coefficients for the Consumer Staples sector is the 3-month realized volatility and the long-term yield. The inflationary effect is negative which is what we predicted, however we cannot statistically prove this. The IPI is also insignificant, which is economically reasonable since this sector is steady throughout the business cycle. The interest rate is a significant factor, which is in accordance with what we hypothesized earlier.

Basic Resources

The cyclicality of this sector, i.e. the effect of the IPI, is negative but insignificant, we can not statistically prove that the growth rate in the IPI is negatively related to the return volatility. The inflation rate is positive but insignificant. As with the other sectors, controlling for the 3-month realized volatility is significant at a one percent level. The long-term and the short-term interest rates are negatively related to the volatility, but only the long-term yield can be statistically proven.

Energy

As previously hypothesized the interest rate is a significant factor, the 3-month is slightly positive but insignificant, however the 10-year yield is significant and the largest negative number compared to all the other sectors. The relationship between inflation and the realized volatility in the Energy sector is slightly positive but insignificant which is in line with our expectation. We expected the IPI to be a significant determinant of volatility, we see a negative effect but it is not statistically satisfied.

Financials

The financial sector is heavily dependent on the current interest rate environment and we expected the interest rate to be a significant determinant of the volatility, our results can confirm this as both the long-term and the short-term rates are significant at one percent and five percent respectively. The IPI is negative and significant which confirms the cyclical nature of the financial sector, on top of this the coefficient is the second lowest value which further confirms the relationship. The growth rate in the CPI is positively related to the realized volatility, however it is statistically insignificant.

Health Care

As mentioned in chapter 3, the Health Care sector is characterized as counter-cyclical and has a relative constant demand through time. As hypothesized, we can not find any statistical significance of inflation having an effect on the realized volatility, as is the case with the short-term interest rate. However, we do find evidence of changes in the long-term interest explaining changes in the realized volatility at the 1% confidence level. To our surprise, we do also find evidence at the 5% confidence level that changes in IPI negatively related to the index volatility. The negative relation is an indication of cyclical characteristics, however, the value is rather small in comparison to the other sectoral indices. Finally, as with almost all observations, growth rate in CPI is positively related, but not significantly.

Industrials

Industrials exhibited statistical significance at the 1% level for both the three month lagged index and the long-term interest rate, where the first one is positively related, and the latter negatively. The findings of changes in the interest rate being able to explain changes in the industrial index volatility is in accordance with our hypothesis. The IPI presented a negative value, which indicates a cyclical behaviour, however, it is insignificant.

Telecom

Telecom has the same statistical significance and sign regarding the explanatory variables is industrial, with the addition of a negative IPI, which is significant on the 1% confidence level.

As expressed in sub-chapter 3.3.4, telecommunication has experienced a rapid growth in recent years and developed a sensitivity to the growth rate of IPI, which is in accordance with the above findings. Telecom did not exhibit any statistical significance with regards to inflation or longer lags of the realized volatility.

Technology

Firstly, an important factor to have in mind when analyzing the result regarding the technology sector is the huge impact of the dot-com bubble. The statistical significance of the fundamental macroeconomic variables being able to explain the changes in the realized volatility is relatively low, compared to the alternative indices. The three month lagged realized volatility is positive and statistically significant at the 1% level, the long-term interest rate is negative and significant at the 10% level, while the rest of the explanatory variables are insignificant. In accordance with the presented hypotheses, IPI did not have any explanatory properties.

6.3 Discussion, Limitations and Improvements for Future Research

The purpose of this thesis is not to delve too deeply into the specific mechanism involved in the movement of sectoral return volatility, entire papers are dedicated to answer the question of what the underlying forces are that drive the returns and return volatility of a certain sector. Nonetheless, what we try to dissect and answer is how the different sectors can be explained by movements in macroeconomic fundamentals and if there are any discrepancies between the explanatory strength of the variables between the sectors.

A surprising effect we found is that when interest rates decrease, the volatility of the sector tends to be higher, and the opposite effect when interest rates increase. Generally, when interest rates increase, the stock market performs worse. However, as previously mentioned our dataset covers a time frame where the interest rates, through the Swedish Riksbank's repo rate, have continuously been lowered. This may be a significant factor defining the relationship presented between interest rates and volatility in this thesis. Including a larger dataset that incorporates both a higher- and lower interest rate environment is beneficial and something we would have liked to do. The inflation rate suffers from the same problem as the interest rates, in our considered time frame the inflationary environment is fairly low throughout our dataset. Expanding the time frame, a low inflation environment is not something that has been constant.

An important note when considering the results is that the OMX Stockholm's weights with respect to the different sectors is not constant across time and some sectors have a much larger weight compared to others. Furthermore, in the sectoral indices, there are also discrepancies between the weights, in some cases there are only two constituents such as the Energy index and in others certain firms are so large that they dominate the index. Therefore the results related to an index may be skewed as one single firm may be responsible for the movement of an entire index.

One essential aspect of our variables relates to the relationship between inflation and the yield on both long-term and short-term government bonds. The rates on these instruments are nominal, which means that rates are a combination of expected inflation and the real interest rate. This has impacted our result and may help to explain why the inflation rate coefficient is insignificant for most of the sectors.

A great addition for further research on this topic would be to analyze only time varying effects between different periods as well as different states of the economy, and put it into comparison. However, in order for it to have a meaningful result, it would require a larger data set with enough observations in order to do this division. With a larger data set you are able to divide the whole sample into different time periods in order to study any potential difference, or change in "trend" between these, e.g. analyzing turbulent times in comparison to more stable times, with regards to the economic environment. However, considering our sample with relatively few observations, we made the decision to exclude such groupings because of the potential drawbacks of even smaller sample periods. Including this will be a great and interesting addition to future research.

A further addition to improve this study is the inclusion of dummy variables. In the time frame considered are some events causing abnormal activities, such as the dot-com bubble, the 2007 financial crisis and the COVID-19 pandemic. These events could potentially pose a threat and thereby lead to faulty or skewed results. Including a dummy variable could capture the effects of events with a large impact on the sectoral indices, and thus a more valid and statistically significant result.

Another interesting addition to further research would be to analyze any discrepancies between countries, or continents. The inclusion of such comparisons would further improve the understanding of macroeconomic variables' effect on the different sectors of the stock market, and thus help with optimal asset allocation and the diversification of risk. As mentioned earlier, this is something we were limited by and would like to see more research on.

To further improve our thesis for further research is to include a larger amount of fundamental macroeconomic variables. In order to get a broader view and a better understanding of the intertwining of the sectoral stock market and fundamental macroeconomics, both for investors and policy makers, it would require a larger data sample in the form of more explanatory variables.

Furthermore, in this thesis we have solely relied on one model in order to analyze our research questions. Improvements for further research on this topic could include different models, as well as analyzing using multiple models in order to verify the above presented results.

Lastly, a limitation we encounter is the continuously decreasing nature of the interest rate in Sweden. As mentioned, this led to a majority of the observed interest rate changes being negative throughout the data sample. This characteristic may affect the results robustness regarding the explanatory power of interest rate on changes in the indices realized volatility, and may lead to somewhat skewed results, and should be interpreted with care.

7 Conclusion

This thesis has its foundation in the HAR-RV model developed by Corsi (2009), in order to study the explanatory effect that changes in fundamental macroeconomics has on the realized volatility of sectoral indices in Sweden.

The regressions conducted in this thesis considered two different alternatives, where one excluded the one period lagged sectoral index volatility, and the other included it. Depending on the variables inclusion we received relatively different results. By including the variable, we lost statistical significance for some variables, mainly IPI. We believe that there are two plausible explanations for this. The first one being omitted-variable bias causing the IPI and the average 3-month realized volatility to absorb the significance of the omitted lag. The second one is that the explanatory power of the macro variables are instead being priced in one period ahead due to expectations about the future state of the economy. Hence the effect enters twice, once through the lag and the other through the dependent variable.

To present the main findings in this thesis, we did find several statistically significant effects of changes in fundamental macroeconomic variables that explained both an increased, and decreased volatility in the different sectoral indices in Sweden. On top of this we find evidence that there are clear discrepancies between the sectors with regards to what extent macroeconomic variables explain volatility. We mainly found evidence of explanatory properties for the three month lagged realized volatility, for all respective indices, but also the long-term interest rate. Additionally, some changes in indices realized volatility can be explained by IPI, and only the changes in the financial sectors realized volatility can be explained by the short-term interest rate. Furthermore, inflation only exhibits explanatory properties for changes in the Utilities sectors realized volatility.

To conclude our thoughts, the thesis finds statistical significance of changes in fundamental macroeconomic variables being able to explain changes in sectoral indices realized volatility in Sweden. The long term interest rate and the three month lagged realized volatility exhibit the largest explanatory power, where the first one is negatively related and the latter positively. IPI is mainly negatively related (except Technology) and able to explain some change. Finally, inflation and the short term interest rate both had low explanatory power, which exhibited both positive and negative relation to the sectoral indices realized volatility.

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Appendix

Table A1. Augmented Dickey-Fuller test on the realized volatility of the Swedish sectoral indices

	Test Statistic	1% Crit. Value	5% Crit. Value	10% Crit. Value		Test Statistic	1% Crit. Value	5% Crit. Value	10% Crit. Value
	---------- Interpolated Dickey-Fuller ---------					---------- Interpolated Dickey-Fuller ---------			
Basic Resources				Number of obs = 253	Healthcare				Number of obs = 253
Z(t)	-6.831	-3.460	-2.880	-2.570	Z(t)	-7.915	-3.460	-2.880	-2.570
Consumer Discretionary				Number of obs = 253	Industrials				Number of obs = 253
Z(t)	-9.754	-3.460	-2.880	-2.570	Z(t)	-6.993	-3.460	-2.880	-2.570
Consumer Staples				Number of obs = 253	Real Estate				Number of obs = 253
Z(t)	-7.108	-3.460	-2.880	-2.570	Z(t)	-8.766	-3.460	-2.880	-2.570
Energy				Number of obs = 217	Technology				Number of obs = 253
Z(t)	-7.319	-3.471	-2.882	-2.572	Z(t)	-6.250	-3.460	-2.880	-2.570
Financials				Number of obs = 253	Telecom				Number of obs = 253
Z(t)	-6.530	-3.460	-2.880	-2.570	Z(t)	-6.680	-3.460	-2.880	-2.570
Utilities				Number of obs = 253	OMX All-Share				Number of obs = 253
Z(t)	-10.467	-3.460	-2.880	-2.570	Z(t)	-6.867	-3.460	-2.880	-2.570

All indices: MacKinnon approximate p-value for Z(t) = 0.0000

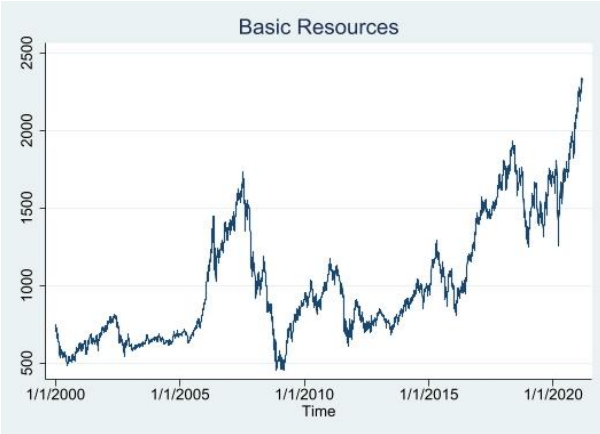
This table presents the values of an Augmented Dickey-Fuller test on the 12 different Swedish sectoral indices,including OMX All-Share, transformed as log of first difference.

Table A2. Augmented Dickey-Fuller test on the fundamental macroeconomic variables

	Test Statistic	---------- Interpolated Dickey-Fuller --------- 1% Crit. Value	5% Crit. Value	10% Crit. Value
ipi			Number of obs = 250	
Z(t)	-31.947	-3.460	-2.880	-2.570
π			Number of obs = 252	
Z(t)	-27.227	-3.460	-2.880	-2.570
Δ*yield* (10y)			Number of obs = 252	
Z(t)	-11.836	-3.460	-2.880	-2.570
Δ*yield* (3m)			Number of obs = 252	
Z(t)	-8.674	-3.460	-2.880	-2.570

All variables: MacKinnon approximate p-value for Z(t) = 0.0000

The table above presents the values of an Augmented Dickey-Fuller test on the 4 different fundamental macroeconomic variables: growth rate of IPI, growth rate of CPI, growth rate of a 10 year Swedish government bond, and growth rate of a 3 month Swedish government bond.


Basic Resources
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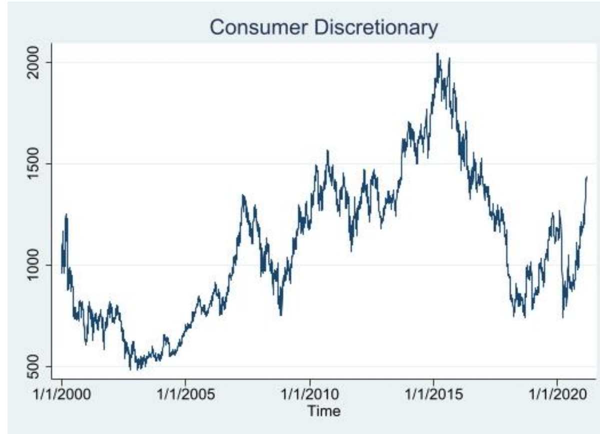
2000
1500
1000
500
1/1/2000
1/1/2005
1/1/2010
1/1/2015
1/1/2020
Time


Consumer Discretionary
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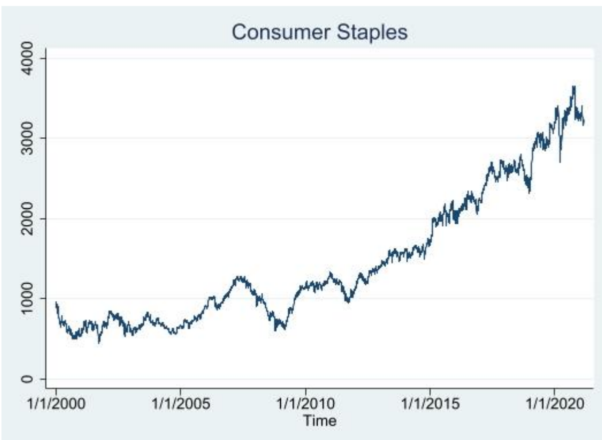
1500
1000
500
1/1/2000
1/1/2005
1/1/2010
1/1/2015
1/1/2020
Time


Consumer Staples
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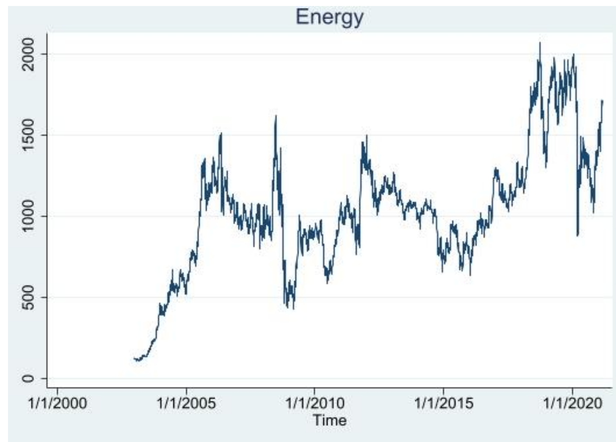
2000
1000
0
1/1/2000
1/1/2005
1/1/2010
1/1/2015
1/1/2020
Time


Energy
2000
1500
1000
500
0
1/1/2000
1/1/2005
1/1/2010
1/1/2015
1/1/2020
Time


Financials
Health Care
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1/1/2015
1/1/2020

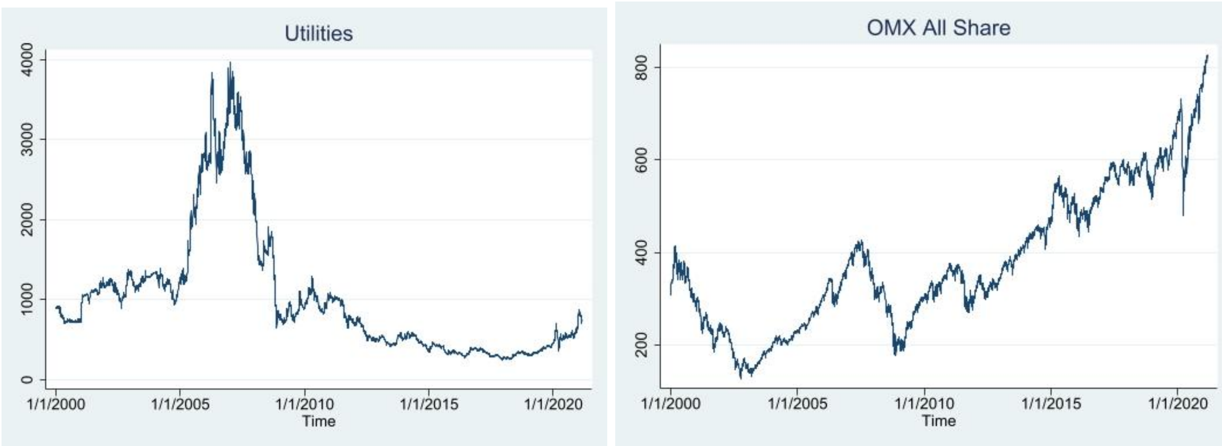

Figure A1. Plotted values of the chosen Swedish sectoral indices and OMXS30 and OMX All-Share