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Green bubble?

An analysis of explosive behaviour in the Norwegian stock market

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Preface

This master thesis is written as the final part of our MSc studies in business administration with a specialization in Applied Finance at the University of Stavanger. It has been a challenging and educational semester, where we have been able to use all the tools, we have developed throughout our studies to research a topic we find both relevant and interesting.

During this semester, our programming and data visualization skills in R have been put to the test, and we can honestly say that it was more challenging than we would have anticipated.

We would like to thank our supervisor, Bård Misund, for his guidance and constructive feedback. Furthermore, we would like to thank our professors Tom Brökel and Siri Valseth and Head of Nordic Equities in Danske Bank, Lars Erik Moen, for their valuable input.

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Abstract

Green investing has never been more relevant than it is today. Investors are flocking to green stocks and 2020 and 2021 saw a record high number of green companies being listed on the Oslo Stock Exchange. As green stocks are new to the market, several of them are growth stocks that have negative earnings due to their high investment levels. The high number of investments being made into green stocks and the price level of these stocks have led many academics and financial analysts to question whether the stock market is experiencing a green bubble. The purpose of this thesis is to investigate whether there is a green bubble in the Norwegian stock market. We use data for 48 green companies that are listed on the Oslo Stock Exchange and Euronext Growth, as well as the OSEBX index representing the Oslo Stock Exchange for comparison. The data is tested for unit roots against periods of exuberance using different variations of the Augmented Dickey-Fuller (ADF) test. We detect periods of exuberance in the OSEBX and among the green stocks. However, there is insufficient evidence to suggest that the stock market is currently experiencing a bubble, yet we discover tendencies that might indicate that a green bubble took place around 2020/2021. Moreover, the thesis will explore the drivers behind asset bubbles to better understand why bubbles occur, and we will see how macroeconomic factors and trends influence stock markets.

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1. Introduction

Sustainability is becoming increasingly more relevant and investments in green stocks on the Norwegian stock exchange are booming. This is a direct result of the increased focus on ESG (Economic, Social, and Governmental) factors among companies and their stakeholders, and the number of green stocks on the exchange has nearly doubled in the last few years (Nilsen & Lang-Ree, 2021). Despite the increased popularity of green stocks, there is no fixed definition for green stocks. Different criteria are applied when classifying assets as green, making it difficult for investors to differentiate between assets. Over the last few years, we have also seen green bonds growing in popularity, with a growth rate of 49% in the five years prior to 2021 (World Bank, 2021). Green bonds are debt securities used to fund environmental or climate-friendly projects. This increase in green bonds is referred to as the "green bond boom" by Morgan Stanley (Morgan Stanley, 2017). As investors seem to be increasingly aware of sustainability, green bonds can be a good way for companies to attract investors.

The explosion in demand for green stocks and the price levels of those assets has academics and professionals drawing parallels to previous asset bubbles and suggesting that there could be a green bubble taking place. NHH-professor Ola Grytten claims that green stocks are overvalued as their price is not rooted in market fundamentals, and he fears that we could be experiencing a bubble where a correction is imminent (Lorch-Falch & Sættem, 2020). Our thesis aims to shed some light on whether this is the case, by analyzing a selection of green stocks on the Norwegian stock exchange. For this purpose, we have formulated the following research question:

"Is the Norwegian stock market experiencing a green bubble?"

To examine this research question, we use a methodology developed by Phillips, Shi, and Yu (2011). This methodology allows us to identify and date stamp explosive bubbles in stock returns. Specifically, the methodology uses the Augmented Dickey-Fuller (ADF), sup ADF (SADF), and generalized sup ADF (GSADF) tests for this purpose. Using these tests and applying relevant theory we will also address the following research questions:

- Are there previous indications of a green bubble taking place?
- What can be drivers behind a green bubble?

In the first part of our thesis, we will provide some background on green investing and the history of asset bubbles. We will continue by outlining some relevant theories and explain how asset bubbles develop. Next, we move over to the methodology and explain our data and the tests we will perform using the programming language R. In the last section, we will present our results with an in-depth discussion and draw a conclusion based on our findings.

2. Background

This chapter explores the background for our research question. It dives into the history of asset bubbles and looks at the status green stocks have in the market. Furthermore, we elaborate on the impact recent events have had on the global financial markets and more specifically the Norwegian stock market.

2.1 Green Stocks and ESG

Sustainable investing is a growing trend, and there are several reasons for this. First, people are becoming more concerned with sustainability, which is an increasingly discussed topic throughout society. In general, people are becoming more aware of the effect global climate gas emissions have on the planet, which may influence investors preferences and their views on future returns on stock investments. In line with the increasing global awareness of sustainability, investors wish to make sustainable investments that align with their values and positively impact society (Danske Bank, 2023). Investors can use their impact and voting rights to make businesses more concerned with sustainability (The Economist, 2022).

Climate gas emissions are a form of market failure (negative externalities), and Governments will continue to introduce regulations and environmental taxation and subsidies that will 1) increase costs for companies that create negative externalities, and 2) reduce costs or increase revenues for companies that create positive externalities (benefits for society). Environmental taxes such as climate gas emission taxes or fees will negatively impact the profitability of these firms (internalization of negative externalities). This includes taxes on energy, transport, and pollution. In addition, policymakers will introduce stringent environmental regulations, such as quotas, standards, and requirements for specific technologies. Moreover, regulations require companies to be transparent about their environmental impact, not only their own emissions (Scope 1), but also their impact on the entire value-chain (Scope 3). A recent EU law requires all large companies and all listed companies to disclose information on their risks and opportunities arising from social and environmental issues, and on the impacts of their activities on people and the environment (European Commission, 2023).

Another reason investors are choosing green stocks is that they expect better returns on green investments than alternative investments (Danske Bank, 2023). There are several reasons why investors believe green stocks generate better returns. An example of this can be that they believe that the demand for green stocks will keep rising and push the price upwards (Pastor, Stambaugh & Taylor, 2022) and that sustainable practices within a company can help to reduce costs (American Express, 2021). For instance, green companies will save money on taxes and other governmental expenses, and this can result in higher returns. The EU introduced a taxonomy classifying green activities, where companies classified as green will get lower taxes compared to "brown" companies. The companies classified as "brown" have not adopted sustainable practices, unlike the green companies (European Commission, n.d.) Furthermore, green companies can receive better interest rates from banks and face lower equity requirements (European Commission, 2021). Based on this, green companies might have better opportunities for growth and investments compared to "brown" companies, which can lead to an expectation of high returns among investors. However, according to finance theory, an increase in demand can lead to a bubble in asset prices if the prices are not rooted in fundamental value (Aliber & Kindleberger, 2015).

Green investing is a growing trend for several reasons, and in 2021 more than half of the IPOs on the Oslo Stock Exchange were "green". According to statistics published by Euronext, by the end of May 2021, the market value of green companies made up 9 percent of the total market value of the Oslo Stock Exchange (Præsterud, 2021). A clear definition of a green stock does not exist, and people have various opinions on which stocks they choose to define as green. Some examples of definitions of sustainable investments are:

«*Green finance is a broad term that can refer to financial investments flowing into sustainable development projects and initiatives, environmental products, and policies that encourage the development of a more sustainable economy. Green finance includes climate finance but is not limited to it. It also refers to a wider range of „other" environmental objectives, for example industrial pollution control, water sanitation, or biodiversity protection.* » (Höhne, Khosla, Fekete, & Gilbert, 2012).

«*Green investing seeks to support business practices that have a favorable impact on the natural environment. Often grouped with socially responsible investing (SRI) or environmental, social, and governance (ESG) criteria, green investments focus on companies or projects committed to* *the conservation of natural resources, pollution reduction, or other environmentally conscious business practices.* » (Chen, 2022).

«*Investment necessary to reduce greenhouse gas and air pollutant emissions, without significantly reducing the production and consumption of non-energy goods*. » (Eyraud, Clements, & Wane, 2013).

ESG is a term that is closely related to green investments. ESG is not a new term but is becoming increasingly relevant in line with the growing awareness of sustainability in the global society and of the impact companies have on society. ESG metrics are used by investors to measure a company along three dimensions. The environmental dimension (E) addresses the company's impact on the environment on the planet, including corporate policies addressing climate change, pollution, and energy use. The social dimension (S) evaluates a company's impact on society, employees, suppliers, and customers. While the governance dimension (G) measures the company's leadership, internal controls, audits, and shareholder rights (Investopedia, 2022).

Some people argue that ESG might not be the best measurement for investors to classify green stocks. In an article published by The Economist (2022), the author argues that ESG should be reduced to one criterion, emissions. The author argues that in several non-Anglo-Saxon countries basing investment decisions on social or governmental factors, the S and G in ESG, is not as easy. Tesla is used as an example; the company scores well on the E part of ESG and is therefore included as an ESG-friendly company, but if one also considered the G part Tesla would display bad results because of their working conditions and lack of codes of business conduct (Chen & Dey, 2022). This caused Tesla to be kicked out of the ESG version of the S&P 500, while oil giants like ExxonMobil were kept in the index. Only focusing on emissions would therefore make it easier to determine which companies score well, and people can choose whether this is what matters to them (The Economist, 2022).

ESG does make for a good tool to measure a company's impact among three important dimensions, however the S and G part can result in companies with low emissions receiving an overall bad ESG score. Regardless, this is a tool used by investors to measure the sustainability of stocks and ESG can therefore impact stock prices.

In this thesis, we use Euronext's assessment of which companies are considered green. Their assessment is based on the environmental dimension of ESG and includes companies with a green profile and companies with more environmentally friendly practices than their competitors (Præsterud, 2021).

2.2 Impact of Covid-19 and the Russia - Ukraine War

Both the Covid-19 pandemic and Russia’s innovation of Ukraine are events that took place during the testing period used in this thesis. Both events had an impact on investors' behavior across the world. Looking at how these events impacted investment patterns, therefore gives us a better understanding of the developments in the stock market and provides a foundation for understanding the results we present in chapter 7 of this thesis.

Following the Covid-19 pandemic outbreak in March 2020, the stock market experienced one of the biggest crashes in history. The market experienced big and rapid falls within all sectors (Bradley & Stumpner, 2021), and both S&P500 and Dow Jones faced one of the biggest one-day declines in values throughout history (Blakeley, 2020). Some sectors quickly bounced back to normal, while others were stuck at a low value for a prolonged period. In the USA the sectors natural gas, food, health, and software produced the highest positive returns during corona, while the petroleum, real estate, entertainment, and hospitality sectors fell dramatically (Mazur, Dang, & Vega, 2020). The growth that followed in the stock market was supported by domestic fiscal- and monetary policy (Klose and Tillmann, 2022).

A study by Kummernes and Kosmo (2021) shows that in Norway the average dividend per stock increased during the pandemic, even if the value of companies stagnated. The Norwegian government's support package, which offered financial aid to companies whose revenue was negatively impacted by Covid-19, was a key factor in explaining why dividends were higher than pre-pandemic numbers (Fraser, Ro, Solheimsnes, Sagmoen, & Hopland, 2021).

During the pandemic, more buyers were attracted to the stock markets and Norway experienced a boom of new investors. This sudden explosion of interest in financial assets can be explained by several factors: In general, people had more time on their hands due to an increase in the unemployment rate, extensive use of home offices throughout society that eliminated travel time to work, as well as the effect government enforced restrictions had on daily life by limiting leisure activities. In addition, many people had more free capital to invest, due to a reduction in private consumption and the low interest rates at the time. Finally, the stock prices were plunging due to the increased uncertainty in the markets. The price drop made investments into stocks and funds more attractive and affordable, as the uncertainty was regarded as short-term and future optimism was high (Bougroug, Kjos & Sletten, 2021).

The war between Russia and Ukraine has kept the market from stabilizing after Covid-19. Boungou and Yatié (2022) published an article showing that the war contributed to a fall in stock prices. Moreover, Ahmed, Hasan & Kamal (2022) published a study showing that on the 21 of February 2022, when Russia declared two Ukrainian states as autonomous regions, European stocks had a considerable negative return, and the negative stock returns continued in the period after the event. Russia was one of the world's biggest export countries within the oil sector but because of the war, several countries did impose sanctions against trading with Russia. This led to a growth in the price of green stocks as many started speculating that these companies would have to replace the oil from Russia and several countries adapted new strategies to become less dependent on Russian-produced energy (Defiance, 2022).

A study by Sun and Zhang (2022) found that listed companies in EU member countries or countries with a high dependence on Russian exports experienced lower returns because of the Russian innovation. They also found that compared to other industries, companies within the oil- and gas industry and the defense industry have had higher returns. The high returns within the oil- and gas sector can be explained by the imminent threat of energy shortage, which led to an increased focus on energy security and a higher energy demand due to the limitations of Russian exports.

As Covid-19 is a recent event, and the war is still ongoing, there is not a lot of research surrounding this, and we do not know the final effect this will have on the market. Nonetheless, the research mentioned in this chapter indicates a significant impact on the stock markets, one that could result in bubble tendencies in the market.

2.3 Historical Asset Bubbles

Throughout history, the market has been through several bubbles. Studying historical asset price bubbles will provide insight into their drivers and effects on stock markets and the wider economy. Today there are differences in opinions on how to define an asset price bubble, and we do not have a framework for identifying bubbles. Several people are speculating on whether we will enter a green bubble because too much capital is being invested in too few green companies. In this chapter, we will present some of the most well-known bubbles throughout history.

2.3.1 The Tulipmania

The Dutch Tulipmania is the first well-known financial bubble and took place in 1636 and 1637. The tulip had recently been introduced in Holland and quickly became a popular status symbol among the wealthy Dutch. The rapid price growth of rare tulip types, created by professional growers and wealthy flower fanciers, attracted speculators. This led to the price of normal tulip bulbs also rising. The tulip market was driven by future contracts, where buyers and sellers would agree on a price for bulbs that would be delivered in the future. This allowed speculators to make huge profits without ever taking possession of the physical bulbs.

In addition, people were spending more money than they could afford and purchased tulip bulbs on credit. The price of tulip bulbs rose to extremely prominent levels, with the rarest tulip bulbs selling for up to six times the average person's annual salary (Hayes, 2022). However, buyers were not able to pay the agreed price as this was set too high. The price reached its peak in February 1637 before it eventually collapsed, and the bulb could not even be sold for 10% of the top value. Those who had purchased bulbs on credit were forced to sell for a lower price and could not pay back their loans, forcing them to declare bankruptcy (Garber, 1990).

2.3.2 The South Sea Bubble

The South Sea Bubble was a bubble that formed in the British market in 1720. The firm South Sea Company was granted a monopoly on trading in the South Sea and on the west coast of South America. The company got this monopoly in exchange for taking on a substantial portion of the national debt. This led to expectations for the South Sea Company to accomplish remarkable success, and a lot of speculation in the company's stocks made the value rise from 110 to 1000 british pounds. The stock price bubble collapsed when it was made clear that the company would not be able to secure profits high enough to reflect the stock price, and the price declined back to a value of around 100 british pounds (Høvik, 2020).

2.3.3 The Kristiania Crash

During the summer of 1899, the Kristiania Crash arose after declining prices on stocks and property. Prior to the crash, construction activity in Kristiania had been at an elevated level because of the large population growth, and new banks made it easy for people to get mortgages. Newly established banks had liberal policies and even accepted loans with security in stocks. Salaries rose, and Kristiania experienced economic growth. Prices in the stock market were also rising, and people were making easy profits. This, together with low interest rates, contributed to a lot of speculation and optimism among investors (Norges Bank, n.d.).

Between 1890 and 1899, housing prices rose by 160%, and many made a fortune on trading property. During the same period, the amount of housing being built quadrupled. When the bubble burst six out of the seven new banks went bankrupt, and it would take 100 years before the prices of the properties bought in Kristiania during June 1899 would reach the same level. One out of ten apartments in Kristiania were left empty. Following the crash, Norges Bank became a central institution in the Norwegian credit market (Lilleby, 2018)

2.3.4 The Wall Street Crash of 1929

The Wall Street Crash took place in 1929 on the New York stock exchange. The crash arose from high economic growth and stock market activity in the US during the 1920s. This period before the crash is today known as the roaring twenties, and in this period the unemployment rates were low, and the economy was growing.

During the summer of 1929, speculators drove stock prices to record-breaking levels. The prices of stocks on average went up by 10 times, and speculation became a hobby for some investors. Many investors were buying stocks on the margin, borrowing the money they were lacking to be able to invest. People were borrowing up to two-thirds of the value of stocks, making them extremely fragile to a decline in stock prices. The stock market eventually crashed, and the crash lasted for 6 days. During this crash, American stock market values were almost halved. On the day that is now known as Black Tuesday, panic broke out and everyone wanted to sell their stocks at the same time. During this day, Wall Street investors traded around 16 million shares on the New York stock exchange and the market lost 11% of its total value. The Dow Jones experienced a loss of 89.2% from its peak (Kramer, 2021).

The market crash led to a financial crisis which resulted in The Great Depression that lasted for several years. Fifteen million Americans lost their jobs, and half of the country's banks went bankrupt. The Dow Jones did not return to its pre-crash values before 1954, 25 years after the crash (Kenton, 2023).

2.3.5 The Dot-Com Bubble

The Dot-Com bubble lasted from 1995-2000 and was a bubble where stock markets in the western world experienced high growth within the technology sector. Technology, as well as the internet, was growing fast and people expected companies within this sector to make good profits over time. Investors put a lot of money into startups within this sector, even though many of these companies did not have positive earnings. Venture capitalists were also optimistic about the sector and by 1999, 39% of all venture capitalist monetary investments went into internet companies. Low interest rates in the late 90s created an attractive environment for new start-ups, as it led to an increase in private consumption and more money was being poured into the economy. Some of the new start-ups that emerged did not have a business plan or product to show for. The Nasdaq Index, which is dominated by technology companies, rose from a value below 1000 to above 5000 in just five years. When the bubble finally burst in March 2000, the price fell by almost 77%. Prices continued to fall throughout 2001, and it would take 15 years before Nasdaq would reach its all-time high again. Several internet companies went bankrupt due to the bubble collapse (Hayes, 2019).

2.3.6 The Financial Crisis

The Financial Crisis from 2008-2009 is one of the most well-known bubbles today. The U.S. economy had enjoyed a lengthy period of growth, and there was a great belief in the U.S. society that housing prices would continue to rise. Borrowing money was easy, even with a low credit score, which led to many people having high mortgages they were unable to serve. Banks sold these loans on to Wall Street banks, which packaged them into seemingly low-risk financial instruments such as mortgage-backed securities and collateralized debt obligations (Singh, 2022).

The housing market experienced a breakdown in 2007 when several people were not able to manage their loans following a recent rise in interest rates. The breakdown led to a drop in housing prices, and people were unable to sell their houses for a price that would pay off their mortgage loans. The mortgage defaults affected those who had invested in these loans and the crash led to a lot of distrust towards the financial markets, and obtaining credit became difficult. The U.S.'s biggest financial institutions experienced big losses, and several went bankrupt. This developed into a global crisis, and the stock market plunged (Notaker, 2018).

3. Economic Theories on Bubbles

In this chapter, we will review the economic theories related to asset price bubbles to investigate what asset bubbles are and how they occur. Asset bubbles are not a new phenomenon and extensive research has been done on the topic, yet there is no specific framework for it. On the other hand, there are several frameworks that can be useful in describing asset bubbles and some of them will be introduced in this chapter.

3.1 Efficient Market Hypothesis

A relevant starting point to discuss irrational asset pricing is the Efficient Market Hypothesis (EMH), which is a fundamental economic theory that originates from Eugene Fama's analysis of capital markets from 1970 «Efficient Capital Markets: A review of Theory and Empirical Work» (Fama, 1970). The theory suggests that capital markets are effective and that excess returns cannot be achieved using historical data or other publicly available information. All relevant information relating to a company, or a financial instrument, is already reflected in the price of that company or asset. According to the theory all assets trade at fair value, which implies that no assets are overvalued or undervalued in the market (Beaver, 1981). Given that the EMH holds, financial bubbles will never occur due to all assets being traded at fair value.

In the past, the EMH was widely accepted by academics within finance (Ying, Yousaf, Ain, Akhtar, & Rasheed, 2019). An index fund is an example of a financial instrument where one, in theory, should gain market return on investments in line with the EMH. The popularity of index funds has skyrocketed in the last decade (Parr, 2020). In more recent times, the EMH has been challenged by research that indicates that excess returns can be achieved by investors. The existence of excess returns means that the market is not efficient, and assets are not traded at fair value, both preconditions of the EMH (Ying et al., 2019).

3.2 Asset Bubbles

The fair value of a company equals the present value of all future cash flows generated by the company. A commonly used valuation method within fundamental analysis is the Discounted Cash Flow (DCF) method. Investors use DCF to determine whether a financial instrument is a sound investment, based on the present value being above or below the market value of the asset (Bøhren, Michalsen, & Norli, 2017).

Asset bubbles occur when the price of one or more financial instruments grows rapidly over time, and the initial price increase leads to an expectation of continued price growth. The expectation attracts new buyers, especially investors who prioritize yield, rather than the assets use and the ability to generate earnings. It is a precondition that the price cannot be explained by earning capacity and that the asset is overvalued (Siegel, 2003). The price growth is led by momentum and speculation. Harrison and Kreps (1978) introduce a new motive for speculation and claims that "investors exhibit speculative behavior if the right to resell an asset makes them willing to pay more for it than they would pay if obliged to hold it forever."

According to Aliber & Kindleberger (2015), an asset bubble has the following 5 steps:

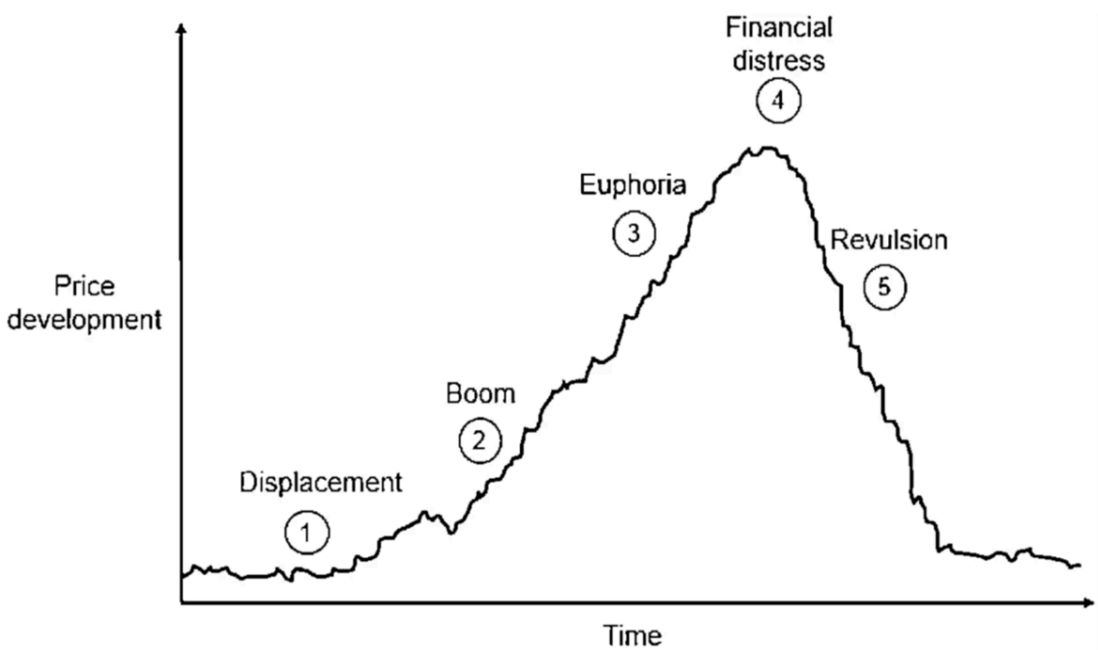

Figure 3.1: The Kindleberger-Minsky bubble pattern (Aliber & Kindleberger, 2015)

Displacement

Displacement can occur because of an exogenous shock on the macroeconomic level that leads to an economic expansion. Bubbles usually begin with a new idea or innovation that causes increased interest and investments in a particular asset or market. This can be driven by good monetary terms, political events, innovative technology, or regulatory changes.

Boom

In line with the spike in demand for the asset or market, the price increases. This attracts new investors, as buyers have a fear of missing out ("FOMO") on the investment opportunity, while the price remains at today's level - given the expectation of continuous growth. The spike in demand is also driven by increased media coverage of the assets or sector, or extensive marketing of the product or service behind the asset. Investors purchase assets with the sole purpose of making a quick yield from the price growth, even if they have an insufficient understanding of the assets' fundamental value.

Euphoria

The new buying and selling pattern of investors will lead to a market imbued with irrationality, where investors ignore risks in the search for profits. In this phase, the market prices are no longer rooted in fundamental value and the market is characterized by speculation and euphoria. In this scenario, investors will be lured into believing that the upside is limitless, resulting in record high price levels.

Financial distress

After a while, the bubble will burst as investors realize that the prices are not sustainable. This will result in an abrupt price decline and a state of panic among investors who hurry to sell off their assets. At this point, many investors have spent beyond their means, which results in great financial distress.

Revulsion

In the end, investors will withdraw from the financial markets as they become less attractive. Many investors have now lost money on their investments, as they did not exit the market before the collapse. What was once a state of euphoria, has been turned into revulsion.

3.3 Irrational Exuberance

Irrational Exuberance is a concept within behavioral finance and was first introduced by former chairman of the Federal Reserve, Alan Greenspan, in 1996 and elaborated by Shiller. The term refers to a state of mania where investors are so confident that the price of an asset will continue to rise, that they lose sight of its underlying value. The stock market will be characterized by high valuations and indifferent thinking among millions of people. Indifferent thinking refers to a common belief among investors that the upside is limitless. Furthermore, the investors have in common that they do not examine the long-term value of stock investments. On the contrary, the motivation behind their investments are emotions, random attentions, and perceptions of conventional wisdom - a behavioral pattern that is heavily influenced by news media. The news media do not necessarily provide investors with a correct impression of aggregate stock market level. In fact, the media's need to attract viewers or readers gives them little incentive to report on quantitative analysis. Additionally, news can be unreliable when the focus is to provide the audience with a compelling story - rather than a story based on reality (Shiller, 2000).

There are opposing views on irrational exuberance. On one hand, Shiller argues that in a free society it is not feasible to protect people completely from the consequences of their own errors, as this means depriving them of the possibility to achieve their own fulfillment. Furthermore, society cannot be protected from irrational exuberance or irrational pessimism - both emotional reactions that are a part of the human condition. The solution is to develop policies that deal with asset bubbles in a way that provides people with better opportunities to take positions in the free market. This requires better forms of social insurance and better financial institutions, to manage risks effectively (Shiller, 2000). Others argue that society needs irrational exuberance because it allows entrepreneurs to gain access to the cheap financing necessary to fund ventures with heavy startup costs. Furthermore, it gives the investors direct access to the risks and rewards of promising investment opportunities that can generate significant wealth. This is often not the case for such ventures, as they are mostly funded by large corporations or government agencies (Brenner, 2005).

3.4 Rational Bubbles

In economic theory, given the assumption of rationality, asset prices must reflect market fundamentals. Hence, the price of an asset is based on available information on current and future returns derived from the asset. Therefore, all price deviations from fundamentals are considered evidence of irrationality. The theory of rational bubbles was developed as an alternative to this assumption, suggesting that rational asset bubbles can exist even if expectations and behaviors are rational, and information is symmetrical. The theory is based on the work of Blanchard and Watson (1982) and Jean Tirole (1982) and has since gained the support of many, such as Diba and Grossman (1988). Despite the underlying assumptions of rationality and symmetrical information, deviations from an asset's fundamental value and the market price may still occur, as the market price may contain a bubble element.

Rational bubbles may arise from investors' expectation of future price increase for the asset, one that exceeds the investors' required return. In this instance, investors have good reason to believe that an asset is undervalued based on its prospects, and therefore continue to buy the asset even when the price exceeds its fair value. Based on the theory of rational bubbles, Cuthbertson and Nitzsche (2005) defines the following equation:

$$P_t \;=\; \sum_{i=1}^{\infty} \delta^i \, E_t D_{t+1} + B_t \;=\; P_t^f + B_t \qquad (1)$$

Where P_t is the market price and B_t is the rational bubble term. The actual market price, P_t, will deviate from the fundamental value by the value of the rational bubble term, B_t. According to the rational bubble theory, rational investors are still willing to hold the stock and no abnormal returns are made.

It is necessary to understand rational bubbles, to be able to differentiate rational behavior from irrational behavior among investors. By acknowledging that investors can pay a price that exceeds fair value for stocks and still exhibit rational behavior, we can better understand the behavior of investors who buy into stocks or markets that show signs of irrational exuberance. In the next chapter we will have a look at a selection of the research that currently exists on asset bubbles.

4. Literature Review

Research into asset bubbles has been ongoing for years as asset bubbles are not a new phenomenon. However, as mentioned previously there is no fixed definition of an asset bubble and no standard framework to apply for detecting bubbles. This thesis will use recursive ADF tests to detect asset bubbles, yet there are several other approaches that can be applied. This section will review literature on asset bubbles and explore some of the most common methods for bubble detection.

4.1 Research into Asset Bubbles

Studying behavioral finance can provide valuable insight into how asset bubbles occur. Minsky has been one of the most influential voices in explaining how behavioral factors can systematically lead to macroeconomic bubbles. He argues that periods of stability in the financial markets lead to overconfidence among investors, resulting in over-investing and the emergence of asset price bubbles (Minsky, 2008). Moreover, Shiller´s theory that continually rising prices might induce mass euphoria driven by sensationalist news media coverage, has inspired a lot of research (Shiller, 2000). Shiller´s theory suggests that a stage of euphoria occurs among investors, in accordance with Aliber & Kindleberger´s 5-step model that we introduced in chapter 3 of this thesis. (Aliber & Kindleberger, 2015).

Sornette and Cauwels (2014) define a bubble as "*a period of unsustainable growth, when the price of an asset increases ever more quickly, in a series of accelerating phases of corrections and rebounds".* They argue that since bubbles leave specific traces, they can be recognized before they burst. Sornette and Cauwels's findings show that unregulated or loosely regulated financial markets tend to give rise to speculative and Ponzi-type finance, making financial markets intrinsically unstable (Sornette & Cauwels, 2014).

Another area of interest for researchers is to study the consequences of asset bubbles. Historically, asset bubbles have impacted output rates, employment rates and consumption. The burst of bubbles has resulted in a banking crisis on several occasions, as the collapse of asset prices has caused defaults and bankruptcies. This scenario can have negative, long-lasting effects on the economy, where banks stop lending money to businesses – causing a drop in investment levels (Aliber & Kindleberger, 2015). Furthermore, bubbles can influence societal attitudes toward financial markets, as many people lose faith in the market and withdraw from it (Dagher, 2018). Together with the introduction of financial regulation that often follows a bubble collapse, negative attitudes could slow down financial innovation, increase credit costs for businesses and hinder the creation of new businesses. Overall, financial markets play an essential role in economic growth and the financing of innovation and entrepreneurship, so a hindrance of financial markets has large economic and societal costs (Beck & Levine, 2004).

While most researchers argue in favor of the prevention of asset bubbles, there are some that point to the benefits of asset bubbles. Many historical bubbles have been associated with transformative technologies that have had a significant impact on the economy by stimulating growth and productivity (Gordon, 2016). Olivier (2001) argues that the developed technology can help stimulate future innovation and encourage more people to become entrepreneurs, even bubble companies may use the technology that is developed during the bubble to move into different industries.

There have also been discussions on how politicians should act when a bubble is present. In an article published in 2007, Barlevy argues that policymakers need to be careful when deciding to stem asset bubbles. This is because bubbles will only occur under certain conditions which may be relevant to the desirability of acting to burst a bubble. That is, if a bubble is occurring this can be a sign that the economy is experiencing certain structural problems. In this case, one will have to carefully decide if bursting the bubble will alleviate or worsen these problems (Barlevy, 2007). Cogley (1999) points out that it can be hard to identify whether an asset is overvalued, and therefore we have a risk of deflating assets that are not overvalued, possibly causing great harm.

Throughout the years several methods for detecting asset bubbles have been developed and some of the most common methods are presented below.

4.1.1 Variance Bounds Tests

Variance bounds tests were first introduced by Shiller (1981), and LeRoy and Porter (1981). Shiller argues that stock markets are inefficient and fluctuate too much. According to economic theory, stock prices should equal the present value of expected dividends. Dividends are very stable and only experience small fluctuations, likely due to the signal effect. Consequently, stock prices should also be stable, but this is not the case.

The variance bounds tests demonstrate how the variability in dividends sets an upper bound to the variability of stock prices. It derives from the present value model and assumes that prices are formed accordingly. The following equation is used to test for variance bound:

$$V(P_t^*) = V(P_t) + \varphi V(\varepsilon_t) \geq V(P_t) \quad (2)$$

Where P_t^* is the ex-post rational price, P_t is the price according to fundamentals, φ is $\frac{\left[\frac{1}{(1+r)}\right]^2}{\left[1-\left(\frac{1}{(1+r)}\right)^2\right]}$ and ε_t is the difference between actual and expected dividends.

A violation of the variance bound might indicate the presence of a bubble. However, a critique against this model is that it has several implementation issues that makes it unsuitable for bubble detection. For instance, the test cannot be applied to non-stationary data and the use of the mean price as the terminal ex-post rational price creates a bias towards rejection in small samples (Gürkaynak, 2005).

4.1.2 West´s Two-Step Tests

West (1987) introduced the two-step test. This tests both the model and no-bubble hypotheses at the same time. West discovered that in the absence of bubbles, the Euler equation, which is fundamental to asset pricing without arbitrage, can be estimated alone providing information regarding the discount rate. By representing dividends as an autoregressive process, one can determine the connection between dividends and the fundamental stock price of the market by knowing the discount rate and the parameters of the AR process. One can directly estimate the relationship between stock prices and dividends by egressing the stock prices on dividends. Under the null hypothesis that there are no bubbles, the ‘actual’ relationship should not differ from the ‘constructed’ one. If the two estimates of the impact of dividends on equity prices differ, one can apply specification tests to the Euler equation and the AR representation of dividends. By doing this one can rule out model misspecification and leave bubbles as the only possible reason for this difference in estimates (Gürkaynak, 2005).

There are, however, issues with this test. The first issue is related to non-stationarity, according to West the test can be applied to appropriately differenced data if the data is nonstationary. Detecting non-stationarity can be difficult, West, therefore, runs his tests in levels and in differences. Another issue with this test lies in determining the order of the AR process that governs dividends, as well as the issue of information available to agents but not to the econometrist: Investors form their expectations about future dividends by considering more information than just the history of the dividend process. Dezhbakhsh and Demirguc-Kunt (1990) also criticize West's methodology by arguing that his tests have size distortion in small samples, rejecting the null too often, and are inconsistent under the bubble alternative. Another issue critics point out is that a rejection of the coefficient restrictions may be due to other factors than a bubble. This is argued for by pointing to the fact that agents might attribute a small probability to an event that will have a large impact on the asset price (Gürkaynak, 2005).

4.1.3 Integration/Cointegration Bases Tests

Diba and Grossman (1987) found that a rational bubble cannot start, therefore if a bubble exists it must have always existed. Their reasoning depends on the impossibility of negative prices and the lack of arbitrage. A lack of arbitrage implies that there are no excess returns from holding an asset with a bubble component, that is:

$$E_t(B_t + 1) = (1 + r)B_t \qquad (3)$$

In this case, the actual bubble process follows a stochastic difference equation:

$$B_{t+1} - (1 + r)B_t = z_{t+1} \qquad (4)$$

$$with\, E_t(z_{t+i}) = 0 \forall i \geq 1 \qquad (5)$$

If B_t is zero, the bubble will start with the next nonzero realization of z. If this is a negative number, the bubble will be negative and expand in absolute value. This implies that the stock price will be negative in a finite time, however, this is impossible given free disposal. When the expected realization of z can't be negative when the bubble component is zero, it cannot be positive either. To rule out arbitrage opportunities it needs to be zero. Therefore, when B_t is zero all future realizations of z must be zero with probability one. When this is the case the bubble can´t start. Diba and Grossman find that this argument rules out rational bubbles and proposes a way to empirically test the absence of bubbles (Gürkaynak, 2005).

This test was criticized by Evans (1991). He points out that it is possible that a bubble will collapse to a small nonzero value and then continue increasing. This goes against Diba and Grossman who argue that bubbles only start on the initial date of trading, implying that a bubble cannot pop and restart. Evans performed Monte Carlo experiments of the Diba and Grossmans test. Here he tried using values up to 0.95 for the probability of the bubble collapsing, so that the case would be that the bubble periodically collapses. Doing this Evans found that the tests do not perform well in this case, as the test failed to reject the no-bubble hypothesis in most cases. Evans also tested for the probability of the bubble collapsing being smaller than 0.75 and found that the tests almost never detect bubbles (Gürkaynak, 2005).

4.1.4 Intrinsic Bubbles

When Froot and Obstfeld (1991) presented their theory, they suggested that a bubble is tied to the level of dividends. Their bubble identification process depends entirely on the level of dividends. Under the null hypothesis of no bubbles, prices are a linear function of dividends, and the price-dividend ratio is constant. Different behavior of the price-dividend ratio in the lack and presence of bubbles can be used to form a bubble test. Froot and Obstfeld test for bubbles by running regressions of price-dividend ratios on a constant and dividends. Not finding any significant coefficients, except for the constant, in these regressions will indicate a lack of bubbles, while finding a nonlinear relationship between prices and dividends will be interpreted as signaling the presence of a bubble (Gürkaynak, 2005).

This test shows that a nonlinear relationship between stock prices and dividends does exist, but this is taken as a sign of a bubble only because the model is assumed to be linear. Driffill and Sola

(1998) criticize Froot and Obstfeld by focusing on the case when the underlying stock pricing model is nonlinear. Driffill and Sola find that the assumption of the time invariance of Froot and Obstfeld's random walk characterization of the log dividends, which is central to the analysis and results, can be rejected when specification tests are applied to data (Gürkaynak, 2005).

4.1.5 Bubble as an Unobserved Variable

Wu (1997) presented estimated values of bubbles under the 'bubble as a deviation from the present value model' detection interpretation. He specified the present value model, assuming that different dividends follow an AR process. Using a Kalman filter, Wu estimates the bubble as an unobserved variable subject to the no-arbitrage condition. This shows that a big portion of the movement in stock prices can be explained by the bubble. However, Wu often ends up with a negative estimated bubble. The fact that bubbles cannot be negative is a well-established theoretical prediction. Therefore, Wu´s bubble process serves as a clear indication of the model's failure in other dimensions (Gürkaynak, 2005).

5. Methodology and Data

In this chapter we will present the methodology and data used to detect irrational exuberance in the Norwegian stock market. The methodology is based on the Augmented Dickey-Fuller test (ADF) and other versions of the test - the SADF and GSADF tests. Combined the tests provide a foundation for examining explosive behavior in markets. Finally, we will present our data and describe how the model can be implemented.

5.1 Model Specifications

The literature that explains how to identify bubbles from market fundamentals originates from the Lucas model for asset pricing. The Lucas model is based on the idea that individuals and firms have rational expectations and that the economy is in a state of equilibrium. (Lucas, 1978). It can be used to identify asset bubbles by analyzing how changes in monetary or fiscal policy affect the economy and prices of different assets.

Based on Blanchard & Watson's (1982) efficient market condition, the fundamental price of an asset is given by:

$$P_t = \frac{1}{1+R} E_t(P_{t+1} + X_{t+1}) \qquad (6)$$

Where P_t is the asset price in period t, R is the risk-free rate and X_{t+1} represents the economic fundamentals that can affect the stock market in period t. E_t is the expectation. The equation represents what the price of an asset should be given that it does not contain a bubble element and can be used by investors to evaluate the price of an asset.

The main model used in this thesis is variations of the ADF model that are used to examine behavior that cannot be explained by market fundamentals and is explosive in nature. (Vasilopoulos, Pavlidis, & Martínez-García, 2020).

5.2 The ADF Test

The standard ADF test, introduced in 1981 by Dickey and Fuller, is used to test for a unit root in time series (Dickey & Fuller, 1981). The ADF regression equation which sets the basis for the SADF and GSADF is the following:

$$\Delta y_t \ = \ \alpha_{r1,r2} + \beta_{r1,r2}\, y_{t-1} + \sum_{i=1}^{k} \delta_{r1,r2}^{i}\, \Delta y_{t-1} + \varepsilon_t \tag{7}$$

Here k is the lag order, t is the error term and y show the variable of interest at time t. The Δ is the difference operator, $r1$ symbolizes the starting point while $r2$ is the ending point. The total period of the sample is given by T, and $r2 = r1 + rw$ where rw is the window size of the regression and are all regression coefficients. The null and alternative hypothesis of the regression are:

$$H_0 : \beta_{r1,r2} \ = \ 0 \ \rightarrow \ (unit\, root)$$

$$H_1 : \beta_{r1,r2} \ > \ 0 \ \rightarrow \ (\exp l\, osive\; behavior)$$

Here unit root would be the case of no bubble. Unit root is a stochastic trend, having unit root means we have a systematic pattern that is unpredictable. On the other hand, explosive behavior would signal that we do have a bubble. When the beta coefficient is bigger than 1 it suggests explosive behavior because the time series is growing faster than its historical performance. ADF_{r1}^{r2} is the denotation of the ADF test statistics corresponding to the null hypothesis listed above, and the equation is given by:

$$ADF_{r1}^{r2} = \frac{\widehat{\beta}_{r1,r2}}{se(\widehat{\beta}_{r1,r2})} \tag{8}$$

This standard ADF test is obtained by estimating the equation (7) on the full sample of observations. By setting $r2 = 1$ and $r1 = 0$ we get $rw = 1$

The following equation gives us the limit distribution of ADF_0^1 under the null unit of a unit root.

$$\frac{\int_0^1 \widetilde{W} dW}{(\int_0^1 \widetilde{W}^2)} \tag{9}$$

Where W is a Wiener process.

There are some limitations to the ADF test. First, it cannot date stamp explosive behavior. Another limitation is that it only works if the bubbles collapse periodically.

5.3 The SADF Test

The SADF test was developed as a new way of testing explosive behavior by Philips, Wu, and Yu (2011), due to the limitations of the traditional ADF test. Their approach uses a supremum ADF test, incorporating recursive regression, right-sided unit root tests and a new method for confidence interval construction for growth parameters in the stock market exuberance. The SADF test proves far better than traditional cointegration-based tests at detecting exuberance arising from various sources, including behavior that is mildly explosive. In addition, it allows for explosive behavior to be date stamped.

The SADF statistic can be defined as:

$$SADF_{(r0)} = \sup_{r_2 \in [r_0, 1]} \tag{10}$$

And has a limit distribution of:

$$\sup_{r_2 \in [r_0, 1]} \frac{\int_0^{r_2} \widetilde{W} dW}{(\int_0^1 \widetilde{W}^2)^{1/2}} \tag{11}$$

The test runs the ADF test on a forward expanding sample sequence. The obtained results are the sup value of the corresponding ADF test statistic sequence. The model uses a fixed point, $r0$ and a point, $r2$, that can expand freely from $r0$ to 1 .

The null hypothesis is rejected if the SADF statistic exceeds the right-tailed critical value from its limit distribution. Since the test allows for date stamping, the alternative hypothesis is that explosive behavior occurs at a certain point in time within the data sample. A limitation with the SADF model is that it does not provide a consistent estimate of the end date for later occurrences of explosive behavior when several episodes of exuberance are present in the data set. (Vasilopoulos et al., 2020).

5.4 The GSADF Test

The GSADF test was first introduced by Philips, Shi and Yu (2015) to solve the time stamping issues of the SADF test, and it has proven more powerful than the ADF and SADF test at detecting explosive behavior (Vasilopoulos et al., 2020). The test produces a consistent estimate of the starting point and the end point for explosive behavior. The general idea of the model is consistent with the SADF test, the difference being that the regression extends the sample sequence to a broader and more flexible range. In addition to having a flexible end point, $r2$, which lies within the range $r0$ to 1 , it also introduces a flexible end point, $r1$, with a range from 0 to $r2 - r0$.

The GSADF statistic can be defined as:

$$GSADF\ (r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} \left\{ADF_{r_1}^{r_2}\right\} \tag{12}$$

And has a limit distribution of:

$$\sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} = \left\{ \frac{\frac{1}{2} r_w [W(r_2)^2 - W(r_1)^2] - \int_{r_1}^{r_2} W(r)\, dr [W(r_2) - W(r_1)]}{r_w^{1/2} \left\{ r_w \int_{r_1}^{r_2} W(r)^2\, dr - \left[\int_{r_1}^{r_2} W(r) ds \right]^2 \right\}^{1/2}} \right\} \tag{13}$$

5.5 Date Stamping

The ADF-test does tell us if we have episodes of exuberance, however it does not show when these episodes took place. In 2015 Philips et al. introduced backwards SADF test to date stamp bubble periods. This test performs a SADF test on a backward expanding sample sequence, called the BSADF test. Unlike the SADF test, the ending point in the BSADF test is fixed at $r2$ while the starting point varies from 0 to $r2 - r0$. The BSADF is given by the following equation:

$$BSADF_{r2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} \{ADF_{r_1}^{r_2}\} \tag{14}$$

The dating estimates are given by the formulas:

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \{r_2 : BSADF_{r2}(r_0) > scu_{r2}^{\alpha}\} \text{ and } \hat{r}_f = \inf_{r_2 \in [\hat{r}_e, 1]} \{r_2 : BSADF_{r2}(r_0) > cu_{r2}^{\alpha}\} \tag{15}$$

where scu_{r2}^{α} is the $100(1-\alpha)\%$ critical value of the SADF for r_2T observations. r_e is the origination date while rf corresponds to the termination date.

Implementing this test requires a minimum window size, $r0$, and the autoregressive lag length. The choice of k evidence indicates that when the number of lags is fixed to a small amount, the proposed right-tailed unit root methodologies work well.

The minimum window size needs to be big enough to allow initial estimation, however it should not be too big as that can lead to missing short episodes of exuberance. In their article from 2015 Philips et. al. recommends setting the minimum window size to: $r0 = 0.01 + \frac{1.8}{T}$ (Philips et al. 2015).

Critical values need to be obtained either through Monte Carlo simulations or bootstrapping, as the distributions are non-standard and depend on the minimum window size. (Vasilopoulos et al., 2020).

6. Description of Data

As discussed in chapter 2.1 there are different opinions as to what stocks can be considered green. There is no clear generally accepted definition of green stocks. In our study we therefore rely on the Euronext definition of which companies are considered green. The list of green stocks was published in 2021 (Aksjenorge, 2021).

The period we examine stock price return data over is 10 years from 01.01.2013-01.01.2023, based on daily closing prices. We find 10 years to be a suitable period as green stocks are relatively new to the market. By looking at daily prices, we will be able to detect blips, which are unexpected, minor, and typically temporary deviations from the general trend, in the market and separate it from explosive behavior. We have chosen to exclude companies with less than 400 observations. The accuracy of our analysis depends on how many observations we have, and using data collected over a long period will provide us with more observations – resulting in higher accuracy. Given this criterion, we are left with data from 48 companies. All our data is collected from Thomson Reuters Eikon.

Table 6.1 contains descriptive statistics for all the green stocks we use in this thesis. There are large price variations between the stocks as the mean price varies from 0.440 to 151.816. High standard deviations show that there are significant price movements in the stock of certain companies. The standard deviation for our selection of companies ranges from 0.224 to 100.679.

Statistic	N	Mean	St. Dev.	Min	Max
TOMRA.SYSTEMS	2,609	101.213	76.370	22.500	315.500
SCATEC	2,152	94.735	71.647	17.600	397.600
NEL	2,609	7.023	7.234	0.440	34.570
BORREGAARD	2,609	92.069	53.102	20.700	232.000
ARENDALS.FOSSEKOMPANI	2,609	129.159	100.679	42.490	495.410
AKER.HORIZONS	500	24.321	8.344	11.990	48.500
AKER.CARBON.CAPTURE	613	17.960	6.296	4.300	34.370
BONHEUR	2,609	151.816	91.464	45.700	395.500
HEXAGON.COMPOSITES	2,609	26.411	10.236	3.920	72.600
ELOPAK	402	22.028	4.440	13.860	29.000
VOLUE	575	42.276	11.124	22.900	63.900
REC.SILICON	2,609	15.008	8.509	2.070	49.600
EVERFUEL	567	63.708	24.746	19.000	183.440
QUANTAFUEL	1,184	21.965	17.085	4.970	78.900
CADELER	546	33.278	3.082	23.500	41.000
VOW	2,276	11.458	12.040	0.430	49.960
AKER.OFFSHORE.WIND	568	0.440	0.224	0.190	1.220
ZAPTEC	584	42.587	12.324	10.910	68.500
CLOUDBERRY.CLEAN.ENERGY	717	14.708	2.150	9.990	19.660
CAMBI	494	10.224	5.103	4.610	29.000
AGILYX	588	31.198	6.123	19.280	52.750
CIRCA.GROUP	479	11.308	5.481	5.940	28.400
SALMON.EVOLUTION	596	7.711	1.288	5.060	11.240
ANDFJORD.SALMON	874	43.774	7.493	25.000	70.000
BERGEN.CARBON.SOLUTIONS	445	39.023	15.046	10.000	81.890
SAGA.PURE	2,609	1.505	0.766	0.580	5.500
HYDROGENPRO	578	27.969	13.397	11.000	75.600
OTOVO	1,054	63.582	45.273	11.100	275.000
BW.IDEOL	467	24.203	11.274	6.760	49.900
OCEAN.SUN	570	20.649	13.033	6.050	57.500
MAGNORA	2,609	11.126	5.924	4.670	31.400
PRYME	489	28.859	20.220	6.140	70.560
TECO.2030	580	5.966	1.943	2.100	13.600
ALTERNUS.ENERGY.GROUP	513	25.713	4.385	16.800	36.000
MPC.ENERGY.SOLUTIONS	506	26.148	9.046	12.020	52.410
NORSK.SOLAR	445	6.070	2.141	3.270	12.700
HORISONT.ENERGI	503	56.298	16.001	34.890	115.720
INTEGRATED.WIND.SOLUTIONS	462	36.426	3.013	31.000	44.000
DESERT.CONTROL	448	23.630	7.234	11.950	40.720
M.VEST.WATER	416	11.955	3.345	8.600	28.950
HAV.GROUP	477	14.075	2.218	8.400	17.800
PROXIMAR.SEAFOOD	498	8.092	2.574	3.730	18.730
HYNION	446	2.054	0.981	0.620	5.740
KYOTO.GROUP	463	24.863	8.930	16.200	53.770
GREEN.MINERALS	464	12.993	4.473	6.280	30.000
SKANDIA.GREENPOWER	485	7.590	3.660	1.870	15.150
ENVIPCO.HOLDING	487	26.498	4.940	17.800	37.500
AEGA	2,609	5.075	9.093	0.540	36.580

Table 6.1: Descriptive statistics of data in this study

Figure 6.1 displays how the green stocks included in our data set are distributed among different sectors according to data retrieved from Thompson Reuters. Here the 48 companies are split into five sectors. Alternative energy is the largest sector with 44% of the companies operating in this sector, followed by energy support, construction, and components with 27%.

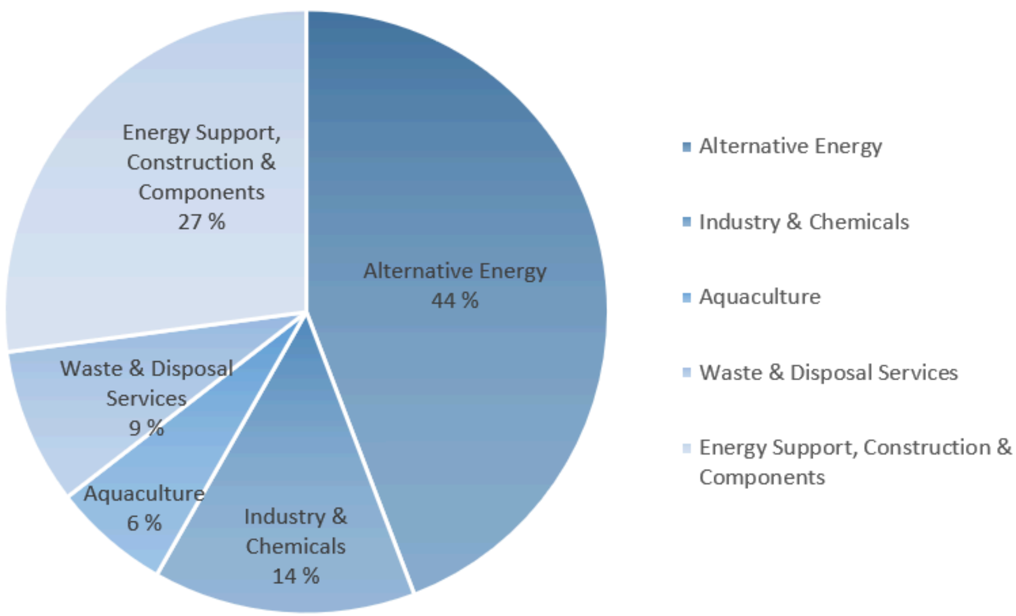

Figure 6.1: Sector distribution among green stocks

We also analyze explosive behavior in a wider stock price index to see if the bubble behavior in our selection of green stocks is unique to these stocks. Here we chose to use the most common index for the Norwegian stock market which is Oslo Exchange Benchmark Index (OSEBX). This index is dividend adjusted and includes 69 of the most traded and largest shares listed on the Oslo Stock Exchange. All the stock included in the index as of 31.12.22 can be found in the appendix (Euronext, 2022). We collected data from the same 10-year period as for the green stocks and ended up with 2632 observations. Using this data, we made a descriptive table showing the mean, minimum and maximum value of the index and the standard deviation (Table 6.2).

Statistic	N	Mean	St. Dev.	Min	Max
OSLO.EXCHANGE.BENCHMARK	2,632	797.096	227.937	444.090	1,287.390

Table 6.2: Descriptive statistics of OSEBX

Figure 6.2 represents a chart where the OSEBX index is given by the blue line, and the Low Carbon 100 Europe index is given by the green line. The chart shows the price movements of both indexes during our research period. The prices are given in Euros. We were not able to find data from Thompson Reuters Eikon on a green index consisting of Norwegian stocks alone, such as OBX ESG, therefore we used the index Low Carbon 100 Europe. This index is designed to reflect price level trends of companies in Europe that have the relative best climate score. All of the stocks included in the index can be found in the appendix (Euronext, 2019). Stock markets tend to correlate with each other. The Norwegian stock market is heavily influenced by other markets, and European markets due to their close affiliation through the EEA agreement (Gjerde & Sættem, 1999). This suggests that by using the Low Carbon 100 Europe index, we will be able to obtain results that match those we would achieve by using a Norwegian index.

As we can tell by figure 6.2, the price movements of the two indexes have been similar during our research period. Here we can see the percentage change in price since the beginning of the period, which makes it easy to spot the relative changes in price between the two indexes. From the graph we can tell that the OSEBX index was harder affected by Covid-19. However, the green index seems to have lower growth in recent years. From the beginning of the period until 2018 the green index was the fastest growing, and the period between 2015-2017 is where the green index was growing the most compared to the OSEBX. In the next chapter, we will look further into this by performing unit root tests to examine exuberance in the market and by looking at the stock's P/E ratios.

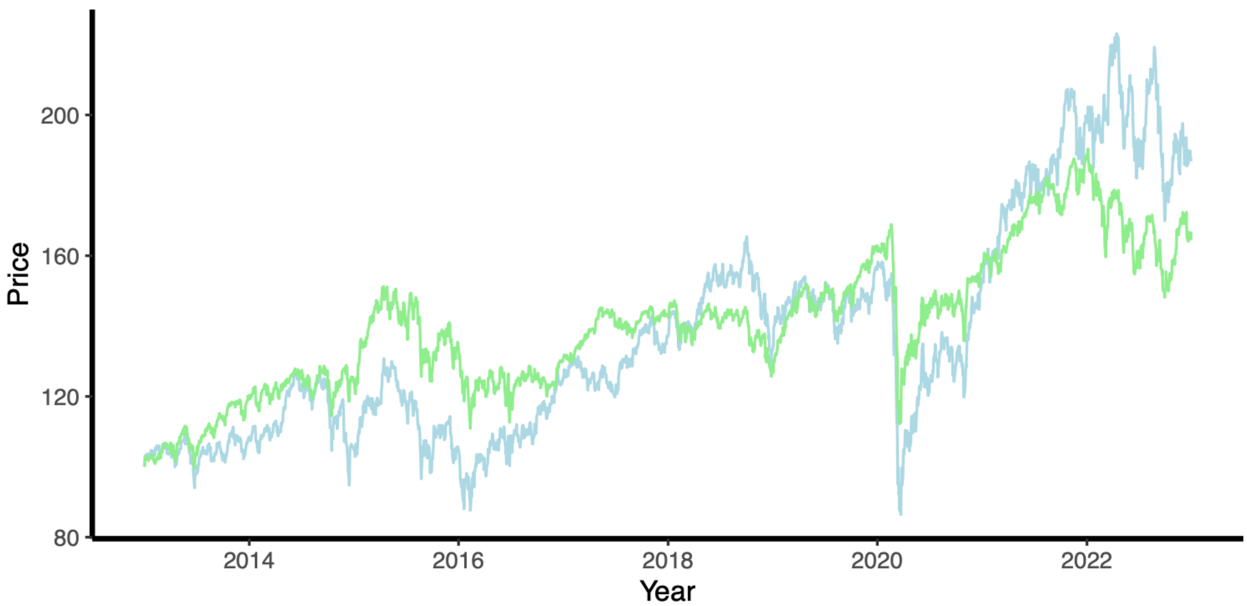

Figure 6.2: Price development of the Low Carbon 100 Europe (green line) and OSEBX Index (blue line)

7. Analysis and Results

In this section we present the results from the unit root tests we performed in R. Furthermore, we will analyze the overall Norwegian stock market and green stocks, to determine whether the market has experienced exuberance that points to the existence of a green bubble. In the end, we will have a look at the Price/Earnings ratio for our selection of stocks, to see how they are priced relative to their earnings and other stocks in the market.

We use the programming language R to perform our analysis of exuberance in the Norwegian stock market. R has several packages that are designed to detect explosive behavior in a data set. We use the *Exuber and Exuberdata* packages since they provide a comprehensive set of tools for analyzing financial time series data and are commonly used to detect bubbles in the stock market. *Exuber and Exuberdata* detect bubbles using different variations of the ADF test that we presented in the methodology part of this thesis. The package can be applied to a group of time series - such as a stock portfolio.

7.1 OSEBX

Prior to examining the results for our selection of green stocks, we want to analyze whether we can detect exuberance on the Norwegian stock exchange. We use the OSEBX index, which is representative of the overall Norwegian stock market.

The first step of the analysis is to obtain the right-tailed critical values for the ADF, SADF and GSADF test statistics. In table 7.1, the test statistics and corresponding 90%, 95% and 99% Monte Carlo critical values are presented.

Stat	OSEBX	90 %	95 %	99 %
Adf	-0.796	-0.422	-0.165	0.641
Sadf	0.459	1.34	1.56	2.39
Gsadf	4.41	2.23	2.39	3.07

Table 7.1: Critical values, 10-year period OSEBX

The null hypothesis of a unit root is rejected at the 1% significance level for the GSADF test, as the test statistic exceeds the critical value. This is indicative of explosive behavior and suggests that a bubble is present in the market. We cannot reject the null hypothesis based on our ADF and SADF test statistics and the corresponding critical values. As we know, the GSADF statistic addresses the limitations of the other tests and is proven more powerful than the ADF and SADF tests at detecting explosive behavior (Vasilopoulos et al., 2020). In other words, our results are in line with previous research.

By date stamping our results, we can determine the duration of the periods of exuberance in the market. Figure 7.1 shows the test statistics for GSADF for OSEBX, and the red dotted line represents the critical values at the 1% significance level. By looking at the figure alone, we can detect explosive behavior in 2020, where the test statistic exceeds the critical value. Date stamping allows us to get accurate dates for the period of exuberance - and a period of exuberance in the Norwegian stock market is detected in March 2020, between the dates 09.03.2020 and 20.03.2020 (Table 7.2).

Figure 7.1: Date-stamping plot for OSEBX

Start	End	Duration
09.03.2020	20.03.2020	9

Table 7.2: Date stamping of OSEBX exuberance

Although we detect an episode of explosive behavior in the Norwegian market, the duration of the episode indicates that it is a blip, rather than a bubble. While a blip is a short-term deviation from the general trend in the market, a bubble typically has a longer duration and is more significant (Vasilopoulos et. al. 2020). Figure 7.1 visualizes the movement in stock prices. The lack of a buildup that is typical for asset bubbles before a collapse in prices also advocates for this. The episode of exuberance found place in March 2020, which was the same time that Covid-19 hit Norway and the country shut down. This led to a lot of uncertainty amongst investors, which caused unusual investment behavior that can explain the exuberance.

7.2 Green Stocks

Although our previous results suggest that there has been no indication of bubble behavior in the wider stock market, it is possible that a bubble is restricted to green stocks. Green stocks are quite new to the Norwegian Stock Exchange from a historical perspective, and several of our stocks do not have data for the entire 10-year period we are testing for. Nonetheless, we believe our data set contains a sufficient enough number of observations from a wide selection of stocks to justify using an unbalanced panel data set.

The Monte Carlo critical values for our data are presented in table 7.3, while table 7.4 consists of the test statistics for the different stocks. Most of the stocks in our portfolio have experienced periods of exuberance within the past ten years. This becomes evident as the null hypothesis is rejected at the 1% significance level for 31 out of the total 48 stocks when applying the GSADF test to our dataset. For the SADF test there is also evidence found of exuberance in the portfolio, as we can reject the null hypothesis for 35 companies at the 1% significance level.

Significance	Adf	Sadf	Gsadf
90 %	-0.492	1.29	2.27
95 %	0.131	1.51	2.45
99 %	0.475	2.08	2.86

Table 7.3: Critical values for green stocks

Stock:	adf	sadf	gsadf	Gsadf Results:
TOMRA SYSTEMS	-1.03	2.61	2.68	Rejects H0 at the 5% significance level
SCATEC	-1.43	7.51	7.51	Rejects H0 at the 1% significance level
NEL	-1.43	5.26	5.28	Rejects H0 at the 1% significance level
BORREGAARD	-1.08	2.55	2.55	Rejects H0 at the 5% significance level
ARENDALS FOSSEKOMPANI	-1.02	6.52	6.52	Rejects H0 at the 1% significance level
AKER HORIZONS	-2.24	2.19	2.19	Cannot reject H0
AKER CARBON CAPTURE	-1.17	11.2	11.2	Rejects H0 at the 1% significance level
BONHEUR	-0.472	2.12	2.81	Rejects H0 at the 5% significance level
HEXAGON COMPOSITES	-2.86	3.57	3.77	Rejects H0 at the 1% significance level
ELOPAK	-0.854	0.0759	1.99	Cannot reject H0
VOLUE	-1.08	4.4	4.4	Rejects H0 at the 1% significance level
REC SILICON	-2.26	1.26	6.49	Rejects H0 at the 1% significance level
EVERFUEL	-1.66	21.6	21.6	Rejects H0 at the 1% significance level
QUANTAFUEL	-1.61	13	13	Rejects H0 at the 1% significance level
CADELER	0.0183	3.37	3.37	Rejects H0 at the 1% significance level
VOW	-1.42	8.82	12.4	Rejects H0 at the 1% significance level
AKER OFFSHORE WIND (BER)	-1.62	12.3	12.3	Rejects H0 at the 1% significance level
ZAPTEC	-1.23	16.6	16.6	Rejects H0 at the 1% significance level
CLOUDBERRY CLEAN ENERGY	-1.26	1.07	1.07	Cannot reject H0
CAMBI	-2.15	19.9	19.9	Rejects H0 at the 1% significance level
AGILYX	-1.05	2.86	2.86	Rejects H0 at the 1% significance level
CIRCA GROUP	-2.24	5.43	5.43	Rejects H0 at the 1% significance level
SALMON EVOLUTION	-0.666	0.879	1.87	Cannot reject H0
ANDFJORD SALMON	-0.967	7.47	7.47	Rejects H0 at the 1% significance level
BERGEN CARBON SOLUTIONS	-1.86	35.6	35.6	Rejects H0 at the 1% significance level
SAGA PURE	-2.15	7.62	11.4	Rejects H0 at the 1% significance level
HYDROGENPRO	-1.61	6.55	6.55	Rejects H0 at the 1% significance level
OTOVO	-3.32	3.71	3.93	Rejects H0 at the 1% significance level
BW IDEOL	-2.46	0.582	0.582	Cannot reject H0
OCEAN SUN	-1.69	23.7	23.7	Rejects H0 at the 1% significance level
MAGNORA	-1.44	2.18	3.77	Rejects H0 at the 1% significance level
PRYME	-2.82	-0.00436	0.357	Cannot reject H0
TECO 2030	0.187	11.4	11.4	Rejects H0 at the 1% significance level
ALTERNUS ENERGY GROUP	-1.74	0.142	0.363	Cannot reject H0
MPC ENERGY SOLUTIONS	-2.45	-0.535	0.601	Cannot reject H0
NORSK SOLAR	-2.32	3.23	3.23	Rejects H0 at the 1% significance level
HORISONT ENERGI	-2.3	2.68	3.1	Rejects H0 at the 1% significance level
INTEGRATED WIND SOLUTIONS	-0.761	0.946	0.946	Cannot reject H0
DESERT CONTROL	-1.26	4.51	4.51	Rejects H0 at the 1% significance level
M VEST WATER	-1.86	21.7	21.7	Rejects H0 at the 1% significance level
HAV GROUP	-1.44	0.86	0.86	Cannot reject H0
PROXIMAR SEAFOOD	-2.86	0.299	1.36	Cannot reject H0
HYNION	-2.53	15.7	15.7	Rejects H0 at the 1% significance level
KYOTO GROUP	-2.32	2.2	2.2	Cannot reject H0
GREEN MINERALS	-3.02	-1.26	0.259	Cannot reject H0
SKANDIA GREENPOWER	-2.42	-0.73	1.62	Cannot reject H0
ENVIPCO HOLDING (OSL)	0.143	5.41	5.41	Rejects H0 at the 1% significance level
AEGA	-3.47	-0.84	8.63	Rejects H0 at the 1% significance level

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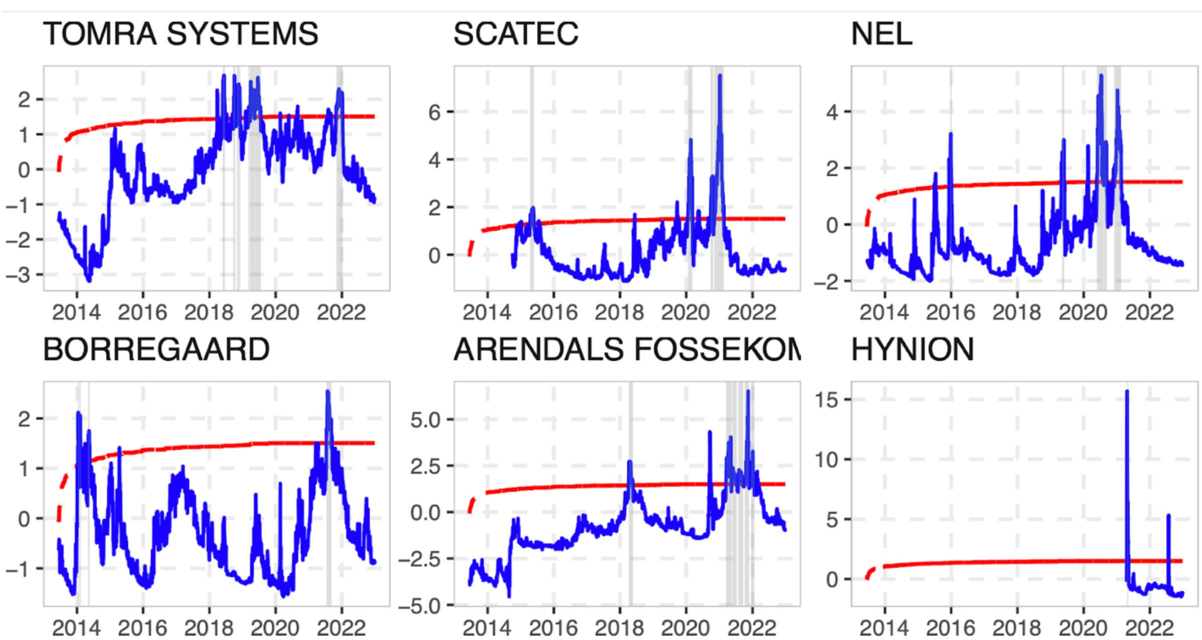
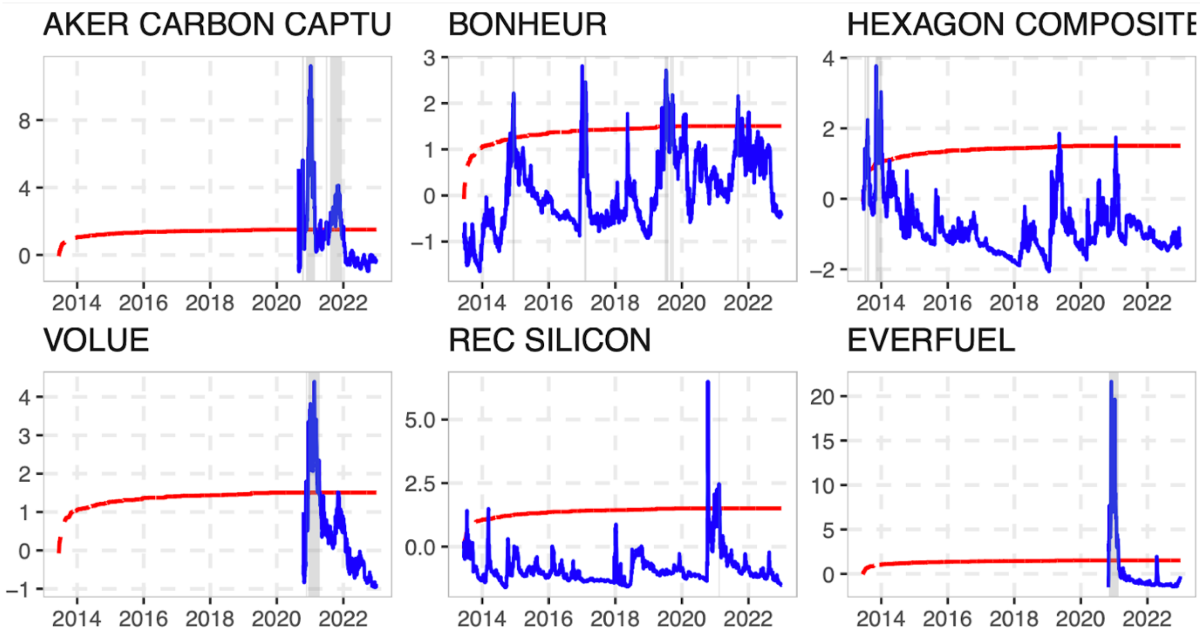
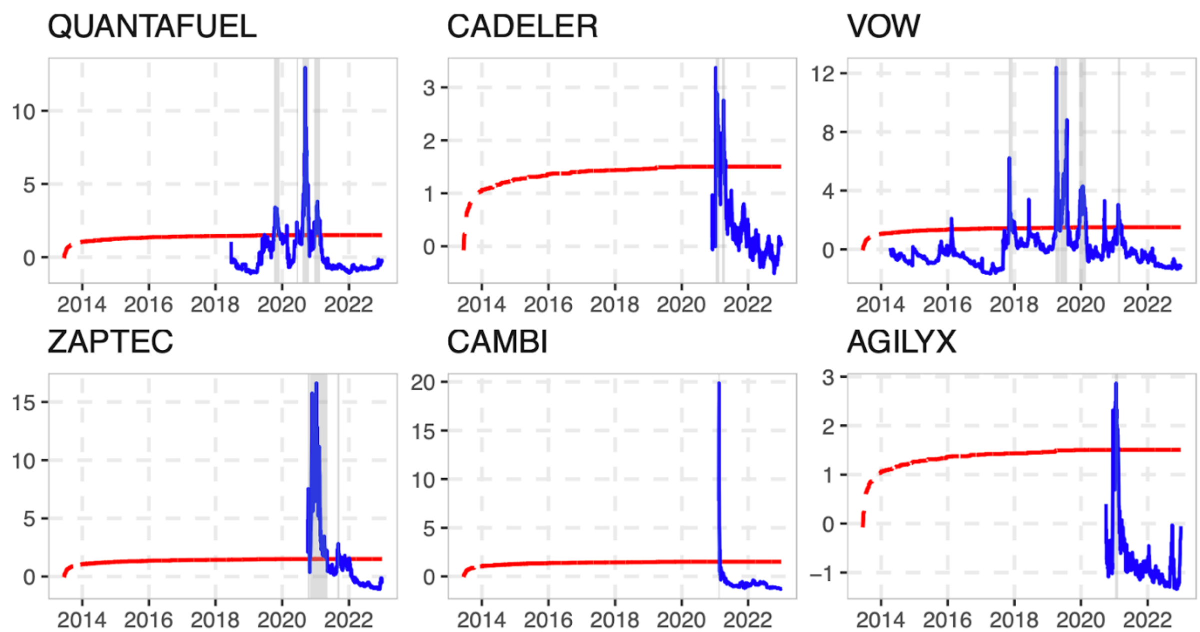
Table 7.4: Test statistics for 10-year period green stocks

It is fair to assume that our portfolio will be more volatile than the OSEBX index since our portfolio contains fewer stocks from a limited segment of the market and is therefore less diversified. The difference in diversification can explain some of the price movements. Figure 7.2 visualizes the GSADF test statistics for the green stocks over a 10-year period. The red line still represents a 1% significance level.

Our results show that we can reject the null hypothesis of a unit root at the 1% significance level for the GSADF test for 31 companies (Table 7.4). With a unit root at the 5% significance level, we can reject the null hypothesis for 3 companies. Overall, our results indicate explosive behavior for 34 companies. We used the rules-of-thumb proposed by Phillips et al. (2015) to compute the minimum window size and the minimum duration of an episode of exuberance, respectively. This gave us a minimum window size of 8 days for our dataset, and we have only included episodes of exuberance lasting at least 8 days. This left us with periods of exuberance for 30 companies.




AKER CARBON CAPTU
BONHEUR
HEXAGON COMPOSITE
VOLUE
REC SILICON
EVERFUEL
2014 2016 2018 2020 2022


QUANTAFUEL
CADELER
VOW
ZAPTEC
CAMBI
AGILYX
2014 2016 2018 2020 2022

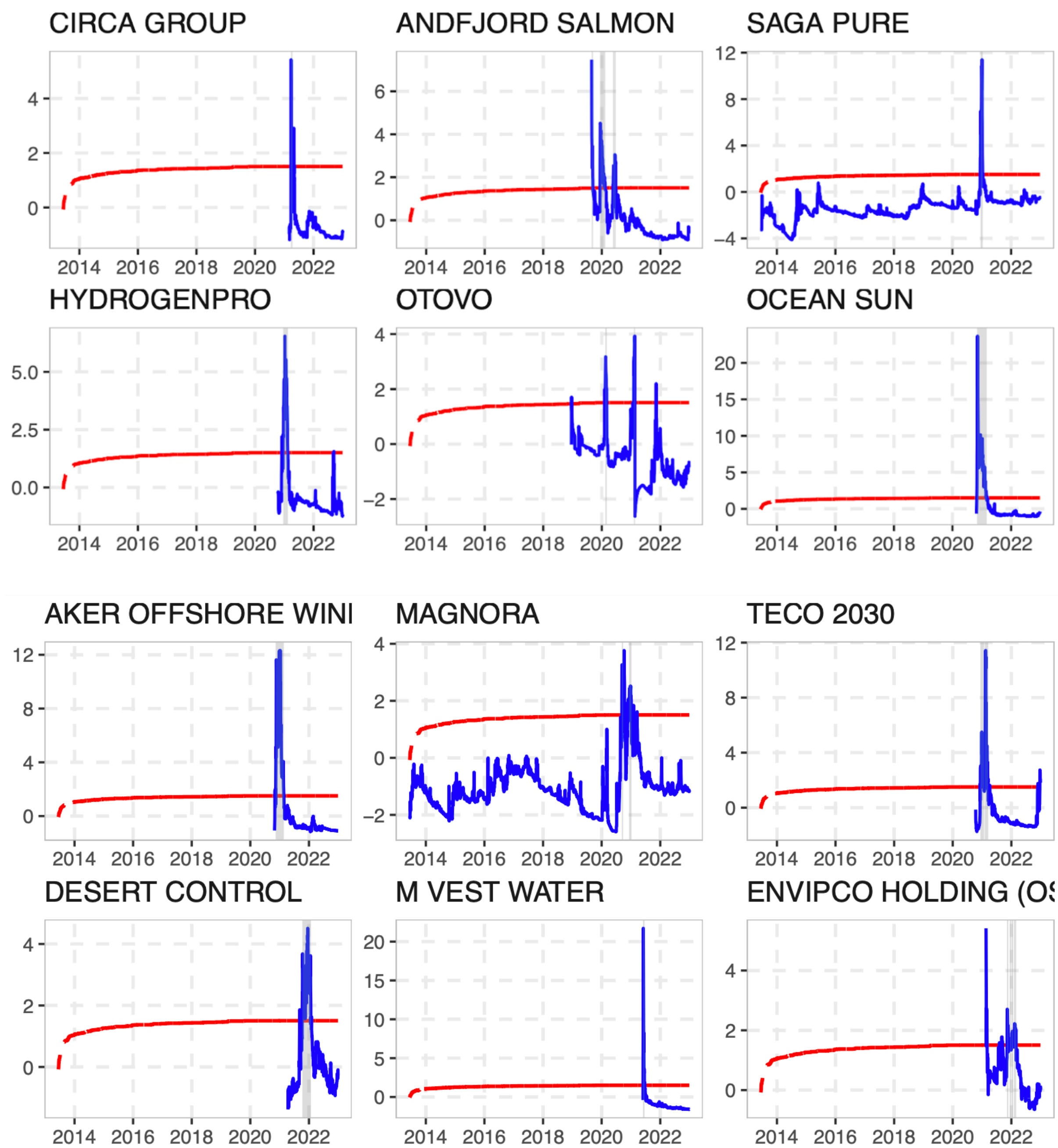


Figure 7.2: Date-stamping plot for green stocks (explosive behavior threshold = red line)

We would like to establish whether the periods of exuberance for the different stocks coincide with each other. By looking at table 7.5, we can see a pattern where most stocks had longer periods of exuberance in 2021, with some stocks experiencing significant periods of exuberance between 2019 and 2022. The long duration of the exuberance suggests that we are talking about a bubble and not a blip. The sudden and sharp drop in stock prices after the period of exuberance, which is shown in figure 7.2, is also indicative of a bubble. However, the results suggest that none of the stocks in our portfolio are currently showing signs of explosive behavior.

The listing date of the companies can also explain why we identify more periods of exuberance in the past few years, as some of the stocks are new to the Oslo Stock Exchange from a historical perspective and have only been listed for a few years. We had a look at the listing date of the stocks in our portfolio and compared it to the periods of exuberance. Fourteen out of the thirty stocks where evidence of exuberance is found, experienced exuberance within 2 months after they were listed on the Norwegian Stock Exchange. Most of these stocks were listed on the exchange in 2020 or 2021. There is no direct link between IPOs and exuberance, unless the pricing is too low according to market participants - in which case they will be willing to pay more than the initial offering price, resulting in exuberance. Our results seem to indicate that there might be a correlation between exuberance and IPOs in our portfolio. This can be due to initial hype caused by extensive media exposure, as it is frequently observed that the listing price of IPOs is significantly lower than the closing price on the day it is listed. The price will eventually stabilize once the hype is over, and the stocks receive less media exposure (Jang, 2010). This is also according to the "Displacement" step in the Kindleberger-Minsky model where a new idea or innovation leads to increased interest and investments in a specific asset or market (Aliber & Kindleberger, 2015).

TOMRA SYSTEMS

Start	End	Duration
28.05.2018	21.06.2018	18
21.09.2018	11.10.2018	14
31.10.2018	21.11.2018	15
26.11.2018	06.12.2018	8
08.03.2019	22.03.2019	10
26.03.2019	13.05.2019	34
15.05.2019	22.07.2019	48
01.11.2021	10.01.2022	50

SCATEC

Start	End	Duration
15.04.2015	27.05.2015	30
20.01.2020	09.03.2020	35
25.09.2020	23.10.2020	20
04.11.2020	18.02.2021	76

NEL

Start	End	Duration
22.12.2015	05.01.2016	10
08.05.2019	31.05.2019	17
27.05.2020	10.08.2020	53
11.08.2020	14.09.2020	24
04.12.2020	18.02.2021	54

BORREGAARD

Start	End	Duration
14.01.2014	27.01.2014	9
03.02.2014	13.02.2014	8
02.05.2014	20.05.2014	12
15.07.2021	08.09.2021	39

ARENDALS FOSSEKOMPANI

Start	End	Duration
06.04.2018	23.05.2018	33
16.03.2021	12.05.2021	41
19.05.2021	12.07.2021	38
28.07.2021	20.09.2021	38
07.10.2021	24.11.2021	34
16.12.2021	21.01.2022	26

AKER CARBON CAPTURE

Start	End	Duration
05.10.2020	23.10.2020	14
17.11.2020	23.02.2021	70
24.06.2021	07.07.2021	9
09.08.2021	14.12.2021	91

BONHEUR

Start	End	Duration
28.11.2014	22.12.2014	16
25.01.2017	17.02.2017	17
27.06.2019	05.08.2019	27
26.08.2019	10.09.2019	11
17.09.2019	02.10.2019	11
30.08.2021	15.09.2021	12

REC SILICON

Start	End	Duration
08.02.2021	18.02.2021	8

EVERFUEL

Start	End	Duration
03.11.2020	18.02.2021	77

QUANTAFUEL

Start	End	Duration
04.10.2019	03.12.2019	42
09.06.2020	24.06.2020	11
10.08.2020	20.10.2020	51
18.12.2020	18.02.2021	44

CADELER

Start	End	Duration
06.01.2021	18.02.2021	31
22.03.2021	20.04.2021	21

VOW

Start	End	Duration
31.10.2017	29.11.2017	21
01.12.2017	13.12.2017	8
28.03.2019	29.04.2019	22
30.05.2019	14.05.2019	10
21.05.2019	01.08.2019	52
13.12.2019	24.02.2020	51
08.02.2021	05.03.2021	19

AKER OFFSHORE WIND (BER)

Start	End	Duration
13.11.2020	22.02.2021	71

ZAPTEC

Start	End	Duration
07.10.2020	28.10.2020	15
02.11.2020	10.05.2021	135
27.08.2021	20.09.2021	16

CAMBI

Start	End	Duration
10.02.2021	23.02.2021	9

AGILYX

Start	End	Duration
08.01.2021	11.02.2021	24

CIRCA GROUP

Start	End	Duration
26.03.2021	12.04.2021	11

HEXAGON COMPOSITES

Start	End	Duration
03.07.2013	17.07.2013	10
26.07.2013	22.08.2013	19
31.10.2013	05.12.2013	25
06.12.2013	08.01.2014	23

OTOVO

Start	End	Duration
14.02.2020	03.03.2020	12
05.02.2021	18.02.2021	9

OCEAN SUN

Start	End	Duration
02.11.2020	04.03.2021	88

MAGNORA

Start	End	Duration
10.09.2020	24.09.2020	10
09.12.2020	07.01.2021	21

TECO 2030

Start	End	Duration
11.12.2020	27.01.2021	33
04.02.2021	17.03.2021	29

DESERT CONTROL

Start	End	Duration
11.10.2021	25.01.2022	76

M VEST WATER

Start	End	Duration
01.06.2021	18.06.2021	13

HYNION

Start	End	Duration
22.04.2021	06.05.2021	10

ENVIPCO HOLDING (OSL)

Start	End	Duration
09.11.2021	24.11.2021	11
13.12.2021	28.12.2021	11
04.01.2022	24.01.2022	14
03.02.2022	01.03.2022	18

ANDFJORD SALMON

Start	End	Duration
28.08.2019	13.09.2019	12
11.12.2019	13.02.2020	46
20.05.2020	09.06.2020	14
11.06.2020	23.06.2020	8

SAGA PURE

Start	End	Duration
16.12.2020	13.01.2021	20

HYDROGENPRO

Start	End	Duration
18.12.2020	15.02.2021	41

VOLUE

Start	End	Duration
16.11.2020	27.11.2020	9
11.12.2020	16.04.2021	90

Table 7.5: Periods of exuberance

Focusing on when the periods of exuberance found place, 21 out of the 48 companies in our dataset experienced episodes of exuberance during the period November 2020 – April 2021 (Table 7.5). During this period, our dataset consisting of green stocks had an average price increase of 47.30%. The 21 stocks experiencing episodes of exuberance had an average increase in price of as much as 87.99% during the same period. Six of the companies in our data set were not listed in this period and are therefore not considered in these calculations. During the period from November 2020 to April 2021 the OSEBX increased by 42.83%.

7.3 Financial Ratio Analysis

In addition to our time series analysis performed in R, we will be using financial ratio analysis to provide another angle to our research and help us determine whether a green bubble is present in the Norwegian stock market.

The Price/Earnings ratio (P/E ratio) of a stock equals the price of a share of the stock relative to its earnings per share. Investors and stock analysts are using P/E ratios to help determine whether a stock is reasonably priced, by looking at whether the valuation of the stock in the market can be justified from an earnings perspective (Shen, 2000). Return on equity (ROE) measures the profitability of a company by looking at net income relative to shareholder equity (Damodaran, 2007).

$$\frac{P}{E} = \frac{Market\ value\ per\ share}{Earnings\ per\ share} \tag{16}$$

$$ROE = \frac{Net\ income}{Shareholders\ equity} \tag{17}$$

Overall, a high P/E ratio represents a high valuation. A high P/E ratio and a low ROE indicates that a stock is overpriced, as the pricing in the market is high compared to its earnings and thereby cannot be justified by market fundamentals (Liu, Han, & Wang, 2016). Our analysis's objective is therefore to examine the relationship between the two measurements. Table 7.6 presents the P/E ratio and ROE of our green stock portfolio as of 30.12.2022, which represents the final date included in our dataset where data was available from Thompson Reuters Eikon.

Stock	P/E-ratio	ROE	Stock	P/E-ratio	ROE
TOMRA SYSTEMS	44.98	17.88	BERGEN CARBON SOLUTIONS	-6.81	-25.29
SCATEC	-8.71	-15.22	SAGA PURE	-31.58	-2.25
NEL	-17.52	-22.33	HYDROGENPRO	-15.86	-17.98
BORREGAARD	19.09	20.71	OTOVO	-5.07	-60.61
ARENDALS FOSSEKOMPANI	2072.19	0.18	BW IDEOL	-1.96	-15.53
AKER HORIZONS	-2.25	-41,08	OCEAN SUN	-16.31	-25.18
AKER CARBON CAPTURE	-40.36	-20.89	MAGNORA	104.74	4.49
BONHEUR	24.2	7.94	PRYME	-6.79	N/A
HEXAGON COMPOSITES	-20.85	-10.21	TECO 2030	-17.6	N/A
ELOPAK	54.72	4.05	ALTERNUS ENERGY GROUP	-1.37	N/A
VOLUE	151.39	2.46	MPC ENERGY SOLUTIONS	-4.65	-7.46
REC SILICON	-8.65	-188.3	NORSK SOLAR	-4.01	-41.75
EVERFUEL	-12.17	-24.64	HORISONT ENERGI	-1.58	N/A
QUANTAFUEL	-2.89	-27.31	INTEGRATED WIND SOLUTIONS	-32.75	-3.22
CADELER	19.58	8.05	DESERT CONTROL	-6.4	-59.43
VOW	67.7	4.28	M WEST WATER	-8.87	-41.92
AKER OFFSHORE WIND (BER)	N/A	N/A	HAV GROUP	5.2	N/A
ZAPTEC	-120.53	-6.16	PROXIMAR SEAFOOD	-9.7	-5.78
CLOUDBERRY CLEAN ENERGY	23.4	3.72	HYNION	-1.67	-52.12
CAMBI	-102.18	N/A	KYOTO GROUP	-1.89	N/A
AGILYX	-16.81	N/A	GREEN MINERALS	-4.83	-57.55
CIRCA GROUP	-11.58	-15.18	SKANDIA GREENPOWER	-0.21	N/A
SALMON EVOLUTION	-82	-2.29	ENVIPCO HOLDING (OSL)	-30.77	-15.59
ANDFJORD SALMON	-34.56	N/A	AEGA	-1.97	-25.52

Table 7.6: P/E ratio and ROE of green stocks, 30.12.2022

The P/E ratio used is a trailing P/E ratio, meaning that it uses actual earnings over the past 12 months. This can explain why some of the green stocks have missing values, as some of them are new to the market and earnings cannot be retrieved for a 12-month period. Out of our stock portfolio of 48 stocks, 11 are listed as N/A. By looking at table 7.6, we can see that most stocks have a negative P/E ratio and ROE. This is because most companies are currently experiencing negative earnings, which relates to current macroeconomic conditions elaborated in chapter 2. Nonetheless, the stocks may still have a high price due to the expectation of positive cash flows in the future. Most of the companies that make up our portfolio were founded in the last 5 years, meaning that the stocks are typically growth stocks. The companies will therefore be characterized by high investment levels to support growth, and this will result in a negative cash flow and thereby negative financial ratios.

The large variation in financial ratios between different stocks can be partially explained by the companies operating in different sectors. The extent to which companies are affected by macroeconomic conditions may vary between different sectors. We have compared how the different sectors the green stocks operate in with the periods of exuberance to determine whether we can establish a pattern. We can see that among the stocks that experienced three or more periods of exuberance, most of them operate in the Alternative Energy sector. The sector that appears to be the least affected by exuberance is the Energy Support, Construction, and Components sector – suggesting that the companies in this sector experience less volatility. See figure 6.1 for an overview of how the companies in our portfolio are distributed between sectors.

There are very few companies that have excessive P/E ratios, which seems to indicate that the Norwegian stock market is not currently experiencing a green bubble. The most extreme example of an excessive P/E ratio is Arendals Fossekompani ASA with a P/E ratio of 2072.19 and a ROE of a mere 0.18. Given that our portfolio overall showed similar traits, we would have evidence in support of a green bubble.

Since the periods of significant exuberance do not overlap with the period these financial ratios were taken from, it is appropriate to look at financial ratios from 2021 when exuberance is detected for several stocks. By doing so, we can determine if there are further indications of a green bubble happening in the past.

Table 7.7 consists of P/E ratios and ROE for the green stocks as of 01.01.2021. Most of the stocks still have a negative P/E ratio and ROE and only a very few companies have excessive P/E ratios. The most extreme example of an excessive P/E ratio from 2021 is yet again Arendals Fossekompani ASA with a P/E ratio of 1991.02 and an ROE of 3.09 – a significant difference between the two financial ratios. However, excessive P/E ratios do not appear to be a trend amongst our selection of green stocks and based on financial ratios we do not have the evidence to conclude that a green bubble has taken place in the past.

Stock	P/E-ratio	ROE	Stock	P/E-ratio	ROE
TOMRA SYSTEMS	46.5	19.11	BERGEN CARBON SOLUTIONS	-6.7	-36.85
SCATEC	-9.27	4.3	SAGA PURE	-31.54	24.86
NEL	-17.66	-31.73	HYDROGENPRO	-15.86	-10.9
BORREGAARD	19.62	17.54	OTOVO	-4.99	-46.75
ARENDALS FOSSEKOMPANI	1991.02	3.09	BW IDEOL	-1.94	-27.38
AKER HORIZONS	-2.4	-72.05	OCEAN SUN	-16.55	-21.03
AKER CARBON CAPTURE	-39.94	-25.17	MAGNORA	117.59	-43.33
BONHEUR	24.41	-2.35	PRYME	-6.52	-14.19
HEXAGON COMPOSITES	-20.59	-7.55	TECO 2030	--17.56	-66,16
ELOPAK	55.94	14.84	ALTERNUS ENERGY GROUP	-1.47	42.8
VOLUE	149.17	3.7	MPC ENERGY SOLUTIONS	-4.69	-6.34
REC SILICON	-8.61	-64.95	NORSK SOLAR	-3.91	-32.27
EVERFUEL	-12.26	-12.93	HORISONT ENERGI	-1.52	-109.77
QUANTAFUEL	-2.82	-0.47	INTEGRATED WIND SOLUTIONS	-32.75	-5.43
CADELER	18.81	2.62	DESERT CONTROL	-6.4	-27.65
VOW	66.5	76.5	M WEST WATER	-8.49	-64.52
AKER OFFSHORE WIND (BER)	N/A	-50.96	HAV GROUP	5.13	68.3
ZAPTEC	-126.41	2.34	PROXIMAR SEAFOOD	-10.55	-11.79
CLOUDBERRY CLEAN ENERGY	22.98	-3.42	HYNION	-1.64	-53.09
CAMBI	-100.93	4.62	KYOTO GROUP	-1,9	-64.15
AGILYX	-16.58	-54.05	GREEN MINERALS	-4.67	-44.29
CIRCA GROUP	-11.43	-34.4	SKANDIA GREENPOWER	-0.21	-20,04
SALMON EVOLUTION	-81.5	-2.54	ENVIPCO HOLDING (OSL)	-32.05	2.28
ANDFJORD SALMON	-34.47	-10.49	AEGA	-2.03	-3.3

Table 7.7: P/E ratio and ROE of green stocks, 01.01.2021

8. Discussion

Green investments are trending, and this has sparked concerns over a possible green bubble in the stock market. Acquiring knowledge of historic bubbles can be a useful tool to help us understand the development of asset bubbles, as there are limited tools to detect bubbles. By comparing historic bubbles to today's market for green stocks, we can draw parallels between the two.

In chapter 2.3 we focused on some of the most well-known and biggest asset bubbles in history. All of these share similarities with the market of green stocks today, which is characterized by speculation and large investment volumes. Out of the bubbles mentioned in this chapter, there is one that stands out and shares several similarities with today's green stock market. The Dot-Com bubble in the late 90s arose from people investing in internet companies as these were fast-growing, on trend and expected to generate high returns. In chapter 3.2 we focused on the Kindleberger-Minsky bubble pattern consisting of 5 steps. The first step is displacement, and it explains how bubbles usually begin with a new idea or innovation that raises interest and investments in a particular asset or market (Aliber & Kindleberger, 2015). Green stocks have experienced an increase in interest and investment volumes during recent years. The green stocks are expected by several investors to generate high returns, and there is no doubt that sustainability is a very relevant theme in today's global environment. Similar to the green initiatives pushed forward by the government nowadays, the government also put political focus and funds into new technology in the times before the Dot-Com bubble.

Our results from the GSADF test suggest that most of the stocks in our portfolio have experienced one or more periods of exuberance within the timeframe we studied. Many stocks experienced exuberance in 2020/2021 and as we know Covid-19 was on everyone's radar during these years. In chapter 2.2 we elaborated on the impact Covid-19 had on the Norwegian stock market and investments peaked during this period. The exceptionally high investment level during this period can explain why we find evidence of exuberance. However, the observed exuberance may also have an alternative explanation to the “green” bubble hypothesis. It can be explained by the fact that most of the stocks in our portfolio were listed on the Norwegian Stock Exchange in 2020/2021, as it has been observed that stocks tend to trade for a higher price than the initial listing price shortly after being listed (Jang, 2010). Kindleberger and Minsky's model describes the boom phase as the period when investors are attracted to a stock by the sudden increase in demand and price

(Aliber & Kindleberger, 2015). Today, green stocks are getting a lot of media exposure, and the demand and prices have reached a high level. We also saw similar tendencies in the times before the Dot-Com bubble, when technology stocks were getting a lot of attention and had an extremely high demand and price. During the boom phase, companies will often hurry to get listed as the demand and prices are both high. One can say that this might be the case today as 23 out of the 54 stocks considered green by Oslo Børs in June 2021, were new listings as of 2021 (AksjeNorge, 2021).

Euphoria is the third phase in the Kindleberger-Minsky bubble pattern model, and the final step before the bubble bursts. During this phase prices rise to extreme levels, attracting more investors who are ignoring the risk in hopes of a good profit. Prices are no longer rooted in fundamental value, and the market is full of speculation with investors being lured into believing that the upside is limitless (Aliber & Kindleberger, 2015). As we saw in chapter 7.3, 36 out of the 48 green stocks used in this report have a negative P/E ratio. This tells us that these companies have negative earnings, but investors still seem to be willing to buy into these companies in the hope of a future profit.

As previously mentioned, sustainability is a much-talked-about topic these days. It is a focus point of governments around the world, and it receives a lot of media exposure. This leads to a lot of speculation in the market for green stocks. Investors in today's market can display exuberant market behavior, where they forget the stock's fundamental value, and a mix of enthusiasm and confidence drives the stock price to extreme levels. In an article by Finansavisen, Lars Erik Moen discusses how the government is setting strict demands for fund managers considering sustainable portfolios (Hammernes, 2021). An EU regulation requires fund managers to be transparent regarding the sustainability of their stock portfolios, by reporting to the authorities and sharing reports with the media, which acts as an incentive to include more green companies in the funds. The regulation was introduced to better display the negative impact investments have on various sustainability factors (World Bank, 2021). Lars Erik Moen points out that there are not enough green companies fulfilling the government demands for fund managers to choose from, which will lead to an over demand for the stocks they can choose to invest in. He also points out how investors want to stay ahead of the requirements from authorities, leading to an even higher demand for these stocks (Hammernes, 2021).

We must expect our portfolio of green stocks to be volatile compared to the overall market given by the OSEBX index, as it does not have the same level of diversification as the index. Even though the portfolio consists of companies that operate within different sectors, the companies are all considered green and share similarities. The amount of volatility can be sector dependent and this might explain why some stocks show no indications of exuberance, as the stocks in our portfolio operate in different sectors. We find that the stocks of companies in the Alternative Energy sector appear to be more exposed to exuberance, while the Energy Support, Construction, and Components sector experienced far less exuberance. This can also be a result of varying interest in different sectors and investors might favor a certain sector when they opt to invest in green stocks. For instance, the Alternative Energy sector has gained a lot of media exposure lately due to the increased focus it has gained because of the Russia-Ukraine war. Media exposure influences investors' trading habits and Alternative Energy is therefore likely to be a hot sector to invest in nowadays. If the Alternative Energy sector receives a larger portion of the investments into green stocks as opposed to the Energy Support, Construction, and Component sector, it can explain why exposure to exuberance appears to be sector dependent.

Overall, we do not find evidence of a green bubble currently existing in the Norwegian market based on the conducted time series analysis in R and financial ratio analysis. There are very few episodes of exuberance detected in our portfolio during 2022. Moreover, most stocks have negative P/E ratios due to their negative earnings and we observe that excessive P/E ratios are the exception in our portfolio. We cannot conclude that a bubble took place around 2020/2021, even though most stocks experienced one or more periods of exuberance at the time which is indicative of an asset bubble. As mentioned prior in the thesis, there are several other factors that can explain the periods of exuberance. According to Siegel (2003), one cannot identify bubbles immediately but must wait for a sufficient amount of time to establish whether prices can be justified by subsequent cashflows. Based on our financial ratios analysis most stocks had negative P/E ratios in 2021 as well and excessive P/E ratios did not appear to be a trend amongst the green stocks.

It is important to note that detecting bubbles in financial markets is not a definitive way to predict market crashes, but it can be used as a signal for potential market corrections or increased risk. The detection of bubbles using econometric analysis is not a straightforward task and it is not always possible to detect them with high accuracy. Combined with historical knowledge of bubbles it will however help us gain a better understanding of the market and contribute to better risk management among investors.

9. Conclusion

The demand for sustainable investments is growing in line with the green transition the global society is facing. Companies are becoming increasingly more aware of their ESG rating, and especially the environmental aspect is gaining more recognition among investors who are buying into green stocks on an unparalleled scale. There is little doubt that green investing is trending, and the substantial media exposure of green companies and opportunities in green technology is evidence of this. Governments are also incentivizing companies to implement sustainable solutions and reduce their carbon footprint, through efforts like environmental taxes and climate gas emission taxes. Overall, this has led to an increase in IPOs of green companies on the Norwegian Stock Exchange.

During Covid-19 the Norwegian Stock Exchange experienced a boom of investors that were attracted to the stock markets and before the market was able to stabilize, the Russian innovation of Ukraine was a reality and resulted in yet another shock on the global financial markets. Simultaneously, the Norwegian stock market has seen many stocks reach prices that surpass fundamental value even if the macroeconomic environment did not call for growth. Nonetheless, many green companies are experiencing negative earnings and are losing equity due to the high investment levels that are necessary to support growth.

The aim of our thesis is to establish whether a green bubble is, or has been, present in the Norwegian stock market. Prior to doing so we have provided some background to the situation in today's stock market, and presented a selection of literature on asset pricing bubbles and some of the models that can be used to detect such bubbles. Variations of the Augmented Dickey-Fuller (ADF) tests have been applied to our selection of 48 green stocks and the OSEBX index. The results indicate that there is no green bubble in the Norwegian stock market as of today. However, there are indications of a bubble taking place in the years 2020/2021, as most stocks experienced significant periods of exuberance at the time. Nonetheless, it is difficult to conclude that a bubble took place during this period, as there are several other factors that can explain the explosive behavior of the stocks. For instance, many stocks were listed during this period and research suggests that stocks often trade at a higher price than the initial offering price, shortly after the IPO. Moreover, Covid-19 likely played a role as the stock markets attracted many new investors during this period and investment volumes peaked. Even though we find evidence that can be indicative of a bubble, one can never be confident that a bubble exists before it eventually bursts.

The main limitation of this study relates to the sample size used and the potential errors of the model. As mentioned earlier, green stocks are new to the market and several of the stocks in our green stock portfolio only have data from the last few years. Some stocks were excluded from the analysis, as they had what we considered to be an insufficient number of observations. Another limitation is that the recursive ADF tests are relatively new, and it is likely that alterations will be made to the model to make it more accurate in terms of detecting bubbles. In fact, the model has difficulties discovering bubbles before they reach their peak and burst, which is a clear disadvantage given that the aim is to become aware of bubbles before the market collapses. Another limitation that is worth mentioning is the use of the Low Carbon 100 Europe index. It would be more ideal to use a green index from the Norwegian Stock Exchange, as we cannot be sure that the European stock markets behave the same as the Norwegian stock market.

There are additional avenues for future research that we have not touched upon as these are outside the scope of our thesis. Future research should aim to develop a standard framework for detecting asset bubbles, as no universal framework currently exists. A framework must be able to distinguish between rational bubbles and irrational bubbles, and a study must therefore involve behavioral finance and consider macroeconomic factors. An extension of this study would be to include the stocks that are new to the market and therefore have fewer observations. Moreover, a study could dive deeper into the behavioral aspect of asset bubbles by studying investor behavior under different conditions.

References

Ahmed, S., Hasan, M. M., & Kamal, M. R. (2022). Russia-Ukraine crisis: The effects on the European stock market. *European Financial Management*, 1–41. https://doi.org/10.1111/eufm.12386

AksjeNorge. (2021, August 4). Hver 10. krone er grønn. Retrieved from AksjeNorge website: https://aksjenorge.no/aktuelt/2021/08/04/10green/

Aliber, R. Z., & Kindleberger, C. P. (2015). *Manias, panics and crashes* (7th ed.). Houndmills, Basingstoke, Hampshire ; New York: Palgrave Macmillan.

American Express. (2021, January 22). How Sustainability Can Reduce Costs & Help Grow Your Business. Retrieved from Business Class: Trends and Insights | American Express website: https://www.americanexpress.com/en-gb/business/trends-and-insights/articles/business-benefits-of-sustainability/

Barlevy, G. (2007). Economic Theory and Asset Bubbles. *Economic Perspectives*, *31*(3). Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1012865

Beaver, W. H. (1981). Market Efficiency. *The Accounting Review*, *56*(1), 23–37. Retrieved from https://www.jstor.org/stable/246460

Beck, T., & Levine, R. (2004). Stock markets, banks, and growth: Panel evidence. *Journal of Banking & Finance*, *28*(3), 423–442. https://doi.org/10.1016/s0378-4266(02)00408-9

Blakeley, G. (2020). *The Corona Crash*. Verso Books.

Blanchard, O. J., & Watson, M. W. (1982). BUBBLES, RATIONAL EXPECTATIONS AND FINANCIAL MARKETS. *NBER WORKING PAPER SERIES*, *945*. Retrieved from https://www.nber.org/system/files/working_papers/w0945/w0945.pdf

Bøhren, Ø., Michalsen, D., & Norli, Ø. (2017). *Finans teori og praksis*. Fagbokforlaget.

Bougroug, A., Kjos, Ø. K., & Sletten, P. (2021). Økonomisk utvikling gjennom Covid-19. In *ssb.no*. Statistisk sentralbyrå. Retrieved from Statistisk sentralbyrå website:

https://www.ssb.no/nasjonalregnskap-og-konjunkturer/artikler-og-publikasjoner/_attachment/450956?_ts=178ca845f00

Boungou, W., & Yatié, A. (2022). The impact of the Ukraine–Russia war on world stock market returns. *Economics Letters*, *215*. https://doi.org/10.1016/j.econlet.2022.110516

Bradley, C., & Stumpner, P. (2021, March 10). The impact of COVID-19 on capital markets, one year in. Retrieved from www.mckinsey.com website: https://www.mckinsey.com/capabilities/strategy-and-corporate-finance/our-insights/the-impact-of-covid-19-on-capital-markets-one-year-in

Brenner, R. (2005). WHY SOCIETY NEEDS "IRRATIONAL EXUBERANCE"-AND WHAT THIS MEANS FOR VALUATIONS AND MONETARY POLICY. *Journal of Applied Corporate Finance*, *13*(2), 112–117. https://doi.org/10.1111/j.1745-6622.2000.tb00059.x

Chen, E., & Dey, E. (2022, May 18). Tesla Loses Spot on S&P ESG Index Due to Concerns Over Crashes, Working Conditions. Retrieved from www.bloomberg.com website: https://www.bloomberg.com/news/articles/2022-05-18/tesla-crashes-work-conditions-see-it-pushed-off-s-p-esg-index?leadSource=uverify%20wall

Chen, J. (2022, November 1). Guide to Green Investing. Retrieved from Investopedia website: https://www.investopedia.com/terms/g/green-investing.asp

Cogley, T. (1999). Should the Fed take deliberate steps to deflate asset price bubbles? *Economic Review-Federal Reserve Bank of San Francisco*, 42–52. Retrieved from https://www.frbsf.org/economic-research/wp-content/uploads/sites/4/42-52.pdf

Cuthbertson, K., & Nitzsche, D. (2005). *Quantitative financial economics : stocks, bonds and foreign exchange*. Chichester, West Sussex: John Wiley & Sons, Ltd.

Dagher, J. (2018). Regulatory Cycles: Revisiting the Political Economy of Financial Crises. *IMF Working Paper*, *2018(008)*. Retrieved from https://www.imf.org/en/Publications/WP/Issues/2018/01/15/Regulatory-Cycles-Revisiting-the-Political-Economy-of-Financial-Crises-45562

Damodaran, A. (2007). Return on Capital (ROC), Return on Invested Capital (ROIC) and Return on Equity (ROE): Measurement and Implications. *SSRN Electronic Journal*. http://dx.doi.org/10.2139/ssrn.1105499

Danske Bank. (2023, January 18). Bærekraftige investeringer: Trender 2023. Retrieved April 13, 2023, from danskebank.no website: https://danskebank.no/webinars/live/2023/esg-trender-2023

Defiance. (2022, March 23). What does Russia's invasion of Ukraine mean for green energy stocks? Retrieved from Defiance ETFs website: https://www.defianceetfs.com/what-does-russias-invasion-of-ukraine-mean-for-green-energy-stocks/

Dezhbakhsh, H., & Demirguc-Kunt, A. (1990). On the Presence of Speculative Bubbles in Stock Prices. *The Journal of Financial and Quantitative Analysis*, *25*(1), 101–112. https://doi.org/10.2307/2330890

Diba, B. T., & Grossman, H. I. (1987). On the Inception of Rational Bubbles. *The Quarterly Journal of Economics*, *102*(3), 697–700. https://doi.org/10.2307/1884225

Diba, B. T., & Grossman, H. I. (1988). Explosive Rational Bubbles in Stock Prices? *The American Economic Review*, *78*(3), 520–530. Retrieved from https://www.jstor.org/stable/1809149

Dickey, D. A., & Fuller, W. A. (1981). Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. *Econometrica*, *49*(4), 1057–1072. https://doi.org/10.2307/1912517

Driffill, J., & Sola, M. (1998). Intrinsic bubbles and regime-switching. *Journal of Monetary Economics*, *42*(2), 357–373. https://doi.org/10.1016/s0304-3932(98)00021-x

Euronext. (2019). Low Carbon 100 Europe® PAB Index. In *Euronext*. Retrieved from https://live.euronext.com/en/product/indices/QS0011131735-XAMS/market-information

Euronext. (2022). *Oslo Børs Benchmark GI Index*. Euronext. Retrieved from Euronext website: https://live.euronext.com/nb/product/indices/NO0007035327-XOSL/market-information

European Commission. (2021). *FAQ: What is the EU Taxonomy and how will it work in practice?* Retrieved from https://finance.ec.europa.eu/system/files/2021-04/sustainable-finance-taxonomy-faq_en.pdf

European Commission. (2023). Corporate Sustainability Reporting. Retrieved from finance.ec.europa.eu website: https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

European Commission. (n.d.). EU taxonomy for sustainable activities. Retrieved from finance.ec.europa.eu website: https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

Evans, G. W. (1991). Pitfalls in Testing for Explosive Bubbles in Asset Prices. *The American Economic Review*, *81*(4), 922–930. Retrieved from https://www.jstor.org/stable/2006651

Eyraud, L., Clements, B., & Wane, A. (2013). Green investment: Trends and determinants. *Energy Policy*, *60*, 852–865. https://doi.org/10.1016/j.enpol.2013.04.039

Fama, E. F. (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *The Journal of Finance*, *25*(2), 383–417. https://doi.org/10.2307/2325486

Fraser, S. A., Ro, H. J. M., Solheimsnes, P. A., Sagmoen, I., & Hopland, S. (2021, November 23). Coronastøtten: Bedriftene tok ut mer utbytte i kriseåret enn året før. Retrieved from e24.no website: https://e24.no/naeringsliv/i/0Grelg/coronastoetten-bedriftene-tok-ut-mer-utbytte-i-kriseaaret-enn-aaret-foer

Froot, K. A., & Obstfeld, M. (1991). Intrinsic Bubbles: The Case of Stock Prices. *The American Economic Review*, *81*(5), 1189–1214. Retrieved from https://www.jstor.org/stable/2006913

Garber, P. M. (1990). Famous First Bubbles. *Journal of Economic Perspectives*, *4*(2), 35–54. Retrieved from https://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.4.2.35

Gjerde, Ø., & Sættem, F. (1999). Causal relations among stock returns and macroeconomic variables in a small, open economy. *Journal of International Financial Markets, Institutions and Money*, *9*(1), 61–74. https://doi.org/10.1016/S1042-4431(98)00036-5.

Gordon, R. J. (2016). *The rise and fall of American growth : the U.S. standard of living since the Civil War*. Princeton University Press.

Gürkaynak, R. S. (2005). Econometric Tests of Asset Price Bubbles: Taking Stock. *Finance and Economics Discussion Series Divisions of Research & Statistics and Monetary Affairs Federal Reserve Board, Washington, D.C.* https://doi.org/10.2139/ssrn.658244

Hammernes, L. M. (2021, February 23). Mener myndighetenes krav gir grønn boble. Retrieved from Finansavisen website: https://www.finansavisen.no/nyheter/finans/2021/02/23/7631462/mener-myndighetenes-krav-gir-gronn-boble

Harrison, J. M., & Kreps, D. M. (1978). Speculative Investor Behavior in a Stock Market with Heterogeneous Expectations. *The Quarterly Journal of Economics*, *92*(2), 323–336. https://doi.org/10.2307/1884166

Hayes, A. (2019, June 25). Dotcom Bubble. Retrieved from Investopedia website: https://www.investopedia.com/terms/d/dotcom-bubble.asp

Hayes, A. (2022, November 22). Tulipmania: About the Dutch Tulip Bulb Market Bubble. Retrieved from Investopedia website: https://www.investopedia.com/terms/d/dutch_tulip_bulb_market_bubble.asp

Höhne, N., Khosla, S., Fekete, H., & Gilbert, A. (2012). *Mapping of Green Finance Delivered by IDFC Members in 2011*. Ecofys. Retrieved from Ecofys website: https://www.idfc.org/wp-content/uploads/2019/03/idfc_green_finance_mapping_report_2012_06-14-12.pdf

Høvik, K. Ø. (2020, February 21). South Sea Bubble. Retrieved from Store norske leksikon website: https://snl.no/South_Sea_Bubble

Investopedia. (2022, February 23). What Is Environmental, Social, and Governance (ESG) Investing? Retrieved from Investopedia website: https://www.investopedia.com/terms/e/environmental-social-and-governance-esg-criteria.asp

Jang, W.-Y. (2007). Media Exposure or Media Hype: Evidence from Initial Public Offering Stocks in Taiwan. *Journal of Media Economics*, *20*(4), 259–287. https://doi.org/10.1080/08997760701668151

Kenton, W. (2023, March 16). Stock Market Crash of 1929: Definition, Causes, Effects. Retrieved from Investopedia website: https://www.investopedia.com/terms/s/stock-market-crash-1929.asp

Klose, J., & Tillmann, P. (2022). *Stock Market Response to Covid-19, Containment Measures and Stabilization Policies - The Case of Europe*. Retrieved from https://www.uni-marburg.de/en/fb02/research-groups/economics/macroeconomics/research/magks-joint-discussion-papers-in-economics/papers/2022-papers/08-2022_klose.pdf

Kramer, L. (2021, December 31). What caused the Stock Market Crash of 1929? Retrieved from Investopedia website: https://www.investopedia.com/ask/answers/042115/what-caused-stock-market-crash-1929-preceded-great-depression.asp

Kummernes, A., & Kosmo, S. K. (2021). Hvordan har covid-19 pandemien påvirket utbyttebetalingene i norske selskaper? In *Nord*. Retrieved from https://nordopen.nord.no/nord-xmlui/bitstream/handle/11250/3020106/KummernesogKosmo.pdf?sequence=1

LeRoy, S. F., & Porter, R. D. (1981). The Present-Value Relation: Tests Based on Implied Variance Bounds. *Econometrica*, *49*(3), 555–574. https://doi.org/10.2307/1911512

Lilleby, J. (2018, June 18). Kristiania-krakket: Da boligboblen sprakk. Retrieved from e24.no website: https://e24.no/norsk-oekonomi/i/Adb91n/kristiania-krakket-da-boligboblen-sprakk

Liu, Z., Han, D., & Wang, S. (2016). Testing Bubbles: Exuberance and collapse in the Shanghai A-share stock market. *China's New Sources of Economic Growth*, *1*. https://doi.org/10.22459/cnseg.07.2016.11

Lorch-Falch, S., & Sættem, J. B. (2020, November 5). NHH-professor frykter grønn børsboble: – Kan skje en kraftig korreksjon. Retrieved from NRK website: https://www.nrk.no/norge/nhh-professor-frykter-gronn-borsboble_-_-kan-skje-en-kraftig-korreksjon-1.15225738

Lucas Jr., R. E. (1978). Asset Prices in an Exchange Economy. *Econometrica*, *46*(6), 1429–1445. https://doi.org/10.2307/1913837

Mazur, M., Dang, M., & Vega, M. (2020). COVID-19 and the March 2020 Stock Market Crash. Evidence from S&P1500. *Finance Research Letters*, *38*. https://doi.org/10.1016/j.frl.2020.101690

Minsky, H. P. (2008). *Stabilizing an unstable economy*. New York: Mcgraw-Hill Professional.

Morgan Stanley. (2017, October 11). Behind the Green Bond Boom. Retrieved from Morgan Stanley website: https://www.morganstanley.com/ideas/green-bond-boom

Nilsen, J. B., & Lang-Ree, A. (2021, August 9). Nordmenn strømmer til grønne aksjer: – Nesten ubegrenset hva vi kan få inn. Retrieved from e24.no website: https://e24.no/boers-og-finans/i/rWQ8qR/nordmenn-stroemmer-til-groenne-aksjer-nesten-ubegrenset-hva-vi-kan-faa-inn

Norges Bank. (n.d.). Kristianiakrakket. Retrieved from www.norges-bank.no website: https://www.norges-bank.no/tema/Om-Norges-Bank/historien/Pengepolitikk-finansiell-stabilitet-og-kapitalforvaltning/Finansiell-stabilitet/1899-krisen/

Notaker, H. (2018, September 17). Finanskrisen i USA 2008-2009. Retrieved from Store norske leksikon website: https://snl.no/Finanskrisen_i_USA_2008-2009

Olivier, J. (2001). Growth-Enhancing Bubbles. *International Economic Review*, *41*(1), 133–152. https://doi.org/10.1111/1468-2354.00058

Parr, O. S. (2020, January 19). Ekspertenes beste sparetips. Retrieved from www.finansavisen.no website: https://www.finansavisen.no/nyheter/personlig-okonomi/2020/01/19/7489568/ekspertenes-beste-sparetips-sverger-til-indeksfond

Pastor, L., Stambaugh, R. F., & Taylor, L. A. (2022, August 24). Should investors expect to earn high returns on sustainable investments? Retrieved from PRI website: https://www.unpri.org/pri-blog/should-investors-expect-to-earn-high-returns-on-sustainable-investments/10339.article

Phillips, P. C. B., Wu, Y., & Yu, J. (2011). EXPLOSIVE BEHAVIOR IN THE 1990s NASDAQ: WHEN DID EXUBERANCE ESCALATE ASSET VALUES? *International Economic Review*, *52*(1), 201–226. Retrieved from https://www.jstor.org/stable/23016628?seq=1&cid=pdf-reference#references_tab_contents

Phillips, P., Shi, S.-P., & Yu, J. (2015). TESTING FOR MULTIPLE BUBBLES: HISTORICAL EPISODES OF EXUBERANCE AND COLLAPSE IN THE S&P 500 TESTING FOR MULTIPLE BUBBLES: HISTORICAL EPISODES OF EXUBERANCE AND COLLAPSE IN THE S&P 500 *. *INTERNATIONAL ECONOMIC REVIEW*, *56*(4). Retrieved from http://korora.econ.yale.edu/phillips/pubs/art/p1498.pdf

Præsterud, P. S. (2021, June 8). Hver tiende krone på børsen er "grønn." Retrieved from www.finansavisen.no website: https://www.finansavisen.no/nyheter/energi/2021/06/08/7686120/hver-tiende-krone-pa-borsen-er-gronn

Shen, P. (2000). The P/E Ratio and Stock Market Performance. *Economic Review*, *85*, 23–36. Retrieved from https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=99cdd22a2ea2b0e7215efb5bdee3eab690683842

Shiller, R. J. (1981). Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends? *The American Economic Review*, *71*(3), 421–436. Retrieved from https://www.jstor.org/stable/1802789

Shiller, R. J. (2000). Irrational Exuberance. *Philosophy and Public Policy Quarterly*, *20*(1), 18–23. https://doi.org/10.13021/G8pppq.202000.333

Siegel, J. J. (2003). What Is an Asset Price Bubble? An Operational Definition. *European Financial Management*, *9*(1), 11–24. https://doi.org/10.1111/1468-036x.00206

Singh, M. (2022, March 19). The 2007-08 Financial Crisis in Review. Retrieved from Investopedia website: https://www.investopedia.com/articles/economics/09/financial-crisis-review.asp

Sornette, D., & Cauwels, P. (2014). Financial Bubbles: Mechanisms and Diagnostics. *ArXiv Preprint ArXiv:1404.2140*. https://doi.org/10.2139/ssrn.2423790

Sun, M., & Zhang, C. (2022). Comprehensive analysis of global stock market reactions to the Russia-Ukraine war. *Applied Economics Letters*, 1–8. https://doi.org/10.1080/13504851.2022.2103077

The Economist. (2022, July 23). ESG investing. Retrieved from The Economist website: https://www.economist.com/special-report/2022-07-23

Tirole, J. (1982). On the Possibility of Speculation under Rational Expectations. *Econometrica*, *50*(5), 1163–1181. https://doi.org/10.2307/1911868

Vasilopoulos, K., Pavlidis, E., & Martínez-García, E. (2020). exuber: Recursive Right-Tailed Unit Root Testing with R. *Federal Reserve Bank of Dallas, Globalization Institute Working Papers*, *383*. https://doi.org/10.24149/gwp383

West, K. D. (1987). A Specification Test for Speculative Bubbles. *The Quarterly Journal of Economics*, *102*(3), 553–580. https://doi.org/10.2307/1884217

World Bank. (2021, December 8). Climate Explainer: Green Bonds. Retrieved from World Bank website: https://www.worldbank.org/en/news/feature/2021/12/08/what-you-need-to-know-about-ifc-s-green-bonds

Worldfavor. (2023, February). SFDR: What are the PAI indicators? Retrieved from blog.worldfavor.com website: https://blog.worldfavor.com/sfdr-what-are-the-pai-indicators

Wu, Y. (1997). Rational Bubbles in the Stock Market: Accounting for the U.S. Stock-Price Volatility. *Economic Inquiry*, *35*(2), 309–319. https://doi.org/10.1111/j.1465-7295.1997.tb01912.x

Ying, Q., Yousaf, T., Ain, Q. ul, Akhtar, Y., & Rasheed, M. S. (2019). Stock Investment and Excess Returns: a Critical Review in the Light of the Efficient Market Hypothesis. *Journal of Risk and Financial Management*, *12*(2), 97. https://doi.org/10.3390/jrfm12020097

Appendix

Company	Sector	Weigth %	Company	Sector	Weigth %
EQUINOR	Energy	23.10	ATEA	Technology	0.53
DNB BANK	Financials	10.69	AF GRUPPEN	Industrials	0.45
NORSK HYDRO	Basic Materials	5.83	HAFNIA LIMITED	Industrials	0.45
AKER BP	Energy	5.68	GOLDEN OCEAN GROUP	Industrials	0.40
MOWI	Consumer Staples	4.34	CRAYON GROUP HOLD	Technology	0.39
YARA INTERNATIONAL	Basic Materials	4.21	BW LPG	Industrials	0.38
TELENOR	Telecommunications	3.41	DNO	Energy	0.37
ORKLA	Consumer Staples	3.15	STOLT-NIELSEN	Industrials	0.37
STOREBRAND	Financials	2.38	KAHOOT!	Technology	0.37
TOMRA SYSTEMS	Industrials	2.32	BONHEUR	Industrials	0.36
GJENSIDIGE FORSIKR	Financials	2.27	ENTRA	Real Estate	0.34
KONGSBERG GRUPPEN	Industrials	2.18	MPC CONTAINER SHIP	Industrials	0.32
BAKKAFROST	Consumer Staples	1.83	KITRON	Industrials	0.31
NORDIC SEMICONDUC	Technology	1.68	NORWEGIAN AIR SHUT	Consumer Discretionary	0.30
SUBSEA 7	Energy	1.50	BOUVET	Technology	0.29
SALMAR	Consumer Staples	1.34	NYKODE THERAPEUTIC	Health Care	0.29
NEL	Energy	1.28	REC SILICON	Basic Materials	0.23
SPAREBANK 1 SR-BK	Financials	1.28	ARCTICZYMES TECHNO	Health Care	0.21
ADEVINTA	Consumer Discretionary	1.13	HEXAGON COMPOSITES	Industrials	0.21
AUTOSTORE HOLDINGS	Industrials	1.09	ARENDALS FOSSEKOMP	Financials	0.21
SCHIBSTED SER. B	Technology	1.03	CADELER	Industrials	0.19
AKER	Financials	0.95	AKER HORIZONS	Utilities	0.18
TGS	Energy	0.91	MULTICONSULT	Industrials	0.16
LEROeY SEAFOOD GP	Consumer Staples	0.87	KID	Consumer Discretionary	0.16
BORREGAARD	Basic Materials	0.85	PHOTOCURE	Health Care	0.15
SCHIBSTED SER. A	Technology	0.80	ABG SUNDAL COLLIER	Financials	0.14
VAaR ENERGI	Energy	0.74	ULTIMOVACS	Health Care	0.13
EUROPRIS	Consumer Discretionary	0.68	KONGSBERG AUTOMOT	Consumer Discretionary	0.12
FRONTLINE	Industrials	0.61	CLOUDBERRY CLEAN	Utilities	0.11
WALLENIUS WILHELMS	Industrials	0.61	B2HOLDING	Financials	0.10
ELKEM	Basic Materials	0.60	ELMERA GROUP	Utilities	0.10
FLEX LNG	Industrials	0.56	CARASENT	Health Care	0.05
SCATEC	Energy	0.55	SATS	Consumer Discretionary	0.04
AKER SOLUTIONS	Energy	0.54	BERGENBIO	Health Care	0.03
VEIDEKKE	Industrials	0.54			

Table A1: Companies included in the OSEBX as of 31.12.2022

Company	Sector	Weigth %	Company	Sector	Weigth %
SAP	Technology	6.42	LOGITECH INTL SA	Technology	0.44
LVMH	Consumer Discretionary	6.17	SEGRO	Real Estate	0.44
NESTLE SA	Consumer Staples	6.00	SVENSKA HANDELSBNKEN	Financials	0.43
NOVO NORDISK A/S	Health Care	5.35	HALEON	Health Care	0.43
NOVARTIS	Health Care	4.81	PHILIPS KON	Health Care	0.42
ASTRAZENECA	Health Care	4.30	BT GROUP PLC	Telecommunications	0.41
SCHNEIDER ELECTRIC	Industrials	2.97	DSM KON	Consumer Staples	0.39
RECKITT BENCKISER GR	Consumer Staples	2.94	LEGAL AND GENERAL	Financials	0.39
SANOFI	Health Care	2.69	SMURFIT KAPPA GP	Industrials	0.36
INFINEON TECHOLOGIE	Technology	2.64	BURBERRY GROUP	Consumer Discretionary	0.36
L'OREAL	Consumer Discretionary	2.48	CARLSBERG A/S CL. B	Consumer Staples	0.35
BANCO SANTANDER CENT	Financials	2.20	EPIROC AB	Industrials	0.35
CIE FIN RICHEMONT	Consumer Discretionary	1.98	ALSTOM	Industrials	0.35
DIAGEO	Consumer Staples	1.79	ZALANDO SE	Consumer Discretionary	0.33
DEUTSCHE POST AG	Industrials	1.67	MONDI PLC	Industrials	0.31
GSK PLC	Health Care	1.52	INTERCONTINENTAL HTL	Consumer Discretionary	0.31
ZURICH INSURANCE AG	Financials	1.51	KINGSPAN GROUP PLC	Industrials	0.30
AXA	Financials	1.41	FRESENIUS SE & CO	Health Care	0.29
HERMES INTL	Consumer Discretionary	1.40	ALFA LAVAL	Industrials	0.29
NORDEA BANK ABP	Financials	1.38	HALMA PLC	Industrials	0.29
CAPGEMINI	Technology	1.32	ST JAMES'S PLACE	Financials	0.29
DSV A/S	Industrials	1.19	SYMRISE AG	Basic Materials	0.29
MUNICH RE	Financials	1.19	CONTINENTAL AG	Consumer Discretionary	0.28
INDITEX	Consumer Discretionary	1.11	UNIBAIL-RODAMCO-WE	Real Estate	0.28
SIKA AG	Industrials	1.01	TERNA RETE ELETTRICA	Utilities	0.28
ESSITY CLASS B	Consumer Staples	1.01	EDP RENOVAVEIS	Utilities	0.27
ATLAS COPCO A	Industrials	0.99	GETLINK SE	Industrials	0.26
VODFONE GROUP	Telecommunications	0.97	KNORR-BREMSE AG	Industrials	0.26
PUBLICIS GROUPE SA	Consumer Discretionary	0.96	NORDEX SE	Energy	0.26
PRUDENTIAL PLC	Financials	0.90	SMITHS GROUP PLC	Industrials	0.26
NOKIA	Telecommunications	0.85	SEVERN TRENT	Utilities	0.26
LONDON STOCK EXCHANG	Financials	0.85	ROCKWOOL B	Industrials	0.25
SOCIETE GENERALE	Financials	0.81	STORA ENSO OYJ	Basic Materials	0.25
ASM INTERNATIONAL	Technology	0.79	RED ELECTRICA CORP	Utilities	0.25
DANONE	Consumer Staples	0.79	NEOEN	Utilities	0.24
WPP	Consumer Discretionary	0.79	EIFFAGE	Industrials	0.24
LEGRAND	Industrials	0.78	ELIA GROUP	Utilities	0.24
SWISS RE AG	Financials	0.76	SOLARIA ENERGIA	Utilities	0.23
UMG	Consumer Discretionary	0.71	NEL	Energy	0.23
ORANGE	Telecommunications	0.68	ENCAVIS	Utilities	0.23
ASSA ABLOY AB-B	Industrials	0.68	CRODA INTERNATIONAL	Basic Materials	0.22
BEIERSDORF AG	Consumer Staples	0.66	WHITBREAD	Consumer Discretionary	0.21
KBC	Financials	0.65	INTL CONS AIRLINES	Consumer Discretionary	0.21
VESTAS WIND SYSTEMS	Energy	0.65	NOVOZYMES	Health Care	0.20
MICHELIN	Consumer Discretionary	0.60	SVENSKA CELLULOSA B	Basic Materials	0.19
CELLNEX TELECOM	Telecommunications	0.59	BARRATT DEVELOPMENTS	Consumer Discretionary	0.15
GEBERIT AG REG.	Industrials	0.58	UMICORE	Basic Materials	0.14
DNB BANK	Financials	0.54	SIEMENS ENERGY AG	Energy	0.14
GIVAUDAN SA	Basic Materials	0.50	SCATEC	Energy	0.14
CNH INDUSTRIAL NV	Industrials	0.45	EUROAPI	Health Care	0.01

Table A2: Companies included in the Low Carbon 100 Europe as of 31.03.2023