Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Economics and Management
Department of Economics

Maria Olsen

Do we have a green bubble in the Norwegian stock market?

Master's thesis in Financial Economics
Supervisor: Colin Green
June 2021

NTNU
Norwegian University of
Science and Technology

Maria Olsen

Do we have a green bubble in the Norwegian stock market?

Master's thesis in Financial Economics
Supervisor: Colin Green
June 2021

Norwegian University of Science and Technology
Faculty of Economics and Management
Department of Economics

NTNU
Kunnskap for en bedre verden

Preface

This Master's thesis was written as the final part of NTNU's Master of Science program in Financial Economics during the spring semester of 2021. My interest in green finance started some years ago with my part time job in AksjeNorge, and I have since then wanted to write about this theme. After reading countless articles, both in international and Norwegian newspapers, about the "green bubble" I decided on my research question. Formulating my own research question has been challenging but also very motivating.

I would like to thank my supervisor, Professor Colin Green, for helpful guidance and valuable feedback during the work with this thesis.

Further I want to thank Mikael for the support and encouragement during this period.

Trondheim, June 2021

Abstract

In recent years green investments have gained particular interest from politicians and participants in the stock market. Green stocks are new to the market, and as many of the companies still do not have positive cash flows, the prices have significantly increased, and the media is filled with speculations of a green bubble. This master's thesis investigates if we have a green bubble in the Norwegian stock market. Using data both from the Oslo Børs Benchmark Index (OSEBX) and 21 green companies listed on Oslo Børs and Euronext Growth, the results are ambiguous. The data is tested for unit roots against episodes of exuberance using the recursive Augmented Dickey-Fuller (ADF) tests first published by Philips et al. (2011). The generalized supremum ADF finds episodes of exuberance in both the OSEBX and green stocks. However, there is no indication of a bubble in the Norwegian market and OSEBX today. However, in green stocks, there are some tendencies which might indicate a bubble forming. In addition, the thesis also concludes that there is a foundation in today's green stock market, according to Minsky (1983), that a bubble can develop.

Keywords: Green finance, bubble, exuberance, GSADF

Sammendrag

De siste årene har grønne investeringer fått spesielt stor interesse fra politikere og deltakere i aksjemarkedet. Grønne aksjer er nye i markedet, og mange av disse selskapene har enda ikke en positiv kontantstrøm, Prisene har økt signifikant og mediebildet er fylt med spekulasjoner om en grønn boble. Denne masteroppgaven undersøker om vi har en grønn boble i det norske aksjemarkedet. Ved å både bruke data fra Hovedindeksen (OSEBX), og 21 grønneselskaper notert på Oslo Børs og Euronext Growth, får vi tvetydige resultater. Datasettet er testet for unit roots mot episoder av overflod (exuberance) ved å benytte tilbakevendende Augmented Dickey-Fuller (ADF) tester, først publisert av Philips et al. (2011). Generalized supremum ADF (GSADF) finner episoder av overflod i både OSEBX og grønne aksjer. Det er derimot ingen indikasjon på en boble i det norske markedet og OSEBX i dag. I grønne aksjer er det tendenser som kan indikere at det er i ferd med å danne seg en boble. I tillegg konkluderer også oppgaven med at dagens marked kan være i starten på en boble i henhold til Minsky (1983).

Contents

List of Figures

List of Tables

1 Introduction

"Even if we were unwise enough to wish to prick an asset bubble, we are told it is impossible to see the bubble while it is in its inflationary phase." (George Cooper, 2008, p. 3).

In the 1970s, we discovered an expanding hole in the ozone layer and the concern about the effect of human behavior on our planet spread. The emission of greenhouse gases and other pollutants associated with fossil fuels is undesirable, and replacing them with cleaner, more sustainable fuels is a reasonable goal. As the focus has grown among consumers and investors, the pressure on companies to meet these expectations has grown. Going through any company webpage today, in most cases, you will find something about sustainability. Either companies that solve selected environmental problems or work on more environmentally friendly ways to operate.

The Norwegian stock market has been on a solid upward trend since the Global Finance Crisis of 2007-2009. New investors are jumping on the investing trend in Norway in the last few years, and companies are rushing to the stock exchange to get listed. Many of these companies are green companies that are taking advantage of an increasing willingness to invest in more sustainable solutions. At the same time, the media is full of professors and investment professionals warning the public of a green bubble.

Despite the increasing demand for green investments and sustainable company structures, there is still a lack of a uniform definition of what a "green stock" is. Often different institutions have their individual definition, but the increasing political interest in green finance has led to proposals that hopefully will make it easier for market participants to differentiate a green investment from others.

The literature on asset bubbles is extensive, but there is yet to be a standard economic model to detect exuberance and bubbles in the market. An influential model in the research on asset bubbles in the last decade has been the recursive ADF tests by Philips et al. (2011 & 2015). The supremum augmented Dickey-Fuller (SADF) and the generalized SADF (GSADF) test for unit roots against episodes of exuberance. In addition, by employing the backward SADF (BSADF), we can data stamp the episodes of exuberance. Periods of exuberance or high volatility in the market can be indicators of a bubble.

However, to develop into a bubble, the price needs to develop over a long period and eventually burst.

Experience can be a powerful teacher, and in addition to the unit root tests, history from previous bubbles and Minsky's (1986) model is discussed. All bubbles develop in different ways and are not perfectly comparable, but all follow the same five stages according to the Minsky model. Knowing the main points from the history of bubbles throughout the last centuries will also give a basis for comparison for today's market.

This thesis uses data from the OSEBX and 21 individual green stocks to address the following research question:

Do we have a green bubble in the Norwegian market?

In answering this question, I employ the SADF, GSADF, and BSADF tests and find episodes of exuberance in both the OSEBX and green stocks. However, there are no indications of a bubble in the OSEBX, but there might be tendencies of a bubble in the green stock after a significant increase in green stock prices the last year. Furthermore, the first steps the Minsky model is in place. If this will develop into a bubble is yet to be known.

The format of this thesis is organized as follows. In Chapter 2, I will go through the background for this thesis, including today's market, standard and political interest, and a short recap on the history of financial bubbles. Chapter 3 reviews previous literature of interest about asset bubbles. Chapter 4 cover the methodology based on Philips et al. and the present datasets. In Chapter 5, the analysis and results from the recursive ADF tests are presented together with the PE ratios of the green stocks. Chapter 6 discusses the results from previous chapters and compares today's market to different historical events and the Minsky model. Chapter 7 concludes the paper.

2 Background

This chapter outlines the development of the green asset market and presents definitions of and standards for green companies. I also present recent media coverage. Finally, I discuss the history of asset bubbles with examples.

ESG is currently one of the key topics in financial markets and stands for environmental, social, and governance. Even though ESG matters are not new to the investment process, they are becoming more important. This is because society, and especially voters, regulators, and investors, increasingly value sustainability. From 2004 to 2013, climate-specific investment, namely clean-energy asset finance, grew at a rate of 32 % per year (World Economic Forum, 2013). Along with public funding, individuals must drive climate action in their roles as consumers, voters, leaders, and activists. Market participants who invest in green stocks can do this purely for financial reasons and significantly impact a greener and more sustainable future. With increasing pressure from governments on long-term green investments, the incentives of investing in green stocks increase. However, this should not be at any cost.

Despite the increasing demand for green investments, there is a lack of definition of what constitutes a green company. Going forward in this thesis, a definition will be helpful. Most companies that use a green process or technology can be defined as green stocks; hence, this leads to a broad definition and will include many IT companies that do not necessarily deliver products for green businesses. For later reference, a stricter definition is used when discussing green stocks: A green company is a company that delivers green products or services.

Due to the Covid-19 pandemic, 2020 was a turbulent year in stock markets all over the world. Despite this, there were 58 new listings on Euronext Growth Oslo and the main market on Oslo Stock Exchange in 2020. Oslo Stock Exchange has not had more IPOs during a year since before the Finance Crisis in 2008 (Nilsen, 2021). Many of these new stocks are green. Figure 2.1 shows IPOs from 2016 to April 2021, which shows the increasing IPO entry. Furthermore, investing in the stock market has become more popular and known during the last years. In Norway, the number of individuals who directly own stocks on Oslo Børs is 514.000 per the first quarter of 2021. Where 38.000

of them bought their first stock in 2021 (AksjeNorge, 2021), this is a growth of 47 % over the last six years. This means more investors put pressure on the companies going forward but also leads to more investors with little experience in the market.

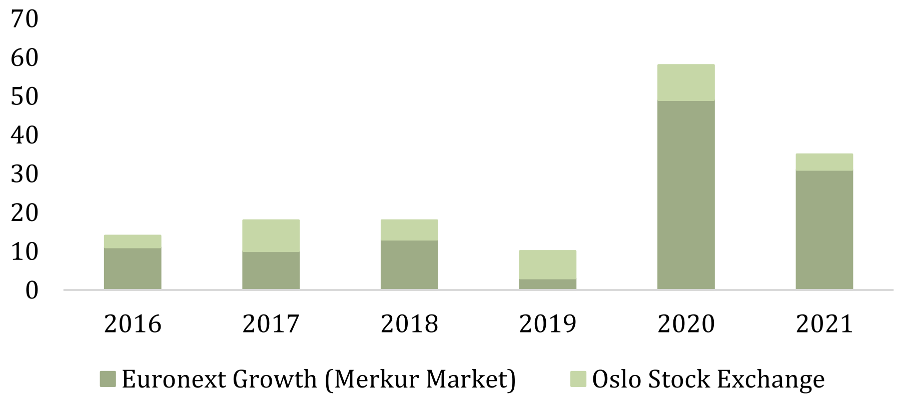

Figure 2.1 Sum IPOs Oslo Børs 2016- April 2021

In the last year, the media has been filled with articles about green investment, sustainability, and a possible green bubble. Smith (2020) writes about how the numbers suggest that there is a green investing "mega trend", and it is here to stay. The rise in green investments for individuals are backed by governments increasing investments and subsidies for green industries. Alternative Investment Management Association (AIMA) and KPMG conducted a survey where 84 % of 135 institutional investors, hedge funds, and long-only managers across 13 countries reported an increased interest in ESG-orientated funds and strategies.

Globally, and in Norway, many have speculated if we have a bubble in green stocks, and many professors and experienced investment professionals have drawn links between the increasing popularity and prices in green stock and the tech stocks during the Dot-Com bubble in the late 1990s. The stocks are high valued and the price to expected earnings have not been this high since the Dot-Com bubble (Brown, 2021). We also have the highest spike in initial public offerings (IPOs) in twenty years, independent of whether the companies are profitable or not profitable (Phillips, 2020). Many new green companies were listed on Euronext Growth Oslo during the fall, where several of them tripled their value in just a few weeks. Professor at NHH, Ola Grytten, believes that investors instinctively have great faith in green companies when the government is announcing the green shift going forward. The prices we have seen could experience a severe correction in the future (Lorch-Falch & Sættem, 2020).

2.1 Standards and political interest

For a long time, there have not been standard criteria or requirements for what makes a stock "green", and most companies and brokers have made up their own criteria. There are many ways to define a green company. There is also a concern with greenwashing[1]due to the increasing pressure on companies to demonstrate their environmental credentials. Despite many years of growing popularity, there is still no good framework for deciding if a company is green. Today more and more countries have created official definitions of sustainable finance and more extensive classification systems, referred to as sustainable finance taxonomies (OECD, 2020). These aim to provide investors with information and assurance, as well as improve general market clarity.

The European Union is now developing its own taxonomy. The EU Taxonomy is a tool to help investors, companies, issuers, and project promoters navigate the transition to a low-carbon, resilient and resource-efficient economy (EU, 2020). In a consultation from the Ministry of Finance in Norway they have suggested that the disclosure requirements and reporting obligations that follows from the regulations are enforced in a new law on information on sustainability (Finansdepartementet, 2020). This will change the way companies today communicate and report sustainable measures and make it even easier to see the "good" from the "bad".

The new EU taxonomy primarily covers financial markets, but sustainability has also been of strong political interest over the last decade. In 2015, 196 Parties in the United Nations adopted the Paris Agreement. The Paris Agreement is a legally binding international treaty on climate change, where the goal is to limit global warming to well below 2 degrees Celsius, compared to pre-industrial levels (United Nations, 2015). By 2030, zero-carbon solutions could be competitive in sectors representing over 70 % of global emissions. In the same year, the 17 Sustainable Development Goals (SDGs) was adopted at the UN Sustainable Development Summit. The Norwegian government has also implemented

1 Greenwashing: to make people believe that your company is doing more to protect the environment that it really is (Cambridge Dictionary, https://dictionary.cambridge.org/dictionary/english/greenwash)

these goals, and the work is being updated frequently on their website. Norway's Prime Minister, Erna Solberg, is also Co-chair of the Sustainable Development Goals Advocacy Group together with the President of Ghana, Nana Addo Dankwa Akufo-Addo (Regjeringen, 2020).

2.2 History of Financial Bubbles

Throughout history, there have been many bubbles and episodes of exuberance. What is a bubble bursting or an episode of exuberance in the market has been discussed by numerous researchers over the years. We do not have a standard framework to detect a bubble developing in the market today. However, we can learn a lot by looking at the history and development of previous bubbles. They will help to categorize what we mean by a bubble and show some of the key features present in times of irrational exuberance and the building, and bursting, of a bubble. In this section, I will give a brief presentation of the most known bubbles in history.

2.2.1 The Tulip Mania

The tulip mania originated in the Netherlands in the 1630s. Tulips differed from other flowers with their bright colors and their resilience to different weather. This made the tulip coveted and fashionable, and both demand and production increased rapidly. From being a luxury good, by the 1634, people from all ranks of society were trading tulips (Porras, 2016). The spot market where tulips were traded took place between June and September, and for the rest of the year tulip traders signed notarized contracts to purchase bulbs in the end of the season.

As the popularity of tulips grow, by 1636, tulips were the fourth leading export good from the Netherlands. People began speculating in the tulip market and tulips were auctioned for tremendous prices. In 1637, 70 tulips were auctioned for 53 000 guilders, that would compare to the annual salary of 350 skilled craftsmen. This trade made the underlying nervousness in the market increase, and only a month later tulip traders were no longer able to sell to buyers willing to pay the prices that they had just done a short period of time before. The demand for tulips collapsed, and prices plummeted. Traders were left holding contracts with prices ten times greater than in the open market.

2.2.2 South Sea Bubble

The term “bubble” stems originally from the South Sea Company’s inflated stock prices, and the bubble in 1720 (Porras, 2016). Along with the war of the Spanish Succession, a lot of British government obligations were issued, and the administration needed to remove the interest of the obligations to ease its financial pressure. The South Sea Company, that was given a trade monopoly within Spain’s South American provinces, wanted to hedge its risk by purchasing the obligations with its overvalued stocks and gain a steady income. This provided an incentive for people to purchase the stock of the South Sea Company and the stock price went from 128 pounds in January 1720, to 1000 pounds in the beginning of August the same year (Karimov, 2017). The already overpriced stock then decreased down to around 100 pounds during the next month, and many investors lost huge amounts of money. One of the investors was Sir Isaac Newton who famously declared that he “could calculate the motions of the heavenly stars, but not the madness of people” (Chancellor, 2019).

2.2.3 The Great depression of 1929

After World War I (1914-1918), industrialization and, the development of new technologies gave the people of the US expectations of a time of certainty, good faith, and welfare. The majority of financial experts believed that shares were a certain investment in the economy in the early 1920s, and the Dow Jones Industrial Average expanded. In this period only 10-20 % of the stock cost were paid by the purchaser and the rest of the expense were paid by the broker (Karimov, 2017). This led to many people investing, and speculators began buying stocks on margin, that is borrowing money to purchase stocks. Because a great part of the risk was laying on the broker, they would most likely issue a margin-call if the stock would decline more than the loan amount.

These speculations made the Dow Jones index increase from 60 to 400 between 1921 and 1929 (Karimov, 2017). As the market went up more individuals wanted to be a part of this, and numerous people sold their homes so they could put their savings into the stock market. During the summer of 1929, the stock market saw some of its highest peaks, and during the last month speculators started selling. Panic spread and the beginning of the Wall Street crash occurred on October 24, 1929, known as Black Thursday. After the crash, the Dow Jones continued decreasing and by July 8, 1932, the index had lost 90 % of its value since its highest on September 3, 1929 (Richardson, Komai, Gou & Park, 2013). The

American economy spiraled into a depression that would plague the nation for a decade, and the Dow Jones index would not return to its pre-crash value until November 1954.

2.2.4 The Dot-Com bubble

"Experience can be a powerful teacher. The rise and fall of internet stocks, which created and then destroyed $8 trillion of shareholder wealth, has led a new generation of economists to acknowledge that bubbles can occur" (Krueger, 2005)

The Dot-Com bubble, also known as the Tech Bubble, started in the early 1990s before it burst between 2001 and 2002. The Dot-Com bubble was due to a rapid boost in technology stocks in the US in the late 1990s. The technology-dominated Nasdaq index went from under 1000 to more than 5000 during the time from 1995 to 2000. It would take 15 years for the Nasdaq index to regain its peak from this period, which it finally did on April 24, 2015 (Hayes, 2019). See Figure A.1.

After the Clinton-Gore victory in 1992, the US government began redirecting funds towards the "Information Superhighway" (Goodnight & Green, 2010). In the new plan, a minimum of $30 billion over four years was put into research into different tech areas such as robotics, smart roads, biotechnology, machine tools and national computer networks. The aim of this was to have "research discoveries and applications that will flood the economy with innovative goods and services, lifting the general level of prosperity and strengthening American industry for the international trade wars of the 1990s and beyond" (Broad, 1992). This, together with other acts the private enthusiasm increased, on the way to build the digital future.

Many stocks were traded solely on future expectations of value. Some start-ups spent as much as 90 % of their budget on advertising to make their brand stand out from the competition (Hayes, 2019). Part of the bubble was supported by overly optimistic investors and momentum traders who was trying to capitalize on the belief that prices would continue to rise, and not undergo a correction anytime soon. Investors were putting their money in a digital revolution, with the hope that the internet would improve the productivity of a company and therefore increase the expected profits (Kohn & Pereira, 2017).

Together with an increase in the number of IPOs during the 1990s, the average first-day return between 1990 to 1994 was between 9-13 %, compared to an average of 69,6 % in 1999 and 55,4 % in the following year (Ritter, 2008). In the beginning of 1996, the company Yahoo offered an IPO that traded up 152 percent on its first day. This investment success was becoming the new norm (Goodnight & Green, 2010). Figure A.2 shows the number of U.S. IPOs with an offer price greater than $5 that doubled in price on the first day of trading. Investors could not get enough companies to invest in.

In the two-year period from early 1998 through February 2000, the Internet sector earned over 1000 percent returns on its public equity. By the end of 2000, these returns had completely disappeared (Ofek & Richardson, 2003).

2.2.5 Financial Crisis 2008

The financial crisis of 2008-09 started with the American housing bubble bursting. This created a global financial crisis that affected nations worldwide, and that will impact generations to come. The 2008 global financial crisis is an example of there being no stock bubble before a stock market crash, but a housing bubble that affected the stock market.

After the peak in the US housing market in 2006 it began declining, and as the losses on mortgage-related financial assets began to cause strains in global financial markets. In December 2007 the US economy entered a recession. Despite the support programs from the Federal Reserve, by the fall of 2008, the economic contraction worsened and ultimately became what we now know as "the Great Recession" (Weinberg, 2013).

3 Literature Review

Asset bubbles are not a new phenomenon and there is substantial research on this topic, but to this day there is no standard framework. First, I introduce studies that address pricing and behavior in finance markets focusing on the definitions on a bubble. Next, I outline models and research used to find exuberance in the market and detect bubbles. The last part of this chapter introduces the financial instability hypothesis and the stages of a bubble.

3.1 Efficient Market Hypothesis

The Efficient Market Hypothesis (EMH) is an essential cornerstone in financial market theory. The theory was first derived from Eugene Fama's research in, "Efficient Capital Markets: A Review of Theory and Empirical Work", in 1970. EMH predicts that economic behavior will result in "a market where, given the available information, actual prices at every point in time represent very good estimates of intrinsic value" (Goodnight & Green, 2010, p. 116). This theory states that since stock always trades at its fair market value, it is impossible to buy undervalued or overvalued stocks. Therefore, given that the EMH holds, people will always invest in stocks at a fair value and there should never be bubbles.

The last 20 years of technical analysis together with research on psychological and behavioral elements in the determination of the stock price, have enabled investors to earn excess rates of return in the stock market (Malkiel, 2003). The growing popularity of index funds tells another story. In 2020, one-third of Norwegians investments in funds were placed in index funds, over double from the year before (Bjørnestad, 2021).

3.2 What is an Asset Bubble?

We have seen many bubbles bursting since the beginning of trading, and there have been a tremendous amount of research and analysis dedicated to the subject of stock market bubbles. However, there are not a uniform economic theory that explain this phenomenon. A bubble can appear in different parts of the economy and many researchers have different definitions of what is an asset bubble. In this part I will go through some of them.

Penman (2013) compares a bubble to a chain letter, also called a Ponzi scheme. The few investors at the start of the scheme and are early in the chain make considerable money, but most participants are left with nothing when the bubble burst. During a bubble, investors will adopt speculative beliefs that are spread throughout the public. In the last few decades, this information also gets spread faster. It is facilitated by social media, where private investors talk, and analysts and poor financial reporting is a big problem. Throughout a bubble more investors will believe that they can benefit from this rise in the prices, and as more people are buying the stock, the price will get pushed upwards. At the end, a bubble must burst as the speculative beliefs that started this bubble in the first place are eventually not fulfilled.

The value of a company can be viewed as the present value of all future cash flows, where the discounted cash flow method is a well-known and straightforward used model. Based on this Siegel (2003) writes that to define a bubble from this there must be an implication that either the expectations of the cash flow or the discount rate is not rational. "It is impossible to judge the "rationality" of the price of a long-lived asset by looking at only the next few years." (Siegel, 2003, p. 12). Therefore, he suggests a period of 30 years to measure the realized returns on equities for the determination of a bubble. If, at time t, considering the historical risk and return characteristics of that asset, it can be shown that the realized return of the asset is more than two standard deviations from the expected return it can be described as a bubble. Commenting on the Dot-Com bubble Siegel (2003, p. 23) stated: *"It is theoretical possible for those stocks to rise in price sufficiently in the future so that the peak of these stock prices in late 1999 or early 2000 will not be labelled a bubble. But this is highly unlikely".*

Porras (2016) uses Tirole's model to illustrate the idea of a bubble, where the fundamental value of a company is based on the discounted present value of its future payoffs, proxied by expected dividend payments. If then the price of the asset in the market is above what can be justified by its fundamentals, we have a bubble. A general model would then be:

$$x_t = F_t + B_t$$

Where, x_t is the price of the asset today, F_t is the part of the price that corresponds to the fundamental value and B_t is the part of the price that corresponds to the bubble. In the case where $x_t = F_t$ there is no bubble. This raises a new problem, because determining the fundamental value of an asset is not a simple matter, and in most cases one stock will have a different fundamental value depending on whom you are asking. However, with this model the definition of a bubble refers to the mispricing of an asset. A mispricing of an asset will not be a concern before this spread to larger parts of the stock market and eventually could lead to a burst and have a negative impact on the economy.

Despite the mathematics and complex technical analysis used in the stock market many economists have used behavioral approaches to try to understand bubbles. Goodnight & Green (2010) describe bubbles as a special case of "contagion" that go outside the ordinary rules for evaluating risk and information. The withdrawals from the market equilibrium and fundamental value are a consequence from investors copying popular but bad investment decisions from other investors and institutions trying to maximize their profits. This is more common when credit is abundant, and an economy is doing well.

A stock market bubble only has a strong effect on the general economy if the price of the asset rises much over its fundamental value, is a commonly held asset or constitutes an entire market. The belief that the increase in the stock price always will become profitable causes irrational expectations and inflates the size of the bubble as the optimism grows (Karimov, 2017).

3.3 Irrational Exuberance

The phrase "irrational exuberance" was first used by former Fed Chairman Alan Greenspan in December 1996, when he warned the markets during the building of the Dot-com bubble: "We can see that in the inverse relationship exhibited by price/earnings ratios and the rate of inflation in the past. But how do we know when irrational exuberance has unduly escalated asset values (…) We as central bankers need not be concerned if a collapsing financial asset bubble does not threaten to impair the real economy, its production, jobs, and price stability" (The Federal Reserve Board, 1996).

Irrational exuberance refers to investor enthusiasm that drives asset prices higher than those assets fundamentals justify (Hayes, 2021). After Greenspan held his famous speech the stock market in Tokyo and Hong Kong fell 3 %, while the markets in Frankfurt and London fell 4 % (Shiller, 2005).

Wei-Fong Pan (2020) presents in his article that investor sentiment significantly predicts stock bubble probability, and a more optimistic investor sentiment also increases the size of a bubble. As the bubble reach its peak, the sentiment is already reached.

3.4 Testing for exuberance

It is difficult to detect rational asset bubbles in time series dataset using standard economic approaches. A strategy for detecting and testing for rational asset bubbles is to look at the stationarity properties of asset prices and attempt to observe the fundamentals using unit-root tests, autocorrelation patterns, and cointegration tests (Evans, 1991). The presence of a unit root suggests that after a shock the data has no tendency to revert to its equilibrium value or stable path. Evans (1991) then criticizes this approach and concludes that the periodically collapsing bubbles are not detectable by using the standard tests since the characteristics of bubbles are too complex. Standard unit roots tests have extremely low power in detecting episodes of explosive dynamics when interrupted by market crashes. The tests cannot find the difference between a stationary process and a periodically collapsing bubble model (Phillips et al., 2011).

There is still no standard framework for detecting bubbles, but after the financial crisis of 2007-2008 interest increased in testing exuberance in the asset market. The majority of earlier testing on explosive behavior used the standard Augmented Dickey Fuller (ADF) on the entire sample of available data. Building on Evans paper from 1991 and other research in this area Phillips, Wu and Yu (2011) developed a technique for identifying bubble behavior with consistent dating of their origin and collapse. The two models that have increased in popularity and use are the supremum augmented Dickey-Fuller (SADF) (Philips et al., 2011) and the generalized SADF (GSADF) (Philips et al., 2015). The SADF and GSADF methodologies involve a recursively evolving algorithm that estimates ADF regressions on subsamples data, to deal with the effect of a collapse in a time series on the test's performance. The SADF procedure sequentially tests for explosive behavior by using a forward expanding window.

The tests developed by Philips et al. (2011) and further extensions have now been widely used. Liu et al. (2016) identified different bubbles in the Shanghai stock market using the SADF and GSADF tests. Using monthly data, they employed the price index of the Shanghai A-Share stock market and the dividend yield of the 1061 listed companies in the market, from 2000 to 2015. The GSADF test confirmed two prominent episodes of exuberance and collapse in the market, while the SADF test only found a single bubble. Pan (2020) examines the relationship between stock market bubbles and investor sentiment, as proxied by consumer confidence indices (CCIs). To detect an interaction between investor sentiment and stock bubbles he first employs the GSADF on dividends and S&P 500 index prices and then compares this to a logistic regression analysis on two CCIs. He finds that investor sentiment significantly predicts stock bubble probability, with a higher probability of bubble occurrence following periods of higher investor sentiment, and that this has a strong explanatory power in stock bubbles and their bursts. The empirical results from the different studies suggest that the generalized supremum augmented Dickey-Fuller test is, in practical terms, better than the supremum ADF test to detect multiple bubbles. Additionally, it has only identified previous bubbles, and not to predicting future bubbles.

The GSADF test can also be used to detect bubbles in other markets and data than the stock market. Li et al. (2019) examines the existence of bubbles in Bitcoin markets and location of the origination and termination of them. The empirical results show that there are six and five explosive bubbles in the China and US Bitcoin price, respectively. Investors demand Bitcoin as safety to hedge against potential risk or as a speculative vehicle to earn profits. Furthermore, these tests have been used looking at bubbles in the housing market that have been in an upward trend for many years together with the stock market. Pavlidis et al. (2016) examines changes in the time series properties of three widely used housing market indicators for a large set of countries to detect episodes of explosive dynamics. In addition to the GSADF they also use an extension with a panel setting to exploit the larger cross-sectional dimensions of the international dataset. They find strong evidence of a period of exuberance in the early 2000s that eventually collapsed around 2006-07, preceding the 2008-09 global recession. They also detect three main macro and financial variables to help predict episodes of exuberance in housing markets: long-term interest rates, credit growth and global economic conditions.

3.5 Stages of a Bubble

For historians, each event is unique, and for economist there is always a pattern in the data and particular event are likely to induce similar responses. Hyman Minsky followed Keynes and established the idea of the financial instability hypothesis to explain how swings between robustness and fragility in financial markets generate business cycles in the economic system. Minsky believed that the only way to break the pattern of boom and burst was through public policy (Knell, 2015). Swings in the credit cycle went through five stages: displacement, boom, euphoria, profit taking, and panic. This also outline the basic form of a bubble. Hence, while no bubbles are identical they all share the same structure.

The first stage that leads to a crisis, the displacement, is an exogenous, outside shock to the macroeconomic system (Kindleberger & Aliber, 2005). This can be a new paradigm, such as an innovative new technology or historical low interest rates. If the shock were sufficient large the economic outlook and the anticipated profit opportunities would improve in at least one important sector of the economy. Both firms and individuals will borrow to take advantage of the increase in the expected profits associated with a wide range of investments.

The boom in the Minsky model is driven by an expansion of credit. After gaining more and more participants in the market, the boom phase is evolving. During this stage, the assets or industry in question attracts widespread media coverage. The fear of missing out on what could be a once-in-a-lifetime opportunity provokes more speculation, drawing an increasing number of investors and traders into the fold (Segal, 2021). This drives the market prices up and more positive feedback develops as the increase in investments leads to increases in the rate of growth of national income. At this stage, Euphoria develops. When the bubble gets to this stage the caution gets thrown into the wind as the prices skyrocket. Valuations reach extreme levels during this stage as new valuation measures and metrics are touted to justify the relentless rise. Historical euphoria has often spread from one country to others through one of several different ways (Kindleberger & Aliber, 2005).

As the speculative boom and euphoria continues the profit-taking stage begins. Interest rates, the speed of payments and the commodity price level increase. The purchase of securities by “outsider” means that the insider – those who owned or purchased these assets earlier – sell the same securities and take profits. Institutional investors, market mavens, central banks, funds, and other financial professionals will notice that the bubble is about to burst and start selling positions with profits. When the exactly "right" time is and estimating when a bubble is due to collapse can be a difficult exercise. The final stage is panic or financial distress. It often takes a relatively minor event to prick a bubble, but once it is pricked, the bubble cannot inflate again. Investors and speculator, faced with margin calls and plunging values of their holding, now want to liquidate at any price. As supply overwhelms demand, asset prices slide sharply.

Pirie & Chan (2016) discusses the finding of interviews with 25 investment professionals from five global financial institutions to find if they use momentum consistent with the Financial Instability Hypothesis of Minsky. Nearly all the investors interviewed used momentum as a part of their strategy, but not alone. This provides evidence that supports the process underlying Minsky's Financial Instability Hypothesis. The participants agreed that the markets follow a defined cycle, and they try to make use of the trends that develop withing it. With following these trends, they also try to avoid the "Minsky Moment" when the market reverse.

4 Methodology and Data

To examine periods of exuberance in the Norwegian markets, we need a methodological foundation. This chapter aims to provide the reader with the framework for the unit root tests used in the following chapters. The last part presents the data collection procedure and descriptive statistics of the data used in the empirical analysis in Chapter 5.

4.1 Model specifications

The literature on identifying bubbles from market fundamentals originates from the Lucas asset pricing model (Lucas, 1978). Any economists have improved upon this method so that it is appropriate to test for financial bubbles (Li et al., 2019). Following Blanchard & Watson's (1982) standard efficient market condition, we have the fundamental price of the asset:

$$P_t = \frac{1}{1+R} E_t(P_{t+1} + X_{t+1}) \tag{4.1}$$

Where P_t is the asset price in the period t, R is the risk-free rate, X_{t+1} indicates the economic fundaments that may affect the stock market for period t. $E_t(\cdot)$ is the expectation. We can then illustrate the fundamental price as,

$$P_t^f = \sum_{i=1}^{\infty} \frac{1}{(1+R)^t} E_t(X_{t+1}) \tag{4.2}$$

Equation (4.2) states that the fundamental price equals the present value of all expected future economic information. Imposing the transversal condition:

$$\lim_{k\to\infty} E_t\left[\frac{1}{(1+R)^k} P_{t+k}\right] = 0 \tag{4.3}$$

This condition ensures that $P_t = P_t^f$ is the unique solution for the fundamental price of the asset (4.1), and hence, this excludes the existence of bubbles. If (4.3) does not hold, P_t^f is not the only price process that solves equation (4.1). Consider the process $\{B_t\}_{t=1}^{\infty}$ with any sequence of a random variable that satisfies the homogenous expectational equation. This gives us:

$$E_t(B_{t+1}) = (1 + R)B_t \tag{4.4}$$

If $\{B_t\}_{t=1}^{\infty}$ is a process that satisfies (4.4), by adding B_t to P_t^f in equation (4.1), we get:

$$P_t = P_t^f + B_t \tag{4.5}$$

This equation presents that the price contains two components: one is the fundamental component, P_t^f, and the other is referred to as the bubble component, B_t. If a bubble exists in the asset price, we see from equation (4.4) that an investor willing to buy the asset must expect the bubble to grow at rate R. If B_t is strictly positive, this sets the stage for speculative investor behavior. A rational investor is willing to buy an "overpriced" asset since she believes that she will be sufficiently compensated for the extra payment B_t through price increases. If investors expect prices to increase at rate R then they will buy more, the asset price will indeed rise and complete the loop of a self-fulfilling process.

When a stock market bubble bursts, it can trigger financial crises that spread to the real economy. The main model used in this thesis is based on the work of Philips et al. (2011) and Philips et al. (2015). This is based on the following ADF regression equation:

$$\Delta p_t = a_{r_1,r_2} + \beta_{r_1,r_2} p_{t-1} + \sum_{j=1}^{k} \varphi_{r_1,r_2}^{j} \Delta p_{t-j} + \varepsilon_t \tag{4.6}$$

Where Δ is the first difference operator, p_t is the variable of interest at time t, k is the lag order and $\varepsilon_t \sim i.i.d.(0, \sigma_{r_1,r_2}^2)$ is the error term. Suppose that r_1 is the starting point and r_2 is the endpoint used for estimation. With T as the total number of time periods in the sample, r_1 and r_2 are expressed as fractions of T, we can then define $r_w = r_2 - r_1$ as the window size of the regression. Our interest is to test for a unit root versus a bubble or episodes of exuberance. The null and alternative hypothesis of the tests are as follows:

H_0: $\beta_{r_1,r_2} = 1$ (unit root, no bubble)

H_1: $\beta_{r_1,r_2} > 1$ (explosive behavior/bubble)

The ADF test statistic corresponding to this null hypothesis is denoted $ADF_{r_1}^{r_2}$. The equation is given by:

$$ADF_{r_1}^{r_2} = \frac{\hat{\beta}_{r_1,r_2}}{s.e.(\hat{\beta}_{r_1,r_2})} \quad (4.7)$$

The standard ADF test equation (4.7) is obtained by estimating regression (4.6) on the full sample of observations. By setting $r_1 = 0$ and $r_2 = 1$, the limit distribution of ADF_0^1 under the null of a unit root is given by:

$$\frac{\int_0^1 WdW}{(\int_0^1 W^2)^{\frac{1}{2}}}$$

Where W is a Wiener process. Rejection of the null hypothesis of a unit root requires that the test statistic exceeds the right-tailed critical value from its limit distribution.

4.1.1 The SADF Test

Because of limitations in the standard ADF, Philips, Wu and Yu (2011) they developed a new approach for testing explosive behavior in stock prices. This included a right tailed unit root test and a new method of confidence interval construction for the growth parameter in stock market exuberance. This approach uses a supremum ADF (SADF) test called a forward recursive right-tailed ADF test. The SADF test significantly improves power compared to the conventional cointegration-based test, by detecting market exuberance arising from various sources, including mildly explosive behavior.

The SADF test is based on the idea of repeatedly running the ADF test on a forward expanding sample sequence. The test results obtained is the sup value of the corresponding ADF test statistics sequence. Under this model specification, the starting point is fixed at r_0 and the end point, r_2, can freely expand from r_0 to 1 (Liu, et al., 2016). The SADF statistic can be defined as:

$$SADF(r_0) = \sup_{r_2 \in [r_0, 1]} ADF_0^{r_2} \quad (4.8)$$

And has a limit distribution of:

$$\sup_{r_2 \in [r_0, 1]} \frac{\int_0^{r_2} WdW}{(\int_0^{r_2} W^2)^{\frac{1}{2}}}$$

Rejection of the null hypothesis of a unit root is similar to the standard ADF test and requires that the SADF statistic exceeds the right-tailed critical value from its distribution. In contrast to the ADF test which examines the presence of explosive dynamics during the entire period, the alternative hypothesis of the SADG test is that of explosive dynamics in some part(s) of the sample (Vasilopoulos et al., 2020).

4.1.2 The GSADF Test

When performing the SADF test on data that includes multiple episodes of exuberance and collapse it may suffer from reduced power, can be inconsistent and therefore fails to detect the existence of different bubbles. This is especially likely when analyzing long time series or high volatility market data where one suspect more than one episode of exuberance. To overcome this weakness Philips et. al (2015) proposed the generalized sup ADF (GSADF) test. The GSADF is based on the same idea as the SADF of repeatedly implementing the right tailed ADF test, but it extends the sample sequence to a broader and more flexible range. Instead of fixing the starting point of the sample, the GSADF test extends the sample sequence by changing both the starting point and the ending point of the sample over a feasible range of flexible windows. Varying the end point of the regression r_2 from r_0 to 1, it also allows for the starting points r_1 to change within the range from 0 to $r_2 - r_0$. The GSADF statistic is defined as:

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} ADF_0^{r_2} \qquad (4.9)$$

Under the null hypothesis of a unit root, the limit distribution is given by:

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

4.1.3 Date-stamping Strategies

Running the different ADF tests only tell us if we have episodes of exuberance or not. It will therefore be interesting to know when these episodes took place. To date stamp a bubble period Philips et al. (2015) introduced the sequence of backward SADF statistics. The BSADF test has the same arithmetical logic as the GSADF test, except for having a different test direction. As the regular SADF test sets a fixed starting point of r_0, the BSADF test chooses a fixed end point at r_2. The starting point becomes a changeable point varying from 0 to $r_2 - r_0$. The BSADF test statistic sequence applies a right tailed ADF test on backward expanding samples using the following:

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} ADF_{r_1}^{r_2} \tag{4.10}$$

Letting r_e correspond to the origination and r_f the termination dates it can be estimated according to (Vasilopoulos, 2020):

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

Where $scu_{r_2}^{\alpha}$ is the $100(1 - \alpha)\%$ critical value of the SADF for $[r_2 T]$ observations.

Employing this test, we also need the minimum window size, r_0, and the autoregressive lag length, k. The minimum window size must be large enough to allow initial estimation but should not be so large that short episodes of exuberance will not be observed. Philips et al. (2015) recommend setting the minimum window according to: $r_0 = 0.01 + 1.8/\sqrt{T}$. When selecting the lag length, k, simulation evidence indicates the proposed right-tailed unit root methodologies work well when the number of lags is fixed at a small value, i.e., 0 or 1 (Vasilopoulos, 2020). Furthermore, the limit distributions of the SADF, GSADF and BSADF test statistic are non-standard and depend on the minimum window size. As a result, critical values need to be obtained through either Monte Carlo simulations or bootstrapping.

4.2 Data Description

In order to answer the research question, I both want to investigate the total Norwegian market and specific green companies on Oslo Børs. The first step of data collection was to identify a representing index for the Norwegian market. From our knowledge of earlier bubbles we know that they typically start in a sector or part of the economy and later spread to the entire stock market and economy. The most commonly used market index in Norway is the Oslo Børs Benchmark Index (OSEBX). The OSEBX is an index which includes the most traded and largest shares listed on Oslo Børs. The OSEBX index is adjusted for dividend payments. Stocks are screened to ensure liquidity and selected, and free float weighted to ensure that the index is investable.

The OSEBX is used to represent the Norwegian market in this thesis because it is the main index used when looking at the stock market in Norway. The index consists of 69 stocks as of March 2021. The entire list of companies is in the Appendix. The OSEBX was first published in 1995 and the dataset is both daily and monthly data in time period 10 and 20 years. All data is retrieved from Thomson Reuters Eikon.

Table 4.1 Descriptive statistics, OSEBX in the period 2011-2021 and 2001-2021

variable	T	mean	median	max	min
OSEBX 10	2588	658.1	623.0	1064.9	323.9
OSEBX 20	5198	438.84	438.84	1064.91	98.57

Figure 4.1 OSEBX Total Return 2001-2021

The next step was to identify all green companies on the Oslo Børs. The data collection is based on a list published by Oslo Børs, and added some new companies listed after this list was published (Oslo Børs, 2020). This includes stocks that now trade on Euronext Growth, formerly Merkur Market, but are based in Norway and traded through Oslo Børs. All stocks listed before November 2020 and are still trading are used for the selection. To define the list and exclude companies from the data selection, I use the definition introduced in Chapter 2: *"A green company is a company that delivers green products or services".* For the dataset I am using only ten years, 2011-2021, because green stocks are new to the market and going back further will not give us that many more observations. I therefore use also here daily returns to get a more extensive set of data points. More specifically, each stock's daily ending price from April 18. 2011 up until April 15, 2021. The selection resulted in a cross-sectional dataset including 21 companies. All data was downloaded from Thomson Reuters Eikon and are traded in NOK.

Green companies and investing in green stocks are an increasing trend. The ten first months of 2020, there was listed 10 new green stocks, and from 2019 to 2020 the total percentage of the value green stock constituted to Oslo Børs doubled from 4 % to over 8 % (Oslo Børs, 2020). Only 6 of the 21 companies was listed before April 2011, and 8 of them was listed in 2020 and have therefore limited number of values to use in the analysis.

Table 4.2 Descriptive statistics for green stock

	T	mean	median	min	max
NEL	2609	5.981	3.050	0.440	34.570
Scatec	1706	82.90	47.55	17.60	397.60
TECO 2030	134	6.558	6.690	2.100	13.600
Hydrogenpro	132	46.91	42.56	26.20	75.60
Tomra	2609	133.89	89.25	34.50	423.50
Borregaard	2216	71.74	73.25	18.20	190.00
Hexagon Composites	2609	21.57	22.86	2.16	72.60
Fjordkraft	802	54.85	48.90	30.40	100.00
Arendals Fossekompani	2609	83.67	66.72	43.52	316.00
Atlantic Sapphire	982	114.54	101.50	29.00	300.00*
Quantafuel	738	22.20	13.80	5.00	78.90
Aker Carbon	167	12.57	13.00	4.30	22.70
Vow	1830	9.277	2.985	0.490	56.700
Aker Offshore	167	6.584	6.500	2.600	12.500
Agility	142	36.86	37.00	22.80	52.75
Rec Silicon	2609	19.77	14.12	2.07	162.00
Andfjord Salmon	428	45.08	47.18	25.00	70.00
Salmon Evolution Holding	150	6.202	6.170	5.040	7.520
Magnora	2609	9.578	7.900	3.460	93.650
Zaptec	139	38.95	44.85	10.91	68.50
Cloudberry Clean Energy	271	13.37	12.95	10.00	18.45

**Atlantic sapphire had a stock split 2018-01-05 with a ratio of 10:1*

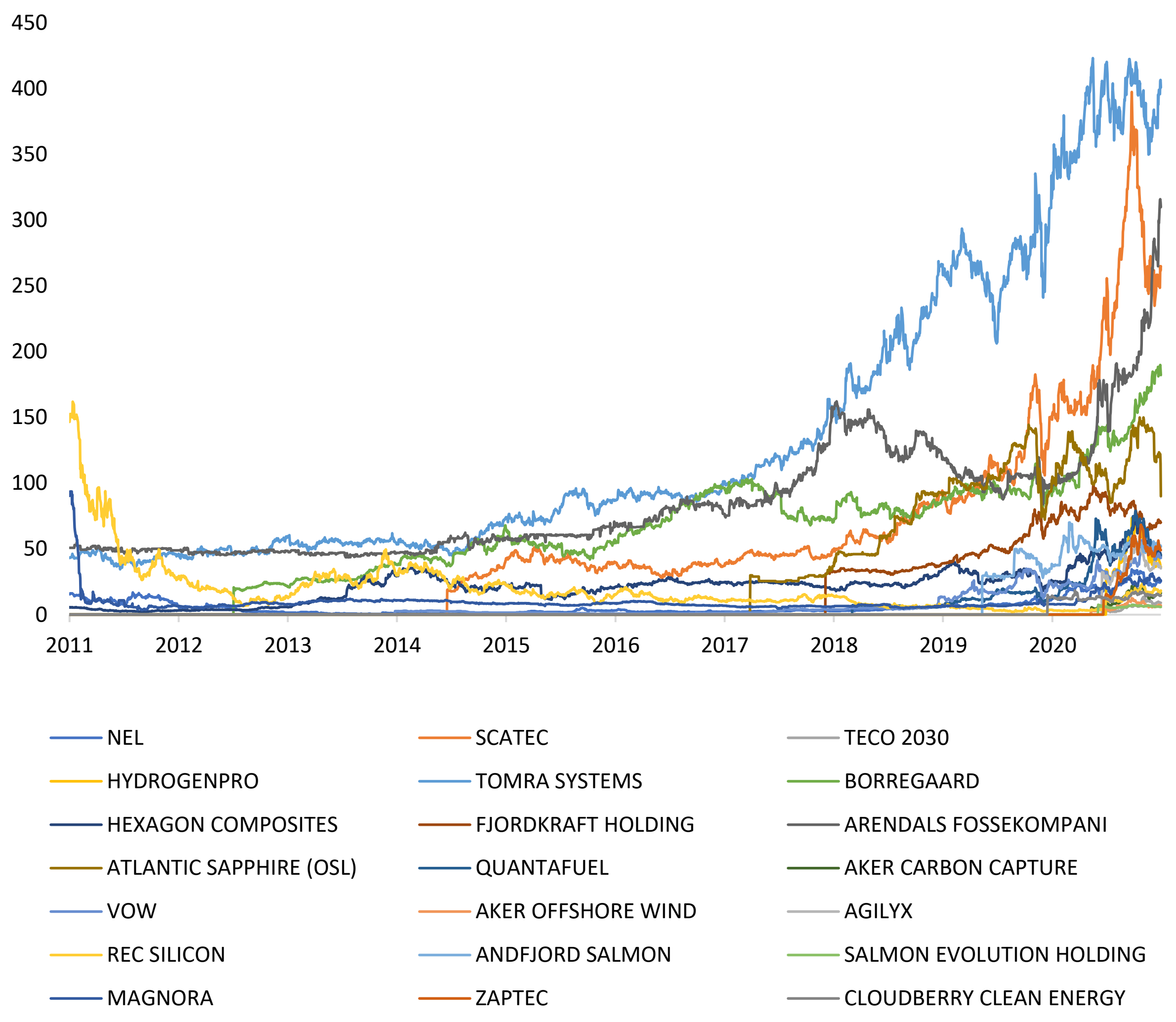

Figure 4.2 Total return green stocks 2011-2021

5 Analysis and Results

This section presents the results from the unit root tests. This analysis aims to examine whether there are periods of exuberance in the Norwegian market and green stocks and see if there are signs of a bubble. Finally, I will look at the price-over-earnings ratios for the green stocks to see how they are priced in relation to their earnings and other stocks in the industry.

To perform the tests for exuberance and bubbles, I use the R package *exuber*. For all datasets I have used the ADF, SADF, GSADF, and BSADF test. The minimum bubble length, window size, is set to default in all tests. Because of this all "blips", short episodes in which the BSADF statistic is above the critical value will be shown. The default window size is the recommended size from Philips et al. (2015): $r_0 = 0.01 + 1.8/\sqrt{T}$. The lag length is a non-negative integer, with default 0L. The critical values are computed using a Monte Carlo simulation based on 2000 replications, with a seed equal to 123.

5.1 Oslo Børs Benchmark Index

The first step is to employ the tests on the Oslo Børs Benchmark Index (OSEBX). I do this because I want to see if there exists any episodes of exuberance in the Norwegian market before, I go into specific green stocks. The time evolution of the OSEBX can be visualized in Figure 4.1. The data used in this thesis extends over a maximum of 20 years, and numerous episodes have happened might can be expected to show up as episodes of exuberance. In the early stages of the 2000s, the Dot-Com bubble burst and the September 11 attack also affected the stock market in 2001. In the period from 2007-2009 the Housing Bubble in the US developed and burst and spread to markets all over the world. In 2014 the Oil Price decreased substantially and reduced throughout 2015 until it reached the bottom in 2016. Despite the decrease in the oil price there has been a steady positive trend in the OSEBX since 2009, apart from the fall when Covid-19 was declared a pandemic by the World Health Organization in March last year. These are all episodes where we might expect to detect exuberance. In addition, the most interesting and relevant possible observation is to find observations that can be seen in context with the green stock in the second dataset.

Before applying the tests to the entire dataset of 20 years, I wanted to test the last 10 years. This is because green stocks and investments were not as widespread before the last ten years and have not gained substantial attention before the last couple of years. The first stage in the analysis compares the ADF, SADF, and GSADF statistics containing their corresponding right-tailed critical values. In Table 5.1, the test statistics and Monte Carlo critical values are summarized.

Table 5.1 Critical values, 10 years OSEBX

name	tstat	\`90\`	\`95\`	\`99\`
<fct>	*<dbl>*	*<dbl>*	*<dbl>*	*<dbl>*
adf	-0.198	-0.404	-0.0405	0.582
sadf	0.584	1.40	1.65	2.17
gsadf	4.41	2.24	2.45	2.83

According to the output in Table 5.1, the null hypothesis of a unit root in OSEBX is rejected in favor of explosive dynamics at the 5 % significance level by the GSADF test, but not by the SADF and the standard ADF test. The SADF and ADF have been found to have a lower power to detect bubbles that burst in-sample and these results are in line with other research where the same tests have been used.

The results from the tests conclude that we have episodes of exuberance in the dataset, but not when they appeared. We can date-stamp the episode(s) of exuberance running the backward SADF. Table 5.2 shows the episodes with dates and duration of the episodes. All observations of exuberance are detected during March 2020 and are short episodes that can be defined as blips and not a bubble period, because of the length and the absence of a build up before the fall in stock prices. Figure 5.1 visualize these episodes. The blue line is the BSADF statistic; the red dotted line is the sequence of 95 % critical value. The shaded grey area is where the BSADF statistic exceeds the critical value, and exuberance is detected.

As initially assumed, the two episodes from 2014-16 and March 2020 all have high BSADF statistics, but only the episodes of March 2020 exceed the critical values associated with a 5 % significance level. Despite a positive trend all these years, excluding March last year, the building of a possible bubble does not seem present in this period.

Table 5.2 Episodes of exuberance, 10 years OSEBX

	Start	End	Duration
1	09.03.2020	10.03.2020	1
2	11.03.2020	19.03.2020	6
3	23.03.2020	24.03.2020	1

Figure 5.1 Plot of date-stamping, 10 years OSEBX

Because green stocks and investments are a new trend the relevant period to test might be the last ten years of the OSEBX. But a concern is that the test may not have enough statistical power in such a short period. For operational reasons, I also applied the tests to the OSEBX 20, with twenty years of data instead of ten. A comparison of the SADF and GSADF test statistics to their critical values suggest that the null hypothesis of a unit root against the alternative hypothesis of explosive behavior is rejected at all conventional levels of significance. For this period the standard ADF test also rejects the null hypothesis, and there is strong evidence that there have been episodes of exuberance. Across 20 years, the stock market will experience blips; hence, the results indicates that periodic bubbles characterize the OSEBX and Norwegian stock market. Table 5.3 shows the summary of the test statistics, and the ADF, SADF, and GSADF can reject H_0 at the 1% significance level.

Table 5.3 Critical values, 20 years OSEBX

name	tstat	\`90\`	\`95\`	\`99\`
<fct>	*<dbl>*	*<dbl>*	*<dbl>*	*<dbl>*
adf	0.305	-0.433	-0.0978	0.243
sadf	3.76	1.36	1.59	2.17
gsadf	3.77	2.34	2.49	2.94

Estimating the BSADF statistic, we get the results shown in Table A.2. The date-stamping for the last 20 years shows 34 different episodes of exuberance, where 32 of them happened before 2009. For the period after 2009, this test also detected blips in March 2020. For 2020 we only have two episodes of exuberance, one with a duration of a day and the other five days, which is shorter than the results in OSEBX 10. Excluding the shortest episodes of exuberance, the 15 episodes of the 34 in total are shown in Table 5.4, where they all have a duration of 5 or over. Shaded areas in the plot in Figure 5.2 show many episodes in the first half of the dataset, but as expected with the positive and stable trend the last ten years, only March 2020 gives significant results, despite a few episodes that almost reach the 95 % critical value line.

Table 5.4 Episodes of exuberance with duration over 4, 20 years OSEBX

	Start	End	Duration
2	18.09.2002	03.10.2002	11
5	01.09.2003	10.09.2003	7
6	06.01.2004	15.03.2004	49
8	02.04.2004	14.04.2004	8
12	02.02.2005	30.03.2005	40
13	31.03.2005	15.04.2005	11
14	10.06.2005	13.10.2005	89
17	25.11.2005	22.05.2006	126
19	26.05.2006	07.06.2006	8
20	18.12.2006	04.01.2007	13
22	18.01.2007	27.02.2007	28

25	02.04.2007	12.04.2007	8
27	20.04.2007	11.05.2007	15
28	14.05.2007	26.07.2007	53
33	12.03.2020	19.03.2020	5

Analyzing the plot in Figure 5.2 after the ending of the episodes of exuberance in March 2020, we have an increasing BSADF statistic. From March 19, 2020, which is the end date of episode 33, the market has recovered and has the last year increased by 59,6 % as of March 15, 2021. This is still far away from being able to exceed the critical value, but as of earlier bubbles it might be difficult to conclude if we have a bubble in the market before the bubble burst.

Figure 5.2 Plot of date-stamping, 20 years OSEBX

5.1.1 Monthly data

In the literature referred to in Chapter 3, the tests were performed on either weekly or monthly data. This can be helpful to exclude smaller blips in the market. I employed the same tests to monthly data over 10 and 20 years, but the null hypothesis of a unit root could not be rejected at a 5 % significance level.

5.2 Green stocks

Based on the results of the tests employed on the OSEBX, it does not seem that we have a bubble in the Norwegian stock market as of today, even though one might question the rising BSADF statistic in the last year. In the second application, I employ the dataset of a portfolio consisting of 21 individual green stocks. Each stock was tested individually against the same set of critical values calculated for the portfolio.

Table 5.5 present the stock-specific results of the ADF, SADF, and GSADF test statistics. Table 5.6 shows the Monte Carlo simulated critical values. For the majority of the stocks, we find periods of exuberance in the past ten years. Of the 21 companies employed, 16 of the companies in this dataset can reject the null hypothesis of a unit root at a significance level of 1%. For the GSADF, there is strong evidence of exuberance in green stocks, with the null hypothesis of a unit root being rejected for all but four companies at the 1 % significance level. Furthermore, the number of the rejections of the null hypothesis for the SADF is close to the GSADF with rejecting H_0 in 15 of the 21 stocks at 1 % significance level. As expected, I find more periods of exuberance in the dataset containing individual stocks. Volatility can be larger in one stock without it affecting the market and, hence, this might be expected. The interesting thing to look at here is if we find many overlapping episodes of exuberance across the various stocks. Table A.3 provides the entire list of the individual stocks and a summary of the hypothesis tests.

Table 5.5 Unit root test results – green stocks

	id	adf	sadf	gsadf
1	NEL	-0.3974	2.3644	5.3291
2	SCATEC	1.0559	8.2923	8.2922
3	TECO 2030	0.9140	12.6200	12.6200
4	HydrogenPro	-1.0029	7.2527	7.2527
5	Tomra Systems	0.6459	3.0841	3.1034
6	Borregaard	0.9365	1.2842	2.1188
7	Hexagon Composites	-1.3896	6.6645	6.6645
8	Fjordkraft Holding	0.0222	3.1229	4.2397
9	Arendal Fossekompani	3.8379	4.1840	4.3282
10	Atlantic Sapphire	-2.9156	-0.0248	2.3617
11	Quantafuel	-0.2244	14.2998	14.2998
12	Aker Carbon Capture	1.5095	12.4115	12.4115
13	Vow	0.5646	9.8734	12.4571
14	Aker Offshore Wind	0.0957	10.8463	10.8463
15	Agilyx	-0.4852	3.1981	3.1981

16	Rec Silicon	-7.3380	-0.6500	6.4937
17	Andfjord Salmon	-0.0575	8.3829	8.3829
18	Salmon Evolution Holding	-1.3503	-0.3134	-0.2316
19	Magnora	-14.1102	-3.3929	3.7652
20	Zaptec	2.3529	18.3526	18.3526
21	Cloudberry Clean Energy	-1.0022	1.2289	1.2289

Table 5.6 Monte Carlo critical values

sig	adf	sadf	gsadf
90	-0.398	1.28	2.24
95	-0.0188	1.47	2.49
99	0.623	2.12	3.04

The main interest is when these episodes took place. Running the BSADF test gives 168 episodes of exuberance across all stocks. Since only the last years are of interest, the entire table of the different episodes is in the Appendix, Table A.4. At the ending of 2020 and the first months of 2021, many green stocks experienced periods of exuberance. From November to February 13 of the 21 stocks have had episodes of exuberance. On average, the entire portfolio of green stocks increased by 67,7 %. The 13 stocks presented in Table 5.7 that were experiencing episodes of exuberance in the period had almost doubled their values with an average price increase of 95,6 %. In the same period, the OSEBX increased 24 %. The rapid increase in the stock prices for some stocks continued into March, but for most stocks, the price either stabilized or decreased.

Table 5.7 Episodes of exuberance in green stock November 2020 - February 2021

NEL	Start	End	Duration
11	19.11.2020	25.11.2020	4
12	26.11.2020	03.12.2020	5
13	04.12.2020	18.02.2021	54
14	19.02.2021	22.02.2021	1
SCATEC	**Start**	**End**	**Duration**
20	30.10.2020	22.02.2021	81
21	11.03.2021	12.03.2021	1
TECO 2030	**Start**	**End**	**Duration**
1	08.12.2020	09.12.2020	1
2	11.12.2020	29.01.2021	35
3	01.02.2021	18.03.2021	33
4	06.04.2021	09.04.2021	3
HydrogenPro	**Start**	**End**	**Duration**

1	30.11.2020	02.12.2020	2
2	18.12.2020	16.02.2021	42
Hexagon Composites	**Start**	**End**	**Duration**
14	18.01.2021	21.01.2021	3
Quantafuel	**Start**	**End**	**Duration**
18	05.11.2020	13.11.2020	6
19	17.12.2020	23.02.2021	48
20	25.02.2021	26.02.2021	1
21	02.03.2021	03.03.2021	1
Aker Carbon Capture	**Start**	**End**	**Duration**
5	03.11.2020	25.02.2021	82
6	26.02.2021	03.03.2021	3
7	11.03.2021	15.03.2021	2
8	06.04.2021	07.04.2021	1
9	15.04.2021	NA	1
VOW	**Start**	**End**	**Duration**
16	06.01.2021	11.01.2021	3
17	19.01.2021	20.01.2021	1
18	04.02.2021	08.03.2021	22
19	09.03.2021	15.03.2021	4
20	16.03.2021	17.03.2021	1
21	18.03.2021	24.03.2021	4
Aker Offshore Wind	**Start**	**End**	**Duration**
4	19.11.2020	22.02.2021	67
Agilyx	**Start**	**End**	**Duration**
1	16.12.2020	23.12.2020	5
2	28.12.2020	29.12.2020	1
3	08.01.2021	12.02.2021	25
Rec Silicon	**Start**	**End**	**Duration**
4	23.12.2020	29.12.2020	4
5	07.01.2021	08.01.2021	1
6	19.01.2021	22.01.2021	3
7	08.02.2021	18.02.2021	8
Magnora	**Start**	**End**	**Duration**
3	23.11.2020	27.11.2020	4
4	30.11.2020	08.12.2020	6
5	09.12.2020	07.01.2021	21
6	02.02.2021	04.02.2021	2
7	12.03.2021	15.03.2021	1
8	18.03.2021	19.03.2021	1
Zaptec	**Start**	**End**	**Duration**
2	30.10.2020	NA	120

The findings from the BSADF statistic tells us that there has been an increase in green stocks and episodes of exuberance that could be signs of a bubble. Figure 5.3 presents the BSADF statistic plots exceeding the critical value and the test detected episodes of exuberance. A chronology of the identified periods of exuberance for each stock is in Figure A.3. There are intensifying episodes of exuberance in the last year. Since several companies were listed in the last year, the higher number of episodes of exuberance could be because of this. However, there is no necessary direct correlation between a stock's IPO and exuberance unless it is priced too low according to the market participants.

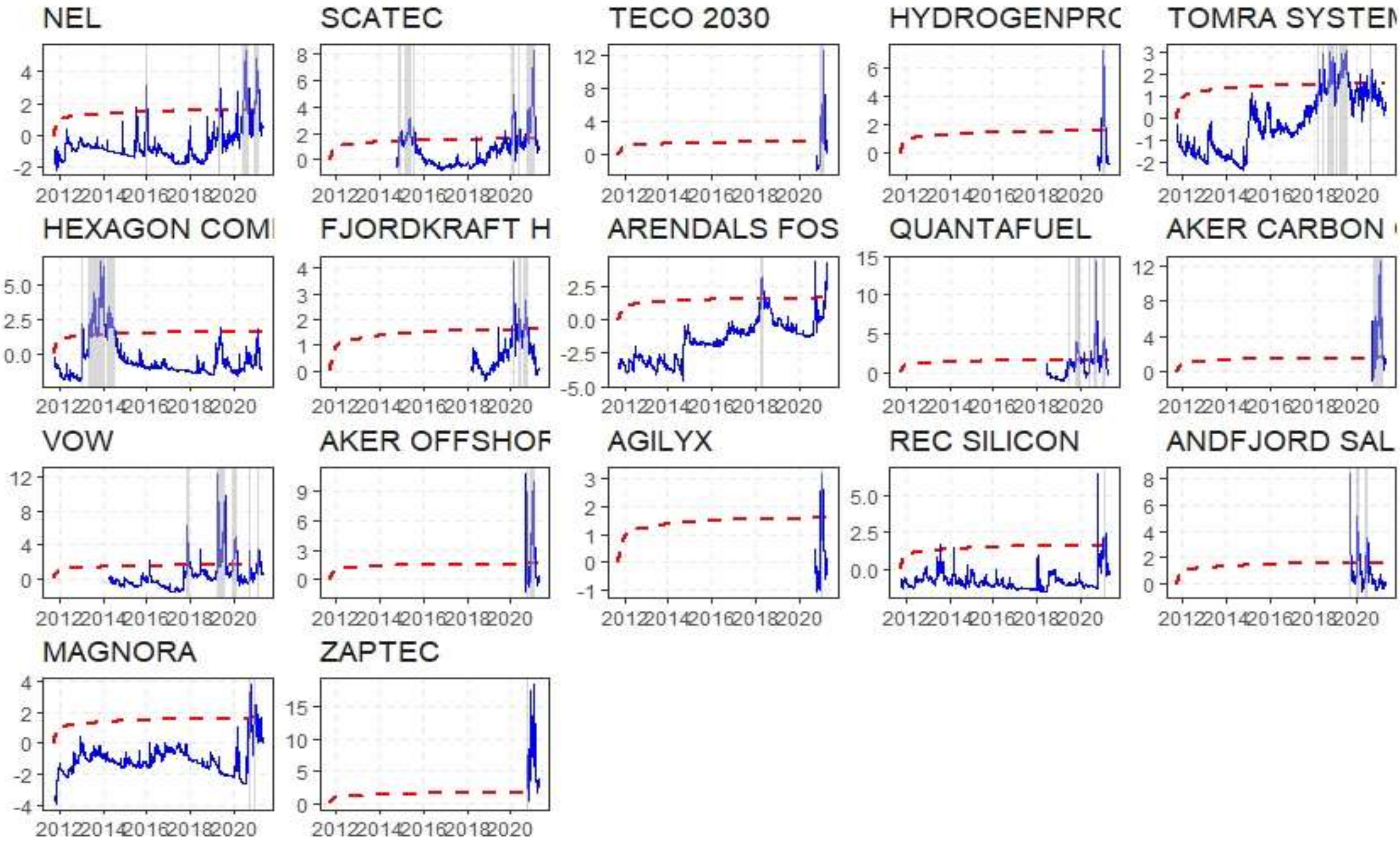

Figure 5.3 Plot of date-stamping, green stocks

5.3 Price-over-earnings ratio

The Price-over-earnings ratio is a well-known measure used by investors to determine the relative value of a company's stocks. The formula is simple and might be why it is so widespread among investors. What is a good, bad, or "normal" ratio is different between markets and periods. However, for extreme values, one can often conclude if a company is overpriced or underpriced.

$$^{P}/_{E}\ ratio = \frac{Market\ value\ per\ share}{Earnings\ per\ share} \tag{5.1}$$

Common characteristics in bubble formulation are a high PE ratio, high turnover, and irrational behavior (Liu et al., 2016). Table 5.8 present the PE ratios for the green stocks in the dataset. Many of them have a negative price-over-earnings ratio. Often, a negative value will not get reported since it tells us little about the price but tells us that the company does not have any earnings and is now losing equity. The fundamental value of a stock is the discounted cash flow of future earnings, and for most green stocks used in this thesis, there is today a long way to go before the price matches the earnings. The eight companies with a positive cash flow are priced substantially higher than the industry median.

Table 5.8 Price-earnings-ratios green stocks

	Price-earnings-ratio			Price-earnings-ratio	
Name	**Trailing 12 Months**	**Industry Median**	Name	**Trailing 12 Months**	**Industry Median**
NEL	40.97	-16.23	Aker Carbon Capture	-139.69	-0.21
Scatec	-315.80	6.61	Vow	109.10	17.09
TECO 2030	-1.90	-16.23	Aker Offshore Wind	-34.19	6.61
Hydrogenpro	-203.42	13.99	Agility	-28.56	17.09
Tomra	66.28	17.09	Rec Silicon	-22.39	-2.74
Borregaard	35.75	10.71	Andfjord Salmon	-99.79	13.99
Hexagon	-50.96	18.09	Salmon Evolution Holding	-75.49	13.99
Fjordkraft	14.24	6.61	Magnora	34.18	-0.21
Arendals F	472.81	-5.96	Zaptec	162.24	19.17
Atlantic Sapphire	-14.96	13.99	Cloudberry Clean Energy	-44.01	6.61
Quantafuel	-12.52	-16.23			

6 Discussion

As mentioned throughout this thesis, green investment is a hot topic of discussion as are concerns over a possible bubble. As discussed earlier, a complication is that it is challenging to detect bubbles before they burst, and this is, in fact, one of the possible reasons we experience asset bubbles. The results from the empirical analysis on stock prices, lessons from historical bubbles, and a closer look at the stages of bubble formation can help us to answer the main research question of this thesis.

Irrational exuberance does not necessarily cause a bubble and refers to investor enthusiasm that drives stock prices higher than the company's fundamental value. High stock prices might simply be mispriced stocks. Nevertheless, mispriced stocks are an indication of the possible development of a bubble. The bubble occurs when the mispricing holds over a long time and eventually bursts, affecting the rest of the economy (Siegel, 2003). A concern would be that the deviation from the true equilibrium price is a consequence of market participants following popular investment decisions trying to maximize their profit before it is too late. Optimistic investor sentiment can then increase the size of a developing bubble (Pan, 2020).

The results from the GSADF tests employed on the OSEBX rejected the null hypothesis of a unit root for both the period of 10 and 20 years. This means that there are episodes of exuberance in both periods. Date stamping the result, many episodes of exuberance were detected before 2009, but in the last ten years, only short episodes in March 2020 were detected. In summary, there is no indication of a bubble in the Norwegian market today. Despite an increase in the BSADF statistic after March last year, it is difficult to conclude that this reflects a bubble building and may result from the market's recovery after the Covid-19 shock.

The green stocks show tendencies that could develop into a bubble. There is no index for only green stock on Oslo Børs, but by comparing the portfolio of 21 listed green companies, the results show that 13 companies experienced episodes of exuberance in the last month of 2020 and the first months of 2021. With an average stock price increase of 67,7 % for all green companies in the period November to February, the media coverage and bubble increased. This might be one of the contributing factors to the decrease in some stocks the following month, but for the total portfolio of green stocks, the prices were steady at February prices in March also.

The history of asset bubbles is a helpful basis for comparison. With limited models to use detecting a bubble, history can help us to detect similarities. Before the Dot-Com bubble in the late 1990s, the political interest in and redirecting of government funds to, new technology snowballed. Today the focus on sustainability and the green shift permeates the public, as well as the private sector. As the digital revolution was a fact in the 1990s, the green and sustainable revolution take a position in today's market. The promoting of green and sustainable companies and products might create an overly optimistic investor base, and the fear of missing out on what could be a once-in-a-lifetime opportunity (Segal, 2021).

The fear of missing out, widespread media coverage and high market participation are also essential factors in the second stage in the Minsky model, the boom. In the time leading up to the burst of the Dot-Com bubble numerous technology stocks were traded solely on future value expectations, and companies were rushing to the stock exchanges to get listed before it was "too late". Norway, more specific Oslo Børs, have not experienced more IPOs the last year since before the Finance crisis in 2007, see Figure 2.1. In 2020 there were 58 IPOs and this year 35 new IPOs, including the main market and Euronext Growth Oslo before the first half of the year have gone by. Many new green companies have substantially increased in value and have price-over-earnings ratios many times the industry median or have negative ratios. For stocks with a negative PE ratio, they have no earnings to back up the price, and investors fully depend on this to change in the future.

It should be noted that there are also several differences between these two periods. In Norway and internationally, numerous articles have compared the pricing in green stock to the Dot-Com bubble. Nevertheless, as in every bubble or episode of exuberance, there are many differences. Because of the digital revolution, we now have access to a new technology. In 2021 almost everyone invested in the stock market has a phone to get information and buy and sell stocks quickly. This makes the shifts in the market happen at a much higher speed. In addition, the Norwegian and US market is operating in two different economies that also will impact the comparability.

The first stage in the Minsky model is displacement, where an opportunity in the economy opens. This can be a new technology, historical low interest rates, or other things that can change the outlook of the future. In the 1630s this was export of tulips from the Netherlands, in 2021 the opportunities are in green technology and companies, backed by low interest rates.

After the displacement and boom, the third stage is euphoria. When a bubble gets to this stage valuations reach extreme levels and spread from one country to others, and people become more cautious about stock prices. The green revolution or, "megatrend" (Smith, 2020) is already an international phenomenon, but for the Norwegian market the exuberance detected in the green stocks can spread to other parts of the market. Following the euphoria investors that already have been in the market and participated in the increase sell their positions to take profit in the profit-taking stage before the remaining market participants go into the panic stage.

For the Norwegian market today, there is no substantial indication that there is a bubble, but the results for green stocks from the ADF tests, historic events and the Minsky model might argue that there is a bubble developing. High prices, increases in IPOs, political interest, and media coverage are factors that can be involved in the inflationary phase of a bubble. Nevertheless, from what we have learned from all research and historic events in this field we cannot be sure we have a bubble before it eventually bursts.

7 Conclusion

The demand for environmentally sustainable investments is growing among market participants. Opportunities in green technology and companies are prominent in the media and politics, and the number of green stocks listed on Oslo Børs are increasing. Since the Covid-19 shock on the stock market last year, the Oslo Børs Benchmark Index (OSEBX) has recovered and reached an all-time high. Simultaneously, green stocks have increased substantially in the last months. Despite that, many green companies still do not have a positive cash flow and are losing equity.

This thesis investigates if we have a green bubble in the Norwegian stock market. First, it provided a brief introduction to today's market and the history of financial bubbles. Every asset bubble is different from another, but they share many of the same features. Second, a selection of literature on asset price bubbles and the models used to detect bubbles in stock prices were presented. While several methodical advantages have occurred over the last years, testing for and dating periods of exuberance remains a topic of ongoing econometric research.

By employing recursive augmented Dickey-Fuller tests to the OSEBX and a dataset consisting of 21 different individual green stocks, there were episodes of exuberance in all of them. As for the OSEBX, no significant results are indicating a bubble in the Norwegian market today. However, many of the green stock show episodes of exuberance since November 2020, together with a significant increase in the stock prices. In addition, the interest in sustainability and green investments in all parts of society and low interest rates make a foundation for a bubble to develop. There are indications of a bubble in green stocks, but this has not affected the main market, and we will not know with certainty if there is a bubble before it bursts.

The main limitations of this study relate to the sample size and the maturity of the model. Green stocks limit the available data for analysis because this is a new field and many of the green stocks are listed in the last years. The recursive ADF tests are new models have gained much attention after first published but are still relatively new and will probably get more precise and better as new research develops these further. Another concern is that they have difficulties discovering bubbles that have not yet reached their peak and burst.

The scope of a master's thesis is, of course, limited. However, this study raises opportunities for future research. The general field of asset bubbles has not yet had a breakthrough that gives a standard solid framework to detect bubbles. A model might also include economic factors and behavioral finance and separate an episode of exuberance from a bubble. The answer to the research question also gives possibilities to look closer into the datasets already presented and might include the Euronext Growth Index. If prices continue to increase, new models and the test employed in this thesis could be of interest.

References

AksjeNorge. (2021, April 4). *Over 500.000 eier aksjer* [Over 500.000 owns stocks]. https://aksjenorge.no/aktuelt/2021/04/09/vekst_q1/

Berk, J. & DeMarzo. (2017). *Corporate finance* (4th ed.). Pearson Education Limited.

Bjørnestad, S. (2021, March 17). Folk flest tar innpå, men henger fortsatt etter proffene i fondssparing. [Most people catch up but are still far behind professionals in fund savings] *E24*. https://e24.no/privatoekonomi/i/AlGjpz/folk-flest-tar-innpaa-men-henger-fortsatt-etter-proffene-i-fondssparing

Blanchard, O. J, & Watson, M. W. (1982). *Bubbles, Rational Expectations and Financial Markets*. https://doi.org/10.3386/w0945

Broad, W. J. (1992, November 10). Clinton to Promote High Technology, With Gore in Charge. *The New York Times.* https://www.nytimes.com/1992/11/10/science/clinton-to-promote-high-technology-with-gore-in-charge.html

Brown, J. (2021, February 11). The Secret to Investing in 2021? Look To the 2000 Dot-Com Bubble. *Forbes*. https://www.forbes.com/sites/investor/2021/02/11/the-secret-to-investing-in-2021-look-to-the-2000-dot-com-bubble/?sh=1b5d4e594c93

Chancellor, E. (2019, December 12). Breakingviews – Chancellor: A 300-year bubble worth remembering. *Reuters*. https://www.reuters.com/article/us-england-finance-breakingviews-idUSKBN1YG2NH

Cooper, G. (2008). *The Origin of Financial Crises: Central Banks, Credit Bubbles and the Efficient market Fallacy*. Harriman House LTD.

Evans, G. W. (1991). Pitfalls in Testing for Explosive Bubbles in Asset Prices. *The American Economic Review*, *81*(4), 922-930.

Fama, E. F. (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *The Journal of Finance, 25*(2), 383-417.

Finansdepartementet. (2020, October 30). *Høring – Forslag til ny lov om opplysninger om bærekraft*. https://www.regjeringen.no/no/dokumenter/horing-forslag-til-ny-lov-om-opplysninger-om-barekraft/id2781264/?expand=horingssvar

Goodnight, G. T. & Green, S. (2010). Rhetoric, Risk, and Markets: The Dot-Com Bubble. *Quarterly Journal of Speech, 96*(2), 115-140. http://doi.org/10.1080/00335631003796669

Hayes, A. (2021, January 26). *Irrational Exuberance*. Investopedia. Retrieved April 25, 2021, from https://www.investopedia.com/terms/i/irrationalexuberance.asp

Hayes, A. (2019, June 25). *Dotcom Bubble*. Investopedia. Retrieved April 23, 2021, from https://www.investopedia.com/terms/d/dotcom-bubble.asp

Karimov, A. (2017). *Identifying Stock Market Bubbles*. Springer International Publishing. https://doi.org/10.1007/978-3-319-65009-8

Kindleberger, C. P., & Aliber, R. Z. (2005). *Manias, panics and crashes: a history of financial crises* (5th ed.). Palgrave Macmillan

Knell, M. (2015). Schumpeter, Minsky and the financial instability hypothesis. *Journal of Evolutionary Economics*, *25*(1), 293–310. https://doi.org/10.1007/s00191-014-0370-8

Kohn, M. H. & Pereira, P. L. V. (2017) Speculative bubbles and contagion: Analysis of volatility's clusters during the DotCom bubble based on the dynamic conditional correlation model. *Contingent Economics & Finance, 5*(1), 1411453. https://doi.org/10.1080/23322039.2017.1411453

Krueger, A. B. (2005). Economists Try to Explain Why Bubbles Happen. *The New York Times*. https://www.nytimes.com/2005/04/28/business/economists-try-to-explain-why-bubbles-happen.html

Li, Z-Z., Tao, R., Su, C-W. & Lobont, O-R. (2019). Does Bitcoin bubble burst? *Qual Quant*, 53, 91-105.

Liu, Z., Han, D. & Wang, S. (2016). Testing Bubbles: Exuberance and collapse in the Shanghai A-share stock market. In L. Song, R. Garnaut, C. Fang & L. Johnston (Ed.), *China's New Sources of Economic Growth: Vol. 1: Reform, Resources and Climate Change* (pp. 247-270). ANU Press.

Lorch-Falch, S. & Sættem, J. B. (2021, November 5). NHH-professor frykter grønn børsboble: -Kan skje en kraftig korreksjon [Professor at NHH is worried about a green Stock Exchange bubble: - A powerful correction can happen]. *NRK.* 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: Journal of the Econometric Society*, 46(6), 1429-1445.

Malkiel, B. G. (2003). The Efficient Market Hypothesis and Its Critics. *Journal of Economic Perspectives*, 17(1), 59-82.

Nilsen, A. A. (2021, January 6). 2021 kan gi nytt børsrush: - Ekstemt høy aktivitet [2021 can bring a new Stock Exchange rush: - Extremely high activity]. *E24*. https://e24.no/boers-og-finans/i/41bX6q/2021-kan-gi-nytt-boersrush-ekstremt-hoey-aktivitet

OECD (2020). *Developing Sustainable Finance Definitions and Taxonomies, Green Finance and Investment*, OECD Publishing. https://doi.org/10.1787/134a2dbe-en

Ofek, E. & Richardson, M. (2003). DotCom Mania: The Rise and Fall of Internet Stock Prices. *The Journal of Finance*. *58*(3), 1113-1137. https://doi.org/10.1111/1540-6261.00560

Oslo Børs (2020, October 14). *Dobling for grønne aksjer* [Green stocks doubles]. https://www.oslobors.no/layout/set/print/Oslo-Boers/Om-Oslo-Boers/Nyheter-fra-Oslo-Boers/Dobling-for-groenne-aksjer

Pan, W. (2020). Does Investor Sentiment Drive Stock Market Bubbles? Beware of Excessive Optimism! *Journal of Behavioral Finance, 21*(1), 27-41.

Pavlidis, E., Yusupova, A., Paya, I., Peel, D., Martínez-García, E., Mack, A. & Grossman, V. (2016). Episodes of Exuberance in Housing Markets: In Search of the Smoking Gun. *The Journal of Real Estate Finance and Economics*, *53*(4), 419–449. https://doi.org/10.1007/s11146-015-9531-2

Penman, S. H. (2013). *Financial Statement Analysis and Security Valuation* (5th ed.). McGraw-Hill Education.

Phillips, M. (2020, December 26). Market Edges Toward Euphoria, Despite Pandemic's Troll. *The New York Times*. https://www.nytimes.com/2020/12/26/business/investors-bull-market-pandemic.html

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. https://doi.org/10.1111/j.1468-2354.2010.00625.x

Philips, P. C. B., Shi, S. & Yu, J. (2015). Testing for Multiple Bubbles: Historical episodes of exuberance and collapse in the S&P 500. *International Economic Review, 56*(4), 1043-1078. https://doi.org/10.1111/iere.12132

Pirie, S. & Chan, R. K. T. (2016). Following momentum and avoiding the "Minsky Moment" evidence from investors on the Financial Instability Hypothesis. *Qualitative Research in Financial Markets*, *8*(3), 205–217. https://doi.org/10.1108/QRFM-08-2015-0034

Porras, E. (2016). *Bubbles & Contagion in Financial Markets, Volume 1: An Integrative View*. Palgrave Macmillan.

Regjeringen (2020, December 31). Arbeidet med bærekraftsmålene [The work on the sustainability goals]. https://www.regjeringen.no/no/tema/fns-barekraftsmal/innsikt/sdg/id2483062/

Richardson, G., Komai, A., Gou, M. & Park, D. (2013, November 22). Stock Market Crash of 1929. *Federal Reserve History*. https://www.federalreservehistory.org/essays/stock-market-crash-of-1929

Ritter, J. (2008, December 15). *Some Factoids About the 2008 IPO Market*. https://people.bath.ac.uk/mnsrf/Teaching%202011/IB/Literature/IPOs2008Factoids.pdf

Shiller, R. J. (2005). *Definition of Irrational Exuberance.* Irrational Exuberance. http://www.irrationalexuberance.com/definition.htm

Segal, T. (2021, March 11). *5 Stages of A Bubble*. Investopedia. https://www.investopedia.com/articles/stocks/10/5-steps-of-a-bubble.asp

Siegel, J. J. (2003). What is an Asset Price Bubble? An Operational Definition. *European Financial Management, 9*(1), 11-24.

The Federal Reserve Board. (1996, December 6). *Remarks by Chairman Alan Greenspan*. https://www.federalreserve.gov/BOARDDOCS/SPEECHES/19961205.htm

United Nations. (2015). Paris Agreement. https://unfccc.int/sites/default/files/english_paris_agreement.pdf

Vasilopoulos, K., Pavlidis, E. & Martínez-García, E. (2020). *exuber: Recusive Right-Tailed Unit Root Testing with R*. Economic Working Paper Series No. 2020/007. Lancaster University Management School. Available at: https://eprints.lancs.ac.uk/id/eprint/143989/1/LancasterWP2020_007.pdf

Weinberg, J. (2013, November 22). The Great Recession and its Aftermath. https://www.federalreservehistory.org/essays/great-recession-and-its-aftermath

World Economic Forum (2013). *The Green Invest Report.* http://www3.weforum.org/docs/WEF_GreenInvestment_Report_2013.pdf

.

A Appendix

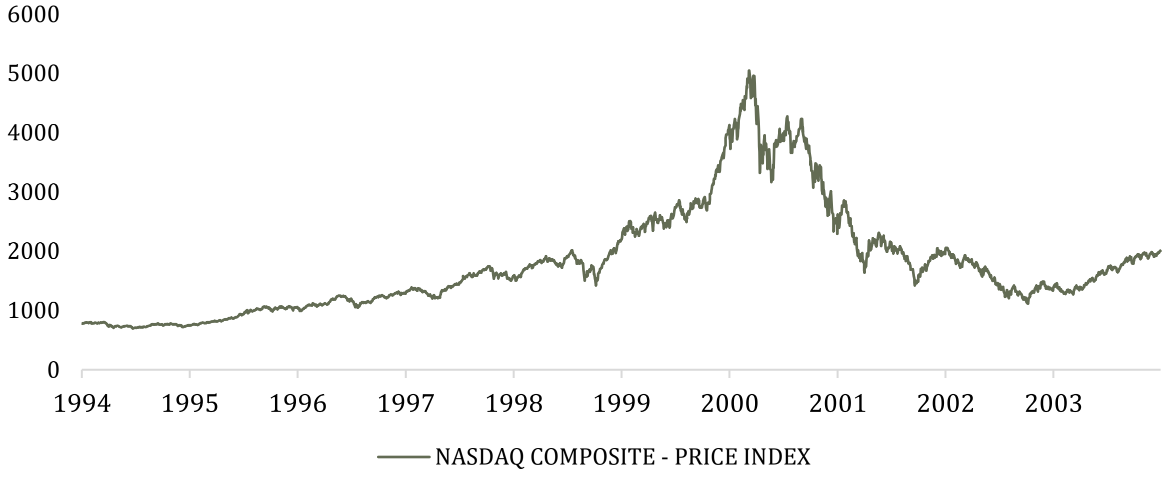

Figure A.1 Nasdaq Index 1994-2003

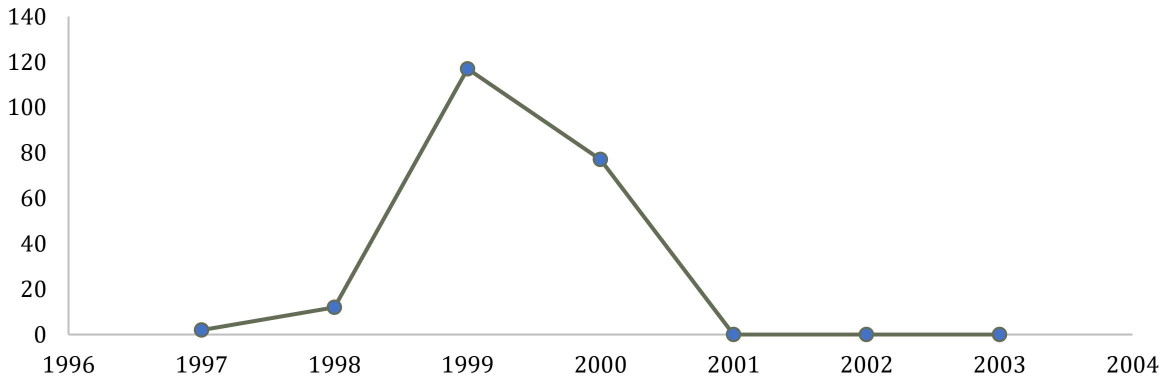

Figure A.2 Number of U. S. IPOs with an offer price of greater than $5.00 that doubled (offer to close) in price on the first day of trading

Table A.1 Overview green stocks

Ticker	Name	Industry	Market value*	Market
NEL	NEL	Renewable Fuels	36 811 334 547	OSE
SCATC	Scatec	Independent Power Producers	42 098 964 770	OSE
TECO	TECO 2030	Renewable Energy Equipment & Services	1 109 800 000	EG
HYPRO	Hydrogenpro	Fishing & Farming	2 108 579 888	EG
TOM	Tomra Systems	Environmental Services & Equipment	59 356 051 278	OSE
BRG	Borregaard	Specialty Chemicals	18 220 000 000	OSE
HEX	Hexagon Composites	Non-Paper Containers & Packaging	8 988 206 761	OSE
FKRFT	Fjordkraft Holding	Electric Utilities	8 005 440 090	OSE
AFK	Arendals Fossekompani	Leisure & Recreation	17 358 527 500	OSE
ASA	Atlantic Sapphire	Fishing & Farming	7 264 219 590	OSE
QFUEL	Quantafuel	Renewable Fuels	6 320 520 257	EG
ACC	Aker Carbon Capture	Oil Related Services and Equipment	9 328 675 392	EG
VOW	Vow	Environmental Services & Equipment	4 922 315 200	OSE
AOW	Aker Offshore Wind	Electric Utilities	4 832 667 768	EG
AGLX	Agilyx	Environmental Services & Equipment	2 679 804 059	EG
RECSI	Rec Silicon	Software	6 841 220 527	OSE
ANDF	Andfjord Salmon	Fishing & Farming	1 854 020 420	EG
SALME	Salmon Evolution Holding	Fishing & Farming	1 769 896 219	EG
MGN	Magnora	Oil Related Services and Equipment	1 481 036 020	OSE
ZAP	Zaptec	Electrical Components & Equipment	3 705 236 158	EG
CLOUD	Cloudberry Clean Energy	Electric Utilities	1 536 055 212	EG

**Market value from April 15, 2021*

Table A.2 Episodes of exuberance with duration over 4, 20 years OSEBX

	Start	End	Duration
1	24.07.2002	25.07.2002	1
2	18.09.2002	03.10.2002	11
3	18.08.2003	20.08.2003	2
4	21.08.2003	25.08.2003	2
5	01.09.2003	10.09.2003	7
6	06.01.2004	15.03.2004	49
7	17.03.2004	19.03.2004	2
8	02.04.2004	14.04.2004	8
9	04.10.2004	06.10.2004	2
10	07.10.2004	11.10.2004	2
11	17.01.2005	19.01.2005	2
12	02.02.2005	30.03.2005	40
13	31.03.2005	15.04.2005	11
14	10.06.2005	13.10.2005	89
15	03.11.2005	08.11.2005	3
16	22.11.2005	24.11.2005	2
17	25.11.2005	22.05.2006	126
18	23.05.2006	24.05.2006	1
19	26.05.2006	07.06.2006	8
20	18.12.2006	04.01.2007	13
21	15.01.2007	17.01.2007	2
22	18.01.2007	27.02.2007	28
23	23.03.2007	26.03.2007	1
24	29.03.2007	30.03.2007	1
25	02.04.2007	12.04.2007	8
26	13.04.2007	18.04.2007	3
27	20.04.2007	11.05.2007	15
28	14.05.2007	26.07.2007	53
29	08.10.2008	09.10.2008	1
30	10.10.2008	13.10.2008	1
31	16.10.2008	17.10.2008	1
32	27.10.2008	29.10.2008	2
33	12.03.2020	19.03.2020	5
34	23.03.2020	24.03.2020	1

Table A.3 GSADF hypothesis test green stocks

NEL	Rejects H_0 at the 1% significance level
Scatec	Rejects H_0 at the 1% significance level
TECO 2030	Rejects H_0 at the 1% significance level
Hydrogenpro	Rejects H_0 at the 1% significance level
Tomra	Rejects H_0 at the 1% significance level
Borregaard	Cannot reject H_0
Hexagon	Rejects H_0 at the 1% significance level
Fjordkraft	Rejects H_0 at the 1% significance level
Arendals Fossekompani	Rejects H_0 at the 1% significance level
Atlantic Sapphire	Rejects H_0 at the 10% significance level
Quantafuel	Rejects H_0 at the 1% significance level
Aker Carbon	Rejects H_0 at the 1% significance level
Vow	Rejects H_0 at the 1% significance level
Aker Offshore	Rejects H_0 at the 1% significance level
Agility	Rejects H_0 at the 1% significance level
Rec Silicon	Rejects H_0 at the 1% significance level
Andfjord Salmon	Rejects H_0 at the 1% significance level
Salmon Evolution Holding	Cannot reject H_0
Magnora	Rejects H_0 at the 1% significance level
Zaptec	Rejects H_0 at the 1% significance level
Cloudberry Clean Energy	Cannot reject H_0

Table A.4 Periods of exuberance in green stocks between 2011-2021

NEL	**Start**	**End**	**Duration**
1	30.06.2015	01.07.2015	1
2	03.07.2015	06.07.2015	1
3	10.07.2015	15.07.2015	3
4	09.12.2015	10.12.2015	1
5	22.12.2015	05.01.2016	10
6	02.05.2019	31.05.2019	21
7	17.02.2020	24.02.2020	5
8	26.05.2020	10.08.2020	54
9	11.08.2020	14.09.2020	24
10	12.10.2020	13.10.2020	1
11	19.11.2020	25.11.2020	4
12	26.11.2020	03.12.2020	5
13	04.12.2020	18.02.2021	54
14	19.02.2021	22.02.2021	1
SCATEC	**Start**	**End**	**Duration**
1	18.11.2014	21.11.2014	3
2	24.11.2014	14.01.2015	37
3	20.02.2015	23.02.2015	1
4	24.02.2015	18.06.2015	82
5	22.06.2015	24.06.2015	2
6	25.06.2015	29.06.2015	2
7	08.07.2015	14.08.2015	27
8	11.06.2018	13.06.2018	2
9	03.09.2019	10.09.2019	5
10	18.09.2019	18.10.2019	22
11	27.12.2019	06.01.2020	6
12	15.01.2020	11.03.2020	40
13	17.04.2020	21.04.2020	2
14	22.04.2020	24.04.2020	2
15	07.05.2020	28.05.2020	15
16	29.05.2020	08.06.2020	6
17	25.08.2020	04.09.2020	8
18	15.09.2020	21.09.2020	4
19	22.09.2020	28.10.2020	26
20	30.10.2020	22.02.2021	81
21	11.03.2021	12.03.2021	1
TECO 2030	**Start**	**End**	**Duration**
1	08.12.2020	09.12.2020	1
2	11.12.2020	29.01.2021	35
3	01.02.2021	18.03.2021	33
4	06.04.2021	09.04.2021	3

HydrogenPro	Start	End	Duration
1	30.11.2020	02.12.2020	2
2	18.12.2020	16.02.2021	42
Tomra Systems	**Start**	**End**	**Duration**
1	28.03.2018	19.04.2018	16
2	24.04.2018	25.04.2018	1
3	23.05.2018	28.06.2018	26
4	29.06.2018	02.07.2018	1
5	03.07.2018	06.07.2018	3
6	09.07.2018	12.07.2018	3
7	20.08.2018	10.12.2018	80
8	12.12.2018	14.12.2018	2
9	31.01.2019	05.08.2019	132
10	06.08.2019	14.08.2019	6
11	16.08.2019	26.08.2019	6
12	16.12.2019	17.12.2019	1
13	20.02.2020	25.02.2020	3
14	23.04.2020	24.04.2020	1
15	27.04.2020	29.04.2020	2
16	19.05.2020	27.05.2020	6
17	03.08.2020	04.09.2020	24
18	28.09.2020	02.10.2020	4
19	09.10.2020	20.10.2020	7
Borregaard	**Start**	**End**	**Duration**
	NA	NA	NA
Hexagon Composites	**Start**	**End**	**Duration**
1	17.01.2013	23.01.2013	4
2	04.02.2013	06.02.2013	2
3	08.05.2013	29.05.2013	15
4	30.05.2013	24.06.2013	17
5	25.06.2013	26.06.2013	1
6	27.06.2013	25.09.2013	64
7	26.09.2013	01.10.2013	3
8	02.10.2013	21.02.2014	102
9	06.03.2014	07.03.2014	1
10	10.03.2014	19.06.2014	73
11	20.06.2014	25.07.2014	25
12	28.07.2014	29.07.2014	1
13	08.05.2019	14.05.2019	4
14	18.01.2021	21.01.2021	3
Fjordkraft Holding	**Start**	**End**	**Duration**
1	03.06.2019	04.06.2019	1
2	31.01.2020	12.03.2020	29
3	07.04.2020	08.04.2020	1
4	14.04.2020	24.04.2020	8

5	07.05.2020	08.05.2020	1
6	11.05.2020	09.06.2020	21
7	10.06.2020	11.06.2020	1
8	15.06.2020	23.06.2020	6
9	24.06.2020	25.06.2020	1
10	26.06.2020	29.06.2020	1
11	21.07.2020	24.07.2020	3
12	04.08.2020	05.08.2020	1
13	12.08.2020	25.09.2020	32
14	28.09.2020	20.10.2020	16
Arendal Fossekompani	**Start**	**End**	**Duration**
	NA	NA	NA
Atlantic Sapphire	**Start**	**End**	**Duration**
	NA	NA	NA
Quantafuel	**Start**	**End**	**Duration**
1	21.06.2019	25.06.2019	2
2	26.06.2019	02.07.2019	4
3	03.07.2019	04.07.2019	1
4	25.07.2019	29.07.2019	2
5	26.09.2019	27.09.2019	1
6	30.09.2019	02.01.2020	68
7	03.01.2020	06.01.2020	1
8	09.01.2020	10.01.2020	1
9	17.01.2020	27.01.2020	6
10	29.01.2020	04.02.2020	4
11	12.02.2020	25.02.2020	9
12	08.06.2020	24.06.2020	12
13	25.06.2020	10.07.2020	11
14	17.07.2020	23.07.2020	4
15	27.07.2020	28.07.2020	1
16	05.08.2020	20.10.2020	54
17	22.10.2020	23.10.2020	1
18	05.11.2020	13.11.2020	6
19	17.12.2020	23.02.2021	48
20	25.02.2021	26.02.2021	1
21	02.03.2021	03.03.2021	1
Aker Carbon Capture	**Start**	**End**	**Duration**
1	27.08.2020	28.08.2020	1
2	17.09.2020	18.09.2020	1
3	21.09.2020	29.09.2020	6
4	05.10.2020	26.10.2020	15
5	03.11.2020	25.02.2021	82
6	26.02.2021	03.03.2021	3
7	11.03.2021	15.03.2021	2
8	06.04.2021	07.04.2021	1

9	15.04.2021	NA	1
VOW	**Start**	**End**	**Duration**
1	10.02.2016	18.02.2016	6
2	31.10.2017	29.11.2017	21
3	30.11.2017	13.12.2017	9
4	27.12.2017	05.01.2018	7
5	06.06.2018	15.06.2018	7
6	28.03.2019	29.04.2019	22
7	30.04.2019	16.05.2019	12
8	21.05.2019	14.08.2019	61
9	20.08.2019	21.08.2019	1
10	30.08.2019	03.09.2019	2
11	22.11.2019	25.11.2019	1
12	27.11.2019	03.12.2019	4
13	09.12.2019	26.02.2020	57
14	11.09.2020	21.09.2020	6
15	23.09.2020	24.09.2020	1
16	06.01.2021	11.01.2021	3
17	19.01.2021	20.01.2021	1
18	04.02.2021	08.03.2021	22
19	09.03.2021	15.03.2021	4
20	16.03.2021	17.03.2021	1
21	18.03.2021	24.03.2021	4
Aker Offshore Wind	**Start**	**End**	**Duration**
1	27.08.2020	28.08.2020	1
2	17.09.2020	29.09.2020	8
3	30.09.2020	13.10.2020	9
4	19.11.2020	22.02.2021	67
Agilyx	**Start**	**End**	**Duration**
1	16.12.2020	23.12.2020	5
2	28.12.2020	29.12.2020	1
3	08.01.2021	12.02.2021	25
Rec Silicon	**Start**	**End**	**Duration**
1	16.07.2013	19.07.2013	3
2	07.03.2014	12.03.2014	3
3	12.10.2020	20.10.2020	6
4	23.12.2020	29.12.2020	4
5	07.01.2021	08.01.2021	1
6	19.01.2021	22.01.2021	3
7	08.02.2021	18.02.2021	8
Andfjord Salmon	**Start**	**End**	**Duration**
1	28.08.2019	17.09.2019	14
2	04.10.2019	09.10.2019	3
3	11.12.2019	26.02.2020	55
4	19.05.2020	09.06.2020	15

5	11.06.2020	25.06.2020	10
Salmon Evolution Holding	**Start**	**End**	**Duration**
	NA	NA	NA
Magnora	**Start**	**End**	**Duration**
1	10.09.2020	24.09.2020	10
2	28.09.2020	13.10.2020	11
3	23.11.2020	27.11.2020	4
4	30.11.2020	08.12.2020	6
5	09.12.2020	07.01.2021	21
6	02.02.2021	04.02.2021	2
7	12.03.2021	15.03.2021	1
8	18.03.2021	19.03.2021	1
Zaptec	**Start**	**End**	**Duration**
1	07.10.2020	28.10.2020	15
2	30.10.2020	NA	120
Cloudberry Clean Energy	**Start**	**End**	**Duration**
	NA	NA	NA

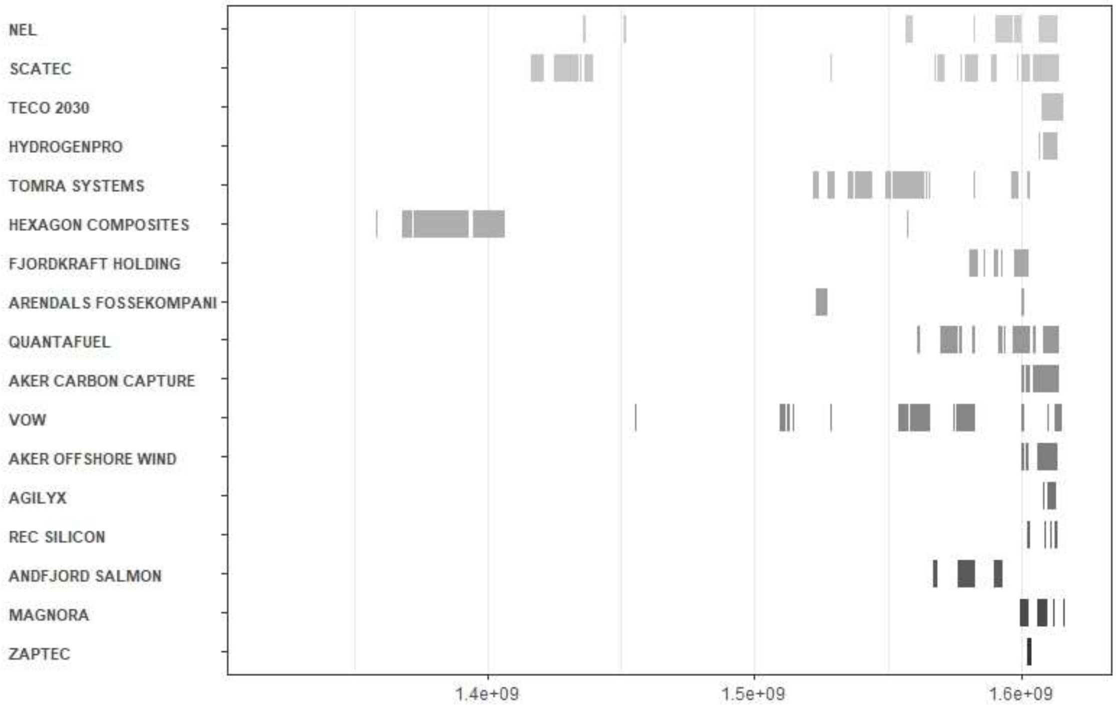

Figure A.3 Chronology of the identified periods of exuberance for each stock

NTNU
Norwegian University of Science and Technology