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LONG- AND SHORT-TERM DYNAMICS OF NORDIC ESG EQUITY MARKETS: COINTEGRATION ANALYSIS & GRANGER CAUSALITY

Master's Thesis

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Declaration

I declare that this thesis has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a degree. Except where states otherwise by reference or acknowledgment, the work presented is entirely my own.

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ABSTRACT OF THE MASTER'S THESIS

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Abstract

As concerns about climate change intensify, there is a growing interest in sustainable and environmentally responsible investments. This thesis investigates the long- and short-term dynamics of Nordic Environmental, Social, and Governance (ESG) equity markets, aiming to determine the potential for diversification within the equities markets for socially responsible investors. Utilizing cointegrating analysis using vector autoregressive (VAR) modeling and Granger causality analysis, the study examines the existence of cointegration relationships between and predictive power of ESG indices in Denmark, Norway, Sweden, and Finland.

Motivated by the growing cooperation in sustainable finance across the Nordic region, this research addresses the need to understand the interconnectedness of these markets and the associated risks for socially responsible investors. Despite a growing body of research on overall stock market index cointegration, there remains a gap in the literature concerning ESG market dynamics within the Nordic context.

Findings reveal the absence of cointegrating relationships among Nordic ESG equity markets, consistent with prior studies in other regions. However, Granger causality tests demonstrate the predictive power of certain ESG stock indices, indicating unidirectional predictability of returns between Swedish ESG markets and those of Denmark and Finland, Denmark and Norway, and Norway and Sweden.

This study contributes to the literature by extending empirical research on ESG markets in the Nordic region and on a broader scale on socially responsible investing. For investors, it highlights diversification opportunities within Nordic ESG markets, aiding in portfolio management and risk mitigation. For policymakers, it underscores the importance of monitoring market dynamics for crafting effective policies to foster sustainable financial systems.

Keywords Socially Responsible Investing (SRI), Environmental, Social, and Governance (ESG), Johansen cointegration, unconditional correlation, Vector Autoregressive (VAR) model, Granger causality.

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1 INTRODUCTION

This thesis is written as part of the assessment of the degree Master of Science (Economics and Business Administration) majoring in Finance. The purpose of this thesis is to identify if equity investors focusing on socially responsible investing or sustainable and responsible investing (SRI) has the opportunity for long term diversification within the Nordic environmental, social, and governance (ESG) equity markets by looking into the existence of a cointegrating relationship between Nordic ESG indices using vector autoregressive (VAR) model and Granger causality between the indices.

In recent years, there has been a noticeable paradigm shift in the realm of finance, with investors increasingly considering ESG factors in their decision-making processes (Abhayawansa & Mooneeapen, 2022; Dauggaard & Ding, 2022; Li et al., 2021; & Matos, 2020). This burgeoning trend toward SRI, which has its origins in religious-led exclusionary practice (Martini, 2021 & Renneboog et al., 2008), reflects a broader societal consciousness regarding corporate responsibility and sustainability. Scholars attribute this heightened interest to corporate scandals such as 2001 Enron Corporation accounting fraud, the 2010 Deepwater Horizon oil spill, the 2015 Volkswagen emissions test cheating, and the 2018 Facebook data privacy scandal (Matos, 2020); climate change leading to divestments by institutional investors for example divestments from coal by French financial services multinational AXA and the Norwegian Sovereign Wealth Fund (Ibikunle & Steffen, 2017); global financial crises (Abhayawansa & Mooneeapen, 2022); international efforts such as United Nations Sustainable Development Goals (Plastun et al., 2020); and COVID 19 pandemic and its aftershocks and recent European energy crisis due to Ukraine war (Rau & Yu, 2024). The current calls across university campuses in USA, that started in Columbia University, for 'complete divestments' in Israel (Valinsky, 2024) is another example of stakeholders' interest in weaving social responsibility into investment decisions.

According to European Sustainable Investment Forum (Eurosif) (n.d.) 'Sustainable and responsible investing (SRI) is a long-term oriented investment approach which integrates ESG factors in the research, analysis and selection process of securities within an investment portfolio.' Investors who embrace SRI aim to generate financial returns while also promoting positive change within their physical investible universe. Busch's et al. (2022) classification scheme for sustainable investment propose various ways that an investment can be classified as sustainable or not, while allowing for capacity of companies transitioning towards sustainability. According to this classification, a socially responsible investor could exclude or include a company based on five dimensions. These dimensions include general characteristics such as ambition level, main objective, and materiality; pre-investment strategies such as negative screening (by excluding companies involved in controversial activities, e.g., tobacco, weapons, fossil fuels, and norms based screening) and positive screening (ESG integration, best-in-class/best-in-universe/best-in-progress, and sustainability themed); post-investment strategies (engagement and voting); performance measurement (KPIs); and documentation (objective, pre-investment, post-investment, performance measurement and external verification).

ESG criteria serve as the foundational pillars of SRI, guiding investors in assessing the sustainability and ethical impact of their investment choices. While there is no definitive taxonomy of ESG factors (Clément et al., 2023 & CFA Institute, 2024), CFA Institute has given examples of issues that can be classified under these pillars: Environmental (E) factor focuses on conservation of the natural world. It considers issues such as climate change and carbon emissions, air and water pollution, biodiversity, deforestation, energy efficiency, waste management and water scarcity. Social (S) factor focuses on consideration of people and relationships. This includes customer satisfaction, data protection and privacy, gender diversity, employee engagement, community relations, human rights and labor standards. Governance (G) factor evaluated the standards of running a company. This includes board composition, audit committee structure, bribery and corruption, executive compensation, lobbying, political contributions and whistleblower schemes. Eccles et al., (2014) state that 'high sustainability companies' contribute to long-term value creation. Companies that prioritize ESG factors tend to be more resilient (Eccles et al., 2014 & Liu & Nemoto, 2021), attract better talent (Liu & Nemoto, 2021), and foster positive relationships with stakeholders (Eccles et al., 2014).

To evaluate companies' ESG performance, specialized rating agencies, index providers, and research firms employ diverse methodologies to assess corporate ESG performance and provide ESG scores (Clément et al., 2023 & Fichtner et al., 2023). They rely on both quantitative and qualitative metrics based on financial data, disclosures, policies and practices, and performance metrics that measure the actual impact and progress of company's activities that can be classified as ESG (Rau & Yu, 2022). Notably, over 150 rating agencies offer ESG scores for publicly traded companies globally (Fichtner, 2023). Commonly used rating agencies/index providers include MSCI, S&P Dow Jones Indices, FTSE Russel, Bloomberg Indices and JP Morgan (Fichtner, 2023). The ratings are used by investors to make informed decisions of a company's commitment to sustainability and responsible practices (Fichtner, 2023) by quantifying ESG factors and providing a comparative framework upon which investment decisions are made. This thesis use Nasdaq, Euronext and S&P Dow Jones ESG ratings as these are the index providers under study.

The academic discourse surrounding ESG dates back four decades, with early studies primarily focusing on the social and ethical implications of investment decisions (Pour et al., 2014). Scholars examined the relationship between corporate social responsibility (CSR) practices and financial performance, debating whether responsible business practices translate into tangible economic benefits for firms and their investors. Notable contributions include the seminal works of Moskowitz (1972) (cited in Chochran & Wood, 1984) and Margolis and Walsh (2001), who laid the groundwork for understanding the linkages between corporate behavior and financial outcomes.

In recent years, academic research on ESG has expanded significantly, driven by heightened investor interest and regulatory mandates. Scholars have explored diverse aspects of ESG investing, exploring topics such as the financial materiality (Crona et al. 2021) of ESG ratings, financial performance of asset classes and indices (Polbennikov et al., 2016 & Torre et al., 2020), modeling volatility of socially responsible investments (Sadorsky, 2014), integration of various stock markets (Kasibhatla et al., 2006, Dengjun, 2015, Torre et al., 2020, Maysami et al., 2005, Joshi et al., 2021 & Chou et al., 1994) and the role of institutional investors in promoting sustainability (García-Sánchez et al., 2020).

This thesis uses cointegration analysis to evaluate the long-term dynamics of Nordic ESG indices. Cointegration, a concept rooted in econometrics, has emerged as a pivotal tool for analyzing the long-term relationships among economic and financial variables (Brooks, 2019). Its application spans across various fields within economics and finance, offering insights into the interconnectedness and dynamics of markets. Markets that do no exhibit characteristics of co-movement are important for investors in diversifying their investments.

For the purpose of this thesis, the debate surrounding sustainability being equal to ESG scores (Clément et al., 2023 & Fichtner, 2023), low correlation between different ESG scores/ratings (Berg et al., 2022), and interchangeable use of CSR and ESG, and their differences are not considered (Rau & Yu, 2022). This thesis views CSR as a business initiative while ESG includes CSR plus governance and SRI is viewed from the perspective of investors (Rau & Yu, 2023 & Scholtens & Sievänen, 2013).

Cointegration, introduced by Granger (1981) and further developed by Engle and Granger (1987), refers to the long-term equilibrium relationship between non-stationary time series variables. Unlike correlation, which merely captures short-term associations, cointegration implies a connection where any deviation from equilibrium is temporary, leading to a return to the long-term relationship.

Cointegration has found extensive applications in various economic and financial domains. In macroeconomics, it is utilized to analyze the relationship between key economic indicators such as GDP, inflation, and unemployment. In finance, cointegration is employed to examine the long-term equilibrium relationships among asset prices, such as stock markets and exchange rates. Moreover, it plays a crucial role in assessing market efficiency, asset pricing models, and portfolio diversification strategies.

The evolution of cointegration analysis reflects the advancement in econometric techniques and the changing landscape of economic theory. Initially applied to the study of consumption and income dynamics (Engle and Granger, 1987), cointegration analysis gradually expanded to encompass a broader array of economic phenomena. The advent of Johansen's (1988) multivariate cointegration framework, which this thesis adopts, further enhanced the understanding of long-term relationships among multiple variables, paving the way for more sophisticated modeling approaches.

Contemporary research in cointegration analysis emphasizes its application in addressing pressing issues such as financial integration, market efficiency, and sustainability. With the growing awareness of ESG factors in investment decision-making, there is a burgeoning interest in examining the cointegration of ESG markets. Studies by Tularam (2010), Sahoo & Kumar (2022) and Dengjun (2013) have highlighted the importance of using up to date comprehensive modeling frameworks to better understand changed dynamics of ESG markets over the years.

Despite the growing body of research on cointegration of stock indices, there remains a dearth of studies focusing specifically on the cointegration dynamics of ESG markets within the Nordic region. This thesis seeks to address this gap by applying a VAR modeling framework to analyze the interrelationships between ESG indices in Denmark, Norway, Sweden, and Finland. By examining the long-term equilibrium relationships and short-term dynamics among ESG stock market indices, this research aims to offer insights into the integration of Nordic ESG stock markets.

This study contributes to the existing literature on ESG, SRI, and cointegration in several meaningful ways. Firstly, by focusing on the Nordic region, a region characterized by its strong commitment to sustainability and responsible investing (Nordic Council of Ministers, n.d.), it extends the geographical scope of empirical research on ESG stock markets, providing valuable insights into the characteristics of sustainability investing in Nordic markets. Secondly, the utilization of a VAR model enables the exploration of both contemporaneous and lagged relationships between ESG stock market indices, offering a nuanced understanding of their interplay over time. Finally, the findings of this research can outline diversification opportunities within the Nordic ESG stock markets. Transmission of price movements within Nordic ESG markets is important for policymakers for appropriate policy action to mitigate shocks.

The reminder of the thesis is organized as follows. The next section discusses the theoretical framework. Section 3 delves into literature review. Section 4 explains the methodology. Section 5 presents the empirical analysis. Section 6 discusses the results, while the conclusion is made in section 7.

2 THEORETICAL FRAMEWORK

While the following theoretical underpinnings are applicable to all asset classes in general, in this thesis they are viewed from the perspective of SRI.

2.1 Financial Integration Theory

Financial integration theory, discussed by Obstfeld and Taylor (2004) and Bekaert and Harvey (1995), focuses on the degree to which financial markets are interconnected across different regions or countries. As economies become more intertwined through trade and capital flows, the correlation of returns among global stock market indices increases, indicating a higher level of integration. This globalization facilitates portfolio diversification across international markets, allowing investors to utilize indices as benchmarks for diversification strategies and gain exposure to various regions or sectors. Moreover, financial integration tends to enhance market efficiency by reducing arbitrage opportunities, aligning prices of constituent stocks within indices more closely. However, it also brings the risk of contagion and transmission of financial shocks across markets, where events in one market can swiftly impact others due to interconnectedness via cross-border capital flows and investor sentiment. In the context of analysis of Nordic ESG stock market indices, the correlation and cointegration analysis would provide insights into the integration of ESG stock markets within Nordics.

2.2 Shareholder vs. Stakeholder Theory

Shareholder vs. stakeholder theory, as discussed by Freeman (1984) and Jensen (2002), addresses the differing perspectives on corporate responsibility and decision-making. Shareholder theory emphasizes maximizing shareholder value, prioritizing actions that enhance financial performance and profitability, often at the expense of other stakeholders or environmental and social concerns, while stakeholder theory advocates for considering the interests of all stakeholders, including employees, customers, and the community, environment, alongside shareholder interests. This thesis recognizes differing priorities of investors and studies the available equity investment for socially responsible investors to provide information regarding the possibilities of risk management within ESG stock markets in the Nordics.

2.3 Efficient market hypothesis (EMH)

The efficient market hypothesis (EMH) or efficient market theory, as proposed by Fama (1970) posits that asset prices fully reflect all available information, thereby following a random walk pattern. There are three forms of EMH (Bodie et al., 2014): Weak form efficiency states that all past trading information such as historical prices, trading volume, and other market-related data, is already reflected in stock prices. Therefore, technical analysis techniques, which rely on historical price movements, should not consistently generate excess returns; in semi-strong form efficiency all publicly available information is reflected in stock prices. This includes not only historical trading data but also all publicly available information from financial statements, economic data, news releases, and other sources. Therefore, fundamental analysis techniques, which analyze a company's financial health and prospects, should not consistently lead to excess returns; and strong form efficiency asserts that all information, public or private, is already reflected. However, deviations from random walk pattern that EMH theorizes may occur due to market frictions or inefficiencies, behavioral biases, and information asymmetries. In the context of Nordic ESG stock market indices, if the stocks comprising these indices follow strong form efficiency all information, public and private, are included in the prices, a random walk pattern in the returns of these indices should be observed.

2.4 Portfolio Theory

Portfolio Theory, pioneered by Markowitz (1952 cited in Markowitz, 1991), emphasizes the benefits of diversification in reducing portfolio risk. Bodie et al., (2014) provides the following explanation of portfolio theory. Investing in a single stock exposes an investor to idiosyncratic risk, which is the risk specific to that company. However, by investing in a stock market index, which typically comprises a diversified set of stocks across various sectors and industries, investors can reduce idiosyncratic risk and achieve a more stable return. Portfolio theory introduces the concept of the efficient frontier, which represents the set of portfolios that offer the highest expected return for a given level of risk or the lowest risk for a given level of return. By constructing portfolios along the efficient frontier, investors can optimize their risk-return trade-off based on their risk preferences. This theory also emphasizes the importance of asset allocation in achieving optimal portfolio performance. Asset allocation refers to the distribution of investment capital across different asset classes, such as stocks, bonds, and cash. Stock market indices can serve as the equity component of a diversified portfolio, and investors can adjust the allocation to stocks based on their risk tolerance and investment objectives. Furthermore, techniques of portfolio risk management help investors quantify risk and determine the optimal allocation of assets to achieve a desired level of risk-adjusted return. In the analysis of Nordic ESG stock market indices, portfolio theory offers insights into the possible diversification benefits of incorporating these indices into investment portfolios of socially responsible investors across the different geographical areas of the Nordics.

2.5 Hypothesis

H_0^1: There is cointegration in the Nordic ESG equities market. (Johansen's cointegration method (Johansen, 1988 & Johansen & Juselius, 1990)

H_0^2: There is no predictive power in the returns of ESG stock market indices (Granger Causality/Block Exogeneity Wald Test)

3 LITERATURE REVIEW

A substantial body of literature exists regarding time series econometric models to ascertain cointegrating relationships in stock indices across various regions globally. According to Knif & Pynnönen (1999), empirical literature on time series econometric models to examine the short-run and long-run relationships of stock indices can be categorized into two major groups. The first group focuses on examining the temporal variability in the volatility structure of stock prices and returns across international stock markets, as well as investigating the transmission mechanisms of shocks originating from one market to others. The second group of research can be categorized into two subgroups. The primary emphasis of the studies within the initial subgroup revolves around analyzing short-term causal relationships and lead-lag dynamics among equity indices across global exchanges. The current thesis falls into this category. Investigations within the secondary subgroup are mainly concerned with studying the long-term equilibrium connections and dynamic causal interdependencies among equity price indices and asset returns across different nations.

Nordic stock markets, albeit small as per market capitalization and thin compared to other stock markets (Nielsson, 2006), have been studied sufficiently. The literature on stock market integration in the Nordics encompasses various studies examining both the internal interdependence among Nordic markets and their relationship with global markets (detailed in Table 1). The sample period of these studies starts from 1974 (Mathur & Subrahmanyam, 1990) to 2011 (Dengjun, 2015). Times series econometric methods such as Engle & Granger (1987) cointegration (Malkamäki et al., 1993 & Pynnönen and Knif, 1998), Johansen cointegration (Malkamäki, 1992; Booth et al., 1997; Bos et al., 1995; Chan et al., 1997; Pynnönen and Knif, 1998; Mangeloja, 2001; Nielsson, 2007; & Dengjun, 2015), vector autoregression (Mathur & Subrahmanyam, 1990; Malkamäki, 1992; Bos et al., 1995; Pynnönen and Knif, 1998; Knif and Pynnönen, 1999; Mangeloja, 2001; & Dengjun, 2015) and, more recently, principle component analysis & common factor analysis (Nielsson, 2007), and VAR-EGARCH (Dengjun, 2015) have been employed in these studies. Except for Dengjun (2015) and Mangeloja (2001), weak (Nielsson, 2007) or no cointegration has been found within the Nordic stock markets. Mangeloja (2001) found one cointegrating vector between the Nordic stock indices stating an existence of common trend between the Nordic markets. In the case of Dengjun (2015), he found that there are two cointegrating relationships between the 4 Nordic stock indices suggesting two common stochastic trends in the system and hence, interdependence between those markets. Knif and Pynnönen (1999) found a cointegrating relationship between Sweden and Norway and Sweden and Finland. The granger causality tests conducted in these studies present evidence for Sweden leading Finland (Mathur & Subrahmanyam 1990; Mathur & Subrahmanyam 1991; Malkamäki, 1992; Malkamäki et al., 1993; Bos et al., 1995; & Booth et al., 1997), Sweden leading Norway (Mathur & Subrahmanyam 1990; Mathur & Subrahmanyam 1991; & Malkamäki, 1992), Sweden leading Denmark (Mathur & Subrahmanyam 1991) Norway leading Denmark (Mathur & Subrahmanyam 1990, Mathur & Subrahmanyam 1991, & Booth et al., 1997), and Norway leading Sweden (Mathur & Subrahmanyam 1991 & Booth et al., 1997).

Dengjun, (2015) posits that the absence of evidence of cointegration in Nordic stock markets from earlier studies may be attributed to the recent financial cooperation within the Nordics. He states that since those studies (for example. Booth et al., 1997) has been conducted there has been considerable changes in the stock markets in the Nordics such as consolidation of all the Nordic stock markets to Nasdaq OMX group, use of same trading system since May 2005, adoption of same corporate governance codes, increase in foreign ownership especially of smaller markets such as Denmark and Finland, and increased capitalization across the Nordic stock markets, with Sweden leading the equity market in the recent decades. The presence of two cointegrating vectors, spillover coefficients being significant across all Nordic stock markets except for Norway, and the increased interdependence of Nordic stock markets until late 2008 are the major findings of Dengjun (2015) which is quite contradictory to earlier findings.

The interest of this thesis is the Nordic ESG stock markets, a subsection of the Nordic stock markets. As these ESG indices are quite recent (earliest established in 2018), there is no literature available that studied cointegrating relationships within Nordic ESG indices and short- or long-term relationships, to the best of this author’s knowledge. This thesis contributed to the growing literature of SRI and ESG indices in this manner.

Table 1. Summary of previous studies examining cointegration in Nordic stock markets

Author(s)	Sample	Markets studied	Method	Major findings
Mathur & Subrahmanyam 1990	1974 - 1985	Denmark, Norway, Sweden & Finland	1. Granger causality 2. VAR	1. No cointegration among stock indices in Scandinavia 2. U.S. market affected only the Danish, but not the Norwegian, Finnish or Swedish markets. 3. The Swedish market was causally prior to both the Norwegian and Finnish markets. 4. The Norwegian, Danish and Finnish markets did not "Granger cause" any other market.
Mathur & Subrahmanyam 1991	1974 - 1985	Denmark, Norway, Sweden & Finland	1. SUR 2. Granger causality	1. Sweden leads Finland and Norway 2. USA leads Denmark
Malkamäki, 1992	1974 - 1989	Sweden, Finland, Germany and UK	1. Johansen's (1991) multivariate cointegration 2. VAR	1. Influence of Germany and US stock markets on the two Scandinavian markets seems stronger than the influence of Sweden and Finland on each other.
Malkamäki et al., 1993	1988 - 1990	Denmark, Norway, Sweden & Finland	1. Engle and Granger (1987) cointegration 2. Granger causality	1. No cointegration among stock indices in Scandinavia 2. Swedish stock market Granger caused other Scandinavian markets. 3. The world-wide returns seem to have significant leading effects on Scandinavian market returns. This may be due to the growing international capital movements across countries and stock exchanges.

Table 1. *Continued*

Author(s)	Sample	Markets studied	Method	Major findings
Bos et al., 1995	1983 - 1989 Monthly data	Finland, Sweden and US	1. VAR 2. Impulse response function	1. US and Sweden lead Finnish stock market 2. Correlation between Finnish and Swedish stock market returns
Chan et al., 1997		US, Canada, UK, Germany, France, Italy, Denmark, Netherlands, Spain, Norway, Finland, Sweden, Switzerland, Japan, India, Pakistan and Australia)	1. Johansen's (1991) multivariate cointegration	1. No cointegrating vectors for the sample period 1961-92 or subperiods (1961-69, 1970-79, 1980-87, and 1988-92) for Scandinavian countries with constant and trend and with constant and no trend.
Booth et al., 1997	1988 - 1994 Daily data	Denmark, Norway, Sweden & Finland	1. Johansen's (1991) multivariate cointegration 2. Geweke & Porter-Hudak tests for fractional integration 3. EGARCH	1. No cointegration between the four stock prices in Nordics 2. Asymmetric volatility transmissions in the markets except Denmark 3. The existence of price (in 3 pairs) and volatility (in 3 pairs) spillovers for some pairs of stock markets 4. The price and volatility spillover creates a feedback effect between Sweden and Finland.

Table 1. *Continued*

Author(s)	Sample	Markets studied	Method	Major findings
Pynnönen and Knif, 1998	1920 - 1994	Finland and Sweden	1. Engle and Granger (1987) cointegration 2. VAR analysis 3. Geweke and Porter-Hudak tests for fractional integration	1. No cointegration or fractional cointegration, i.e.. No long-term relationship between Helsinki and Stockholm 2. Weak Granger causality for period 1920-38 3. Barely statistically significant causal lead of Helsinki to Stockholm 4. Impulse response analysis showed own shocks had meaningful impact pre 1980 liberalization of capital markets. 5. In the period 1986-94 instantaneous causality between the series become considerably larger and instantaneous response to shocks across series.
Knif and Pynnönen, 1999	1993 - 1996	USA, Japan, Hong Kong, UK, France, Switzerland, Germany, Denmark, Finland, Norway and Sweden	1. Johansen's (1991) multivariate cointegration 2.Structural VAR	1. US price changes, conditioned on the same day changes on the other markets, have an impact on all other markets during the following day, including the US market itself. 2. Price changes on the Asian–Pacific markets are completely absorbed in price changes in Europe and do not have any direct effect on US prices. 3. A cointegration relationship between Sweden and Norway is found, which affects also Finland.

Table 1. *Continued*

Author(s)	Sample	Markets studied	Method	Major findings
Mangeloja, 2001	1990 - 1998	Denmark, Norway, Sweden & Finland	1. Johansen's (1991) multivariate cointegration 2. VECM 3. Impulse response analysis 4. Variance decomposition analysis 5. Granger causality	1. One cointegrating vector found
Nielsson, 2007	1996 - 2006	Iceland, Norway, Denmark, Sweden, Finland, Latvia, Estonia and Lithuania	1. Generalized impulse response function 2. Principal component analysis using maximum likelihood method 3. Common factor analysis 4. Johansen's (1991) multivariate cointegration	1. Weak interdependence of stock indices in Nordics and Baltics

Table 1. *Continued*

Author(s)	Sample	Markets studied	Method	Major findings
Dengjun, 2015	2001 to 2011 Weekly data for cointegration analysis Daily data for short-run dynamics model	Denmark, Norway, Sweden & Finland	1. Johansen's (1991) multivariate cointegration 2. Recursive estimation 3. VAR-EGARCH	1. Existence of two cointegrating relationships between the markets examined. 2. Spillover coefficients (11 out of 12) are significant. Norway is the exception 3. Interdependence between those four stock markets has been improved as financial reforms proceeded in this region 4. The recursive estimation of Johansen's model further reveals that the interdependence had been greatly improving until late 2008.

Adapted from Mangeloja, 2001

Cointegration analysis among ESG indices in Brazil, Russia, India, China and South Africa (BRICS) has been conducted by Sahoo & Kumar (2022) and they found no cointegration within the ESG indices in this region. They employed Johansen's multivariate cointegration analysis, Granger causality, and Baba, Engle, Kraft, & Kroner (BEKK) model to study the volatility spillover effects among the ESG indices. Tularam et al. (2010) studied Australia and 14 other markets (Canada, Denmark, France, Germany, Hong Kong, Ireland, Japan, Netherlands, Norway, South Africa, Sweden, Switzerland, United Kingdom and the United States) correlation between markets. They used dynamic conditional correlation multivariate GARCH model (DCC-GARCH), and the results showed high correlation of Australia with all the other markets. There was also an increased correlation between Australia and other countries (Canada, Denmark, Norway and the United Kingdom) while it remained the same with the rest of the countries, which they concluded to show that Australian SRI market is becoming more integrated with Canada, Denmark, Norway and the UK and possible portfolio diversification opportunities with the other counties (France, Germany, Hong Kong Ireland, Japan, Netherlands, South Africa, Sweden, Switzerland and the US).

ESG indices has been compared with composite traditional indices for financial performance (Jain et al., 2019) and volatility (Mousa et al., 2022) volatility transmission between ESG indices and conventional indices (Balcilar et al. 2017 & Baykut and Kula, 2019), cointegration of ESG indices with non-ESG indices (Sherwood & Pollard, 2018), Islamic indices (Miglietta & Forte, 2011), and macroeconomic variables (Diaye et al., 2021).

4 METHODOLOGY

4.1 Data

For empirical analysis, daily data are used for the four ESG indices, namely OMXC25ESG (Nasdaq Copenhagen, Denmark: OMXC), OMXH25ESG (Nasdaq Helsinki, Finland: OMXH), OMXS30ESG (Nasdaq Stockholm, Sweden: OMXS) and OBX ESG (Euronext Oslo Børs, Norway: OBX). As a benchmark, Dow Jones Sustainability United States Composite Index (S&P Dow Jones, United States: DJSI) is used. Iceland is not included in the study as the data for an ESG index is unavailable. All 467 index observations are from 6 May 2022 to 27 March 2024. The observations are adjusted for public holidays to ensure comparability of the data from different markets. For each index daily close value is used. ESG indices in the Nordics is a recent phenomenon, with earliest index data being available for OMXS30ESG from 9 July 2018. The latest is OBX ESG, where index data was published from 6 May 2022 and hence the beginning of the sample period. The data are obtained from Nasdaq, Euronext and S&P Global websites. The reason for use of daily data is to capture any possible shocks that may last a few days, which will be lost in weekly or monthly data. (Palamali & Devakumar, 2013; Anderson et al., 2002; Brailsford, 1996; & Elyasiani et al., 1998) EViews 12 econometric software package is used to conduct the econometric tests and models.

The trading hours, details of the index construction and the eligibility criteria for stocks to be included in the index is detailed in Table 2. Except for Norway, trading hours of stock exchanges are similar in the Nordics. It is to be noted that Denmark, Norway and Finland uses Sustainalytics in classifying their stocks as ESG, while Sweden uses Institutional Shareholder Services, Inc. There are noteworthy differences in which industries are excluded in the ESG criteria. Since all socially responsible investors might not have the same preferences, it is important to look at the ESG criteria to see if it matches with their own preferences.

Table 2. Stock market indices used in the thesis

Market	Trading hours	Index	Details of index construction	ESG eligibility
Denmark	10:00 a.m. – 6:35 p.m.	OMXC25ESG	The OMX Copenhagen 25 ESG Responsible Index is designed to track the performance of a selection of the largest and most traded securities listed on Nasdaq Copenhagen A/S whose issuers meet specific ESG criteria. Free float market capitalization-weighted index	A security issuer must not be positively identified by Sustainalytics as exhibiting any of the following characteristics: • Non-compliance with the United Nations Global Compact (UNGC) principles and related international norms and standards, such as the Organization for Economic Cooperation and Development (OECD) Guidelines and United Nations (UN) Guiding Principles. • Having a Controversy Rating of five (5). • Involvement of certain degrees in adult entertainment, alcoholic beverages, recreational cannabis, controversial weapons, gambling, military contracting, oil & gas, oil sands, small arms, thermal coal or tobacco products

Table 2. *Continued*

Market	Trading hours	Index	Details of index construction	ESG eligibility
Norway	10:00 a.m. – 5:20 p.m.	OBX ESG	The OBX ESG Index is designed to identify the 40 companies in Norway which demonstrate good management of their Environmental, Social and Governance (ESG) risk.	Companies within the Index Universe that fulfil the eligibility requirements are ranked based on the ESG risk rating as assessed by Sustainalytics Non-Compliant with the UN Global Compact principles, UN Guiding Principles on Business and Human Rights (UNGPs), OECD Guidelines for Multinational Enterprises and ILO Conventions as determined by Sustainalytics are not eligible for inclusion in the index Companies that are involved beyond a certain threshold in tobacco, thermal coal, oil sands, shale energy, arctic oil and gas, small arms and controversial weapons.
			Free float market capitalization weighted index	

Table 2. *Continued*

Market	Trading hours	Index	Details of index construction	ESG eligibility
Sweden	10:00 a.m. – 6:25 p.m.	OMXS30ESG	The OMX Stockholm 30 ESG Responsible Index is designed to track the performance of the securities in the OMX Stockholm 30 Index whose issuers meet specific ESG criteria. Market capitalization-weighted index	Institutional Shareholder Services, Inc. (ISS ESG) is responsible for the Environmental, Social and Governance (ESG) screening of securities to the extent set out in the Security Eligibility Criteria and companies with following characteristics are excluded: • Verified and ongoing breaches of international norms. • Verified and ongoing involvement in cluster munitions, anti-personnel mines, nuclear weapons, biological and chemical weapons. • Companies with involvement of a certain degree in alcohol, tobacco, military equipment, pornography, gambling, fossil fuels, cannabis and oil sand.

Table 2. *Continued*

Market	Trading hours	Index	Details of index construction	ESG eligibility
Finland	10:00 a.m. - 6:25 p.m.	OMXH25ESG	The OMX Helsinki 25 ESG Responsible Index is designed to track the performance of a selection of the most traded securities listed on Nasdaq Helsinki Ltd. whose issuers meet specific ESG criteria. Free float market capitalization-weighted index	A security issuer must not be positively identified by Sustainalytics as exhibiting any of the following characteristics: • Non-compliance with the United Nations Global Compact (UNGC) principles and related international norms and standards, such as the Organization for Economic Cooperation and Development (OECD) Guidelines and United Nations (UN) Guiding Principles. • Having a Controversy Rating of five (5). • Involvement of certain degrees in adult entertainment, alcoholic beverages, recreational cannabis, controversial weapons, gambling, military contracting, oil & gas, oil sands, small arms, thermal coal or tobacco products

All trading hours are in Finnish time in April 2024

Jarque-Bera test is used to check the normality of the times series data. The test statistic measures the departure of the series skewness and kurtosis from that of a normal distribution. Its associated probability will ascertain the normality of the series and possibility of autoregressive conditional heteroskedasticity (ARCH) effects.

4.2 Unit root test

Financial times series are usually non-stationary at levels creating spurious regression results (Hamilton, 2020). The indices are tested for stationarity or unit roots at levels and first difference based on the Augmented Dickey-Fuller (ADF). Instead of Dickey-Fuller (DF) test, ADF is used to combat the issue of the dependent variable being autocorrelated with its own previous values. The general format of the test is as follows:

$$\Delta y_t = \psi y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta y_{t-i} + u_t, u_t \sim N(0, \sigma^2)$$

where:

Δy_t = ESG stock index has been differenced.

The null hypothesis is $\psi = 0$. In other words, daily ESG stock index at levels or first differences has a unit root. This is contrasted against the alternative hypothesis that $\psi < 0$, where daily ESG stock index at levels or first differences does not have a unit root and therefore, stationary. The significance level is at 1% and lag length is automatically selected via Schwarz Information Criterion (SC). If non-stationarity at levels and stationarity at first difference are observed, the possibility of a cointegration can be evaluated.

4.3 VAR & cointegration

The test for cointegration among the ESG stock market indices in the Nordics starts with the estimation of a vector autoregression (VAR) model. VAR model introduced by Sims (1980) models the joint dynamics of multiple times series variables without imposing restriction on the causal relationships among them. In a VAR model, each variable is regressed on its own lagged value as well as lagged values of all other variables. The general form of a VAR(g) model for g variables is as follows (Brooks, 2019):

$$y_t = c + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \cdots + \Pi_k y_{t-k} + u_t \text{ , } t = 1, 2, \ldots, T \tag{1}$$

where:

y_t is a $g \times 1$ vector of return on Nordic ESG stock indices at time t.

c is a $g \times 1$ vector of constant terms.

β_t are $n \times n$ coefficient matrices for lag i for $i = 1, 2, \ldots, g$.

u_t is a $g \times 1$ vector of serially uncorrelated error terms at time t.

The VAR model is then turned into a vector error correction model (VECM) to use the Johansen's cointegration method (Johansen, 1988 & Johansen & Juselius, 1990) by taking the first difference of the left-hand side and $k - 1$ lags of the dependent variables on the right-hand side, each with a Γ coefficient matrix attached to it:

$$\Delta y_t = \Pi y_{t-k} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \cdots + \Gamma_{k-1} \Delta y_{t-(k-1)} + u_t \text{ ,} \tag{2}$$

where:

$$\Pi = (\sum_{i=1}^{k} \beta_i) - I_g$$

$$\Gamma_i = (\sum_{j=1}^{i} \beta_j) - I_g$$

Johansen's cointegration methodology is sensitive to lag lengths. While as a rule of thumb for daily data, the lag length can be selected as five (Brooks, 2019), for this study lag order selection is based on the lag length selected by majority of information criteria. The stability of the VAR model is tested using inverse roots of AR polynomial to ensure validity of tests conducted on the VAR model and impulse response standard errors. If the modulus is less than one and lie inside the unit circle, the estimate VAR is stable.

Taking into consideration the optimal lag length, Johansen's test is conducted. It revolves around examining the Π matrix. Two likelihood ratio tests, namely, trace test statistic and the maximum eigenvalue test statistic are used to determine the number of cointegrating vectors r.

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i) \quad (3)$$

$$\lambda_{max}(r, r+1) = -T \ln(1 - \hat{\lambda}_{r+1}) \quad (4)$$

The λ_{trace} is a joint test that tests the null hypothesis that there are at most r cointegrating vectors against the alternative that the number of cointegrating vectors is greater than r (Brooks, 2019). λ_{max} conducts individual examinations on each eigenvalue, with a null hypothesis the number of cointegrating vectors is equal to r, against an alternative of $r + 1$ (Brooks, 2019). Critical values for trace test statistic and the maximum eigenvalue statistic are provided by MacKinnon, Haug, and Michelis (1999) cited in Eviews software. Within this context, if $r = 0$, there is no cointegration between variables. If $1 \leq r \leq k - 1$, there are long-run relationships. If $r = k$, there is also no cointegration as all variables are integrated of order 0, I(0) (Rehman et al., 2021). If the ESG stock market indices in the Nordics is cointegrated at a rank more than one, then the restricted VECM is recommended. Otherwise, VAR is recommended. (Brooks, 2019)

Johansen's method is used over Engle and Granger (1987) method for testing cointegration due to the former's ability to estimate multiple cointegrating relationships simultaneously.

4.4 Granger causality

Short-term relationship, if any, among ESG stock market indices in the Nordics can be tested through Granger causality tests through a joint hypothesis test within the F-test framework and Wald test applied to the coefficients of the lagged values of the potential cause variables in the regression model (Brooks, 2019). Granger causality does not imply causation in the traditional sense, as it only identifies predictive relationships between variables. Moreover, Granger causality does not indicate the direction of causality; it only identifies whether one variable provides useful predictive information for another (Brooks, 2019).

4.5 Variance decomposition analysis

Variance decomposition analysis is conducted to understand the relationships and interdependencies among ESG stock market in the Nordics. By examining the forecast error variance of each index, this analysis reveals the extent to which shocks in one market are explained by either its own fluctuations or by fluctuations in other markets. Essentially, it quantifies the percentage of forecast error variance attributed to endogenous (self-generated) shocks within an index and exogenous (externally generated) shocks from other indices. If a stock market index explains most of its own shock variance, it suggests that the market is relatively exogenous, meaning its behavior is driven primarily by internal factors rather than external influences from other markets. This provides socially responsible investors opportunity for diversification across the Nordics.

5 EMPIRICAL ANALYSIS

5.1 Data

The daily data covers the period 6 May 2022 to 27 March 2024 for a total of 467 index observations at close (Figure 1).

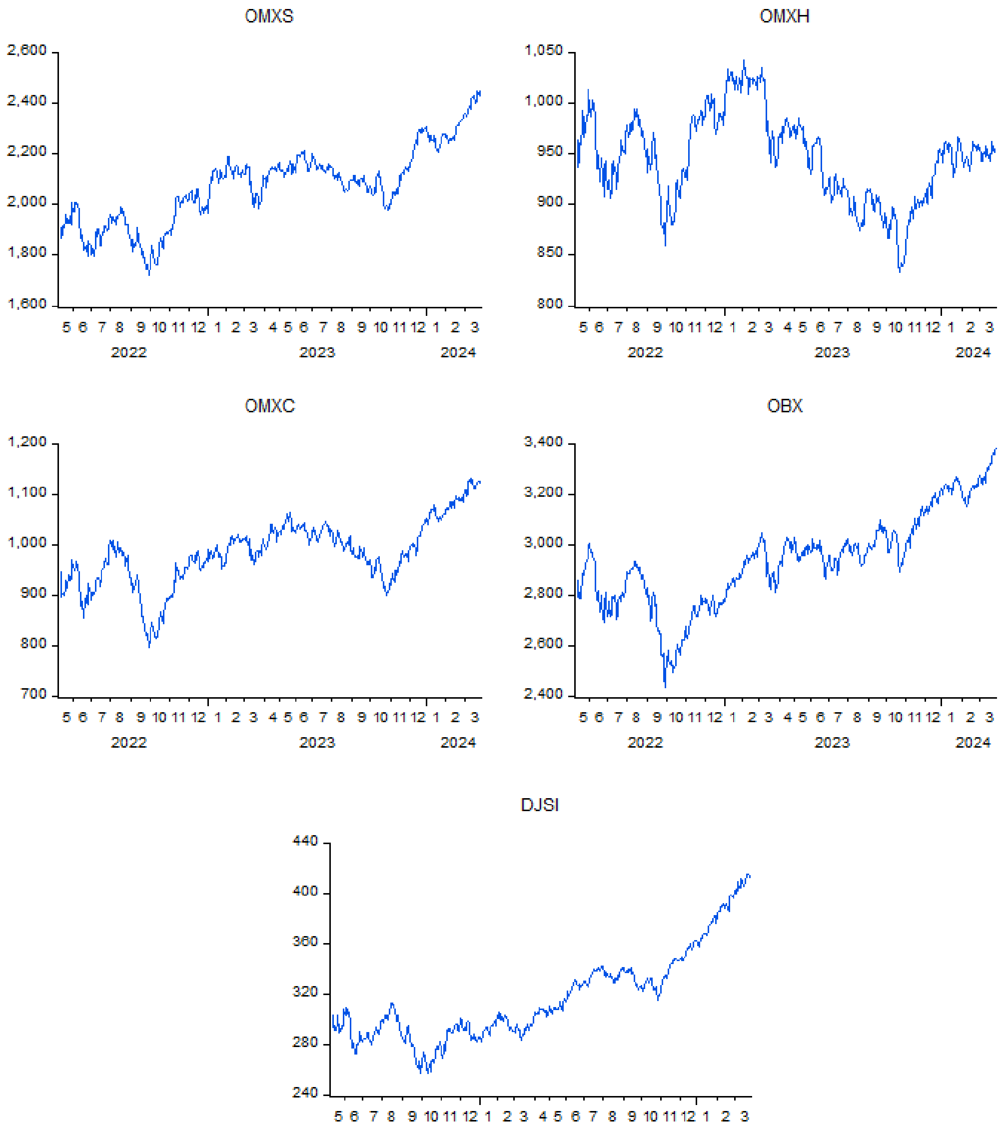

Figure 1. Time series plots

For the sample period, OMXS, OMXC and OBX move together closely with an upward trend, but a clear trend cannot be observed for OMXH. OMXH appears to be more volatile than the rest of the ESG indices in the Nordics. Sharp falls in September

2022 and October 2023 can be observed in all the ESG indices, including the benchmark DJSI. Over the sample period, DJSI exhibits an upward trend.

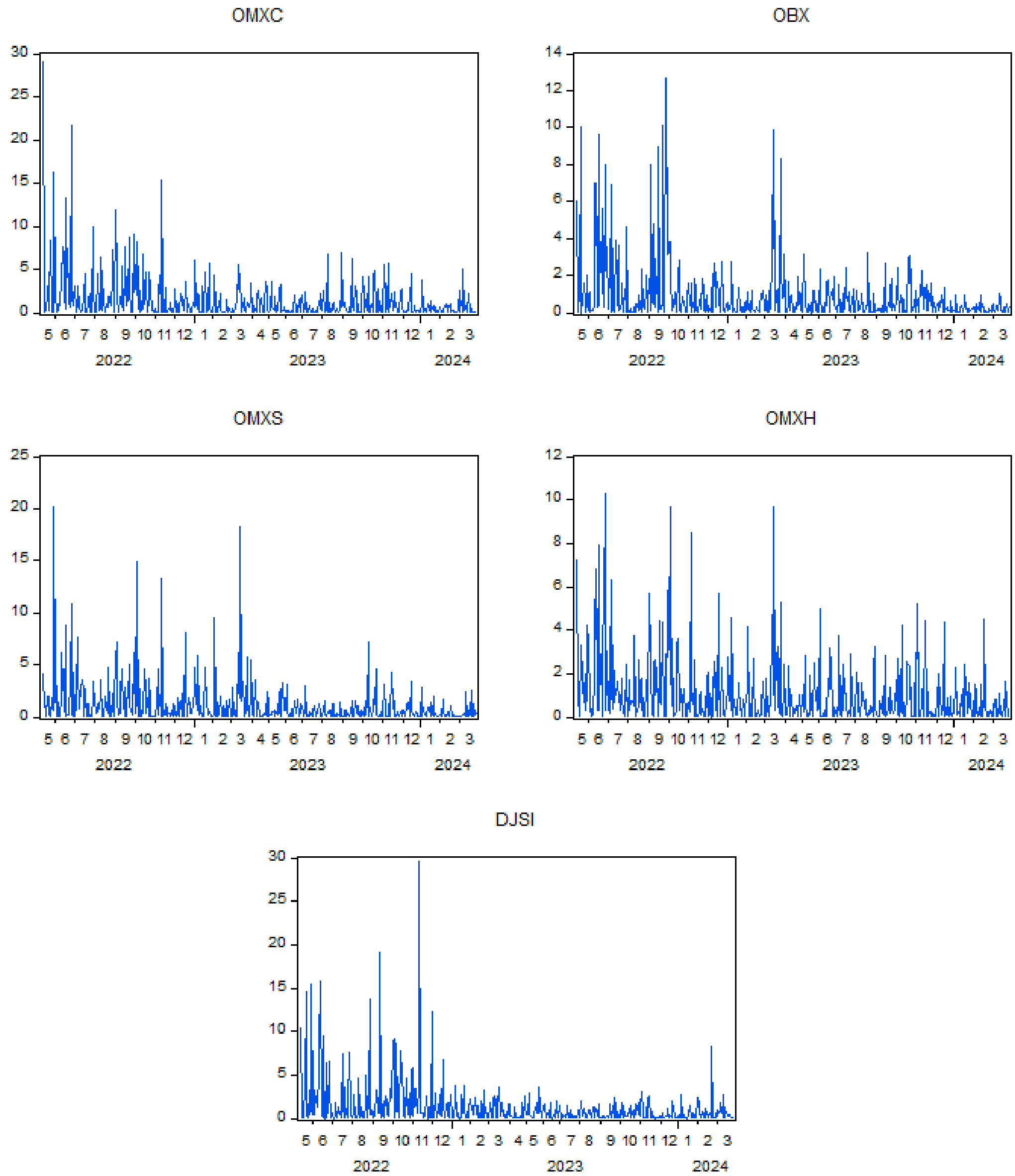

Figure 2. Daily squared returns

The returns of the daily levels of indices are calculated by a continuous compound basis, calculated as $100 * \ln\left(\frac{P_{,t}}{P_{t-1}}\right)$, where P_t and $P_{ij,t-1}$ are the closing index value days t and $t-1$, respectively. To show the volatility across time, the squared daily returns are shown in Figure 2. For all the indices, year 2022 appears to be a highly volatile period. OMXH is showing considerable volatility in its returns across the sample period and calm periods can be observed for OMXC, OBX, and OMXS after

2022, except for March 2023 where high volatility clustering can be observed. The highest spike across all indices is observed in November 2022 for DJSI.

5.2 Distributional properties

To start the empirical analysis, graphical the distribution properties of the ESG stock market indices are reported in Table 3. The mean daily returns of ESG stock indices in the sample, is positive except for OMXH (-0.0016). The highest ESG stock index daily return in the Nordics is OMXS (0.0529) which is closer to the benchmark DJSI (0.0672). The median for OMXC, OBX and OMXH is higher than their respective means indicating that the distribution of the returns on these indices are negatively skewed. This is confirmed by negative skewness of the returns of these indices. Similar to the benchmark DJSI, OMXS' distribution of returns is positively skewed. The standard deviation of daily returns on ESG stock indices in the Nordics is lowest for OBX (0.9342) while the highest was for OMXC (1.1837). For OBX, OMXS, and OMXH, the standard deviation was lower than that of the benchmark DJSI (1.1286), indicating less volatility in ESG markets in Nordics on average. The Jarque-Bera test statistic indicated that returns on OMXH follow a normal distribution, whereas the rest of the Nordic ESG stock indices are not normally distributed and the kurtosis values are greater than 3, indicating a leptokurtic distribution and presence of ARCH effect. This appears to be the case for DJSI as well.

Table 3. Descriptive statistics of daily returns on indices

	OMXC	OBX	OMXS	OMXH	DJSI
Mean	0.0361	0.0364	0.0529	-0.0016	0.0672
Median	0.0843	0.0999	0.0382	0.0272	0.0524
Maximum	4.6584	3.1676	4.4898	3.2039	5.4345
Minimum	-5.3804	-3.5558	-4.2670	-3.1097	4.3646
Std. Dev.	1.1837	0.9342	1.0811	1.0249	1.1286
Skewness	-0.0696	-0.5284	0.1368	-0.0034	0.0339
Kurtosis	4.5621	4.5867	4.3027	3.1520	5.2561
Jarque-Bera	47.7534	70.5715	34.4038	0.4496	98.9162
Probability	0.0000	0.0000	0.0000	0.7986	0.0000
Sum	16.8395	16.9647	24.6382	-0.7454	31.2984
Sum Sq. Dev.	651.5059	405.8162	543.4914	488.4595	592.3046
Observations	466	466	466	466	466

Unconditional correlations between indices are shown in Table 4. There is a positive correlation between all indices. In the Nordic ESG stock markets, the strongest correlation is between OMXS and OMXH (0.8407), while the weakest correlation is between OBX and OMXC (0.6019). The highest correlation between Nordic ESG stock indices and the benchmark is between OMXS and DJSI (0.5238) and the lowest between OBX and DJSI (0.3648). It is important to note that the unconditional correlations within Nordic ESG is markets is considerably high (> 0.50) and can be explained away due to similar policies. However, conditional correlations between Nordic ESG indices will be examined due its relevance in portfolio composition and optimization. For risk management purposes, assets with low or negative correlations are optimal.

Table 4. Correlations between daily returns on indices

Correlations					
t-statistic	OMXC	OBX	OMXS	OMXH	DJSI
OMXC	1.0000				
	-				
OBX	0.6019	1.0000			
	16.2377	-			
OMXS	0.6907	0.6586	1.0000		
	20.5754	18.8542	-		
OMXH	0.6803	0.6997	0.8407	1.0000	
	19.9938	21.0955	33.4486	-	
DJSI	0.4513	0.3648	0.5238	0.4624	1.0000
	10.8945	8.4384	13.2455	11.2340	-

5.3 Unit root and cointegration tests

Table 5 shows the Augmented Dickey-Fuller unit root test results for ESG stock indices in the Nordics along with the benchmark, DJSI.

Table 5. Augmented Dickey-Fuller Unit Root Test

	Level	First Differences
OMXC	-2.0354	-9.9339*
OBX	-2.3312	-6.4099*
OMXS	-2.3225	-6.6551*
OMXH	-2.2245	-21.2823*
DJSI	-1.9986	-21.5223*

*Significance at 1%

The results show that the ESG stock market indices are non-stationary at levels and stationary at first differences with a significance level of 1%. This means all the indices are integrated in the order of I(1).

5.4 VAR model estimates

To conduct the cointegration test on Nordic ESG stock index returns, VAR model is estimated. For VAR estimates, selecting an appropriate leg length is crucial as a too small lag length can cause the model to be mis specified and if it is too large, then the degrees of freedom are wasted. The optimal lag length was found to be one based on the criteria FPE, AIC and HQ. The results are in Table 6. To check for autocorrelation at the lag length, residual tests, correlogram and Lagrange multiplier test, are conducted. From the correlogram (Appendix 1) it is observed that the values are within 2 standard error bounds. The result of the serial correlation using the Lagrange multiplier test show that null hypothesis of serial correlation at lag length one is not rejected as p-value is 0.2061 (Appendix 2).

Table 6. VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2678.212	NA	0.0844	11.7171	11.7621*	11.7348
1	-2626.917	101.2442	0.0752*	11.6023*	11.8726	11.7087*
2	-2610.824	31.4134	0.0782	11.6412	12.1367	11.8363
3	-2593.698	33.0568	0.0810	11.6755	12.3964	11.9594
4	-2572.035	41.3395*	0.0822	11.6901	12.6362	12.0627
5	-2559.730	23.2122	0.0869	11.7456	12.9169	12.2069

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error.
AIC: Akaike information criterion.
SC: Schwarz information criterion. HQ: Hannan-Quinn information criterion

The VAR(1) model estimates are shown in Table 7.

Table 7. VAR (1) model estimates for returns on Nordic ESG indices

Estimates t-statistic	OMXC	OBX	OMXS	OMXH	DJSI
OMXC(-1)	-0.0946	0.1190	0.0554	0.1016	0.0499
	-1.4690	2.2757	0.9255	1.7715	0.7739
OBX(-1)	0.0670	-0.0813	0.1680	0.0876	0.0981
	0.8327	-1.2427	2.2461	1.2211	1.2181
OMXS(-1)	-0.2581	-0.1297	-0.3843	-0.2925	-0.2472
	-2.6884	-1.6631	-4.3084	-3.4202	-2.5723
OMXH(-1)	0.0795	0.0234	0.0534	0.0485	0.1206
	0.7836	0.2841	0.5671	0.5373	1.1875
DJSI(-1)	0.3383	0.1873	0.2697	0.2008	0.0302
	6.2188	4.2379	5.3357	4.1420	0.5537
Constant	0.0406	0.0348	0.0524	-0.0001	0.0805
	0.7811	0.8236	1.0834	-0.0031	1.5458
R squared	0.0827	0.0577	0.0864	0.0589	0.0167

Although forecasts are not conducted in this thesis, the stability of the VAR model is evaluated, and results are presented in Table 8. The estimated VAR is stable as all the inverse roots of the characteristic AR polynomial have modulus less than one. If all the roots lie inside the unit circle in the complex plane or is less than one, the VAR model is considered stable. This condition ensures that the effects of shocks on the variables decay over time, leading to convergence towards a long-run equilibrium.

Table 8. Roots of Characteristic Polynomial for index returns

Root	Modulus
-0.206569-0.066435i	0.216990
-0.206569+0.066435i	0.216990
-0.059669-0.026055i	0.065109
-0.059669+0.026055i	0.065109
0.051023	0.051023
No root lies outside the unit circle VAR satisfies the stability condition	

Johansen and Juselius's (1990) multivariate cointegration test is conducted to investigate the long-term relationship between the ESG stock markets in the Nordics. The findings of this analysis are detailed in Table 9. Both the trace and maximum eigenvalue tests suggest the existence of no cointegrating vector encompassing all examined ESG stock markets, with statistical significance observed at the 5% level. This means a stable long-term equilibrium relationship among the ESG stock markets in the Nordics does not exist within the sample period. Therefore, there might be opportunities for socially responsible equity investors for portfolio diversification across these markets in the long run.

Table 9. Johansen Maximum Likelihood Cointegration Test

Null hypothesis	Alternative hypothesis	Trace test statistics	5% critical value	Maximum Eigenvalue Statistic	5% critical value
H0: r=0	H1: r=1	44.6070	69.8189	15.8926	33.8769
H0: r<=1	H1: r=2	28.7143	47.8561	12.2509	27.5843
H0: r<=2	H1: r=3	16.4635	29.7971	9.9257	21.1316
H0: r<=3	H1: r=4	6.5378	15.4947	6.1587	14.2646
H0: r<=4	H1: r=5	0.3791	3.8415	0.3791	3.8415

5.5 Granger Causality/Block Exogeneity Wald Test based on VAR

The results of Granger causality/Block exogeneity Wald test based on VAR identifying short-run causality within Nordic ESG markets and between the benchmark are provided in Table 10. The null hypothesis of Granger causality test states that independent variable does not Granger cause dependent variable. This is tested at the 5% significance level. It is observed that OMXS returns has predictive information on OMXC returns, OMXC returns has predictive information on OBX returns, OBX returns has predictive information on OMXS returns, and OMXS returns has predictive information on OMXH returns. Only OMXS returns has predictive information on the benchmark DJSI returns while DJSI returns has predictive information on all Nordic ESG indices. It is noteworthy that the combination of all the indices have predictive information all the Nordic ESG indices returns while all Nordic ESG indices returns combined do not have predictive information on DJSI returns, as expected.

Table 10. VAR Granger Causality/Block Exogeneity Wald Tests

Dep. variable	OMXC		OBX		OMXS		OMXH		DJSI	
	χ^2	Prob.	χ^2	Prob.	χ^2	Prob.	χ^2	Prob.	χ^2	Prob.
OMXC	-	-	5.1790	0.0229	0.8565	0.3547	3.1382	0.0765	0.5990	0.4390
OBX	0.6934	0.4050	-		5.0450	0.0247	1.4911	0.2220	1.4837	0.2232
OMXS	7.2276	0.0072	2.7659	0.0963	-		11.6974	0.0006	6.6166	0.0101
OMXH	0.6140	0.4333	0.0807	0.7763	0.3215	0.5707	-		1.4102	0.2350
DJSI	38.6734	0.0000	17.9597	0.0000	28.4699	0.0000	17.1558	0.0000	-	
All	40.8250	0.0000	28.0501	0.0000	41.8066	0.0000	28.3689	0.0000	7.7282	0.1021

5.6 Diagnostic tests

Several diagnostic tests are conducted on the Granger causality test on the VAR(1) model to check its validity and the reliability. The results are in Table 11. The results of the Jarque-Bera test statistic indicate that the residuals from the estimated model does not adhere to a normal distribution and therefore, does not maintain constant variances. Non-normality of residuals in VAR model is not serious as the interest of this thesis is to test the linear interactions and/or interdependencies between Nordic ESG stock indices. Additionally, findings from the Lagrange Multiplier and White heteroskedasticity tests suggest the absence of serial correlation and heteroskedasticity problems within the errors.

Table 11. Diagnostic tests

	Purpose	Test statistics	Probability	Inference
Jarque-Bera test (joint)	Normality	115.1813	0.0000	Not normally distributed
Lagrange Multiplier test	Serial correlation	30.5017	0.2061	No serial correlation
White heteroskedasticity test	Heteroskedasticity	168.8694	0.1390	No heteroskedasticity

Adapted from Palamalai et al., 2013.

5.7 Variance decomposition analysis

To study the extent to which shocks in one ESG stock market are explained by either its own fluctuations or by fluctuations in other markets in the Nordics and against the benchmark, variance decomposition analysis is conducted, and the results are in Table

12. The results show that ESG market in Denmark (OMXC) is 100% explained by its own shock in the first day and subsequently reduced to 91.8% on day 5. ESG stock market in Denmark is exogenous with little to no variation explained by other ESG markets in the Nordics and the benchmark. ESG stock market in Norway is 65.63% explained by its own shock and 34.37% explained by shocks from ESG stock market in Denmark in the first day. Similarly, ESG stock market in Sweden is 44.74% explained by its own shock and 45.31% explained by shocks from ESG stock market in Denmark in the first day. A peculiar case is that of ESG stock market in Finland where just 26.38% is explained by its own shocks, 44.37% is explained by shocks from ESG stock market in Denmark, 13.30% from ESG stock market in Norway, and 15.94% from the ESG stock market in Sweden in the first day. For the benchmark DJSI, 71.43% is explained by its own shock and 19.79% by Denmark.

Table 12. Variance decomposition analysis

Days	S.E.	OMXC	OBX	OMXS	OMXH	DJSI
Variance decomposition analysis of OMXC						
1	1.1150	100.0000	0.0000	0.0000	0.0000	0.0000
2	1.1624	92.0761	0.1131	0.1506	0.1223	7.5379
3	1.1641	91.8220	0.1173	0.1511	0.1338	7.7758
4	1.1641	91.8131	0.1173	0.1513	0.1341	7.7842
5	1.1641	91.8128	0.1173	0.1514	0.1341	7.7844
6	1.1641	91.8128	0.1173	0.1514	0.1341	7.7844
7	1.1641	91.8128	0.1173	0.1514	0.1341	7.7844
8	1.1641	91.8128	0.1173	0.1514	0.1341	7.7844
9	1.1641	91.8128	0.1173	0.1514	0.1341	7.7844
10	1.1641	91.8128	0.1173	0.1514	0.1341	7.7844
Variance decomposition analysis of OBX						
1	0.9057	34.3709	65.6291	0.0000	0.0000	0.0000
2	0.9319	33.7975	62.5262	0.0663	0.0166	3.5934
3	0.9322	33.7950	62.5080	0.0711	0.0343	3.5916
4	0.9322	33.7946	62.5063	0.0713	0.0343	3.5935
5	0.9322	33.7945	62.5061	0.0713	0.0343	3.5937
6	0.9322	33.7945	62.5061	0.0713	0.0343	3.5937
7	0.9322	33.7945	62.5061	0.0713	0.0343	3.5937
8	0.9322	33.7945	62.5061	0.0713	0.0343	3.5937
9	0.9322	33.7945	62.5061	0.0713	0.0343	3.5937
10	0.9322	33.7945	62.5061	0.0713	0.0343	3.5937

Table 12. *Continued*

Days	S.E.	OMXC	OBX	OMXS	OMXH	DJSI
Variance decomposition analysis of OMXS						
1	1.0358	45.3121	9.9443	44.7436	0.0000	0.0000
2	1.0820	41.7602	9.3562	43.2927	0.0638	5.5271
3	1.0829	41.6966	9.3697	43.2498	0.0754	5.6085
4	1.0830	41.6941	9.3704	43.2476	0.0754	5.6124
5	1.0830	41.6940	9.3704	43.2475	0.0754	5.6127
6	1.0830	41.6940	9.3704	43.2475	0.0754	5.6127
7	1.0830	41.6940	9.3704	43.2475	0.0754	5.6127
8	1.0830	41.6940	9.3704	43.2475	0.0754	5.6127
9	1.0830	41.6940	9.3704	43.2475	0.0754	5.6127
10	1.0830	41.6940	9.3704	43.2475	0.0754	5.6127
Variance decomposition analysis of OMXH						
1	0.9933	44.3757	13.3030	15.9414	26.3798	0.0000
2	1.0228	42.5896	12.5644	16.4775	24.9408	3.4278
3	1.0230	42.5701	12.5665	16.4842	24.9402	3.4391
4	1.0230	42.5696	12.5668	16.4845	24.9399	3.4393
5	1.0230	42.5695	12.5668	16.4845	24.9399	3.4394
6	1.0230	42.5695	12.5668	16.4845	24.9399	3.4394
7	1.0230	42.5695	12.5668	16.4845	24.9399	3.4394
8	1.0230	42.5695	12.5668	16.4845	24.9399	3.4394
9	1.0230	42.5695	12.5668	16.4845	24.9399	3.4394
10	1.0230	42.5695	12.5668	16.4845	24.9399	3.4394
Variance decomposition analysis of DJSI						
1	1.1161	19.7911	1.4485	7.3295	0.0000	71.4309
2	1.1250	19.5484	1.5456	8.2464	0.2990	70.3606
3	1.1253	19.5433	1.5629	8.2667	0.2990	70.3281
4	1.1253	19.5430	1.5640	8.2674	0.2990	70.3267
5	1.1253	19.5430	1.5640	8.2674	0.2990	70.3266
6	1.1253	19.5430	1.5640	8.2674	0.2990	70.3266
7	1.1253	19.5430	1.5640	8.2674	0.2990	70.3266
8	1.1253	19.5430	1.5640	8.2674	0.2990	70.3266
9	1.1253	19.5430	1.5640	8.2674	0.2990	70.3266
10	1.1253	19.5430	1.5640	8.2674	0.2990	70.3266

6 DISCUSSION

Unconditional correlations between the Nordic indices are high. However, the absence of a cointegrating vector encompassing all Nordic ESG stock markets suggests that these markets do not share a long-term relationship. This means they move somewhat independently of each other providing diversification benefits to the socially responsible investors. Furthermore, due to no cointegration in Nordic ESG stock markets, a downturn in one market may not spread quickly to other markets, thereby reducing systemic risk to the overall portfolio of the socially responsible equity investor in the Nordics. This finding is in contrary to Dengjun's (2015) and similar to other findings (See Table 2) of overall Nordic stock markets.

The Granger causality tests reveal interesting dynamics in the short-term predictive relationships between returns of different Nordic ESG indices. Unidirectional relations for instance, Swedish market returns predict Danish and Finnish market returns. Danish returns predict Norwegian returns, while Norwegian returns predict Swedish returns. Interestingly, Finnish returns predict the US ESG returns. Notably, the US returns predict all Nordic stock market returns. Investors should consider the predictive relationships identified in the Granger causality tests when designing their investment portfolios. The unidirectional predictive power between certain Nordic ESG indices implies potential opportunities for arbitrage or strategic trading strategies.

One limitation of the study is the relatively small sample size, which may affect the robustness and generalizability of the results. Future research with larger sample sizes could provide more reliable insights into the relationships among Nordic ESG markets. Additionally, the reliance on secondary data may introduce biases or limitations in the analysis. Future studies could consider collecting primary data or using alternative data sources to validate the findings.

Future research could explore the cointegration of Nordic ESG indices with other financial assets, such as green bonds, commodities such as gold, silver and renewable energy, currencies, or alternative investments, to better understand the interconnectedness of ESG markets with broader financial markets. Investigating hedge ratios and optimal portfolio weights for Nordic ESG indices could provide practical guidance for investors seeking to integrate ESG considerations into their investment strategies. Advanced econometric techniques, such as dynamic conditional correlations using models like DCC-GARCH, could offer further insights into the evolving relationships among Nordic ESG markets, particularly in response to changing market conditions or regulatory environments.

7 CONCLUSION

This thesis uses a VAR model, Johansen and Juselius (1990) multivariate cointegration test and Granger causality to investigate the short- and long-run interactions of four Nordic ESG stock market indices along with a US ESG benchmark for the period 6 May 2022 to 27 March 2024. This study of long- and short-term dynamics of Danish, Norwegian, Swedish and Finnish ESG equity markets is motivated by the increased co-operation, including sustainable finance, in the Nordics and the need to ascertain the interconnected of these markets to understand the risk socially responsible investors may face in their investment strategies.

It was found out that there exists no cointegrating relationship among the Nordic ESG equities market. These findings are in alignment with the findings by Sahoo & Kumar (2022) who found no cointegration within the ESG indices in the BRICS region and Tularam et al. (2010) who found no correlation of Australian ESG markets with ESG markets in France, Germany, Hong Kong Ireland, Japan, Netherlands, South Africa, Sweden, Switzerland and the US.

Granger causality test showed predictive power of some ESG stock indices. Swedish ESG stock market returns had unidirectional predive power of Danish and Finnish ESG stock market returns.

The results imply that socially responsible investors in the Nordics have the potential to reap the benefits of diversification within the Nordic ESG markets.

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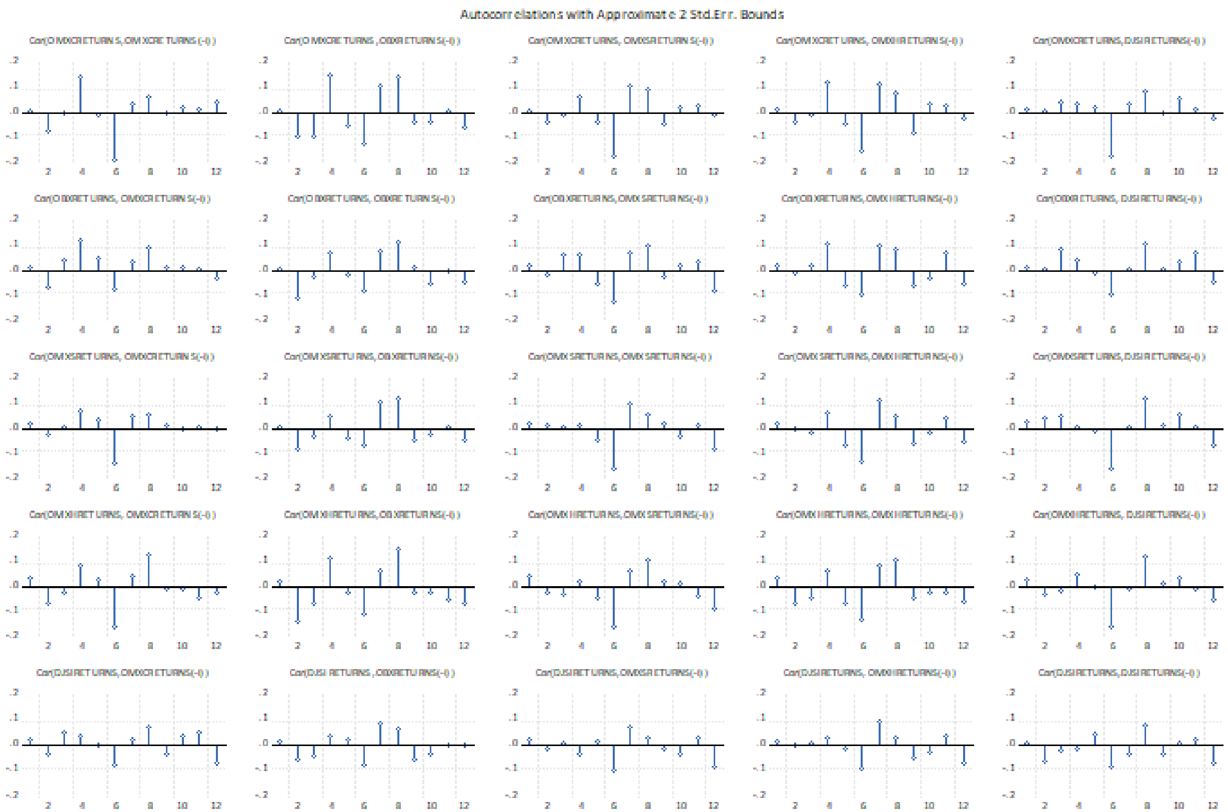
APPENDICES

Appendix 1. Correlogram



Appendix 2. VAR residual serial correlation LM tests.

VAR Residual Serial Correlation LM Tests
Date: 04/26/24 Time: 17:46
Sample: 5/06/2022 3/27/2024
Included observations: 465

Null hypothesis: No serial correlation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	30.50173	25	0.2061	1.222777	(25, 1673.2)	0.2061
2	37.54418	25	0.0512	1.508260	(25, 1673.2)	0.0512
3	34.01297	25	0.1076	1.364964	(25, 1673.2)	0.1076
4	40.07719	25	0.0286	1.611234	(25, 1673.2)	0.0286

Null hypothesis: No serial correlation at lags 1 to h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	30.50173	25	0.2061	1.222777	(25, 1673.2)	0.2061
2	76.39905	50	0.0095	1.538549	(50, 2032.9)	0.0095
3	103.6876	75	0.0158	1.392343	(75, 2111.8)	0.0158
4	131.6301	100	0.0186	1.326374	(100, 2126.8)	0.0187

*Edgeworth expansion corrected likelihood ratio statistic.

Appendix 3. Reporting the use of artificial intelligence

Following are the applications and ways in which artificial intelligence was used in the formulation of this thesis.

Name	How it was used
Copilot (embedded in Microsoft Edge)	To search for concepts along with references
Consensus: AI Search Engine for Research https://consensus.app/	To search for related articles To go through summaries
Connected Papers https://www.connectedpapers.com/	To search for related articles To go through summaries
ChatGPT 3.5 https://chatgpt.com/	To search for concepts and research papers on a certain topic. To get a preliminary understanding of a concept and search for sources

All the relevant information generated from these sources have been checked against references. No information is directly copy pasted from any artificial intelligence outputs.