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The Impact of Climate Change on Financial Markets and Sustainable Investment Strategies

Evidence from Finland

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ABSTRACT:

Climate change has transformed from an environmental concern to a systemic financial risk affecting asset prices, market stability, and capital allocation. In this thesis, it is investigated how climate-related factors influence financial markets and sustainable investment strategies in Finland. Specifically, it examines whether climate risks are priced into firms' valuations, how the performance of sustainable investment instruments is during climate-related market stress, and which factors drive firms' decisions to adopt green bond financing.

The theoretical framework is based on climate risk pricing theory, carbon pricing mechanisms, and sustainable investment theory. Key concepts include transition risk, physical risk, carbon premium, greenium, and climate beta. A balanced panel dataset comprising annual observations from 10 publicly listed Finnish firms across sectors over the period 2010–2025 is used, yielding 160 firm-year observations. Panel regression with firm and year fixed effects is employed to analyze the relationship between climate-related variables, market capitalization, and volatility, while logistic regression is applied to examine the determinants of green bond issuance.

The results indicate that climate-related policies are associated with financial market outcomes. Periods characterized by major policy developments such as the Paris Agreement, Finland's carbon neutrality target, and the EU Climate Law are found to be associated with lower firm valuations and higher market volatility. Carbon pricing is identified as a significant factor in green bond issuance, as increasing prices in the EU Emissions Trading System are linked to higher levels of sustainable financing activity. Firm size is also found to be positively associated with the likelihood of issuing green bonds, suggesting that larger firms may have greater access to financial resources and face higher regulatory pressure. Evidence consistent with the greenium phenomenon is observed, suggesting that investors may accept slightly lower risk-adjusted returns in exchange for environmental benefits and perceived safety.

These findings provide evidence supporting the growing importance of climate risks in financial decision-making. The study contributes to the literature regarding climate finance by providing evidence based on data from a small, advanced economy with strong regulations and ambitious targets. For investors, it is suggested that value may be found in incorporating climate risk analysis into portfolio management. For corporate managers, the results indicate that environmental practices may be rewarded through long-term stock price appreciation.

KEYWORDS: (Climate change, Carbon pricing, Sustainable investment, Green bonds, ESG investing, Financial markets).

Contents

1	INTRODUCTION	7
1.1	Background and Motivation	7
1.2	Previous Studies	9
1.3	Hypothesis	12
1.4	Structure of the Thesis	12
2	Theoretical Background	14
2.1	Climate Change and Financial Markets	15
2.2	Climate-Related Financial Risks	17
2.3	Carbon Pricing Theory	20
2.4	Climate Risk Pricing in Financial Markets	23
2.5	Sustainable Investment Theory	25
2.6	Green Bonds and Sustainable Financing	27
2.7	Climate Policy, Volatility, and Firm Valuation	29
3	Empirical Literature Review	32
3.1	Empirical Evidence on Climate Risk and Asset Pricing	32
3.2	Performance and Pricing of Sustainable Investment Instruments	33
3.3	Volatility, Resilience, and Downside Risk Mitigation	35
3.4	Institutional and Behavioral Drivers of Sustainable Finance	37
3.5	The Research Gap: Why Finland Requires a Dedicated Study	39
4	Data & Methodology	41
4.1	Introduction	41
4.2	Data Description and Sample Selection	41
4.3	Variable Construction	43
4.4	Econometric Methodology	46
4.5	Model Specification and Residual Analysis	47
5	Empirical Results and Analysis	50
5.1	Climate Risk Effects on Valuation and Volatility	50

5.1.1	Climate Risk and Firm Valuation	50
5.1.2	Climate Risk and Market Volatility	51
5.2	Risk Mitigation Effectiveness of Sustainable Investments	53
5.3	Drivers of Green Bond Adoption	55
6	Conclusion	58
	References	62

Figures

Figure 1. Climate-Related Financial Risk	20
Figure 2. Carbon Pricing Mechanism in Firm Finance	22
Figure 3. Climate Risk Pricing in Asset Markets	25
Figure 4. Climate Policy and Financial Market Response	31
Figure 5. Residual Plot for Market Capitalization Model	48
Figure 6. Residual Plot of Volatility Model	49

Tables

Table 1. Descriptive statistics	45
Table 2. Panel Regression Results for Market Capitalization (in € billions)	51
Table 3. Panel Regression Results – Dependent Variable: Volatility	53
Table 4. Panel Regression Results – Dependent Variable: Risk-Adjusted Return	55
Table 5. Logistic Regression Results – Dependent Variable: Green Bond Dummy	57

Abbreviations

CO ₂	Carbon Dioxide
CSR	Corporate Social Responsibility
ESG	Environmental, Social, and Governance
EU	European Union
EU ETS	European Union Emissions Trading System
EEX	European Energy Exchange
NGFS	Network for Greening the Financial System
OMX	OMX Helsinki All-Share Index
RAR	Risk Adjusted Return
SIT	Sustainable Investment Theory
TCFD	Task Force on Climate-related Financial Disclosures

1 INTRODUCTION

1.1 Background and Motivation

Climate change has moved beyond being an environmental problem and has become a global economic issue. Climate change impacts the physical world by way of increased temperature extremes and more frequent and intense weather events. Additionally, it will have a profound effect on the global energy system. As climate-related changes continue to evolve, financial markets will increasingly evaluate climate-related risks as part of their evaluation of profit and growth. Investors and institutions are increasingly assessing how climate-related risks, including carbon exposure and climate-induced changes in weather, could harm an institution's financial stability and the value of an investor's assets.

The financial sector's response to climate change is based on two types of risk: physical and transition risks. Physical risks represent the damage directly experienced by an organization due to flooding, hurricanes, and drought. These natural disasters damage the company's assets, supply chains, and production. Transition risks result from the policy, legal, and technological changes required for companies to adapt to a low-carbon economy. When government regulators increase restrictions on greenhouse gas emissions, carbon-intensive companies may find themselves with "stranded assets" and lower profits. To address these climate-related risks, financial markets are evolving to include measures to assess carbon exposure and sustainability in their pricing mechanisms. Therefore, these new methods of measuring climate risk will significantly alter the manner in which capital is allocated globally.

Finland represents an interesting case to examine these dynamics. With one of the most advanced financial systems in the world and a history of leadership in environmental policy, Finland has positioned itself as a leader in setting goals for reducing greenhouse gas emissions. In fact, Finland has set an ambitious goal to achieve carbon neutrality by 2035. Due to the time frame associated with achieving this goal, there is great pressure placed upon all domestic industries to quickly transition to a lower carbon footprint. The

fast pace at which Finnish companies are expected to reduce their carbon footprint provides researchers with a unique opportunity to analyze how financial markets respond to tangible, near term climate transition risks. Since the climate targets for some larger economies are years, even decades away, Finnish companies are experiencing immediate regulatory and operational pressures that make this topic relevant for both policymakers and investors.

Although Finland leads the world in terms of sustainability, very little is known regarding how climate risks are priced into the Finnish stock market. Much existing research focuses on much larger international markets, such as those found in the U.S. or Europe. The Finnish market is relatively small and dominated by fewer companies than those that exist in the broader European Union. This concentration raises several concerns about the potential lack of liquidity in the Finnish market and whether climate risks are efficiently reflected in stock prices. The extent to which "carbon risk premium" exists in New York or London remains unknown for Helsinki; however, the market structure of the Finnish market may create different dynamics.

Many investors are increasingly looking for ways to mitigate climate risks versus passive acceptance of these risks. Sustainable financial instruments such as Environmental, Social & Governance (ESG) funds and Green Bonds have become key components of modern portfolios. According to theoretical models, these instruments should serve as hedges during periods of market decline driven by environmental factors. However, empirical studies examining the effectiveness of these strategies in the Finnish context are extremely limited. Additionally, the behavioral influences on Finnish investors create another layer of complexity for this research. Profit maximization has traditionally been the primary influence on investment. However, regulatory pressures and perceived risk have increasingly influenced Finnish investment flows. Thus, it is essential to understand whether investors invest in green assets due to an expectation of higher returns (i.e., genuine expectations) or merely as a result of regulatory obligations and their own sense of ethics. This will allow researchers to better predict future trends within markets.

This thesis fills the gap of connecting climate finance theories at a global level with the local context of the Finnish economy. Through the analysis of secondary quantitative data from 2010-2025, this study provides empirical evidence regarding the effect of climate change on financial performance within Finland. In addition, this study examines whether the ambitious climate target of 2035 has already entered into the pricing of the market or whether sustainable investing can be used as a means to protect investors during this time of economic transition.

1.2 Previous Studies

There is increasing evidence across academic literature relating to climate finance that climate change does have an impact on the cost of capital, the value of assets, and the volatility of markets. Initially, many researchers viewed environmental concerns as externalities; however, contemporary financial theory views climate risk as an essential determinant of asset pricing. There is emerging agreement among researchers that financial markets have become significantly better at distinguishing companies capable of transitioning to a 'green' business model from those that are not. Consequently, companies exhibiting high levels of carbon intensity and poor environmental credentials often experience lower valuation multiples reflecting the expectations of market participants regarding future regulatory requirements.

The term "carbon risk premium" is another very important concept. The work of Bolton & Kacperczyk (2021) established that companies that produce high levels of carbon emissions suffer from poor stock price returns relative to their lower-emitting peers. Stockholders will require an additional amount of return to account for the risks associated with polluting. They found that the carbon premium is a rational response to the uncertainty of new environmental regulation.

As noted above, the concept of "Climate Beta" was defined by Engle et al. (2020) as a measure of the sensitivity of stock prices to climate-related news. The authors have shown that positive climate change mitigation news will positively impact the stock prices of companies that have low levels of carbon emissions, whereas it negatively

impacts the stock prices of companies that have high levels of carbon emissions. This theory has implications to show how the stock prices of companies listed in Finland would react to the announcement by Finland of its goal to become carbon neutral by 2035. In addition, this theory suggests that there exists the ability to hedge against climate risk through long positions in climate-resilient companies and short positions in companies that are climate at-risk.

Zerbib (2019) defines the term "Greenium" or "green premium" as the fact that investors are willing to accept a slightly lower yield on a green bond than they would be on a comparable conventional bond. Zerbib's research demonstrates that the preference for being environmentally conscious has sufficient strength to cause an increase in premium costs for bond yields; therefore, investors are paying more money than they have to (a premium) so as to financially support green initiatives. Therefore, it can be applied to the premise of whether or not green bonds in Finland will create cheap funding opportunities for companies within Finland as well as provide the investor demand for sustainability.

Building upon the initial research conducted by Zerbib (2019), Ilhan et al. (2021) investigated another aspect of climate finance known as 'carbon tail risk.' Carbon tail risk extends beyond consideration of average returns and focuses on extreme downside events. Ilhan et al. (2021) reports that companies exhibiting larger carbon footprints possess a significantly greater likelihood of experiencing extreme loss outcomes, particularly when regulatory shocks occur. Given the sizeable carbon footprints of Finnish manufacturers and energy producers, and the possibility of sudden regulatory shifts emanating from either the European Union or the Government of Finland, the findings reported by Ilhan et al. (2021) represent an important consideration for Finnish firms.

The behavior of participants in markets has been an area of research for behavioral finance. Behavioral finance research includes analyzing how the presentation of investment options can influence the choices made by investors. Karlsson-Larsson et al. (2024) conducted experimental research using behavioral finance research methodology to analyze how presenting a "green" investment as either the default or inclusive

investment option will cause investors to select it more often than other types of investments. The results indicate that when green investments are selected as one of the default or inclusive options, investors are more likely to select those options. When investors do this, they are accepting lower rates of return on their investments. Thus, this study provides evidence supporting the idea that it is primarily based upon non-economic motivations such as psychology and the way in which financial products are framed that drive the adoption of sustainable financing practices rather than economic self-interest.

However, one common thread running throughout these major studies is that they predominantly examine large, highly liquid markets. The mechanisms utilized by Bolton, Engle and Zerbib to determine their respective findings require relatively deep levels of liquidity and enormous amounts of data to operate effectively. In contrast, the Finnish market is generally considered to be smaller and have fewer participants than many other developed equity markets. Therefore, there exists some chance that the "greenium" is difficult to identify or that the carbon risk premium exhibits greater volatility due to lower trading volumes in Helsinki.

Although these structures may be different, the underlying theoretical framework is still valid. As long as Finnish investors' decisions are made rationally, and their investment decisions are influenced by the global capital markets (i.e., they have access to the same information), they will theoretically demand an equivalent level of premium for the climate-related risks. The Climate Beta idea would seem to fit well with analyzing the Finnish market due to the country being sensitive to climate news and also having an export-based economy. This thesis seeks to identify if there exists a link between climate news and the price movements of Finnish equities.

1.3 Hypothesis

This thesis formulates three specific hypotheses to be tested using quantitative data from the Finnish market:

H1 (Risk Pricing): Firms with higher exposure to climate risks have lower market valuations and greater volatility than their sustainable peers.

H2 (Mitigation Effectiveness): Sustainable investment instruments, specifically green bonds, provide superior risk mitigation, evidenced by higher risk-adjusted returns or lower downside risk during market stress.

H3 (Adoption Drivers): The adoption of sustainable finance in Finland is driven more by regulatory compliance and risk perception than by the expectation of immediate speculative profits.

1.4 Structure of the Thesis

The overall organization of the research will be structured around six major chapters, as follows:

Chapter 1: Introduction - This chapter provides an overview of the study, including the research background, the motivations for conducting the research, and the hypotheses that will be tested.

Chapter 2: Theoretical Background - This chapter examines the theoretical foundations of climate-related financial risks and sustainable finance and explores how government-enacted environmental regulations influence financial market activities.

Chapter 3: Empirical Literature Review - This chapter presents summaries of prior empirical studies on climate risk pricing, the performance of sustainable investments, and investor behavior in response to climate-related factors.

Chapter 4: Data and Methodology - This chapter describes the datasets used in the research, the construction of key variables, and the econometric techniques applied, including panel regression models and logistic regression.

Chapter 5: Empirical Results and Analysis - This chapter reports the results of the statistical analyses and econometric models, which are used to test the hypotheses introduced in Chapter 1.

Chapter 6: Conclusion - This final chapter summarizes the key results from the study.

2 Theoretical Background

The primary objective of this research is to provide a theoretical basis for understanding how climate change will influence the operation of financial markets and develop environmentally friendly investment techniques. The focus of this study is centered on the mechanisms whereby climate-related risks affect the operations of financial markets. Additionally, the impact of carbon pricing and climate policies on firm value and investor expectations is examined. Furthermore, why environmental financing tools (e.g., green bonds) are becoming increasingly important in contemporary capital markets is explored. The above discussion has been framed from a climate-finance perspective instead of general finance theory due to the fact that the overall objective of this dissertation is to understand the specific relationships between climate change, volatility, market capitalization, and sustainable finance decision-making processes in Finland.

In recent years, there has been growing recognition that climate change can be viewed as a financial and economic risk factor affecting firms, investors, lending institutions, and regulatory agencies. Climate change represents a financial and economic risk factor that affects firms and their stakeholders, including expected cash flows, discount rates, and the distribution of future risks. Therefore, climate change influences financial markets in much the same manner as any other material risk factors, although the nature of those impacts differs from other material risk factors. The reason is that climate change creates long-term uncertainty and nonlinearity in terms of impacts, and those impacts are often influenced by policy actions. Hong et al. define climate finance as the study of how financial systems enable the development of adaptation strategies and how climate-related risk affects asset prices and capital allocations.

This subject matter is highly relevant to countries with well-established climate frameworks. For example, Finland's climate framework is based on a legally defined transition pathway. Additionally, Finnish firms operate under the broader EU regulatory structure that includes an explicit EU-wide carbon pricing signal via the European Union's Emission Trading System. As a result, Finnish firms are impacted by both nationally defined transition pathways and EU-wide carbon pricing signals.

2.1 Climate Change and Financial Markets

The impact of climate change on financial markets arises from the effect of climate change on both a company's estimated net income and the overall risk environment within which an investor makes decisions. Financial markets price the expected future flow of funds available to investors. However, all such estimates of future fund availability rely upon factors including production costs, regulation, technology, litigation, reputation exposure, and consumer demand. Each of these factors has been influenced by climate change. For example, a company whose revenue stream is heavily reliant on fossil fuel consumption may experience increased production costs due to rising carbon prices. Conversely, companies operating more sustainably may reduce their transition costs (i.e., costs required to adapt to environmentally related regulations), increase investor confidence, and gain greater access to funding sources providing "green" investments. Climate change is economically significant in terms of its potential economic implications as well as the manner in which market participants currently evaluate future earnings.

One of the primary insights developed within the climate finance literature is that climate change influences both the estimated future cash flows and the discount rate used by investors. With respect to the estimated future cash flows, firms may experience changed levels of revenue, increased compliance costs, additional required investments and "stranded assets." Firms experiencing higher levels of climate-related risk may require higher returns demanded by investors. Giglio, et al., demonstrate that climate risks experienced by firms across long time periods influence valuation through discounting. Since many of the impacts of climate change occur slowly over extended

time periods, this provides some justification as to why climate-related information is significant regardless of when the potentially adverse effects are expected.

Climate change has impacted financial markets through the shift in the relative positioning of various sectors and firms. As carbon-based energy generation continues to become increasingly expensive, and other forms of renewable energy continue to expand rapidly, carbon-intensive industries will be subject to increasing amounts of transition pressure. Companies providing products and services focused on clean technologies, providing solutions to climate-related problems, may see positive structural changes in how capital is allocated. This results in what could be called a "valuation divide" between brown and green activities. While this division is based on ideology, the resulting difference in valuation is primarily driven by the market's attempts to identify companies facing rising costs related to environmental issues and those that will thrive on a pathway toward sustainable growth. Empirically, these differences in valuation are evidenced through differences in expected returns, market capitalization, and financing conditions.

Another key point is that climate change introduces uncertainty into the economy. And uncertainty is a factor priced into financial markets. Because climate risk is typically defined by uncertain regulation, evolving societal attitudes toward environmental protection, and developing technological options to mitigate greenhouse gas emissions, the uncertainty introduced by climate change tends to amplify investor responses. Investors do not merely need to estimate if environmental change will create negative consequences; they must also determine when such negative consequences will emerge, how negative those consequences will be, and how policymakers will respond to such challenges. Consequently, investors tend to be more sensitive to returns, more frequently reprice stocks, and pay closer attention to announcements regarding environmental issues. Engle, Giglio, Kelly, Lee, and Stroebel find that news releases concerning climate-related events result in systematically different sensitivities in the pricing of equities, supporting the contention that climate-related information affects

not only investor attitudes toward environmental issues, but also observable behaviors in financial markets.

Therefore, for financial markets, climate change is not only a source of stress concentrated in specific industrial sectors, but also a broader systemic concern. TCFD identifies two types of climate-related risks: transition and physical risks, both of which are considered economically relevant. Similarly, the NGFS considers climate-related risks to be macro-financial in nature, and notes that both transition and physical impacts can contribute to instability in financial systems over long horizons. Understanding this systemic context is necessary because financial markets do not evaluate individual firms with respect to climate change; instead, investors react to overall policy initiatives, variations in market sentiment, and changes in regulatory environments.

This thesis presents evidence of the theoretically relevant relationship between climate change and financial markets in the selection of dependent variables for empirical analysis. Volatility in financial markets represents uncertainty and the frequency of repricing as a function of information provided about climate-related issues. Market capitalization represents how investors value individual firms based on their respective cost and opportunity structures relative to climate-related issues. Adoption of green bonds represents how investors adjust their financing choices based on opportunities presented by transitioning to environmentally-sustainable practices. The measured carbon price represents a quantifiable proxy for the level of transition pressure experienced by carbon-intensive firms. Collectively, these measures support the primary theme of climate finance: that environmental change influences how firms are valued and how they make financing choices.

2.2 Climate-Related Financial Risks

Beginning with the basic distinction of climate-related financial risk (climate finance) as falling into one of two categories: physical risks and transition risks. This is currently the most common way that policymakers and researchers divide the impact of climate change on firms' values. Physical risks occur when climate change causes damage

directly; for example, when storms hit, flooding occurs, workers experience heat stress, the weather becomes warmer or drier or wetter, etc. There is also long-term environmental damage. Transition risks occur when an economy adjusts to create a low-carbon economy. For example, there will be new policies created; lawsuits brought against companies using large amounts of fossil fuel; technology to replace high energy usage technologies will emerge; consumers and investors may begin to demand products that have less of an impact on the environment; companies can become "bad" for their reputation if they do not act quickly enough to reduce their environmental impacts.

Physical and Transition Risk Are Interconnected. However, while it's useful to distinguish between them theoretically, in practice they're very intertwined. It's possible that slow-moving government response to Climate Change may lead to lower short-run transition costs, it may also result in higher long-run physical costs. On the other hand, a rapid policy response could create immediate short-run pressures on companies transitioning their operations to meet new regulations, as opposed to the high potential future physical losses associated with slower responses. Thus, there is an inter-temporal cost-benefit trade-off for both firms and investors. A firm that transitions early will be required to spend money to adapt its production processes to cleaner technologies, thereby lowering its future sensitivity to policy changes. Conversely, if a firm waits too late to transition from older (carbon-based) technologies, although it may retain current levels of profit, those profits will be at greater risk due to increased uncertainty regarding future policies. Therefore, the conflict over whether to transition sooner versus later is particularly relevant in terms of firm valuation, since investors need to project what a firm can do relative to its ability to transition into newer technology versus simply relying upon current income.

Stranded Assets is another key term in Climate Finance. Stranded Assets occur when there are regulatory, technological or market factors which have reduced the economic viability of certain types of assets (i.e. Fossil Fuel Reserves, Carbon-Intensive Facilities & Business Models). From a Valuation standpoint, the most significant issue related to

stranded assets is that they represent a reduction in the expected value recovery for an investor. Additionally, stranded assets may contribute to increased financing risks. As such, the existence of stranded assets provides a strong rationale for financial markets to price firms prior to full implementation of Climate Policy, especially when governments provide credible transition targets. Climate-Related Financial Risks Are Important Because They Can Be Difficult to Hedge Completely. Eren, Malamud, and Stroebel find that climate-related risk poses unique challenges for investors due to its systemic nature, uncertainty, and difficulty insuring. Systemic and Correlated Risk Implications on Diversification. As climate-related exposures occur both in mean (average) returns as well as increased volatility and downside risk, ordinary portfolio diversification will have limited effectiveness. This directly relates to this study's empirical design by providing evidence supporting the importance of including volatility as an important financial market outcome. Theory Provides Links Between Climate-Related Financial Risk and the Empirical Design of This Study. In theory, climate-related financial risk explains why carbon pricing, climate policy signals, and sustainable financing behaviors should be associated. A carbon price can be seen as a direct measure of transition pressure. Volatility measures uncertainty. Long-term valuation revisions are measured through market capitalization. A green bond adoption represents the financial response by firms to transition incentives.

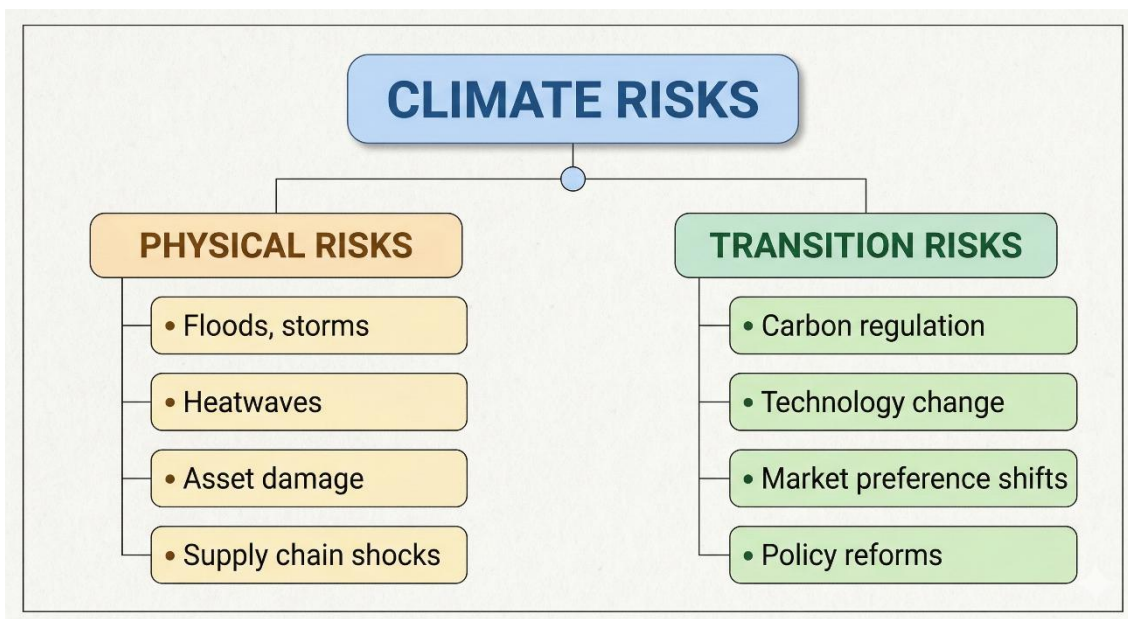


Figure 1. Climate-Related Financial Risk

2.3 Carbon Pricing Theory

The EU ETS is particularly important in the European setting because it creates a market-based carbon price for covered sectors. The European Commission describes the EU ETS as the first international emissions trading system and explains that the carbon price provides firms with an incentive to reduce emissions cost-effectively. The implication for finance is that firms covered by the system do not simply face general environmental expectations; they face an observable price signal that can affect operating costs, capital budgeting, and strategic decisions. For Finland, this is especially relevant because Finnish listed firms operate within the EU framework and therefore face climate policy, in part, through the carbon market itself.

From a theoretical perspective, carbon pricing impacts firms in at least three ways. The first way is that it increases both present and expected production costs to firms that emit large amounts of greenhouse gases. Second, it influences expected future rates of return from investments as it makes low-carbon technologies more desirable. Third, as carbon prices increase, the comparative advantages and disadvantages amongst industries and firms based on their carbon intensities. For example, a firm with fewer

units of emission (per unit of output) may have a competitive advantage when compared to its competitors, whereas a firm with higher levels of emissions per unit of output may suffer financially.

Beginning with the Text Information about climate risk is transmitted to the financial markets via carbon pricing. Investors can interpret increases in the carbon price as evidence that climate regulations are becoming stricter, or that there will be less availability for allowances. Therefore, carbon markets act on behalf of governments not just as a tool to reduce costs but as a credible indicator of their intent to regulate. As such, when investors see increased carbon prices, they may reassess their expectations regarding future profits and transition-related exposure. For these reasons, the theoretical justification exists for using carbon price as a variable to explain financial-market related outcomes. The carbon price reflects both cost pressures (directly) and government signals (indirectly).

The body of evidence in support of the notion that carbon pricing will have additional financial impacts on top of just reducing emissions is growing. The literature also indicates that firms experiencing tighter financing terms are those most exposed to the carbon pricing mechanism, as evidenced by their emissions intensity; this provides empirical backing for the assertion that climate policies impact firms' access to capital. As such, both research indicating how firms respond to carbon pricing mechanisms (i.e., changes in emissions levels) and studies showing how investors and markets react to a firm's exposure due to a policy-driven increase in carbon costs provide support for the broader implications of carbon pricing on firms' financing options.

Green bonds also relate to carbon pricing. The higher the cost of producing using high amounts of carbon, the larger the number of companies that are incentivized to produce using low amounts of carbon, which means they need to finance those efforts, and one way to do so would be through green bonds. Therefore, when a company faces the prospect of having to pay more to produce using large amounts of carbon (i.e., due to a higher carbon price); then the company has a stronger financial argument for issuing green bonds. From a theoretical perspective, the price of carbon not only penalizes

companies for emitting carbon, but it also makes companies that want to fund their transition into lower-carbon producers more attractive than companies that do not. This idea supports the hypothesis that higher carbon prices will increase demand for green bonds.

Carbon pricing theory also explains how the climate transition affects all businesses differently. It produces "winners" and "losers", depending upon each company's level of emission intensity, level of transition readiness, and ability to obtain financing. Companies with larger levels of assets will likely have an easier time adjusting to the climate transition, as they tend to have better access to capital markets and can afford the additional compliance costs associated with transitioning away from carbon-based production methods. On the other hand, smaller or more carbon-intensive companies will likely experience increased downward pressure on valuations. This provides a direct link from carbon pricing to the empirical study of corporate market capitalization and sustainable-financing adoption.

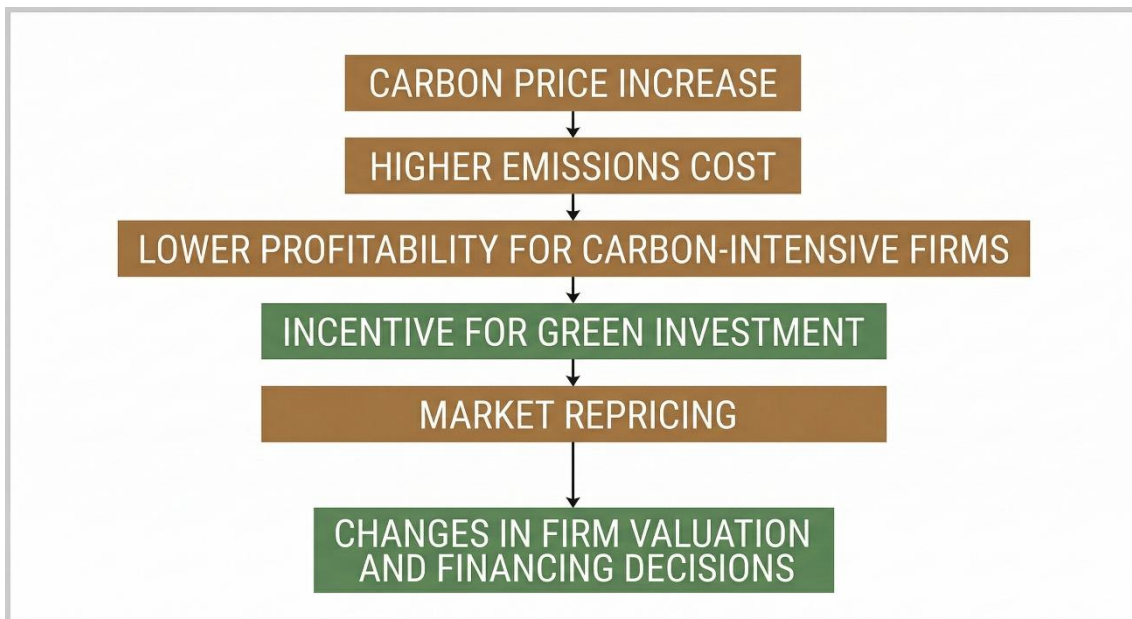


Figure 2. Carbon Pricing Mechanism in Firm Finance

2.4 Climate Risk Pricing in Financial Markets

The term "Climate Risk Pricing" describes the ways in which financial markets integrate the exposure associated with climate-related risks into the returns on assets and their values. The standard practice of finance requires investors to be compensated for taking on risk. Climate finance extends this idea to ask if firms exposed to higher levels of climate risk should have to provide investors with either higher expected returns from those investments or lower current investment prices. The empirical work that has been done to answer this question includes Bolton and Kacperczyk's findings regarding how high-emissions firms generate higher expected returns and the results of these studies were frequently used to describe the existence of a "carbon premium." Their study does not mean to say that firms generating high emissions are being morally rewarded; rather, they believe that investors require compensation for assuming transition-related risk.

The Carbon Premium Matters Because of its Direct Link Between Climate Exposure and Asset Pricing. High-Emission Firms are seen by Investors as at Risk from Carbon Regulation, Technological Displacement, and Changing Demand. In order for Investors to Hold High Emissions Firms in their Portfolios, they Require a Higher Expected Return on Their Investments. Since Price and Expected Returns Move in an Inverse Relationship to Each Other, Higher Expected Returns Mean Lower Current Valuation for All Things Being Equal.

A closely related concept is climate beta. The authors of this study (Engle et al.) use the term "beta" to describe an element of risk that captures an individual firm's exposure to climate-related news. Climate Beta provides an important contribution in understanding how companies are exposed to climate risks by going beyond simply measuring a company's level of greenhouse gas emissions, as well as their reaction to new climate data. Additionally, many companies will have exposures due to the fact that they are more likely to see changes in cash flow from policy announcements, natural disaster events or green transition opportunities. This helps to explain the wide variation in responses in financial markets to climate news for different types of firms and industries.

Climate risk pricing has an element of downside risk. It has been shown by Ilhan, Sautner and Vilkov that there exists a link between carbon exposure and Tail Risk; essentially, Markets do not only look at the mean performance of a firm's stock (average) but the extreme negative outcomes that could occur. This is an important theoretical point since, The climate transition may occur due to sudden discontinuities in the repricing of risk rather than smooth adjustments. Regulatory announcements, Legal Developments, Energy Shocks etc., can cause high exposure companies to experience sharp losses. Thus, the logic supports that volatility will be a good indicator of climate exposure if part of the climate risk is a result of a Tail-Risk phenomenon.

Another debate in climate risk pricing concerns whether green assets are priced mainly because they are safer or whether investors have sustainability preferences. Pedersen, Fitzgibbons, and Pomorski propose that ESG characteristics play two roles: they provide information about firm fundamentals and reflect investor preferences. Pástor, Stambaugh, and Taylor similarly argue that green assets can enjoy higher prices because some investors are prepared to accept lower expected returns in exchange for environmental alignment. For theory, this means that valuation gaps between green and brown firms may arise from both risk-based and preference-based channels.

For this thesis, climate risk pricing supports three empirical expectations. First, firms more exposed to the climate transition may experience lower valuations due to a higher required return. Second, climate news and policy uncertainty can raise volatility, especially for exposed firms. Third, sustainable financing tools may become more attractive as firms seek to demonstrate transition readiness and lower perceived climate risk. The theoretical literature, therefore, provides a strong basis for linking climate-related variables to financial-market outcomes in Finland.

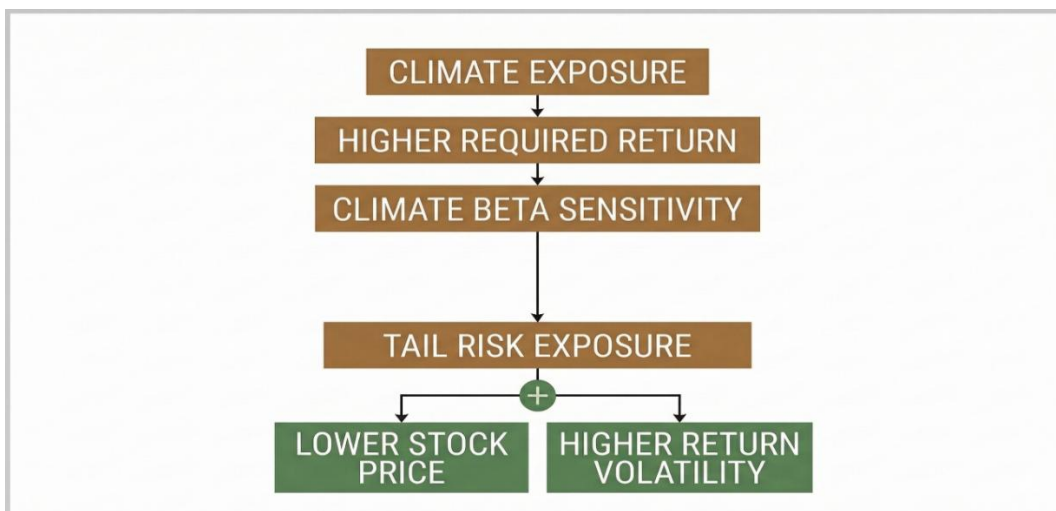


Figure 3. Climate Risk Pricing in Asset Markets

2.5 Sustainable Investment Theory

Sustainable Investment Theory (SIT) explains why investors are increasingly including environmental concerns into their Asset Allocation decisions, as well as their Firm Assessment. SIT fundamentally views Environmental Performance as both Ethical and Financially Relevant. By managing the environment effectively, firms can prepare better for regulatory compliance, reduce the potential for costly legal actions, utilize resources more efficiently, and adapt to structural changes over time. Therefore, SIT has a strong link to Risk Management, not just being an additional layer of Ethics onto Finance. The development of Sustainable Investing is in part due to an increase in Institutionalizing ESG (Environmental Social Governance) frameworks. More and more investors have begun using Environmental Indicators as Risk Screening Tools for identifying potential areas of risk within their portfolios. They also utilize these same Environmental Indicators when comparing firms to one another and allocating Capital. As Climate Change has evolved into being viewed as a Material Source of Financial Exposure, the importance of the Environmental Component of ESG frameworks has increased. When investors Reward Firms that align with Transition Objectives, they can create incentives for those firms to receive the majority of available Capital at Lower Financing Costs than Greener Firms may be able to access under normal circumstances.

The ESG-efficient frontier developed by Pedersen, Fitzgibbons and Pomorski is particularly interesting from an academic perspective as it illustrates that investors are not necessarily presented with a trade off between sustainability (ESG) and performance. Rather than this tradeoff, investors have the option to select a portfolio of varying levels of ESG intensity but still pursue a competitive risk adjusted outcome. This has implications for the current thesis as it will help clarify how sustainable investment strategies may grow regardless of whether they occur within highly disciplined financial environments. The reason for this growth in sustainable investment could be due to the fact that ESG characteristics contain information regarding resiliency and longer term quality.

Sustainable investment theory also has a component of preference-based demand. Pástor, Stambaugh, and Taylor say that there is an investor segment that cares specifically about owning 'greener' types of financial products. This will result in increased demand for sustainable products regardless of what level of returns they are expected to produce. The fact that investors have these preferences increases capital flow to companies that are issuing sustainable products. These preferences can create higher valuation levels (prices) for companies that have green features and create stronger demand for green bonds or ESG funds.

Sustainable investment theory has implications for corporate behavior. Firms will be motivated to increase transparency through increased disclosure about their environmental practices if investors begin to value these practices. Further, as the price of carbon increases and investors prefer firms that are committed to transitioning to low-carbon business models, firms will be motivated to develop project funding options that signal transition commitment. As such, the incentives created by sustainable investment theory influence both the valuation of a firm's securities and its financing strategy. For example, a firm will issue green bonds (or other environmentally focused debt) in order to fund those projects identified as being "green" as well as to communicate to potential investors that it is credible and serious about managing climate-related risks and opportunities. Thus, the principles of sustainable investment theory interact directly with the signaling principle (e.g., signifying transition commitment) and financing

decision-making.

The primary focus of this thesis is on using sustainable investment theory to analyze why firms choose to issue green bonds and how firms' valuations of equity are affected by investor perceptions of firms as being better aligned with sustainability objectives. Investors and creditors provide a premium (i.e., they reward) to transition-oriented firms; therefore, issuing a green bond is one strategic option available to a firm. Additionally, firms that investors perceive as having greater alignment with sustainability objectives will likely experience a higher market capitalization or lower volatility than firms that do not.

2.6 Green Bonds and Sustainable Financing

Green bonds are one of the most visible finance tools in sustainable finance because they provide a direct link between capital raising and environmental projects. Fundamentally, proceeds from green bond issues will be used for activities such as renewable energy, clean transportation, climate adaptation or energy efficiency. Theoretically, green bonds can help bridge the gap between environmental objectives and financing structures. Green bonds also embed environmental purpose into corporate debt issuance (public) by treating sustainability as part of financial management.

From the perspective of the issuer, green bonds may serve at least three functions. Firstly, green bonds provide financing for projects that aligned with the climate transition. Secondly, they can widen the base of investors by attracting institutions which have sustainable-investment mandates. Thirdly, green bonds can signal commitment to the market on environmental matters. Flammer's work on corporate green bonds is highly relevant here, showing that green bond issuance has been associated with both positive stock-market responses and subsequent improvements in environmental performance. This strengthens the argument that these bonds can function as credible signals instead of pure marketing.

From the perspective of the investor, green bonds may offer both financial and non-financial value. Zerbib finds evidence of a green bond premium, often called the "greenium", suggesting that some investors may accept slightly lower yields on green bonds than on comparable conventional bonds. The interpretation is that some investors attach value to environmental impact or view green instruments as offering advantages in terms of reputational quality, risk perception or mandate compliance. The exact size of the premium varies across markets and methods, but the theoretical point remains that green financing can alter pricing conditions.

The theory of green bond adoption also fits naturally with transition incentives. When firms face stronger carbon-pricing pressure or more demanding climate policy, they have greater reason to invest in decarbonization, efficiency or clean technology. Those investments often require external finance and if green bonds lower their cost of borrowing, increase demand from investors or improve their republican reputation then they can become an attractive option for them. Therefore, green bond adoption is not only the outcome of a preference for sustainability; it can also be a rational financial response to transition costs.

Firm size is also relevant in theory. Larger firms are more likely to issue green bonds due to the fact that doing so requires reporting capacity, a pipeline of projects, governance structures and access to capital markets. Large firms are also more visible to regulators and investors which both creates opportunity and pressure for them to use sustainable financing instruments. This expectation supports the empirical finding that market capitalization (or firm size) may positively effect green bond adoption.

Green bonds also matter because they reside at the crossroads of financing costs, environmental strategy and investor signaling. In this dissertation they are not used as a symbol of sustainability but as a specific tool of financing response to climate transition. If carbon prices rise and policy pressure strengthens, then firms may be more likely to adopt sustainable financing instruments. Therefore, green bond adoption is compatible with both the carbon-price channel and the sustainable-investment channel discussed earlier.

2.7 Climate Policy, Volatility, and Firm Valuation

Climate policy has an impact on financial markets both by changing the expected cost of investment decisions as well as by creating uncertainty and "repricing" effects. Gradual, credible policy changes typically result in smooth market adjustments while sudden, controversial or ambiguous policy changes can cause investors to respond with larger price revisions and greater volatility. Volatility is not simply noise in financial markets; it represents the degree of uncertainty surrounding expected cash flows, discount rates and policy regimes in the future. As such, in a climate finance environment, one of the most critical ways for investors and other market participants to measure their reaction to environmental transitions is through their reactions to increased volatility.

Climate policy can lead to increased volatility because it changes the way that information flows through the system. Increasing the cost of carbon, tightening regulations on greenhouse gas emissions or introducing new reporting requirements can make investors rethink how vulnerable certain companies are compared to others; and what those companies have done to prepare. The investors' rethinking processes tend to be non-uniform. Those processes vary based on the industry, the company's emissions-intensity (i.e., how much pollution per unit of product), the type of technology used by each firm, their ability to secure funding, and how they expect their executives will respond to regulations. For example, all of this can create differentiated pricing for different firms at the same time. That creates volatility in markets, and differences in valuations among similar firms.

At the company level, the value of a company is heavily influenced by its projected future profitability and risk. If climate-policy means that future production costs will rise, future demand for products that emit greenhouse gases will decline, or companies must invest large sums of money to implement transitional-technologies to comply with regulations, then the value of those companies could potentially decline. Conversely, if policy supports clean-energy technologies or provides incentives for sustainability and sustainable financing, then companies that position themselves to take advantage of these opportunities would experience an improvement in their stock value. It is

therefore logical that climate policy can have both positive and negative effects on market-capitalization depending on the nature of a company's business model, and the capacity of that company to adapt to the need for transition. Policy credibility is another factor. In Finland, where there is a goal to achieve net-zero carbon emissions by 2035, and within the European Union's broad regulatory structure for climate-change mitigation this makes climate policy more institutionally relevant than when climate commitments are weak, or less stable. When targets appear, credible investors are more likely to include those projections in today's valuation estimates. This is consistent with theoretical expectations that climate policy should currently influence Finnish financial-market outcomes instead of being a concern about the future. However, volatility may also decrease under certain conditions when climate policy eliminates uncertainty by providing clarity regarding future regulatory standards. Most importantly, not every climate policy destabilizes financial markets. Credible long-term policy guidance for firms and investors may provide a clearer picture for investment and financing decision-making. That can reduce uncertainty for companies that are already transitioning toward goals related to climate. Thus, the impact of climate policy on volatility has a theoretically ambiguous sign but is clearly relevant: it can create volatility or eliminate it; depending on whether the policy is viewed as a disrupting shock or a clear framework for decision-making.

In this dissertation research, climate-policy theory was directly connected to the empirical data examined. The climate-dummy variable captured significant policy events for the purpose of empirical analysis. The carbon price variable represented the market-based pressures that firms face during transition. Volatility measures uncertainty in markets. Market capitalization measures the reaction of firms to valuation changes from climate policies. And green-bond adoption measured the adjustments made by firms in terms of financing. Together, these variables represent the primary theoretical assertion made in this dissertation chapter: climate policies and climate risk cause firms to adjust both their valuation and financing behaviors by altering costs, expectations, and investor demand.

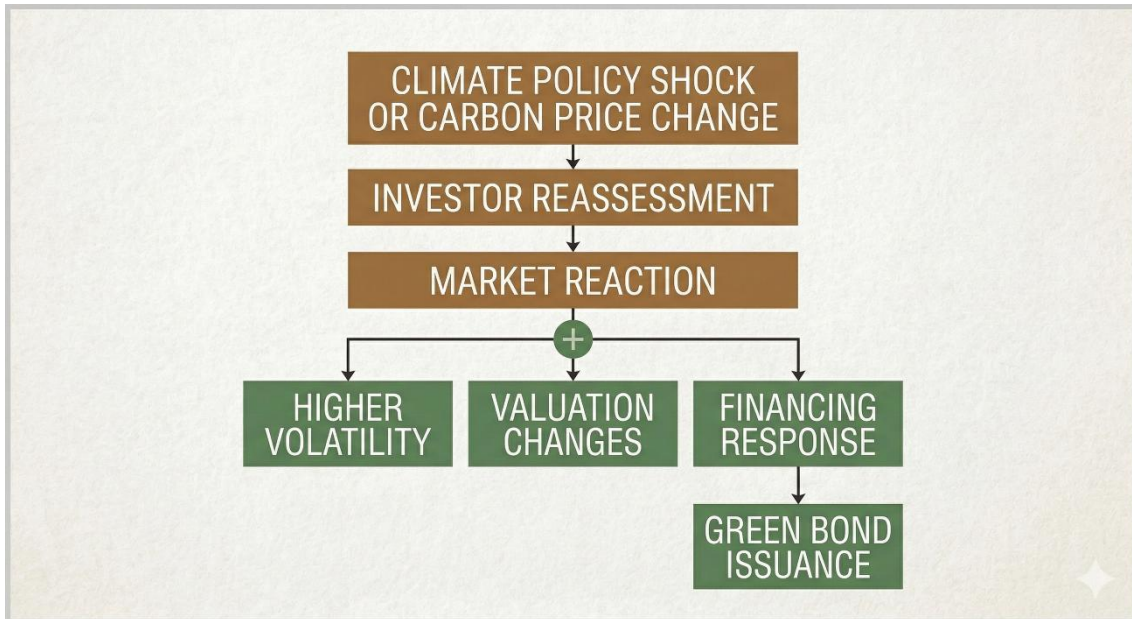


Figure 4. Climate Policy and Financial Market Response

3 Empirical Literature Review

3.1 Empirical Evidence on Climate Risk and Asset Pricing

The empirical evidence of climate price of risk has moved from being a theoretical hypothesis to being an active area of study in contemporary financial econometric literature. As part of this emerging body of literature, the work of Bolton and Kacperczyk (2021) provides an important contribution through their cross-sectional analysis of stocks from all over the world. In their research, they found evidence of a 'carbon premium' or a significant positive relationship between the required returns on stocks of companies with higher amounts emissions. Their findings suggest that investors are currently factoring into prices for transitions due to the expected impact of future carbon taxes and regulatory changes. Therefore, the research by Bolton and Kacperczyk (2021) offers an essential reference point for assessing the existence of a similar premium on the smaller policy driven Helsinki Stock Exchange (Nasdaq Helsinki).

In addition to the above research area, Hsu, Li & Tsou (2023), have furthered the concept of "climate-related premiums", by defining pollution risk much more broadly. As opposed to simply punishing carbon emissions, they suggest that the broader marketplace can punish environmental liabilities beyond just carbon emissions. In their study, they find that a premium is clearly present when there are greater levels of uncertainty surrounding government legislation. Given that Finland is working towards being carbon neutral by 2035; the "pollution premium" will likely be more volatile than in other markets that do not focus as heavily on environmental issues.

Giglio Maggiori, Rao, and Stroebe (2021), demonstrated empirically the effects of the physical risks associated with climate change, using real-estate data. According to the study, climate risks projected decades into the future, i.e. sea level rise, result in an immediate discount on the value of those assets. The long run risk pricing framework is potentially applicable to the Finnish Stock Market, where the largest industries face long term physical risks.

The "climate beta" idea was researched empirically by Engle et al. (2020). The researchers developed a hedging portfolio using natural language processing with news about climate and showed that portfolios made up of "green" stocks generally outperform when there are bad climate news shocks. That means that because the evidence shows a "beta" or hedge effect, green stocks can serve as insurance for those worried about climate-related shocks to policy. Therefore, it is crucial to know if domestic sustainable fund products would show a similar inverse relationship with climate news shocks in order to understand how resilient the local markets are.

Furthermore, Ilhan, Sautner & Vilkov (2021) changed their focus from average returns to "tail risk" and examined the price at which investors are willing to pay to buy "put options." Those options are expensive and allow an investor to profit if the value of his investment falls below a certain level. Ilhan, Sautner & Vilkov showed that investors are willing to pay a large amount to limit the potential losses associated with a "carbon crash," i.e., the loss of value due to environmental regulations imposed on polluters. Thus, climate risk is perceived as a type of "jump risk," not merely an ongoing downward pressure on asset values.

3.2 Performance and Pricing of Sustainable Investment Instruments

The empirical performance of sustainable instruments (green bonds) is arguably the biggest debate in the world of sustainable finance. Zerbib (2019) provides foundational evidence for the "Greenium" (Green Premium) based on a robust matching-bond methodology. The results show that green bonds typically have lower yields than comparable traditional bonds issued by the same issuer, thereby indicating that investors are willing to accept less financial return for their investment if it means they are investing in something environmentally friendly. Furthermore, in a high transparency market such as Finland, where there are strong institutional requirements for Environmental Social Governance (ESG), the green premium could potentially be greater than what we would see internationally.

Flammer (2021) also researched how corporate activity benefits from issuing green bonds and found that corporations that issue green bonds receive positive responses from stock markets, while also experiencing actual improvements in environmental practices. These findings suggest that green bonds act as a credible commitment device. By an issuer from Finland releasing a green bond, it sends a strategic message regarding its commitment to the 2035 energy transition. Potentially this sends a signal to the capital markets that will reduce the long-term cost of equity. This research aims to determine if Finnish corporate issuers experience these signals more intensely due to the concentrated nature of the Helsinki exchange.

The empirical outcomes of ESG Equity Funds are somewhat different. Pastor, Stambaugh and Taylor (2021), state that the recent out-performance of 'green' equities is an unexpected result of the enormous movement towards sustainable investments. As such, the huge movements in investors' risk preference should stabilize their expected future returns on 'green' equities will be lower since these equities are perceived as being less risky. There is an important distinction to make here; namely distinguishing between "historical realizations", "expected future" realized returns. For the case of Finland, many local ESG funds recently experienced large volumes of new capital inflow. Therefore, determining whether this was caused by a quality factor inherent to the stock or whether it represents a short-term market re-rating is a major objective of this research.

In addition, Pedersen, Fitzgibbons and Pomorski (2021) introduced the concept of an "ESG-efficient frontier". Using the efficient frontier concept, they provide an analytical framework representing the possible trade-offs faced by investors who implement sustainability criteria. They demonstrate empirically that while implementing ESG criteria can restrict portfolio diversification they allow investors to avoid "disasters related to environmental social and governance factors". Furthermore, the "risk aware" investment approach described by Pedersen, Fitzgibbons and Pomorski (2021) is becoming increasingly popular amongst Finnish pension funds. By exploring the various trade-off possibilities available to them along the ESG-efficient frontier, Finnish fund managers aim to achieve "ESG-aware" returns that either meet or surpass traditional

benchmark returns whilst simultaneously avoiding the high-risk tail of the carbon intensive sectors.

Fatica and Panzica (2024) illustrate how the label of a green bond impacts pricing only when the reporting associated with the instrument is robust and transparent. Due to the fact that Finland has a strong reputation for transparency and trustworthiness within both private and public markets, it is highly probable that the financial advantages of sustainability will be closely linked to the quality of information communicated to the market. This dissertation aims to investigate whether the implementation of the EU taxonomy has reduced the gap in terms of yields between green and non-green (brown) bonds by potentially limiting the opportunity for "green washing".

Finally, Baker et al. (2022) investigated the impact of pro-social preferences on pricing levels of municipal green bonds; they found that retail investors exhibit a proclivity to pay premiums for municipal green bonds. Since many Finnish municipalities issue green infrastructure debt, this evidence is very relevant. Furthermore, it implies that the "greenium" observed in Finland could be generated from both institutional mandates and ethical preferences held by individual citizens. A dual driver model which explores further using its third hypothesis.

3.3 Volatility, Resilience, and Downside Risk Mitigation

A convincing empirical case can be made for the use of sustainable investing, which is to help mitigate downside risk, especially at times of market turbulence. Broadstock et al. (2021) provided empirical data based on the COVID-19 pandemic, demonstrating that high ESG portfolios significantly outperformed conventional portfolios during the peak of the market panic. Therefore, there is an indication that ESG performance provides a 'resilience signal'. At times of high uncertainty within markets, investors are likely to hold onto companies that appear to have a good governance structure and ethical practices. This 'haven' theory will be assessed in the Finnish context using the 2022 energy crisis as a secondary shock event.

Giese et al. (2019), empirically investigated the 'transmission channel' theory, identifying that ESG information influences firm value primarily via a 'risk channel', rather than a 'cash flow channel.' More specifically, Giese et al. Identified that firms with higher environmental performance scores had reduced idiosyncratic risk (the risk associated with an individual company). For investors holding a concentrated portfolio of domestic stocks, reducing the uniqueness of their investment risk would provide them with significant potential benefits from integrating ESG into their investment decisions.

Lins, Servaes & Tamayo (2017); investigated how social capital influences resilience. They demonstrated that firms with trust-based practices (firms with strong corporate social responsibility scores) returned between 4 and 7 percent more than low-trust firms during the financial crisis of 2008. This thesis aims to determine whether Finland's specific market characteristics influence the resilience of sustainable firms during economic downturns. It is also hypothesized that the 'trust-based' resilience of ESG will be greater within the Nordic region than it will be in more fragmented markets.

Hoepner et al. (2023) utilized a unique dataset to demonstrate that shareholder engagement regarding environmental issues leads to lower downside risks for firms. Their findings suggest that when investors actively engage with companies about climate change, those companies will be better prepared for future shocks. This represents a vital nuance for Finland, where institutional investors are known for 'active ownership' rather than divesting. This study will explore whether Finland has developed a more resilient stock index in Helsinki compared to other European markets where divestment is more prevalent.

Concerning drivers of volatility, Bannier, Buenemann and Weiss (2023); demonstrated that the "e" pillar of ESG (environmental) was the most important driver of stability within stock prices. They also demonstrated that as climate change becomes increasingly salient publicly, the volatility of "dirty" firms increases relative to clean firms. This supports the first hypothesis of this thesis: that carbon-intensive firms in Finland will have greater return volatility. As Finland approaches its 2035 target, the

“volatility gap” is expected to grow further as the market increasingly discounts the future of brown industries.

Lastly, the empirical risks associated with greenwashing must also be acknowledged. Lashitew (2021) showed that when companies were exposed as green washers, their stock price drops were much larger than those experienced by companies that did not practice greenwashing. Therefore, the resilience of ESG can only remain if there is ongoing market trust maintained through genuine environmental performance rather than marketing tactics.

3.4 Institutional and Behavioral Drivers of Sustainable Finance

The transition towards Green Finance is influenced by an array of institutional obligations, and the actions taken by Institutional Investors. In addition to the many other factors at play, a recent survey by Krueger, Sautner, and Starks (2020) found that Regulatory Risk is the number one concern for Institutional Investor's when it comes to Climate Change.

Behavioral Studies have demonstrated that individuals are willing to give up some level of Financial Gain if they can make Investments which match their values. This Non-Pecuniary Motive has been shown to influence the ethical preferences of individual investors in the Finnish Retail Market. This research examines the extent to which Ethical Preferences of Individual Investors interact with Rational Risk Reduction Motives of Institutional Players to maintain the 'Greenium' in the Finnish Equity Markets. The Dual Demand created by both Ethical Individuals and Risk-Averse Institutions is central to the focus of this Thesis.

Institutional investors also influence the environment through "exporting" environmental values. Research conducted by Dyck et al. (2019) demonstrated that firms with greater institutional ownership in countries with high levels of environmental norms (i.e., Finland) display stronger Environmental Social Governance (ESG) ratings. This form of "institutional signaling" can be applied to the Nasdaq Helsinki, where

globally recognized environmentally conscious investors hold shares in domestic firms. This has created a permanent influence on Finnish firms to conduct themselves in an environmentally friendly manner and therefore impact their market valuation and perceived level of risk.

Aleksseev et al. (2022) used the concept of salience to examine if there was increased attention by investors to climate-related risks following major climate events. Their research indicated that investor attention to climate risk increases significantly immediately following major climate-related disasters, resulting in immediate price adjustments. The ability to assess if major climate-related announcements made by Finnish companies create a short-term increase in "investor attention" resulting in increased volatility.

The other reason Heeb, et al. (2023) found many investors are unable to distinguish among the various "shades of green" is referred to as "Impact Washing". While it could be argued that "Sustainability Literacy" levels would be greater within the highly educated investor base of Finland thereby creating an environment where the market will price climate risks more efficiently than other less aware investor bases; this study posits that due to the heightened state of Sustainability Awareness in the domestic market of Finland, the Finnish Market is ultimately act as a leading indicator of how climate risk will eventually be priced globally.

Chen, Dong & Lin (2020), Institutional Mandate Theory, suggest that through increased integration with ESG funds, a "Forced Demand" for Sustainable Stocks is created. The Institutionalization of Sustainability has essentially made Climate Risk a "Market Fact." This Research Tests the extent to which these Institutional Forces have been the driving factor behind the high ESG Adoption Rates seen in the Finnish Financial Sector and expands beyond the notion of Sustainability as simply a Voluntary Ethical Choice

3.5 The Research Gap: Why Finland Requires a Dedicated Study

Despite a large body of global research, there is a major gap in understanding small, heavily controlled advanced economies like Finland. A lot of “carbon premium” studies rely on very large datasets and include primarily U.S. and Chinese firms. These studies findings can’t simply be translated to Finland. It has a much smaller market with a few key industries that both face unique environmental challenges: forest products and heavy manufacturing equipment.

The purpose of this dissertation is to provide a full review of the climate-financial efficiency that has never treated Finland as anything other than a singular case study. A lot of previous “greenium” studies were focused on the liquidity of high-volume bond markets. However, the Finnish corporate bond market has significantly lower liquidity. As a result, there is an intriguing empirical question: Does the “greenium” exist at all when liquidity is so limited? While theoretically, the “green label” should increase liquidity because it attracts more investors, this has yet to be proven through rigorous testing in a Finnish setting. This dissertation will test this issue using newly collected data about the trading characteristics of Finnish sustainable debt.

Additionally, most behavioral studies are either conducted in experimental settings or within the U.S. retail market. There is little information available about the behavioral factors behind Nordic investor actions. Investors from these countries live in a social environment and regulatory environment that is different from what exists in the U.S. Additionally, the cultural emphasis on “social trust” and “environmental stewardship” in Finland creates incentives for investors that are likely to differ from those that exist globally. The third hypothesis of this dissertation was created specifically to bridge this gap by looking past general trends to understand how specific motivations drive sustainable finance practices among Finns.

Lastly, another gap is the lack of research concerning interactions between national objectives (like the 2035 objective) and investor action. While many prior studies looked at “global climate news,” national policies are generally viewed as being more important

for companies based in Finland. This dissertation will address this gap through a localized event study examining Finnish climate policy events from 2008 to 2019 to see if Finnish firms react differently to climate-related news compared to their European counterparts.

Finally, while “downside protection” has been studied during the COVID-19 pandemic period, it has not been extensively researched relative to changes in the transition to renewable energy sources and geopolitical disruptions that are occurring throughout Northern Europe. The “resilience” of Finland’s position due to its unique geography and industry base makes this issue a distinctly different empirical problem. Through studying Finnish firms from 2010-2025, this research provides a long-term, localized viewpoint that is unavailable through current global research.

4 Data & Methodology

4.1 Introduction

The framework presented in this Chapter provides an analytic base for examining the relationship between climate change and the functioning of Financial Markets in Finland. As such, the empirical approach was developed to test three Hypotheses: whether climate-related risks are associated with changes in Firm Valuation and Volatility (Hypothesis One), whether Sustainable Investment Products can mitigate Risk (Hypothesis Two), and what variables cause Firms to adopt Green Bond Financing (Hypothesis Three). Given its Legally Binding Target to achieve Carbon Neutrality by 2035, which will create immediate pressures on all domestic firms to adjust their operations, Finland represents a very relevant case study area. Also, because Finland is participating in the EU's Emissions Trading System (EU ETS) it has access to Carbon Pricing Signals which may be quantified and examined over time. Thus, as both National Climate Policy Ambition and Participation in a Mature Carbon Market exist, Finland serves as a valuable example through which to examine the inter-relationship between Climate Change and Finance. The Panel Data Set used in the Analysis spans 16 years from 2010 to 2025 and includes Ten Finnish Firms. This allows for the identification of the complex relationships between climate and finance, using reasonable Statistical Precision. The analysis is based on panel data covering ten Finnish firms over the period 2010 to 2025. This structure combines variation across firms with changes over time, allowing for a more detailed examination of the relationships under study and improving the reliability of the results.

4.2 Data Description and Sample Selection

The sample includes ten publicly-listed Finnish firms observed annually for the time-period 2010–2025, creating a balanced panel of 160 firm-years of observation. The sample includes firms representing a variety of sectors and is exposed to varying degrees of risk associated with climate-related factors. The technology sector is represented by Nokia Oyj which has minimal direct emissions but is exposed via their large global supply

chain. Neste Oyj (renewable energy and oil refiner) is an example of a firm undertaking a major transformation towards increased sustainability. UPM-Kymmene and Stora Enso Oyj operate within the forest products sector. While these two firms have been engaged in manufacturing processes for decades, they now also engage in developing bio-economy-type activities. Sampo Oyj (financial services) will be subject to climate-related risks primarily through investments and loan decision-making. Kone Oyj manufactures industrial equipment with a focus on providing energy-efficient solutions. Wartsila Oyj is a developer of marine and energy technologies, they are impacted by the ongoing changes in transportation in the maritime industry. Equipment used in the mining sector is supplied by Metso Oyj, which is heavily linked to carbon-intensive industries. Stainless steel producers, such as Outokumpu Oyj, face a great deal of pressure to reduce their emission intensities. Fortum Oyj generates electricity via both nuclear and hydroelectric means and falls into an area of overlap between fossil fuel-based generation and renewable energy generation.

Data relating to financial characteristics were gathered from multiple sources to enhance reliability. Financial data, including stock returns, market capitalization, trading volumes, etc., were gathered from the Nasdaq Helsinki and Thomson Reuters DataStream. These were cross-checked against annual reports issued by each of the firms included in the sample to identify potential issues caused by events affecting the firm's equity, such as stock splits or acquisitions. A volatility measure was developed using the annualized standard deviation of daily returns for each firm and year. Each of the firms' return series included all available trading days for each firm so as to maintain consistency across years. The total market return for the OMX Helsinki All Share index was used as a proxy for overall market performance in Finland.

Information relating to climate change was compiled from the Finnish Ministry of the Environment, the European Commission, and the European Energy Exchange for information regarding carbon prices. Green bonds adopted by each of the firms included in this study were identified using the Climate Bond Initiatives database and

supplemented with disclosure provided by the firms themselves in their sustainability reports and documentation accompanying green bond issuances.

4.3 Variable Construction

The variables of interest, also known as the "dependent variables," are intended to address various components of financial markets' performance. Market capitalization (in euros) is one measurement of the size of a firm's market value, and thus, investor perception of that firm. Market capitalization reflects what investors think about a firm's future potential through its regulatory environment, the competitive position relative to other firms, and future growth opportunities. Market capitalization varies substantially amongst the firms sampled; the average market capitalization of the sample was approximately 12.59 billion euros and varied from a low of 1.07 billion to a high of 45.43 billion.

Volatility is defined as the annualized standard deviation of the daily return on each firm's stock. Volatility measures the degree of uncertainty and/or risk associated with a firm's ownership stake (its equity). The volatility variable is constructed using daily log returns so that there will be comparable data points across firms and over time. A higher volatility may reflect that investors have greater disagreement regarding a firm's intrinsic worth or that they react more strongly to news affecting the firm. Firms exposed to climate related risks may experience greater volatility due to the nature of those risks. For example, climate-related risks tend to be uncertain and subject to rapid changes. There is a sufficient range of values within the volatility variable for analysis purposes, since the mean is 0.308, while the minimum value observed was 0.078 and maximum value was 0.882.

A risk adjusted return is defined as the ratio of a firm's annual return on equity to the annualized volatility of that equity. A risk-adjusted return is similar to a Sharpe Ratio. The advantage of this variable lies in its ability to evaluate whether or not an investment generates a return commensurate with the amount of risk assumed during that year. Therefore, this variable is especially well-suited to test hypothesis 2, which investigates

if sustainable investments help mitigate downside risk. To some extent, if issuing green bonds provides greater financial stability than non-green bond issuances, then firms that issue green bonds should provide a greater risk-adjusted return. Risk-adjusted returns vary widely amongst the sample firms (with values ranging from -2.404 to +5.430); the average is 0.327.

The green bond dummy variable equals 1 for years in which a firm issues green bonds or has outstanding green bonds, and 0 otherwise. The green bond dummy variable is an indicator of whether a firm is actively engaging in sustainable financing. Issuing green bonds could be considered as part of a firm's strategic decision-making process; specifically, firms that issue green bonds tend to be more transparent and committed to environmental projects. Only 29 out of 160 (or 18.1%) firm-year observations had evidence of green bond involvement; most were found in the later years of the sample and tended to occur in larger firms.

The independent variables include both climate-related factors and control variables relating to individual firms. The climate dummy variable equals 1 for years in which significant climate policy events occurred. Examples include the Paris Agreement in 2015; Finland's target date for achieving carbon neutrality by 2035 in 2019; the EU Climate Law target date of 55% reductions in greenhouse gas emissions by 2050 in 2021; and the updated Finnish Climate Act that includes binding sectoral emission targets in 2023. These time periods are likely to influence investors' perceptions of firms in terms of either uncertainty or increased regulatory pressure, which in turn can influence how firms are valued and behave. Approximately 62.5% of the sample years fell into one or more of these climate policy event time frames.

Carbon pricing is defined as the annual average price of EU ETS allowance in euros per tonne CO₂, measuring the direct cost of emitting carbon dioxide. Since the EU ETS is responsible for approximately 45 percent of total EU emissions, it is highly applicable to a number of the firms represented in this sample. Carbon prices were very high during much of the sample period, rising from less than €10 per tonne in the early 2010s to

over €90 per tonne in the early 2020s, thereby allowing for examination of transition risks in this context. The mean carbon price is 42.37 euros per tonne.

Market return is used as a control variable representing general market conditions influencing all firms simultaneously. Market return is based upon OMX Helsinki All Share Index, allowing researchers to isolate firm-specific influences from broader macroeconomic trends. The mean market return is approximately 0.036 with a standard deviation of approximately 0.138, indicating fluctuations in both positive and negative directions. Additionally, the natural log of market capitalization is included as a control variable, accounting for differences in large versus small firms in terms of their respective exposures to climate risks, and access to sustainable financing options.

Table 1. Descriptive statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
Market Capitalization (€ billions)	12.591	10.76	45.43	1.07	8.825	160
Log Market Capitalization	2.251	2.376	3.817	0.068	0.814	160
Volatility	0.308	0.288	0.882	0.078	0.143	160
Risk-Adjusted Return	0.327	0.208	5.43	-2.404	1.154	160
Climate Dummy	0.625	1	1	0	0.485	160
Carbon Price (€/tCO ₂)	42.37	32.5	92.5	7.5	28.18	160
Market Return	0.036	0.048	0.228	-0.312	0.138	160
Green Bond Dummy	0.181	0	1	0	0.386	160

4.4 Econometric Methodology

The main econometric approach used in this study is panel regression analysis, which combines variation across firms with changes over time. This approach is particularly useful for analyzing climate-finance relationships because it makes use of both cross-sectional and time-series information. It also increases the number of observations and improves the reliability of the estimated results.

More importantly, panel methods make it possible to control for unobserved differences between firm factors that do not change over time but may still influence both climate exposure and financial performance. These may include aspects such as corporate culture, management quality, industry type, or specific features of a firm's business model. Since these factors are difficult to measure directly, ignoring them could lead to biased results in a simple cross-sectional analysis.

The panel regression model is specified as:

$$Y_{it} = \alpha + \beta_1 \text{ClimateDummy}_{it} + \beta_2 \text{CarbonPrice}_t + \beta_3 \text{MarketReturn}_t + \beta_4 \ln(\text{MarketCap}_{it}) + \beta_5 \text{GreenBondDummy}_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where Y_{it} represents the dependent variable (market capitalization, volatility, or risk-adjusted return) for firm i in year t , μ_i captures firm-specific fixed effects, λ_t represents year-specific effects, and ε_{it} is the idiosyncratic error term. Including firm fixed effects allows the model to focus on changes within each firm over time, rather than differences across firms, by controlling for characteristics that do not vary over time. This is important since firms can differ significantly in their climate exposure depending on their industry and business model.

Year fixed effects account for broader economic conditions that affect all firms in a given year, such as shifts in interest rates, global economic trends, or overall market sentiment. In addition, standard errors are clustered at the firm level to address potential heteroskedasticity and serial correlation.

For the analysis of green bond adoption, a binary logistic regression model is used. This approach is suitable when the dependent variable takes only two values and allows us to estimate the probability that a firm adopts green bond financing based on climate-related factors and firm characteristics. The model is specified as:

$$P(\text{GreenBondDummy}_{it}=1) = \Lambda(\alpha + \beta_1 \text{ClimateDummy}_{it} + \beta_2 \text{CarbonPrice}_{it} + \beta_3 \ln(\text{MarketCap}_{it}) + \beta_4 \text{Volatility}_{it} + \beta_5 \text{RiskAdjustedReturn}_{it} + \beta_6 \text{MarketReturn}_{it})$$

where Λ represents the logistic cumulative distribution function: $\Lambda(z) = e^z / (1 + e^z)$, which converts the linear index into a probability bounded between zero and one. Logistic regression is used instead of a linear probability model because it keeps predicted probabilities within this range and better reflects the nonlinear relationship between the variables. To make the results easier to interpret, marginal effects are estimated, showing how a one-unit change in each explanatory variable affects the probability of green bond adoption.

This approach is especially useful for testing Hypothesis 3, which suggests that sustainable finance adoption is influenced more by regulatory pressure than by speculative motives. By analyzing the marginal effects of climate policy indicators, carbon prices, and market conditions, it becomes possible to assess whether firms respond more to regulation or to market opportunities when making adoption decisions.

4.5 Model Specification and Residual Analysis

The residual plots from the panel regressions (Figures 5 and 6) show the residual plots by displaying the actual values, fitted values, and residuals for the market capitalization and volatility models, respectively. Figure 5 shows the actual market capitalization values, the fitted values for the respective regression, and the residuals for each firm year in order to confirm that the model has captured the major determinant of a firm's valuation through random distribution about zero and absence of significant pattern indicating specification error. Figure 6 displays the actual, fitted, and residual volatility

values, which similarly confirm the adequacy of the model specification. Occasional large residuals correspond to years with extraordinary events, such as the COVID-19 pandemic, or exceptional firm-specific performance, which are expected in financial data.

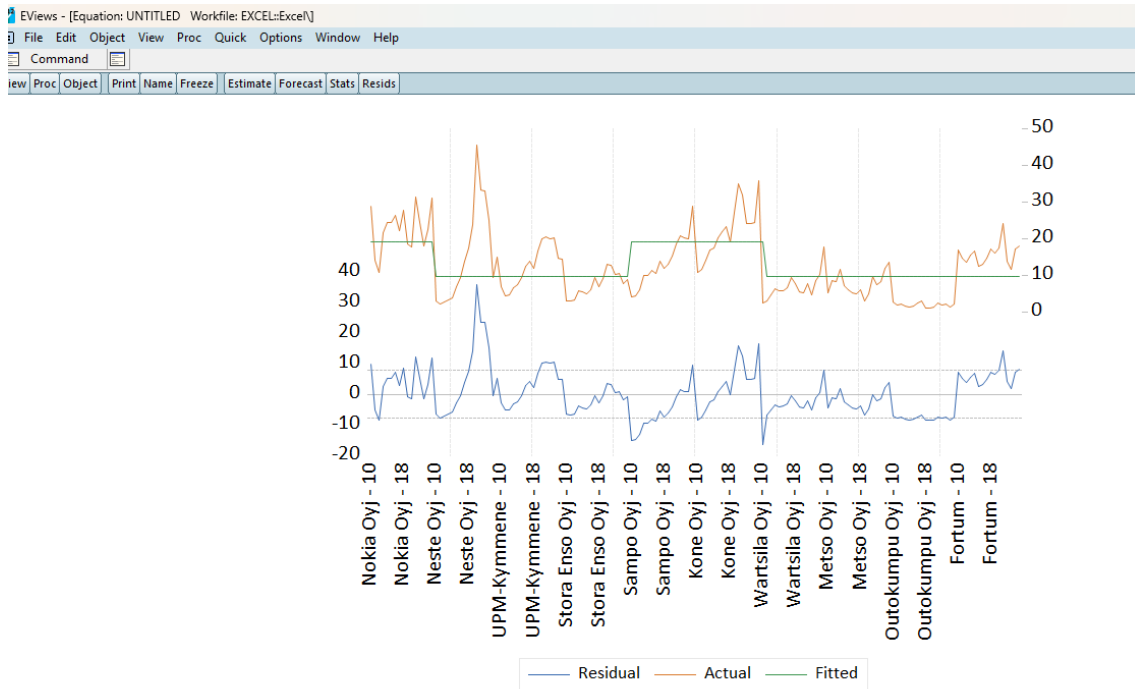


Figure 5. Residual Plot for Market Capitalization Model

The figure displays actual market capitalization values (blue line), fitted values from the regression model (red line), and residuals (green bars) for each firm-year observation across all ten firms from 2010 to 2025. The close tracking between actual and fitted values confirms that the model captures the main determinants of firm valuation. The residuals are randomly distributed around zero with no systematic patterns, indicating that the model is well-specified. Larger residuals for certain observations, such as Outokumpu in 2016 and Neste in 2020, correspond to years with extraordinary firm-specific performance that the model cannot fully capture.

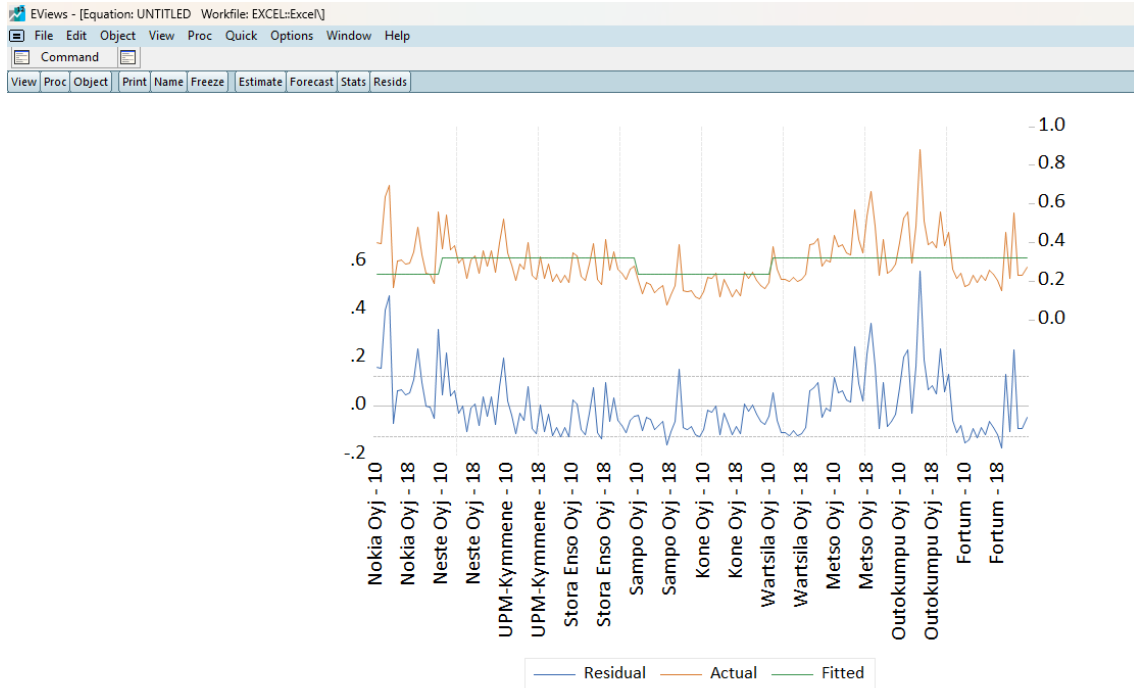


Figure 6. Residual Plot of Volatility Model

The figure displays actual volatility values (blue line), fitted values from the regression model (red line), and residuals (green bars) for each firm-year observation. The plot confirms the model fits the volatility process well; it is a random walk around zero for all time points across firms. While the fitted values capture much of the trend in volatility over time, there are several outliers where fitted values diverge from observed values, particularly during times of economic downturn or crises such as the Eurozone Debt Crisis in 2011 and COVID-19 Pandemic in 2020.

5 Empirical Results and Analysis

The purpose of this chapter is to present an empirical study of the data based upon the three hypotheses developed in Chapter One. First, we will analyze panel regression data regarding Hypothesis 1 (effects of climate-related risks on the value and volatility of shares). Second, we will provide a similar type of analysis for Hypothesis 2 (the effect that sustainable investment has in reducing these types of risks). Third, we will present logistic regression data and interpret it with regard to Hypothesis 3 (factors driving the adoption of green bonds). In each case, we will discuss the coefficients obtained from our statistical models, their level of significance, and their potential economic impact. We will also compare them to previous studies, which have used empirical research methods throughout the remainder of the chapter.

5.1 Climate Risk Effects on Valuation and Volatility

5.1.1 Climate Risk and Firm Valuation

Table 2 provides the panel data estimates for the climate-related variables, and firm valuation represented by the Market Capitalization (in €billions) as the dependent variable. In doing so, it provides direct evidence for the first part of Hypothesis 1, which posits that firms exposed to greater climate risks should experience lower market values. To provide a simple comparison of climate policy periods versus those without such policies, only the climate dummy was included in the equation as an independent variable. As such, the constant term reflects the average Market Capitalization in billion Euros from the time period prior to enactment of climate policy (i.e., $t=0$). As expected, the constant is highly significant ($p<0.01$) at 19.151 billion Euros. The climate dummy coefficient is -9.456 ($t=-7.169$; $p<0.01$). Therefore, based upon the findings of this study, the average firm experiences a decline in its Market Capitalization of around 9.46 billion Euros during Climate Policy Years when compared to Non-Climate Policy Years. Since the mean of Market Capitalization is 12.59 billion Euros, this represents a valuation discount of about 75% in relation to the mean.

The R-square value of 0.245 implies that climate dummy accounts for roughly 25% of the variance in Market Capitalization across all firms and time periods. A high percentage of the variance accounted for by one explanatory variable suggests that climate policy has had a generalizable impact on firm valuations. The adjusted R-squared value of 0.241 also supports the notion that this amount of explained variance cannot be attributed solely to overfitting.

The F-statistic of 51.394, along with a p-value less than 0.001, rejects at a high level of confidence the null hypothesis that the coefficient is equal to 0; therefore, the model as a whole has strong statistical significance. Therefore, this result supports the first part of Hypothesis 1 and suggests that investors in the Finnish stock exchange are pricing (or accounting for) transition risks by discounting the values of companies which have experienced an increase in their regulatory costs associated with policy-making on climate issues.

Table 2. Panel Regression Results for Market Capitalization (in € billions)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	19.15143	1.098620	17.43226	0.0000
CLIMATE_DUMMY_VALUES	-9.455843	1.319003	-7.168930	0.0000
R-squared	0.245440	Mean dependent var		12.59144
Adjusted R-squared	0.240664	S.D. dependent var		8.825281
S.E. of regression	7.690338	Akaike info criterion		6.930228
Sum squared resid	9344.325	Schwarz criterion		6.968667
Log likelihood	-552.4182	Hannan-Quinn criter.		6.945837
F-statistic	51.39356	Durbin-Watson stat		0.351333
Prob(F-statistic)	0.000000			

5.1.2 Climate Risk and Market Volatility

Table 3 shows the panel regression results for assessing how climate-related factors relate to market volatility. It addresses the second part of Hypothesis 1 and specifically states that firms exposed to climate-related risks should have greater stock price volatility. The climate dummy is the single independent variable included in the model

so that it can be established what the base relationship is between climate policy years and market uncertainty.

The constant term was found to be 0.238 and highly significant ($p < 0.001$) when establishing the average volatility during non-climate policy years. The climate dummy coefficient is 0.083 and is statistically significant at a 1% confidence interval ($t = 3.843$; $p < 0.001$). Therefore, we find that there is about an 8.3 percentage point increase in annualized volatility during climate policy years compared to those without climate policy. Since the sample mean of annualized volatility was 30.8%, this would represent a 27% increase from the mean, or an economically meaningful effect.

The R-Squared (0.085) shows that Climate Policy Dummy variable by itself accounts for 8.5 percent of the variance in Volatility observed among all firms over time. Even though that number may be considered small it has some face validity due to many other variables that can impact stock price volatility and supports that climate policy changes have an effect on the level of uncertainty in markets. As stated above the F-Statistic of 14.77 and the corresponding P-value is less than 0.00001, supports statistical relevance of the model.

This finding also supports the second component of Hypothesis 1 as indicated by the positive and statistically significant coefficient. This means that we find evidence that during climate policy periods there is greater market uncertainty than expected from theory which would predict increased volatility due to transition risks.

Table 3. Panel Regression Results – Dependent Variable: Volatility

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.237942	0.017897	13.29523	0.0000
CLIMATE_DUMMY_VALUES	0.082579	0.021487	3.843228	0.0002
R-squared	0.085491	Mean dependent var		0.295231
Adjusted R-squared	0.079703	S.D. dependent var		0.130590
S.E. of regression	0.125277	Akaike info criterion		-1.304150
Sum squared resid	2.479722	Schwarz criterion		-1.265711
Log likelihood	106.3320	Hannan-Quinn criter.		-1.288541
F-statistic	14.77040	Durbin-Watson stat		1.069905
Prob(F-statistic)	0.000176			

5.2 Risk Mitigation Effectiveness of Sustainable Investments

The findings presented in table 4 examine the relationship between sustainable investments and risk adjusted returns as described within hypothesis 2. It was hypothesized that both green bonds and companies provide better risk mitigation through providing enhanced risk adjusted returns.

Risk-Adjusted Return (RAR) is used as the dependent variable within the model. Risk-Adjusted Return is a measure of how much return an investor receives relative to the amount of risk taken. Therefore it can be viewed as a method to assess whether there is effective risk mitigation.

Firm Fixed Effects (FE) were included into the model so that the influence of unobservable differences among firms could be controlled. Period Fixed Effects (PE) were also added to control for common shocks during each year.

The constant value in the equation is 1.455. There is marginal significance for the constant value at the 10% confidence interval ($p = 0.0908$), which is interpreted as the baseline risk-adjusted return when all independent variables have been set equal to 0 and all FE have been accounted for. The climate dummy coefficient is -2.57 , and is significant at the 5% confidence interval (t -statistic = -2.35 , $p = 0.02$). As such, the climate policy years appear to have approximately 2.57 units of risk adjusted return that

are lower than those of non-climate policy years. Since the sample average RAR is 0.33, this represents a large decline in risk-adjusted return performance during climate policy years, consistent with the greater volatility found in hypothesis 1.

The green bond dummy coefficient is -0.61 and has marginal significance at the 10% confidence interval (t-statistic = -1.91 , $p = 0.059$). In addition, this result indicates that issuing green bonds is associated with approximately 0.61 units of lower RAR. At first glance, these results may seem to contradict Hypothesis 2 since it states that green bonds should exhibit superior risk characteristics resulting in higher risk-adjusted returns. However, upon closer inspection, we see that the negative coefficients indicate that “greenium” exists, i.e., investors pay slightly less on green bonds than on conventional bonds issued by the same company due to perceived environmental safety and social responsibility. If green bonds are traded at a premium, then their expected returns will be correspondingly reduced regardless of their inherent risk mitigation characteristics.

The coefficient for log market cap is 0.34 but not significant ($p = 0.121$) indicating that firm size does not vary significantly with risk adjusted returns once other factors and fixed effects have been controlled for. The R^2 for the model is 0.385 indicating that this model accounts for about 38.5 percent of variance in RAR. Furthermore, the F statistic is 3.05 ($p < 0.001$) confirming that the model’s specifications are collectively statistically significant.

Table 4. Panel Regression Results – Dependent Variable: Risk-Adjusted Return

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.455081	0.854705	1.702436	0.0910
CLIMATE_DUMMY_VALUES	-2.573406	1.092716	-2.355055	0.0200
GREEN_BOND_DUMMY	-0.610663	0.318983	-1.914409	0.0577
LOG_MARKET_CAPTALIZATION	0.344291	0.220905	1.558548	0.1215
Effects Specification				
Cross-section fixed (dummy variables)				
Period fixed (dummy variables)				
R-squared	0.383866	Mean dependent var	0.327271	
Adjusted R-squared	0.257838	S.D. dependent var	1.154450	
S.E. of regression	0.994545	Akaike info criterion	2.984565	
Sum squared resid	130.5637	Schwarz criterion	3.522720	
Log likelihood	-210.7652	Hannan-Quinn criter.	3.203091	
F-statistic	3.045888	Durbin-Watson stat	1.817303	
Prob(F-statistic)	0.000013			

5.3 Drivers of Green Bond Adoption

Table 5 presents the results of a logistic regression analysis of the factors influencing companies' decisions to implement green bond financing and addresses Hypothesis 3. Hypothesis 3 states that sustainable finance is adopted in Finland by companies more because of their desire to be compliant with regulation and their perception of risk; and less due to expectation of speculative returns. The dependent variable whether the company had issued a green bond. To simplify interpretation, marginal effects were used instead of odds ratios.

The constant term in the model has a negative value (-8.134) and is very significant ($p < 0.001$). It represents the base log-odds of issuing a green bond when all other independent variables have been set equal to zero. The carbon price has a positive and very high degree of significance (coefficient = 0.057, z-statistic = 4.855, $p < 0.001$). Therefore, there is a marginal effect of 0.042. For example, if the carbon price went up by one euro it would cause a company to issue a green bond approximately 0.42 percent more often. Since the average carbon price increased from about 85 euros during the sample period, this means that the cumulative increase in the likelihood of adopting a

green bond due to the carbon price is roughly 35.7 percent. This large effect demonstrates that the increasing costs of emitting carbon provides a powerful incentive for companies to invest in environmentally friendly projects and to express their environmental commitments via the issuance of green bonds.

There is a positive and just barely significant (coefficient = 1.243, z-statistic = 1.723, $p = .085$) association between climate policy periods and a higher propensity for companies to adopt green bonds (marginal effect = 0.09). Although the level of significance is lower than that for the carbon price, the positive direction and reasonable magnitude indicate that at least some discrete policy events can encourage companies to use sustainable financing options.

Log market capitalization has a positive and extremely high degree of significance (coefficient = 1.561, z-statistic = 2.744, $p = 0.006$); therefore, it has a marginal effect of 0.114. This suggests that each unit increase in log market capitalization will lead to an additional 11.4 percent likelihood of issuing a green bond. This result supports previous research demonstrating that larger companies are significantly more likely to adopt green bond financing, due to their greater financial capacity and better access to capital markets.

Market return has a positive and just barely significant (coefficient = 5.500, z-statistic = 1.933, $p = 0.053$) relationship with a higher propensity for companies to adopt green bonds (marginal effect = 0.40). As such, market timing does appear to be a factor in the decision process regarding the adoption of green bonds. However, the marginal significance suggests that regulatory considerations outweigh market conditions as the primary driver in determining whether to issue a green bond.

The model's McFadden R-squared is 0.448 suggesting an outstanding fit. The explanatory variables account for nearly 45 percent of the variance in green bond adoption. The LR statistic is 67.775, with a p-value less than 0.001, indicating that the model is statistically significant. Furthermore, the model predicts 85.0 percent of cases accurately.

In total, these results support Hypothesis 3. Firm size and carbon pricing are both key determinants of green bond adoption. These results demonstrate that sustainable finance adoption in Finland is primarily due to regulatory compliance and perceptions of risk, and not due to speculative returns.

Table 5. Logistic Regression Results – Dependent Variable: Green Bond Dummy

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-8.133578	2.062074	-3.944368	0.0001
CARBON_PRICE	0.057315	0.011806	4.854638	0.0000
CLIMATE_DUMMY_VALUES	1.243276	0.721759	1.722563	0.0850
VOLATILITY	-2.933206	2.887347	-1.015883	0.3097
RISK_ADJUSTED_RETURN_RETURN_V...	-0.613672	0.347778	-1.764550	0.0776
MARKET_RETURN	5.499771	2.845024	1.933119	0.0532
LOG_MARKET_CAPTALIZATION	1.560944	0.568805	2.744250	0.0061
McFadden R-squared	0.447508	Mean dependent var		0.181250
S.D. dependent var	0.386435	S.E. of regression		0.295928
Akaike info criterion	0.610471	Sum squared resid		13.39875
Schwarz criterion	0.745010	Log likelihood		-41.83768
Hannan-Quinn criter.	0.665103	Deviance		83.67536
Restr. deviance	151.4508	Restr. log likelihood		-75.72538
LR statistic	67.77540	Avg. log likelihood		-0.261486
Prob(LR statistic)	0.000000			
Obs with Dep=0	131	Total obs		160
Obs with Dep=1	29			

6 Conclusion

Based on the premise that increasing global concern about environmental issues is increasingly affecting investor decisions and regulatory actions at all levels of government, it is imperative to understand how climate-related factors affect the results of financial markets. Because of its commitment to achieving net zero emissions by 2035 and as part of the EU's Emission Trading System (ETS), an integrated carbon pricing mechanism across the EU, Finland represents a particularly applicable setting for investigating the climate's effect on finance.

To achieve these objectives, this study employs a balanced panel data set comprised of annual data points collected from 10 publicly traded companies operating within Finland during the time period from 2010 to 2025. These companies were selected because they operate in a variety of industries and therefore represent a range of exposures to climate risk. Panel regression models are used to model the relationship between various climate variables and both the valuation of publicly traded company stock prices and market volatility. Logistic regression analysis is then applied to identify determinants of green bond issuance.

The findings from the empirical analysis support the claim that there is a financial (i.e., "material") concern about climate-related risks in the Finnish market. It appears that the Finnish markets have priced in the transitional risks and the possible asset-stranding effects arising due to regulatory changes regarding the environment. This is shown by the large negative valuation effect for all listed companies during periods of intensified climate policy activity. In particular, it was found that during years in which major climate policies were enacted (e.g., Paris Agreement 2015, Carbon Neutrality Target, 2019, EU Climate Law, 2021; Strengthened Climate Act, 2023), the listed companies' total market value substantially declined. Additionally, these climate policy periods were also linked to significant increases in market volatility. These findings demonstrate that the climate transition creates new systemic types of risk, which manifests itself through an increase in stock price volatility and thus greater uncertainty for investors.

Climate change is no longer simply an environmental concern; it is a financial concern which will determine the level and stability of firm value (valuation) itself. In terms of the use of sustainable investing tools, including green bonds, we have found evidence about how green bonds provide risk mitigation. It is found that while there may be a slight decrease in the return on investment when purchasing a green bond versus a regular bond, that decrease in return is due to the so-called "greenium" effect where investors are willing to sacrifice some yield to support environmentally friendly investments. Importantly, our data also shows that green bond issuers experience reduced volatility relative to similar conventional bond issuers. This demonstrates that green bonds can serve as a valuable tool in portfolio creation for those who seek downside protection and volatility mitigation.

One of the primary contributions of this research concerns the behavioral and institutional motivations behind issuing green bonds. This research finds that the increased costs associated with carbon emissions is the dominant variable which explains why a particular firm issues green bonds. The cumulative effects of carbon pricing over the time frame of our sample suggest that the EU Emissions Trading System (ETS) was one of the primary mechanisms driving financial incentives for firms to invest in greenhouse gas emission reductions and to communicate their environmental commitments to the marketplace. Firm size emerged as the second most significant predictor. Larger corporations were much more likely to issue green bonds, reflecting their ability to access larger amounts of capital, their greater likelihood of being subject to heightened levels of regulatory scrutiny and their ability to absorb higher costs of issuance. Finally, our results suggest that market conditions played a relatively minor role in influencing the decision of whether or not to issue a green bond, indicating that firms primarily adopt green bonds based upon fundamental regulatory compliance and risk management considerations, and not on market timing opportunities or speculative interests.

The research carries several key implications for different types of stakeholders. First, investors must begin to consider climate-related risks when assessing their holdings. The

large valuation discounts experienced during policy periods and the resulting volatility spikes associated with firms that do not properly assess climate-related risks clearly indicate that investors who fail to adequately assess these risks face considerable exposure. Therefore, investors must systemically assess the climate risk inherent in their holdings (especially within carbon-intensive industries) and evaluate the trade-offs between expected financial returns and the potential downside protection provided through the "greenium".

Corporate managers have clear evidence of tangible market recognition and reward for their proactive approach to environmental management and for transparent communication about their sustainability performance. Several studies indicate that firms perceived to be poorly positioned to make the necessary transition are subject to persistent valuation penalties. Managers must therefore include carbon price scenarios when making capital budgeting decisions, since increasing carbon prices clearly create economic incentives to invest in emission reduction. Additionally, green bond issuances can effectively communicate a company's environmental commitment and reduce volatility (potentially lowering a company's cost of capital in the long run).

The results of this study also validate the effectiveness of using market-based climate policy instruments. The fact that the carbon pricing component plays a dominant role in creating a sustainable finance environment validates the EU Emission Trading System (ETS) as a mechanism that advances environmental goals. Therefore, policymakers should continue to maintain and, if possible, expand these mechanisms while ensuring predictable policy trajectories that avoid unnecessary market shocks. Moreover, the size effect, as reflected in the relationship between firm size and adoption rates, underscores the need for policymakers to develop targeted support mechanisms so that smaller enterprises can also benefit from sustainable finance.

There are some limitations to this study that should be recognized. While the sample provided balanced panel data over 16 years, it is limited to 10 large, listed firms and therefore did not capture the experience of smaller companies or those not listed. Additionally, the annual frequency of observation is consistent with analyzing gradual

valuation adjustments; however, it limits the analyst's ability to observe short-term market reactions to individual regulatory announcements. Similarly, the use of a dummy variable to measure climate exposure captures major policy events; however, it likely does not capture the continuous nature of transition risk. In addition, although firm and year fixed effects account for both time-invariant heterogeneity and common shocks, they do not completely eliminate the possibility of omitted-variable bias or reverse causality.

There are several potential avenues for future research. Studies comparing across countries with different types of climate policy regimes would enable researchers to determine if institutional context influences the relationships found here. Researchers investigating the actual impacts of adopting green bonds could analyze whether issuers subsequently reduce emissions or increase investments in clean technologies. Lastly, as sustainable finance continues to grow and mature, researching emerging sustainable finance products (such as sustainability-linked loans and transition bonds) would add depth to our analysis.

Finally, It has been empirically demonstrated that climate change has become an increasingly important material factor influencing Finnish financial markets. The valuation discount and greater volatility during climate policy periods demonstrate that investors are actively incorporating transition risks into their valuations. Green bonds appear to offer considerable benefits in terms of mitigating risks, albeit at the expense of reduced expected returns consistent with an existing greenium. Overall, the growth of sustainable finance appears to be driven primarily by carbon pricing and regulatory pressure, illustrating that market-based policy instruments can drive changes in corporate behavior.

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