Climate Change and Asset Prices –

Evidence on Market Inefficiency in Europe

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

Abstract

There is an emerging consensus that the threat of global warming, as well as regulatory and market initiatives for the reduction of GHG-emissions, result in significant costs for companies today and in the future. The magnitude of these costs is unknown to investors and transforms climate change into a market-wide financial risk. An efficient stock market prices this risk and rewards investors with higher returns for assuming higher levels of systematic risk. The purpose of this thesis is to analyse the efficiency of stock markets with regard to climate change induced systematic risk. To that end, a Carhart 4 Factor Model extended for industry effects is applied to a sample of 433 European companies in the years 2005 to 2009. This research thus contributes to the understanding of the behaviour of stock prices towards the financial implications of climate change.

Results indicate that the stock market was inefficient in pricing all six proxies for climate change induced systematic risk applied in this study, i.e. a company’s affiliation to the European Emissions Trading Scheme or high carbon industries, the existence of disclosure of GHG-emissions, the completeness of such disclosures, the absolute level GHG-emissions and GHG-efficiency. Persistent economically and statistically significant arbitrage opportunities exist when trading on publicly available information concerning these proxies. In this evidenced state of market inefficiency, investors are not rewarded for assuming higher levels of climate change induced systematic risk, but instead can achieve abnormal risk-adjusted returns by exploiting the inefficiently priced positive effects of (complete) climate change disclosure and good corporate climate change performance in the short-term. In conclusion, the financial market did not fulfil its role to correctly allocate ownership of the economy’s capital stock with regard to the risk induced by the financial implications of climate change during the time period analysed in this study.

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List of Abbreviations

ACV	Additional control variables
CAPM	Capital Asset Pricing Model
CDP	Carbon Disclosure Project
CSP	Corporate sustainability performance
C4FM	Carhart 4 Factor Model
EMH	Efficient Market Hypothesis
ESG	Environmental, social and governance
EU ETS	European Emissions Trading Scheme
EW	Equal-weighted
GHG	Greenhouse gas
GRI	Global Reporting Initiative
ICB	Industry Classification Benchmark
MaV	Market value
OLS	Ordinary least squares
SD	Standard deviation
SMP	Stock market performance
SRI	Socially responsible investment
TBL	Triple bottom line
TRI	Toxic Release Inventory
VIF	Variance inflation factor
VW	Value-weighted

Preface

This thesis is dedicated to Frank Figge and Ralf Barkemeyer for their support and supervision during the course of this project. This thesis is also dedicated to Nicole Horwedel, Anne Liesen, Britta Liesen, Julia Hoff, HP Kögeböhn and especially Guido Weyrauch for listening to me whining during the course of this project.

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Chapter 1
Introduction

Climate change has developed into a widely accepted serious threat to our planet that requires urgent regulatory responses (IPCC, 2007; Stern, 2006). In the European Union, the European Emissions Trading Scheme (EU ETS), the emergence or discussions on the introduction of carbon taxes, as well as the EU policy guiding principles to “make polluters pay” (European Council, 2006, p. 5) represent just few examples for such regulatory responses. These political initiatives in conjuncture with market initiatives for the reduction of GHG-emissions aim at the creation of a low carbon economy. It is safe to assume that these initiatives have the potential to significantly impact the financial performance of companies. The exact future costs resulting from the transition to a low carbon economy for companies are however unknown.

The fact that climate change impacts or potentially impacts their financial performance is widely recognised among companies: Out of the 358 FT500 companies that responded to the Carbon Disclosure Project (CDP) in 2006, 87% reported that climate change constitutes a commercial risk and/or challenge to their business (Carbon Disclosure Project, 2006). On financial markets, as a consequence of these risks and the imminent challenge to transform to a low carbon economy, a significant re-distribution of shareholder wealth is expected to take place (Carbon Trust, 2006, p. 4). Nevertheless, and despite the growth of the socially responsible investment (SRI) industry in recent decades, market participants are only slowly adjusting their investment behaviour to incorporate the financial risks represented by climate change. For example, it was estimated that during the time of this study less than 0.10% of the over $ 40 trillion in assets of the investors that are signatories to the CDP were “invested in any investment strategy which explicitly and systematically takes climate risk into account” (Innovest, 2007, p. 3). It is generally expected that financial markets are “only beginning to recognise the magnitude of impact the transition to a low carbon global economy will have on companies’ competitive positions and long-term valuations” (The Goldman Sachs Group, 2009, p. 2). As a result, the financial risk represented by political and market initiatives for the shift towards a low-carbon economy “may not yet be fully reflected in share prices” (FTSE Group, 2012, p. 4).

These statements from the investment practitioner community are in stark contrast to the financial theory of the Efficient Market Hypothesis (EMH). According to EMH, an efficient financial market represents ‘[a] market in which share prices always “fully” reflect available information’ (Fama, 1970, p. 383). Only if share prices “fully” reflect information, they give accurate signals for resource allocation and the financial market can fulfil its task to correctly allocate ownership of an economy’s capital stock (Fama, 1970). Surprisingly, there is no research that allows making conclusive judgements on the level of market efficiency towards information on the market-wide financial impacts of climate change on companies. To fill this gap in existing research, this thesis assesses the level of market efficiency towards the systematic financial impact of climate change on companies in the European Union. The goal of this research therefore is not to prove or disprove EMH, but to apply the theory to contribute to the understanding of share price behaviour with regard to climate change induced systematic risk.

For the assessment of the level of market efficiency towards climate change induced systematic risk, first EMH is introduced and its important notions, methodologies and shortcomings are illustrated in the light of SRI in the following chapter. Subsequently, in chapter *2.2 Literature linking CSP and SMP*, existing research relating corporate sustainability performance (CSP) to stock market performance (SMP) is examined with the aim to possibly derive a judgement on the level of semi-strong market efficiency towards CSP and disclosure of CSP. Semi-strong market efficiency stipulates that prices fully reflect all readily-available public information (Fama, 1970). In chapter *3 Hypotheses Development,* it is argued that the various regulatory and market initiatives for the reduction of GHG-emissions inflict unknown future costs on large parts of the economy and consequently the financial impacts of climate change on companies in the EU constitute a systematic risk. Overall, six hypotheses are developed for the six proxies for climate change induced systematic risk introduced in this research.

The data gathered for each of the six proxies, as well as the sample created to test the hypotheses, are described in chapter *4 Sample and Data*. Overall, the 433 companies from the European Union that were part of the FTSE All World Index in the years 2005 to 2009 constitute the sample of this research. The data necessary for several of the proxies for climate change induced systematic risk applied in this research was gathered from corporate reports, corporate websites and the CDP and is oftentimes reported in an incomplete manner by companies. To be able to control for the incompleteness of, for example, the readily-available public GHG-emissions data reported by companies, the data is categorised according to its completeness. As such, in chapter *4.4 Understanding Sample Characteristics,* this research also presents the first large-scale analysis of the completeness of quantitative GHG-emissions disclosure by companies.

Based on the six proxies for climate change induced systematic risk, portfolios are constructed and regressed on the models used in this research to test the hypotheses developed (cf. chapter *5 Methodology*). Next to the Capital Asset Pricing Model (CAPM) (Lintner, 1965; Mossin, 1966; Sharpe, 1964), which was traditionally used in early tests of market efficiency, this research applies the Carhart 4 Factor Model (C4FM) (Carhart, 1997), which has more recently become a standard model for testing market efficiency (Fama & French, 2010). Furthermore, in this research the C4FM is extended for industry control variables (cf. Derwall, Guenster, Bauer, & Koedijk, 2005; Geczy, Stambaugh, & Levin, 2005; Hoepner, Rammal, & Rezec, 2011a) with the result that next to factors generally known to explain stock performance, the more recently emerged practice in tests of asset pricing and SRI to control for industry effects is accounted for.

Regression results obtained are illustrated and discussed in the light of the hypotheses formulated in chapter *6 Regression Results*. In chapter *7 Conclusions and Discussion*, the results obtained are discussed in the light of EMH, their contribution to knowledge and their implications for investment practitioners and companies as well as the methodologies applied in SRI. This thesis concludes with a discussion of the limitations of this study and an illustration of the avenues it opens up for future research.

Chapter 2
Embedding of the Research in Related Literature

Two bodies of literature are of relevance to this assessment of the market efficiency towards climate change induced systematic risk. In the remainder of this chapter this research is embedded in these two streams of literature, namely research into the efficiency of financial markets and research relating corporate sustainability performance to stock market performance. In chapter *2.1 Literature on EMH,* the short history of EMH is briefly illustrated and the definitions and important notions of EMH are discussed in the light of SRI. Subsequently, the conditions for an efficient market are discussed in the context of SRI, and methodologies and findings of tests of EMH are presented. After presenting existing criticism towards EMH, its application in this research is discussed. In chapter *2.2 Literature linking CSP and SMP*, research linking corporate sustainability and stock market performance is discussed in the light of EMH with the aim to possibly derive a judgement on the level of semi-strong market efficiency towards CSP and disclosure of CSP. To that end, five criteria are developed that need to be fulfilled in association studies relating CSP to SMP to allow drawing conclusions on the level of semi-strong market efficiency. Each criteria is briefly discussed conceptually before being applied in the review of studies from the field at the end of this chapter.

2.1 Literature on EMH

2.1.1 The Short History of EMH

The Efficient Market Hypothesis is one of the most discussed theories in financial economics. Nevertheless, the underlying idea of the hypothesis that “actual prices at every point in time represent very good estimates of intrinsic values” (Fama, 1965, p. 90), was established only half a century ago. At the beginning of the 20th century, although work by scholars like Cowles (1933) and Working (1934) showed evidence to the contrary, it was the general belief that past movements of stocks prices can be used to determine the future price movements of a stock (cf. Alexander, 1961; Fama, 1963; Keynes, 1936). It was only in the late 1950s, more than half a century after the basic idea appeared in the PhD thesis of Louis Bachelier (1900), that a public discussion of what today is referred to today as Random Walk Theory picked up.

Random Walk Theory claims that stock prices do not follow a pattern and that consequently past stock performance does not give any indication for the future performance of a stock (Fama, 1965). Whilst advocates of Random Walk Theory agreed on the fact that prices are random with regard to their past performance, they did not agree on the underlying reason for that fact (for a collection of papers on the topic see Cootner (1964)). It was however one of the early supporters of Random Walk Theory, Eugene F. Fama, who would supply a possible economic rationale behind the studied phenomenon, which established itself as the widely known Efficient Market Hypothesis.

While Fama (1965) already formulated his original concept of an efficient market in 1965, his path-breaking paper would become *Efficient Capital Markets: A Review of Theory and Empirical Work* published five years later (Fama, 1970). In this paper Fama gathers existing evidence from a large number of empirical studies and lets his efficient market model undergo three tests: a weak form test, a semi-strong form test and a strong form test. The research design of those tests is what is referred to today as weak market efficiency (i.e. prices fully reflect all past market prices and data), semi-strong market efficiency (i.e. prices fully reflect all readily-available public information) and strong market efficiency (i.e. all information in a market, whether public or private, is accounted for in a stock price). The strong form of market efficiency has been widely rejected and was mostly introduced by Fama as a theoretical completion of the two more restricted versions of the hypothesis. The weak and semi-strong form of the EMH however were largely accepted as valid in the 1970’s and 1980’s (Jensen, 1978; Pane, 1995) and are still accepted by various scholars and investors today (Arnold, 2002; Dimson & Mussavian, 1998) but remain subject to controversy and constant tests by advocates and opponents.

The body of literature that emerged from advocates and opponents testing EMH is broad and Fama (1991, p. 1575) argues in his own summary *Efficient Capital Markets II* that “the literature is now so large that a full review is impossible”. Interesting summaries on the literature testing the hypothesis of market efficiency at different points in time have been provided by many others (Dimson & Mussavian, 1998; Fama, 1991; Kothari, 2001). In the remainder of this chapter, relevant articles are discussed in the context of SRI that are able to illustrate the definitions and important notions of EMH, its conditions, the relevant methodologies for and findings from testing the hypothesis, as well as critique towards EMH. The chapter ends with an outline of the application of EMH in the SRI context of this study. For the sake of this study, SRI is defined as “a generic term covering any type of investment process that combines investors’ financial objectives with their concerns about Environmental, Social and Governance (ESG) issues” (Eurosif, 2010, p. 7).

2.1.2 Definitions and Important Notions of EMH

Unfortunately, no single definition of EMH exists that summarizes all of its important notions. Initially, Fama (1965, p. 94) defined an efficient market as “a market where prices at every point in time represent best estimates of intrinsic values” or a market in which “actual prices at every point in time represent very good estimates of intrinsic values” (Fama, 1965, p. 90). This interchangeable use of the words *best* and *very good* within one paper indicates that, according to the inventor of EMH, the best estimate of a share price in an efficient market is at most *a very good* estimate. 30 years later, Fama (1995, p. 76) has seemingly further reduced his expectations towards an efficient market when writing that “in an efficient market at any point in time the actual price of a security will be a *good* [italics added] estimate of its intrinsic value“. The important notion here is not the intangible definition of good or very good estimates of intrinsic value, but the fact that Fama did not conceptualize the efficient market to be able to perfectly predict the intrinsic value of a stock correctly. This point is revisited later in this chapter.

The notion of “intrinsic values”, i.e. fundamental value, is crucial to the theory and in the context of EMH represents the sum of future cash flows of a stock discounted to its present value. The intrinsic value of a stock consequently corresponds to its future earnings potential, which in turn depends on fundamental factors such as the quality of management of the company or the general outlook for the industry or the economy. Consequently, in the reality of an uncertain world, the intrinsic value of a stock can never correctly be determined due to the lack of knowledge of future events and their impact on future cash flows. Important in the light of this research is the notion that intrinsic values are consequently not static. Fama (1995) states that

> intrinsic values can themselves change across time as a result of new information. The new information may involve such things as […] a tariff imposed on the industry's product by a foreign country […] or any other actual or anticipated change in a factor which is likely to affect the company's prospects. (p. 76)

Relating this quote back to this research, it is hypothesised in chapter *3 Hypotheses Development* that with the emergence of the EU ETS and other regulatory and market initiatives for the reduction of GHG-emissions, a company’s exposure to the market-wide financial implications of climate change has become a fundamental factor that impacts its future earnings potential, i.e. its intrinsic value.

Early in the history of EMH, Fama (1970, p. 383) defined an efficient market as ‘[a] market in which prices always “fully” reflect available information’. The use of quotation marks, which are perpetually omitted when reference is made to this definition of EMH, is quite relevant here as Fama further clarifies that he does not expect the market to *fully* incorporate all available information, but – as the name would suggest – introduces EMH as a Null-hypothesis with an interest to research “the level of information at which the hypothesis breaks down” (Fama, 1970, p. 383). In 1991, Fama (1991, p. 1575) merged these two points when opening his landmark paper *Efficient Capital Markets II* with the following statement: “I take the market efficiency hypothesis to be the simple statement that security prices fully reflect all available information”.

Only if security prices fully reflect information, they give accurate signals for resource allocation and the stock market can fulfil its primary task to correctly allocate ownership of an economy’s capital stock (Fama, 1970). The basic mechanisms at work in order for stock prices to reflect information are summarized in the following definition (Fama, 1995):

> An "efficient" market is defined as a market where there are large numbers of rational, profit-maximizers actively competing, with each trying to predict

> future market values of individual securities, and where important information is almost freely available to all market participants. (p. 4)

The here mentioned rational, profit-maximising investor is at the heart of the EMH. The rational investor tries to predict the correct future price of a stock exclusively based on relevant and available information concerning the future earnings potential of a firm (Sharpe, 1970) and is only interested in highest possible risk-adjusted returns.

In an efficient market the level of expected returns represent a compensation for the level of risk an investor assumes (Fama, 1970). While the notion that investors want to receive a financial incentive for adopting risk seems like good common sense, it was only with the development of the Capital Asset Pricing Model (CAPM) that this relation became quantifiable (Campbell, Lo, & MacKinlay, 1997). Within the CAPM of Sharpe (1964), Lintner (1965) and Mossin (1966) risk is depicted by the coefficient beta, also referred to as systematic risk, and is calculated by dividing the covariance between the market return and asset return by the variance of the market return (Brooks, 2008). Less technically speaking, risk results from the relative volatility of stock returns compared to market returns, while taking into account the correlation of stock returns with market returns. As according to the EMH investors are rewarded for taking risk, this means that within the framework of the CAPM: the higher the beta the higher the return a rational investor would expect to receive from his or her investment.[1] On a risk-adjusted basis, no abnormal returns can persistently be achieved by investors trading on costlessly and readily available information in an efficient market.

Not adjusting return-figures for systematic risk is at the core of many of the discrepancies of early results in studies relating CSP to SMP. For example, as Cochran and Wood (1984) and Gordon and Buchholz (1978) elaborate, the contradictory results of

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[1] The strong positive relationship between systematic risk and returns, which has been identified in early tests of EMH, is argued to be weaker in some (Fama, 1991) but not all recent studies of the relation between beta and returns (Kothari, Shanken, & Sloan, 1995).

Moskovitz (1972), who found that firms with high CSR ratings outperform, and Vance (1975), who found just the opposite, can partially be attributed to not taking into account the systematic risk of the companies during the time-horizon analysed. There is a large body of literature trying to identify the determinants of systematic risk (cf. Mandelker & Rhee, 1984). Theoretically, systematic risk is associated with macroeconomic variables (Bansal & Clelland, 2004) or other factors that affect a large share of companies and therefore cannot be eliminated through diversification. Relating the concept of systematic risk back to this research, it is hypothesised in chapter *3 Hypotheses Development* that the EU ETS, in conjuncture with other political and market initiatives for the reduction of GHG-emissions, has transformed the market-wide financial impact of climate change on companies into a new source of systematic risk ("climate change induced systematic risk").

Next to systematic risk, there is unsystematic risk, which is not correlated with market returns but is company specific. Note that in contrast to systematic risk, investors are not rewarded for bearing unsystematic risk in an efficient market (Barnett & Salomon, 2006). Unsystematic risk usually does not rest in the centre of interest of EMH, as it can be eliminated in portfolio creation by means of diversification (Markowitz, 1952). However, in the context of SRI, unsystematic risk is argued to play an important role. From an EMH perspective, according to Fama and French, SRI investors are not rational as they are willing to trade in parts of their risk-adjusted return for knowledge that their investments do not violate their social or environmental conscience (Bollen, 2007; Fama & French, 2007). This argument stems from the notion that the exclusion of any stock from the investable universe, for example as a result of social or environmental concerns, results in a not optimized risk-return-relation of the portfolio. As a consequence of exclusion, it is argued, a portfolio cannot be optimized for diversification purposes and consequently carries higher risk (O'Brien Hylton, 1992). While this concern seems theoretically reliable and was confirmed in early studies of SRI (Langbein & Posner, 1980), more recent empirical evidence suggests that the limiting effect of SRI on diversification is not as straight-forward as theoretically proposed (Bello, 2005).

Campbell, Lettau, Malkiel, and Xu (2001) show that in recent times a portfolio can be reasonably diversified with as little as 50 stocks. Applying this number as a rule of thumb is an oversimplification, as the efforts necessary to diversify unsystematic risk depend on the respective unsystematic risk of the companies in a portfolio. Nevertheless, the number proposed by Cambell et al. invites the common sense conclusion that it should be possible to reasonable diversify a portfolio with the over 50.000 stocks listed globally (WFE, 2008) even if large numbers of companies are excluded from the investable universe as a result of a SRI strategies (Barnett & Salomon, 2006; Diltz, 1995). In fact, scholars found that negative effects on unsystematic risk are only true for highly screened SRI funds (Lee, Humphrey, Benson, & Ahn, 2010; Renneboog, Ter Horst, & Zhang, 2008a) and that generally, SRI funds do as good (bad) as other funds. However, other scholars find that there is a curvilinear relationship between SRI screening intensity and risk-adjusted portfolio returns (Barnett & Salomon, 2006) or suggest that companies can reduce their systematic risk through good environmental disclosure, which in an efficient market would reduce expected returns (Reverte, 2011).

Within the concept of EMH, next to these notions of risks and rational investors, there are three conditions that facilitate the market to be efficient. These three conditions and their relevance as a potential source of market inefficiency are discussed in the next section in the context of SRI.

2.1.3 Three Conditions for an Efficient Market

Fama (1970) initially introduced his concept of an efficient market with three explicit conditions: (1) there are no transaction costs, (2) all available information is costlessly available to all market participants and (3) all market participants agree on the implications of information to the future price of a stock. These conditions were specified over time and it must be noted that Fama initially introduced them with the notion that they are sufficient to ensure market efficiency, but may not be necessary. He clarified that “transaction costs, information that is not freely available to all investors, and disagreement among investors about the implications of given information are not necessarily sources of market inefficiency, they are potential sources” (Fama, 1970, p. 388).

(1) There are no transaction costs

The fee an individual investor faces when buying or selling a stock through his or her bank or broker is identical in SRI to any other investment and consequently it does not present a bigger potential source of market inefficiency than in any other assessment of market efficiency. Management fees of mutual funds, however, are argued to be higher in SRI due to the increased cost of information of managed SRI mutual funds (Luther, Matatko, & Corner, 1992), which are discussed in the following paragraphs.

(2) All available information is costlessly available to all market participants

Fama (1970, p. 388) actually relaxed the condition that *all* available information is costlessly available to *all* market participants by stating that ‘the market may be efficient if “sufficient numbers” of investors have ready access to available information’. Nevertheless, this condition represents a potential source of market inefficiency in the context of SRI, where it might be argued that information on CSP is not available free of charge to a sufficient number of market participants. This fact stems from the reality that not every company informs the public about its sustainability performance, for example, in the form of a dedicated report, website or integrated report. This gap in information on CSP is reduced by professional information services, which gather the respective information via written questionnaires and interviews (Aslaksen & Synnestvedt, 2003). This information is however not available free of charge to market participants.

It might consequently be argued that due to the lack of comprehensive legal requirements for the reporting on CSP, no sufficient numbers of investors have access to information on CSP free of charge and that, as a consequence, the semi-strong efficient market cannot be expected to be efficient with respect to that information. This argument is of slightly reduced validity in the special case of corporate climate change performance, where, as a result of the interest of institutional investors represented by the CDP, information on corporate climate change performance is gathered and was readily available to the public free of charge during the time of this study. While this information is also not available for all companies and often incomplete (Kolk, Levy, & Pinkse, 2008; Stanny, 2010), the CDP represents a potential and extensive source of costless information on corporate climate change performance. For example in 2008, 1550 companies responded to the CDP (Carbon Disclosure Project, 2008a). Furthermore, the rankings derived from the CDP data are readily available to the public via the “Key stats and ratios” section of Google Finance (Carbon Disclosure Project, 2010a).

According to Fama, with regard to transaction and information cost, Jensen (1978) arrived at a less strong but economically more reasonable definition of EMH in which ”prices reflect information to the point where the marginal benefits of acting on information (the profits to be made) do not exceed the marginal costs” (Fama, 1991, p. 1575). In Jensen’s version of the EMH the market can consequently expected to be efficient to the point where the transaction and information costs of an investment strategy do not consume the expected risk-adjusted returns generated by that strategy for individuals. So while several scholars argue that SRI investors face a financial disadvantage because the relevant information to make an SRI investment decision is expensive to gather (Aslaksen & Synnestvedt, 2003; Luther et al., 1992) this fact alone does not necessarily imply that the market is inefficient towards fundamental information on CSP in Jensen’s version of the efficient market. As long as risk-adjusted expected returns reward for the level of transaction and information costs, the market can be expected to be efficient concerning the underlying information (Ball, 1994). With regard to transaction and information costs, both Fama’s and Jensen’s version of EMH will be discussed throughout this research.

It is important to note that in Fama’s version of the EMH the strategy of indexing a portfolio to the market is superior to any other strategy, as it would involve little or no information cost and minimal execution costs (Keane, 1983; Malkiel, 2003b). The most important empirical paper in favour of this strategy has probably been published by Jensen (1968, p. 415) who found in his study of 115 mutual funds analysed between 1945 and 1964 that "on average the funds apparently were not quite successful enough in their trading activities to recoup even their brokerage expenses". Similar findings were later reported by other scholars (Fama & French, 2010; Gruber, 1996; Malkiel, 1995). Interestingly, in reality for the market to remain efficient, it is however vital that there are small abnormal returns before fees and expenses. Grossman and Stiglitz (1980) showed that some incentive for security analysis must be achievable through costly information gathering in order to arrive at an efficient market and that, in turn, the market can never be perfectly efficient.

In summary, with regard to information and transaction costs, the particularly costly information gathering in SRI results in the respective information only being available to a restricted number of market participants. Consequently, condition two can be argued to be a potential source of market inefficiency in Fama's original version of the EMH.

(3) All market participants agree on the implications of information to the future price of a stock

The third condition for market efficiency, which states that in an efficient market all investors perceive the value-relevance of available information in the same manner, has been the greatest challenge to the EMH. As a matter of fact, there are numerous methods available for analysing and valuing stocks, each resulting in differing and at times contradictory results. Responding to this criticism, Fama (1970, p. 388) argued that "disagreement among investors about the implications of given information does not in itself imply market inefficiency unless there are investors who can consistently make better evaluations of available information than are implicit in market prices". Fama thus argues that as long as individual investors cannot persistently outperform the market trading on readily available information, disagreement does not imply market inefficiency. 37 years later, Fama and French (2007, p. 672) expanded on this third condition for market efficiency, when stipulating that under conditions discussed later in this chapter "testable predictions about how expected returns relate to risk are also lost" when there is disagreement among investors.

It is the third condition for market efficiency that encourages the greatest criticism from the investment community. As iconic fundamental investor Warren Buffet, who consistently derives better evaluation from freely available information than the market, once famously put it: "I'd be a bum on the street with a tin cup if the markets were always efficient" (Pane, 1995, p. 2). His quote however shows at the same time that Warren Buffet believes that markets are not always, yet sometimes, efficient. A fair share of fundamental investment strategies built on the fact that stock performance is driven by value-relevant information, which is an argument based in EMH.

The discussion of whether information on CSP is value-relevant is a scattered one. While several scholars, based on different theoretical frameworks, argue that CSP should be relevant to the fundamental value of a firm (Freeman, 1984; Hart, 1995; Porter & Kramer, 2006) other scholars disagree (Easterbrook & Fischel, 1991; Friedman, 1970; Jensen, 2002; Levitt, 1958) and empirical evidence is ambiguous. For the analysis whether the third condition of EMH represent a potential source of market inefficiency in the context of SRI it is assumed that, out of the total number of market participants, only SRI investors agree on the value-relevance of information concerning CSP. According to Eurosif research, *core* SRI products, which include for example positive screening, best-in-class approaches and SRI thematic funds, correspond to 10% of the asset management industry in Europe in 2009 (Eurosif, 2010). Consequently, it can be concluded that there is no homogenous belief among investors concerning the financial implications of information on CSP for the future price of a stock.

Assuming that SRI investors are incorrectly assessing the intrinsic value of a stock by incorporating information on CSP in their assessmen, the large number of *correct* investors would not wipe out the price effect of SRI investors completely. Some effect on prices would remain until SRI investors corrected their erroneous belief (Fama & French, 2007). In that case, SRI investors, by acting on their social and environmental conscience rather than rational risk-return-considerations, would consequently make the market less efficient. In Fama and French’s (2007, p. 673) words: “[T]rading based on erroneous beliefs makes prices less rational. And the world is a better place (prices are more rational) when misinformed investors acknowledge their ignorance and switch to a passive market portfolio strategy”. However, the market can be efficient even if not all market participants agree on the implications of information for the future price of a stock, under the condition that erroneous investors do not account for substantial amounts of invested wealth (Fama et al., 2007b). As core SRI products do not represent substantial amounts of invested wealth (Eurosif, 2010), and assuming that information on CSP is not relevant to the fundamental value of the firm, SRI currently does not make the overall market inefficient. Consequently, testable predictions about how expected returns relate to risk are not lost.

On the other hand, assuming that information on CSP is relevant to the intrinsic value of the firm, traditional fundamental investors are mistaken about expected returns by not incorporating corporate sustainability information into his or her valuation of a stock – and the overall stock market in Europe would currently be inefficient. While this is a bold statement it would not be the first time the majority of market participants homogenously makes a wrong assessment, as evidenced by any major stock market bubble. As Malkiel (2003a, p. 80) summarizes: "As long as stock markets exist, the collective judgment of investors will sometimes make mistakes". Evidence that investors do not sufficiently integrate value-relevant information on CSP in their investment decisions exists (Campbell & Slack, 2011; Deegan & Rankin, 1997; Renneboog, Ter Horst, & Zhang, 2008b).

In summary, from an EMH perspective there seems to be theoretical potential for a market inefficiency concerning value-relevant information on CSP, as the conditions for market efficiency do not fully apply. This conclusion is based on the fact that information costs are comparatively high, only a selective share of investors has access to CSP information and market participants do not agree on the value-relevance of information on CSP. Methodologies for testing a possible inefficiency are discussed in the following sections.

2.1.4 Methodologies and Findings

There are two methodologies which dominate the body of research testing market efficiency, i.e. event studies and association studies, which will be discussed in the following paragraphs.

Event Studies

Event studies assess the effect of newly emerging information (i.e. "event") on stock prices by estimating the "returns that would have been expected without the event (normal returns) and the returns that were caused by the event (abnormal returns)" (Bromiley, Govekar, & Marcus, 1988, p. 28). Dolley (1933) was probably the first researcher to perform an event study in his examination of the effect of stock splits on stock prices. However, in the late 1960's, Fama, Jensen, Fisher, and Roll (1969) suggested a comprehensive methodology, which marked the starting point for the still growing body of literature that uses event studies to test market efficiency.

Event studies have since been performed on various kinds of events, such as information on mergers and acquisitions (Lubatkin, 1987; Singh & Montgomery, 1987), major layoff programmes (Worrell, Davidson, & Sharma, 1991), sudden death of CEOs[2] (Johnson, Magee, Nagarajan, & Newman, 1985) and environmental performance. For example, the effects of environmental management – expressed as negative events such as oil spills and positive environmental events such as environmental awards – on stock prices has been researched by Klassen and McLaughlin (1996). They found significant negative abnormal returns when firms had environmental crises and positive returns when firms received environmental awards. Similar findings were reported in an event-study by Shane and Spicer (1983), who found that the release of a ranking on corporate pollution control records and costs of abatement affected stock prices. In a sample of 436 publicly traded firms, Hamilton (1995) found significant negative abnormal returns in 1989 on the day that the Toxic Release Inventory (TRI) was announced for the first time. The abnormal returns identified in the studies discussed above prove that the market classifies the underlying information as relevant to the intrinsic value of a company. Especially with view to expenses for cleaning-up operations, fines or litigation expenses that may come as a result of negative environmental effects, the market incorporates the reduced profit expectation of a company (cf. Ambec & Lanoie, 2008). More recently, Griffin, Lont, and Sun (2011) documented in an event study on climate change disclosures in 8-K reports an almost 2% reduction in stock prices of emission intensive companies (Griffin et al., 2011).

In summary, most event studies found the financial market to be efficient in that it reacts to new publicly available information that is relevant to the intrinsic value of the firm (Jacobs, Singhal, & Subramanian, 2010; MacKinlay, 1997; Yamashita, Sen,

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[2] They found that the sudden death of a CEO is associated with a decrease in stock prices unless the CEO was the founder of the respective company.

& Roberts, 1999). While these studies were able to prove that stock prices – not always but usually – quickly and adequately respond to relevant emerging information, the event-study methodology is not able to examine whether a stock is constantly over- or undervalued over longer time periods.

Joint Hypothesis Problem

Leaving aside the time horizon of tests of market efficiency for a while, is must be noted that any research carried out in this context does not only test the informational efficiency of the market but also the validity of the model applied, i.e. the estimation of the normal returns that would have been expected if there was no event (Watts, 1978). This problem is commonly referred to as the Joint Hypothesis Problem and it becomes more relevant in long-window association studies, as the effect of a flawed model can be small in a week, but can aggravate into large (apparent) effects over years (Fama, 1998). The fact that the EMH cannot be tested without simultaneously testing the underlying model used for the estimation of expected returns results in the fact that it cannot be tested at all, as a rejection of a joint hypothesis does not allow a conclusive judgement on which part of the joint hypothesis is rejected (Lo & MacKinlay, 1999).

Nevertheless, testing market efficiency – and a joint hypothesis at the same time – over long time horizons has given researchers and investment professionals a lot of insight into the behaviour of stock prices. The interpretation of any findings of market inefficiencies must however take place in the context of the conditions for market efficiency and the Joint Hypothesis Problem. A good example in this context is Thompson (1978), who concluded his long range study of 23 closed-end funds, in which he found significant abnormal returns of about 4% per year between 1940 and 1971, with the estimation that the abnormal returns identified are likely due to shortcomings of the underlying asset pricing model rather than market inefficiency. He built this assessment of the results on the fact that “the data on the closed end fund discounts was widely available over the entire period and extensively discussed in the professional press” (Jensen, 1978, p. 97).

Association studies

Long-window association studies, such as the one of Thompson discussed above, often take the form of cross-sectional tests of return predictability. These studies measure the cross section of returns on portfolios, which are formed periodically using a specific trading rule, and then examine whether returns are consistent with an asset pricing model of expected returns. Cross-sectional tests of return predictability in the context of the EMH are often referred to as the *anomalies literature*, as a common motivation of those studies is to identify determinants for abnormal returns.

One of the traditional asset pricing models applied in these association studies is the already mentioned CAPM, which is indicative of the functionalist paradigm in which EMH is embedded (Ardalan, 2008). Within this functionalist paradigm, CAPM helps to acquire knowledge on the level of market efficiency by facilitating quantitative empirical test of the assumption that there is a measurable relation between returns and risk. The CAPM thus serves well to illustrate the epistemological and ontological assumptions that the EMH builds on. The research paradigm underlying EMH is oftentimes also referred to as positivism, which in summary "assumes an objective world which scientific methods can more or less readily represent and measure, and it seeks to predict and explain causal relations among key variables" (Gebhart, 1999, para. 1).

For example, in an association study applying the CAPM, small-cap firms, i.e. firms which are small in terms of their market capitalization, have been found to show higher returns than large-cap firms. Banz (1981) showed that between 1936 and 1975 small-cap firms on the New York Stock Exchange persistently achieved higher average returns than predicted by the CAPM. Advocates of the EMH argue that these higher returns of small-cap companies are a result of rational risk compensation and are found due to the inability of the CAPM to price this risk correctly, rather than market inefficiency (Davis, Fama, & French, 2000). For example, Strugnell, Gilbert, and Kruger (2011, p. 14) summarize their examination of this so called *size effect* with the conclusion that "it is significant and pervasive, and either indicative of some level of market inefficiency or, perhaps more likely, a misspecification of equilibrium pricing models such as the CAPM, which assume that market covariance alone constitutes rewarded systematic risk". Advocates of EMH thus argue that investors in small-cap companies are rationally rewarded for the additional risk taken on when investing in companies that are more risky due to the fact that they may be starting up or are not well-equipped with capital for times of crisis (Varamini & Kalash, 2008). However, opponents of the EMH dispute these risk-based explanations and regard the abnormal returns of small-cap firms as an evidence for market inefficiency. For example, non-risk based explanations have been suggested on the size effect by Liew and Vassalou (2000), who stipulate that it may forecast future economic growth.

Interestingly enough, after Banz's publication of the size effect in 1980, the risk premium for small-cap stocks decreased for a certain period (Schwert, 2003). Schwert argues that investors acted upon the information published and consequently corrected the small-cap inefficiency in the market. The development of this size effect empirically confirms an interesting characteristic of the EMH, which was already discussed theoretically: stock markets are made efficient by market participants believing it is inefficient (Dimson & Mussavian, 1998; Grossmann & Stiglitz, 1980), searching for inefficiencies and acting on potentially identified arbitrage opportunities. Lee (2001, p. 237) summarizes that "[i]f a particular piece of value-relevant information is not incorporated in price, there will be powerful economic incentives to uncover it, and to trade on it. As a result of these arbitrage forces, price will adjust until it fully reflects the information".[3]

Beside the size effect, over the last four decades researchers argued to have found numerous other anomalies, among them the turn-of-the-year effect (Roll, 1983), which describes the phenomenon that abnormal returns are more common in the beginning of January, the weekend effect (French, 1980), which describes the fact that average returns were negative over weekends in the period between 1953 and 1977, or the value effect that describes the effect that firms with high dividend or high earnings-to-price ratios earn positive abnormal returns (Ball, 1978). Research has shown that these effects had predictive power for returns in many markets and

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[3] In line with Lee (2001, p. 237) arbitrage throughout this research is defined "as information trading aimed at exploiting market imperfections". This definition of arbitrage is consequently broader than in some other streams of academic literature.

different periods. Fama (1991), somewhat more reserved when it comes to accepting the existence of anomalies, however argues that:

> If a past anomaly does not appear in future data, it might be a market inefficiency, erased with the knowledge of its existence. (Or, the historical evidence for the anomaly may be a result of the profession's dogged data-dredging.) On the other hand, if the anomaly is explained by other asset-pricing models, one is tempted to conclude that it is a rational asset-pricing phenomenon. (But one should be wary that the apparent explanation may be the result of model-dredging.). (p. 1593)

Until today, Fama has only acknowledged the (1) existence of the post-earnings-announcement drift evidenced by Ball and Brown (1968), which stipulates that a portion of the price response to new information in the form of earnings announcements is delayed, (2) the discussed size effect of Banz (1981), (3) the effect that stocks with a high ratio of book value to market value (value stocks) generated higher returns than stock with a low book to market ratio (growth stocks) (Fama & French, 1992) and (4) the momentum effect of Jegadeesh and Titman (1993), which showed that stocks that performed well in the past six to twelve months (past winners) tend to outperform stocks that underperformed (past losers) in the future.

As briefly discussed above with regard to the size effect, opponents of the EMH tend to interpret these and any abnormal risk-adjusted returns as evidence for market inefficiencies, while advocates of the EMH are inclined to point towards the Joint Hypothesis Problem and search for a risk-based explanation of the abnormal returns identified. If there is a risk-based explanation, and the abnormal returns exist in different markets and time periods, the abnormal returns can be attributed to shortcomings in the underlying asset pricing model. A risk-based explanation of abnormal returns “may therefore be consistent with an efficient market in which expected returns are consistent with risk” (Bodie, Kane, & Marcus, 2008, p. 245). Nevertheless, in some cases, even if there is no risk-based explanation, as in the case of the momentum effect (Liew & Vassalou, 2000; Muga & Santamaria, 2007), but the effect continues to exist in different periods and market and cannot be attributed to data or model dredging, advocates of the EMH accept it without a further discussion of its implications for market efficiency. Consequently, while the question whether there is a risk-based explanation for the size or momentum effect is ideological when interpreting regression results in the context of EMH, it is important to control for these factors generally known to explain stock performance in a test of market efficiency, irrespective of their explanation (Fama & French, 2010). Controlling for these factors is facilitated through multi-factor-models.

Multi-factor-models

As a response to the emerging evidences of patterns in stock returns based on size and book to market ratios, Fama and French (1993) incorporated factors that control for company size and the continuous abnormal returns of value over growth stocks into the CAPM (Fama & French, 1992). This inclusion of additional factors – from the perspective of advocates of EMH – controls for additional risk. Carhart (1997) incorporated the momentum effect of Jegadeesh and Titman (1993) into the model of Fama and French and the resulting Carhart 4 Factor Model (C4FM) is the dominant asset pricing model currently applied in tests of market efficiency (Fama & French, 2010) and one of the models applied in this study. Applying C4FM ensures that any potential market inefficiency identified cannot be explained by factors generally known to explain abnormal stock performance.

After the emergence of the C4FM in 1997, the discussion of whether abnormal returns found qualify as a new risk factor that requires incorporation into the established asset pricing models has usually resulted in a lengthy academic debate. Such a debate requires contributions not just from the scholar that initially identified the abnormal returns, but various other scholars evidencing the existence of the risk-adjusted abnormal returns in different markets and time periods. A good example is the on-going debate on whether accounting quality is a priced risk factor (cf. Core, Guay, & Verdi, 2008; Francis, LaFond, Olsson, & Schipper, 2005; Francis, LaFond, Olsson, & Schipper, 2004; Kim & Qi, 2010; Ogneva, 2008). As briefly illustrated, after almost 20 years the discussion is still on-going whether the size and value effect are risk-based effects, and consequently correct for a shortcoming in the CAPM, or represent market inefficiency.

Given the fact that one study is not sufficient to establish a shortcoming in the established asset pricing models, any potential risk-adjusted abnormal return identified in this research is regarded as a result of market inefficiency relating to the specific market and period analysed in this study. Where there is a potentially risk-based explanation for abnormal returns found, this explanation is discussed in depth to illustrate that it might be possible to align results with the notion of the EMH that investors are rewarded for risk in the long term. However, evidence on whether a potential inefficiency found exists in other markets and different time periods, and therefore qualifies as a factor that requires incorporation in existing asset pricing models, cannot be delivered in this research. It can only be a conclusion of lengthy academic debate with contributions from various scholars. This logic for the interpretation of risk-adjusted abnormal returns in the context of EMH is depicted in a simplified manner in Figure 1.

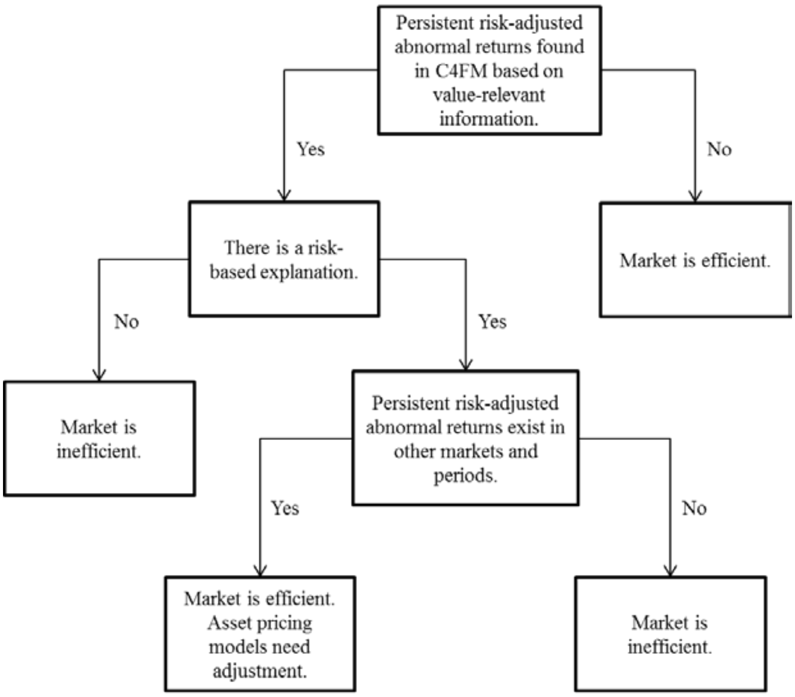

Figure 1: Interpretation of risk-adjusted abnormal returns in EMH

2.1.5 Critiques of EMH

When discussing EMH it must be noted that many academics and even more investors completely reject the idea of EMH on the argument that share prices move for many other reasons than fundamental information (Lee, 2001). Proponents of an inefficient market often stem from the area of behavioural finance, where it is argued that, instead of rationally seeking compensation for risk, investment decisions are made based on emotional factors. Opponents to the EMH are however not limited to the field of behaviour finance. O'Brien Hylton (1992) summarizes that proponents of the *inefficiency hypotheses* believe, for example, that investors base their decisions on noise rather than information (Blacks, 1986), that the volatility of stock prices is higher as can be derived from publicly available information (Cutler, Poterba, & Summers, 1989), that stock prices overreact (DeBondt & Thaler, 1985), that the volatility of stock prices is due to investor emotions and intuitions and not real economic events (Haugen, Talmor, & Torous, 1991), that investors can influence stock prices with irrational behaviour (Lee & Schleifer, 1990).

In the light of the growing evidence on anomalies, Fama addressed the question whether EMH should be discarded due to the arguments of behaviour finance and denied it. He argues that there is an even split between the apparently observed over- and underreaction to events and that this in in line with market efficiency (Fama, 1998). This argument is actually as old as EMH. Fama (1965, p. 94) wrote in the 1960’s that “when an intrinsic value changes […] the actual price will initially overshoot the new intrinsic value as often as it will undershoot it”. He further argues that most long-term return anomalies can (1) reasonably be attributed to chance or (2) represent methodological illusions stemming from shortcomings in the underlying asset price model, (3) are economically marginal or statistically marginal or (4) disappear when portfolios are value-weighted, suggesting that anomalies are limited to very small stocks or that (5) small stocks are sources of problems in the asset pricing model (Fama, 1998).

It becomes clear from this list that EMH required quite some defending in recent times, whereas in the 1970s and 1980s the idea that prices fully reflect information was a fact of life in many academic disciplines (Ball, 1994; Jensen, 1978; Malkiel, 2003a; Pane, 1995) and findings contradicting EMH were rare (Fama, 1970). 40 years later, moderate proponents of EMH argue that markets are fairly but not always efficient (Renshaw, 1984; Worthington & Higgs, 2004) and this is the attitude towards the EMH in the context of this research. This attitude also builds on Malkiel’s (2003a, p. 60) summary that “our stock markets are more efficient and less predictable than many recent academic papers would have us believe" based on the argument that flashy results are likely to get published while confirmations of older stories are not.

2.1.6 Application of EMH in this Research

While Fama (1991, p. 1602) declared in the Journal of Finance that "[a]ttacks on efficiency belong, of course, in the camp of the devil" this research uses EMH – as its name suggests – as a hypothesis to be tested in the light of its conditions and the emergence of climate change induced systematic risk. Consequently, market efficiency as much as market inefficiency with regard to information on a company's exposure towards the market-wide financial implications of climate change are considered as possible outcomes. As discussed, any risk-adjusted abnormal returns found in this research are interpreted as a result of market inefficiency relating to the specific market and period under investigation. Conclusions on shortcomings in existing asset pricing models to price climate change induced systematic risk cannot be delivered in one study, but can only be a conclusion of contributions of various scholars examining different markets and time periods.

Despite its discussed shortcomings, this research is rooted in EMH because it offers an useful benchmark (Brown, 2011) and an interesting theoretical construct with important practical implications that have not been extensively discussed in its entirety in the recent literature relating CSP to financial performance. There is an extensive body of literature that already examined the relation between CSP and SMP via association studies. This literature is examined in the following section from the theoretical perspective of EMH and taking into account the potential sources for a market inefficiency concerning SRI identified in this chapter.

2.2 Literature linking CSP and SMP

The question whether good CSP or disclosure of CSP impacts financial performance – positively, negatively or not at all – has been studied for more than four decades. Nevertheless, reviewing this literature in the light of market efficiency has been of only minor interest to scholars recently. Some important contributions were made in the last millennium (Cochran & Wood, 1984; Langbein & Posner, 1980; O'Brien Hylton, 1992) on which is built here.

The aim of this chapter is thus not to help finding a consensus with regard to the question whether it is financially rewarding for companies to report on CSP or perform well sustainability-wise. Rather this chapter aims to examine the results of related existing research in light of EMH and possibly derive a judgement on the level of semi-strong market efficiency towards CSP and disclosure of CSP. At first sight one might be led to believe that any study showing an outperformance of investments taking into account good CSP or CSP disclosure is a testimony of market inefficiency. However, as is shown in the following this is not the case. Five criteria are developed that are necessary for an assessment of existing association studies relating CSP to SMP in light of EMH and to draw conclusions on the level of semi-strong market efficiency.[4] These five criteria are (1) the economic significance of abnormal returns, (2) the use of a risk-adjusted return figure, (3) the value-relevance of the CSP measure applied, (4) the availability of the CSP measure to market participants and (5) the reasonable use of control factors. Each of these criteria is briefly discussed conceptually before being applied in the review of studies from the field at the end of this chapter.

2.2.1 Abnormal Returns

As it has been shown in chapter *2.1.3 Three Conditions for an Efficient Market*, Fama’s version of EMH stipulates that in an efficient market no abnormal risk-adjusted returns can persistently be generated based on costlessly and publicly available information (Fama, 1970). Jensen’s adaption of EMH stipulates that in an efficient market an investment strategy cannot generate abnormal risk-adjusted returns in excess of its transaction and information costs (Jensen, 1978). When examining market efficiency in light of Jensen’s adaptation, the economic significance of abnormal returns therefore has to be judged taking into account information and transactions costs. The market is argued to be efficient in Jensen’s

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[4] As this research is interested in the question whether markets are efficient with regard to CSP over longer time periods, only association studies will be reviewed here. Event studies are discussed in chapter *2.1.4 Methodologies and Findings*.

less strong but economically more reasonable version of EMH, when the expected risk-adjusted returns of an investment strategy for individuals are consumed by its transaction and information costs (Fama, 1991; Jensen, 1978).

Furthermore, in the context of EMH it is interesting to distinguish between abnormal returns for which there is a risk-based explanation and abnormal returns which cannot be explained with additional levels of systematic risk (cf. chapter *2.1.4 Methodologies and Findings).* Whereas it might be possible to theoretically align abnormal returns for which there is a risk-based explanation with the notion of the EMH that investors are rewarded for taking risk, the latter case with certainty represents market inefficiency.

Consequently, as usually no risk-based explanation exists for abnormal returns of sustainability-wise well-performing companies, the market is inefficient when the positive effects of good CSP are not priced correctly (Herremans, Akathaporn, & McInnes, 1993). For example Derwall, Guenster, Bauer and Koedijk (2005) and Renneboog et al. (2008b) argued that the risk-adjusted returns of companies with good CSP will only be constantly higher than those of companies with poor CSP when the financial market does not price information on CSP efficiently. An efficient market would price the financial impact of good CSP and no persistent abnormal risk-adjusted return would be achievable. If there is a systematic risk related to insufficient CSP and this risk is not reflected in beta, sustainability-wise poorly performing companies would generate abnormal returns. Presuming a shortcoming in the underlying asset pricing model and given that these abnormal returns are confirmed in other markets and periods, these risk-adjusted abnormal returns may be aligned with the basic notion of the EMH according to which investors are rewarded for assuming risk (cf. chapter *2.1.4 Methodologies and Findings),* i.e. they would not present market inefficiency.

In summary, when assessing existing studies linking CSP to SMP in light of EMH, it is consequently important to assess the economic significance of any risk-adjusted abnormal return identified, i.e. to assess whether transaction and information costs would consume the abnormal return found. If the risk-adjusted abnormal return found is economically significant, it must be examined whether there may be a possible risk-based explanation for this outperformance in order to be able to draw a conclusion on market efficiency.

2.2.2 Risk-adjusted Return Figure

As discussed in chapter 2.1.2 *Definitions and Important Notions of EMH*, in an efficient market expected returns compensate for the level of risk undertaken. Whilst in different settings differing measures of corporate returns can serve as a suitable indicator for financial performance, applying a return figure that is adjusted for risk is consequently of crucial importance when reviewing studies that relate CSP to SMP in light of EMH.

To be able to examine the results of existing studies from an EMH perspective and derive a possible judgement on the level of market efficiency, it must consequently not only be observable whether an investor receives persistent above-average returns, but whether he accepts a less beneficial relation of risk and return. Studies that do not apply a return figure that is adjusted for risk are not able to determine whether the “expected returns offer adequate compensation for the inherent level of risk” (Anderson, 2006, p. 587). Consequently, from an EMH perspective, only studies that apply a risk-adjusted return figure allow for a judgement of market efficiency concerning information on CSP.

2.2.3 Value-relevant CSP Measure

As discussed in chapter *2.1.2 Definitions and Important Notions of EMH*, in an efficient market only information that is relevant to the intrinsic value of the firm is priced in (Fama & French, 1995). As it has been shown in chapter *2.1.3 Three Conditions for an Efficient Market*, the discussion on whether information on CSP is value-relevant is a scattered one. From a theoretical EMH perspective, information on CSP has to be priced in to the extent that it impacts the future earnings of a company. The value-relevance of the underlying measure of CSP applied in related studies therefore has to be assessed. For the purpose of this analysis, a CSP indicator is classified as value-relevant if it can be expected to impact the future earnings potential of a company. In turn, it is noticeable that the market can only be expected to be efficient towards information that potentially impacts the intrinsic value of the company. In the absence of better measures (Cochran & Wood, 1984), especially older studies relied on questionable indicators of CSP (Aupperle, Carroll, & Hatfield, 1985) which at times do not meet the criteria of value-relevance.

2.2.4 Readily Available CSP Measure

As discussed in chapter *2.1.3 Three Conditions for an Efficient Market,* it was argued in the original version of EMH by Fama that a condition for market efficiency is that costless information is readily available to a sufficient number of market participants (Fama, 1970). With regard to information on CSP this would mean that a sufficient number of market participants are able to perceive differences in the sustainability performance across firms (Sharfman & Fernando, 2008) and consequently arbitrage forces would result in stock prices reflecting the specific information (Lee, 2001), i.e. the market would be efficient.

Jensen adapted the EMH in this regard and argued that the market can be expected to be efficient to the point where the transaction and information costs of an investment strategy do not consume the expected risk-adjusted returns generated by that strategy for individuals (Fama, 1991; Jensen, 1978). As discussed, if information on CSP is not readily available free of charge to a sufficient number of market participants, it must be assessed whether the risk-adjusted returns generated for an individual by an investment strategy carried out with costly information are economically significant, i.e. whether they surpass the level of transaction and information costs (cf. chapter *2.2.1 Abnormal Returns*).

2.2.5 Control Factors

As described in chapter *2.1.4 Methodologies and Findings*, there are factors which have been identified to determine risk-adjusted returns, such as company size, book to market ratio and the momentum factor. When examining literature relating CSP to SMP in the light of EMH, factors known to explain abnormal financial performance have to be controlled for. If these factors are not controlled for, abnormal returns cannot be attributed to the impact of CSP. This is particularly important in the context of this study, as SRI portfolios have been found to rely quite heavily on small and value stocks (Cortez, Silva, & Areal, forthcoming), which positively impacts the risk-adjusted returns of a portfolio. Especially older studies fail to control for factors generally known to explain SMP (Callan & Thomas, 2009) because perhaps evidence on these factors only emerged after the publication of these studies.

2.2.6 Criteria Matrix

Table 1 summarizes the criteria and illustrates their discussed implications for examining existing association studies in light of EMH and for deriving a possible judgement on the level of market efficiency. For the sake of brevity, the impact of the specific criteria is only presented exemplarily and ceteris paribus where possible.

In summary, as discussed in chapter *2.1.2 Definitions and Important Notions of EMH*, in an efficient market generally speaking no risk-adjusted abnormal returns can persistently be obtained by investors trading on readily available, value-relevant information on CSP. This option of market efficiency is depicted in case number 1 in Table 1 and can only be assessed if factors generally known to impact stock performance are controlled for. However, and only when presuming a shortcoming in the underlying asset-pricing model, investors can receive risk-adjusted abnormal returns for investing in companies that perform poorly sustainability-wise with regard to a systematic and value-relevant CSP measure, which is readily available. Presuming this poor CSP represents a risk-based explanation for abnormal returns, these returns might qualify as risk premium and do not necessarily imply market inefficiency.[5] As depicted in case number 3 of Table 1, these abnormal returns however only be observed if factors that are generally known to explain stock returns are controlled for.

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[5] As discussed in chapter *2.1.4 Methodologies and Findings*, the results of one study would however not suffice to make this case. Nevertheless, this possibility is presented here to illustrate that risk-adjusted outperformance does not always necessarily imply market inefficiency.

Table 1: Criteria for assessing results of studies in light of EMH

Case number	Abnormal returns	Risk-adjusted return figure	Risk-based explanation	Value-relevant CSP measure	Readily available CSP measure	Control factors	Implications for judging market efficiency
1	No	Yes	No	Yes	Yes	Yes	Market is efficient. All conditions for judging market efficiency apply. No risk-adjusted abnormal return is achieved.
2	No	Yes	Yes	Yes	Yes	Yes	Market is efficient if risk is priced by asset pricing model. All conditions for judging market efficiency apply.
3	Yes	Yes	Yes	Yes	Yes	Yes	Market might be efficient. All conditions for judging market efficiency apply. Risk-adjusted abnormal returns may present a risk premium if further research confirms that it is not priced due to shortcoming in asset pricing models.
4	Yes	No	Yes	Yes	Yes	Yes	Market efficiency cannot be judged. It is unknown if returns adequately compensate for risk.
5	Yes	Yes	No	Yes	Yes	Yes	Market is inefficient. No risk-based explanation for risk-adjusted abnormal returns exists.
6	Yes	Yes	No	No	Yes	Yes	Market is inefficient. Information that is not value-relevant is priced.
7	Yes	Yes	No	Yes	No	Yes	Market is inefficient if risk-adjusted abnormal returns in excess of transaction and information costs are achieved.
8	Yes	Yes	Yes	Yes	Yes	No	Market efficiency cannot be judged. Abnormal returns cannot be attributed to CSP measure.

In an inefficient market, companies that perform well sustainability-wise, i.e. where no risk-based explanation for the abnormal returns exists, can generate abnormal risk-adjusted returns. This CSP anomaly can however only be observed if the criteria introduced above for drawing conclusions on market efficiency are fulfilled (see case number 5 in Table 1). If for example, factors generally known to explain SMP are not controlled for, as depicted in case number 8 in Table 1, the abnormal returns achieved cannot be attributed to CSP, but might for example be driven by the size effect (cf. chapter *2.1.4 Methodologies and Findings).*

2.2.7 Review of Studies

By and large the existing body of research relating CSP to financial performance in general comes up with mixed results, depending on the underlying measure of CSP and financial performance, the methodologies applied, the sample size analysed, the time horizon under investigation and the respective industries analysed (cf. Horváthová, 2010; Ullman, 1985). Recently, some scholars see the emergence of a positive relation (Günther, Hoppe, & Endrikat, 2011; Margolis & Walsh, 2003; Orlitzky, Schmidt, & Rynes, 2003; Reverte, 2011).

From the vast body of literature relating CSP to financial performance, only those studies that use stock market performance as an indicator for return are of relevance to this research. This is due to the fact that only stock market performance reflects the valuation by financial markets, which is of interest in this context. Studies that use accounting figures or ratios of accounting and financial market performance as return figure (including e.g. Tobin’s q, price-earnings-ratios or return on equity) will not be discussed in this chapter. These studies represent the majority of studies relating CSP to financial performance. They focus on past financial performance or a combination of balance sheet and financial market performance, rather than the expected future performance as expressed by stock returns, which is relevant to this research. Furthermore, the analysis of studies that examine SRI mutual fund performance is only undertaken exemplary in the remainder of this chapter. This stems from the fact that returns of mutual funds are influenced by fund managers’ skills and unknown screening criteria (cf. Derwall et al., 2005; Diltz, 1995; Kempf & Osthoff, 2007; Sauer, 1997), which makes it impossible to isolate the impact of CSP and consequently hard to derive a clear judgment on the impact of CSP on results or the efficiency of the market towards the information on which the investment strategy rests.

Finally, it should be noted that the following discussion of related studies is not to be understood as critique, but rather an attempt to discuss their results from an at times different theoretical perspective. The studies reviewed in the following are of outstanding academic quality and they are categorized according to the criteria established above to facilitate an assessment of their results in an EMH context. Results of this assessment are summarised in Table 2 at the end of this chapter.

For example, Gordon and Buchholz (1978) looked at 40 US companies from 1970 to 1974 and measured CSP by means of a Business and Society Review ranking, in which students and businessmen rated companies on their perceived degree of social responsibility from outstanding to poor. Gordon and Buchholz used the CAPM, i.e. they adjusted return for risk. They find no statistically and/or economically significant out- or underperformance and conclude – presuming the market to be efficient – that "the effects of the degree of social responsibility on stock prices were either non-existent or had occurred prior to 1970" (Gordon & Buchholz, 1978, p. 485). While the CSP measure applied by Gordon and Buchholz is costlessly and readily available to market participants, it is argued here that a company's rank in the Business and Society Review does not represent information that impacts the intrinsic value of the firm. As a consequence it would not have been priced by the market. Furthermore, as factors known to impact stock performance such as size and book to market ratio are not controlled for, no judgement on the level of market efficiency towards CSP can be derived from this study.

Anderson and Frankle (1980) compared portfolios of equal systematic risk but differing CSP information characteristics by examining the impact of voluntary social disclosure in annual reports of 314 Fortune 500 firms for the year 1972. They applied the CAPM to compare stock market returns of portfolios constructed from companies that only disclose financial information with portfolios composed of companies that voluntarily disclose any kind of non-financial information (i.e. information on environmental controls, minority employment, personnel responsibility, community activities or product improvement). Anderson and Frankle found that in the six months period after publication, firms that disclosed any kind of CSP information outperformed non-disclosing firms. Their study utilized an indicator of CSP that is costlessly and readily available to the market. However, from an EMH perspective, the rather crude indicator of mere existence of any kind of non-financial reporting is argued to not have an impact on the intrinsic value of the company. Anderson and Frankle (1980, p. 477) themselves mention as limitation of their study “the lack of a more critical examination of information contained in each disclosure”. They also noticed that “disclosing firms may be those that have sufficient discretionary income to permit involvement in social activity” (Anderson & Frankle, 1980, p. 477), which suggests that they were not able to rule out the fact that variables other than those observed in their analysis would be able to explain the outperformance found, for example size or book to market ratio. As a consequence, market efficiency cannot be judged.

Mahapatra (1984) looked at 67 US firms from 1967 to 1978. By means of Spearman rank order correlations of the six industries included in the study he found that in the long term higher pollution control expenditures lead to low market returns and low systematic risk. Pollution control expenditures, which were widely discussed during the time of the study and published in companies’ financial reports, can be regarded as value-relevant CSP information, since possible future costs for e.g. cleaning-up operations are reduced. Mahapatra’s results thus hint at market efficiency concerning corporate pollution control expenditures, i.e. the market priced in the value-relevant information and no higher returns are provided to investors of well-performing companies while their systematic risk is reduced. However, as Mahapatra presents his results predominantly at industry level and factors generally known to impact stock market performance are not controlled for, no judgement on market efficiency can be derived. Interestingly, Mahapatra himself interpreted his findings from an inefficient market view and concluded that conventional “[i]nvestors view pollution control expenditures as a drain on resources that could have been invested profitably, and do not reward the companies for socially responsible behaviour” (Mahapatra, 1984, p. 37).

Diltz (1995) examined the daily stock returns of 159 large US firms in the years 1989 to 1991. Using publicly available data from the Council on Economic Priorities he built portfolios according to different sustainability-related trading rules and hypothesized that there are no differences in mean alphas of portfolios from well and poor rated firms, i.e. expecting the market to be efficient. He finds that “social screening appears to have little, if any, impact on portfolio performance" (Diltz, 1995, p. 66) and that there are significant differences in alphas only when nuclear and military involvement were scrutinized. He relates these results to the political climate at the time of the study and "ongoing woes of the commercial nuclear power industry" (Diltz, 1995). He concluded the market to be efficient. Diltz applies the CAPM to calculate alphas, but does not control for factors generally known to impact stock performance, i.e. it cannot be ruled out that his results are driven by differences in company size or book-to-market factors. While he used publicly available information that is – at least in parts – of fundamental value to the future performance of the firm, his research design does not allow for a judgment on the level of market efficiency from today's perspective. The same conclusion is valid for a study of Herremans et al. (1993) which employs a similar research design.

Cohen, Fenn, and Konar (1997) constructed best-in-class portfolios based on the averaged environmental performance of S&P500 companies in the years 1987 to 1989 and looked at risk-adjusted returns from 1987 to 1991. Their nine measures of environmental performance are based on data published by the Investor Responsibility Research Center and are value-relevant. They measures include for example the number of environmental litigation proceedings and the number of oil and chemical spills. However, to adjust for company size, Cohen et al. divide their measures of environmental performance by company sales. While this is frequently done in studies relating CSP to financial performance (cf. Busch & Hoffmann, 2011), dividing by sales dilutes the value-relevance of their indicator of environmental performance.[6] Nevertheless, Cohen et al. find two out of nine high pollution portfolios (oil spills and toxic releases) to significantly outperform. Assuming their diluted measure of CSP is still value-relevant, this result can be regarded as reasonable from an EMH perspective, as companies with higher number of oil spills

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[6] Total sales also include the economic value of the cost of supplies, i.e. the cost of products that have been produced outside the company and then purchased by the company. When relating this financial number to the environmental performance of the company, the environmental indicator no longer allows differentiating between companies that have a high real net output ratio but a poor environmental performance and companies that rely heavily on outsourcing and pre-manufactured products and as a consequence would appear to have a better environmental performance.

and toxic releases can be argued to carry a higher risk. In summary, Cohen et al. use a return figure that is adjusted for risk and publicly available data. However, the value-relevance of their measure of CSP is diluted and they do not control for factors generally thought to explain stock market performance. As a consequence, no judgment on market efficiency can be derived.

Hughes (2000) looked at the market values of 100 US Utilities in the years 1986 to 1993 in the context of the Clean Air Act Amendments in 1990, which required specific utilities to reduce their output of sulphur dioxide. Sulphur dioxide is a source of acid rain, which was a highly discussed environmental problem in the 1980s. Hughes examined two groups of companies: one group, high polluting utilities, are named in the Clean Air Act Amendments and were expected to be “importantly and negatively affected by the Act and another group of utilities whose exposure to future abatement costs was expected to be small” (Hughes, 2000, p. 210). He found that the mean 1990 share price of the high-polluting utilities decreased by 16%. Hughes uses CSP information that is value-relevant and costlessly available to all market participants. However, he does not control his results for the effect of systematic risk or other factors known to impact stock performance. Furthermore, the methodology chosen does not allow for an assessment of any potential abnormal returns and consequently market efficiency cannot be judged. For example, Cormier, Magnan, and Morard (1993) also conclude a study which takes the market value as a return figure with the notion that their research design does not allow for taking into account risk or to identify arbitrage opportunities, i.e. does not allow for judging market efficiency towards the underlying measure of CSP. The same conclusion is valid for more recent studies that apply the market value of companies as a financial return figure, some of which examine the effect of GHG-emissions (Griffin et al., 2011; Matsumura, Prakash, & Vera-Muñoz, 2011).

Thomas (2001) looks at 291 companies from seven different industries in the UK and calculates returns via the CAPM while controlling for company size. Thomas regresses the calculated excess returns against dummy variables representing training, the adoption of an environmental policy and legal prosecutions (Thomas, 2001) to examine whether these factors add to the explanation of the excess returns found. She finds that the adoption of an environmental policy by companies in polluting industries and prosecution by an environmental standards agency “have significant explanatory power in an analysis of excess returns” (Thomas, 2001, p. 125). Thomas’ indicator of prosecution of breach of environmental standards is value-relevant, as it indicates financial liabilities. However, she uses private information obtained by the Croydon Borough Council Pension Scheme, which is not available to a sufficient number of market participants. While Thomas applies a risk-adjusted return-figure, her research design does not allow for the assessment of abnormal returns in general or in excess of transaction and information costs. Furthermore, Thomas does not control for factors generally argued to impact stock performance other than company size. As a result of the research design, market efficiency cannot be judged.

Blank and Wayne (2002) examine S&P 500 companies and particularly those companies which formed part of the Innovest Strategic Value Advisors (Innovest) rating universe, i.e. between 128 and 363 companies in the years 1997 to 2000. They examined whether Innovest ratings, which evaluates environmental performance on over 60 dimensions, “add value by identifying companies the market will reward for their superior management of environmental issues” (Blank & Wayne, 2002, p. 3). Focussing on stocks ranked highly by Innovest, Blank and Wayne construct a portfolio with a risk profile similar to the S&P 500 Index. In three out of four years, the Innovest enhanced portfolio shows a higher Sharpe ratio than the S&P 500, i.e. the Innovest enhanced portfolio better compensates the investor for the level of risk taken. However, the statistical significance of the differences in Sharpe ratios is not addressed and consequently market (in)efficiency cannot be judged (cf. Varamini & Kalash, 2008). Furthermore, Innovest rankings are not readily available free of charge to a sufficient number of market participants. As a consequence, market efficiency would have to be assessed in the light of the transaction and information costs of the underlying investment strategy (cf. chapter *2.2.4 Readily Available CSP Measure*). Unfortunately, while the Sharpe ratio gives insights on how well a portfolio compensates for risk, it does not allow for the identification of the economic significance of any abnormal returns or facilitates controlling for factors generally though to explain stock performance. Consequently, the study of Blank and Wayne does not allow making inferences about market efficiency.

Derwall et al. (2005) also used Innovest ratings and looked at between 170 and 450 US companies from 1995 to 2003. Derwall et al. constructed portfolios according to a simple trading rule and controlled for factors generally assumed to explain stock performance, such as size, systematic risk, book to market ratio and the momentum effect, by applying the C4FM. They concluded that firms that "perform relatively well along environmental dimensions collectively provide superior returns" (Derwall et al., 2005, p. 58). More specifically, they found an annualised alpha of around 6% for a strategy that goes long in (i.e. buys) the best-in-class environmental portfolio and short in (i.e. sells) the worst-in-class environmental portfolio. The indicators chosen by Derwall et al. are at least partially value-relevant and there is no risk-based explanation for the abnormal returns identified. Derwall et al. conclude that their results hint at an inefficiency of the market to price eco-efficiency correctly. The indicators used by Derwall et al. are however not readily available to a large number of market participants and therefore the abnormal returns found must be interpreted in light of the transaction and information costs of the underlying investment strategy (cf. chapter *2.2.4 Readily Available CSP Measure)*. Derwall et al. report that their results hold under transaction costs scenarios of up to 200 basis points. Consequently, even when assuming a rather high annual total expense ratio[7] of 1.50% for carrying out the SRI investment strategy (cf. Geczy et al., 2005; Renneboog et al., 2008b; Statman, 2000), i.e. 150 basis points, the strategy of Derwall et al. generates an economically significant abnormal return. Consequently, the market is inefficient even in Jensen's less strong but economically more reasonable form of EMH, as the risk-adjusted abnormal returns not only compensates the cost of carrying out the active investment strategy. However, the abnormal returns found are not surprising in light of Fama's original version of the EMH, given the fact that the underlying measure of CSP is not costlessly available to a sufficient number of market participants.

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[7] The total expense ratio represents the percentage of a portfolio's total assets that corresponds to management fees and other operational expenses, i.e. the transaction and information costs of an active investment strategy in % of the portfolio's total assets. The ratio is used throughout this research to approximate the economic significance of returns in the context of Jensen's (1978) less strong but more economically reasonable version of the EMH (cf. chapter *2.1.3 Three Conditions for an Efficient Market*).

Using a sample of 103 US, UK and German ethical mutual funds and controlling for size, book-to-market, and momentum effects Bauer, Koedijk, and Otten (2005) find that, after fees, no fund generates abnormal returns in the years from 1990 to 2001. Bauer et al. use funds which apply ethical screens. As unfortunately no further information is given on the CSP criteria applied the value-relevance of the underlying information cannot be evaluated from an outside perspective. Consequently, results do not allow deriving a judgement on market efficiency concerning the ethical funds examined. Also, as discussed before, returns of mutual funds are influenced by fund managers' skills and tastes in the investment process and therefore the performance of funds cannot exclusively be attributed to CSP. Similar problems occur with other studies of SRI mutual funds, which in addition often do not control for factors generally known to explain stock market performance (Cortez et al., forthcoming; Huimin, Kong, & Eduardo, 2010; Statman, 2000).

Hassel, Nilsson, and Nyquist (2005) looked at 71 Swedish companies from June 1998 to September 2000 and used quarterly environmental performance rankings constructed by the CaringCompany (CC) Research. Using the established Ohlson model (Ohlson, 1995) Hassel et al. hypothesized that share prices reflect environmental performance next to financial performance, i.e. stipulating that environmental performance is value-relevant information and consequently "reflected in the current expectations of future earnings that determine market values" (Hassel et al., 2005, p. 46). They find that their measure of environmental performance has incremental explanatory power for the market value of equity of the companies included in their study. More specifically, they find a significant negative relationship between environmental performance and the market value of firms. Hassel et al. control for differences in company size in their model, but the model applied does not take into account risk or other factors generally known to explain stock performance. Furthermore, while the Ohlson model allows determining whether information is contained in a share price, it does not allow drawing inferences about the level of any potential abnormal returns. Furthermore, some of the data used in the measure of environmental performance is privately obtained by CC and consequently "parts of the market might be unaware of the information in CC's environmental performance measure“ (Hassel et al., 2005, p. 49). As a result of the research design, no judgement on market efficiency can be derived with regard to Fama's or Jensen's version of the

EMH. Identical conclusions are valid for other related studies applying the Ohlson model (Chapple, Clarkson, & Gold, 2009).

Over a ten-year period between 1988 and 1997, Murray, Sinclair, Power, and Gray (2006) looked at the 100 largest UK companies and the number of pages that these firms allocated to social and environmental issues in their annual reports. They found by means of Pearson Correlation tests and linear regression that, even after adjusting for company size, sustainability disclosure is related to market returns (Murray et al., 2006). The return figure applied by Murray et al. is not adjusted for risk and the regression model applied does not allow for the discussion of any potential abnormal returns. Their measure of CSP, i.e. number of pages devoted to CSP in annual reports, is not value-relevant. While the impact of size on share performance is accounted for, other factors know to impact share performance are not controlled for. In summary, the study therefore does not allow to draw inferences about market efficiency.

Ziegler, Schröder, and Rennings (2007) look at 212 European companies from 1996 to 2001. Using sustainability performance data by the Swiss bank Sarasin & Cie for the year 2001 as an independent variable, they hypothesized that sustainability performance impacts monthly stock returns. More specifically, their indicator of CSP rated on a scale from 1 to 5 the “average sustainability performance (evaluated in terms of the environmental and social risks) of the industry in which a corporation operates” as well as “the relative sustainability performance of a corporation within a given industry (evaluated in terms of the environmental and social activities of a corporation compared with all other corporations in the same industry)” (Ziegler et al., 2007, p. 662). They used the Fama and French Three Factor Model, i.e. they made reasonable use of control factors by controlling for risk, size and book to market ratio, but not the momentum factor. Ziegler et al. found that while variables of relative sustainability performance of companies had no effect on stock performance, “the average environmental performance of the industry in which a corporation operates has a significantly positive effect on the average monthly stock return from 1996 to 2001” (Ziegler et al., 2007, p. 677). As they use CSP as an independent variable and only report these factor loadings, their research design does not allow for a judgement of the economic significance of abnormal returns in general or in light of transaction and information costs. Furthermore, their measure of CSP was not available to the market during the time period analysed, as they relate sustainability performance data of the year 2001 to stock performance in the years 1996 to 2001. As a consequence of the research design, in summary, market efficiency cannot be judged.

Kempf and Osthoff (2007) looked at 650 stocks in the US from 1992 to 2004. They use the C4FM, i.e. control for factors generally assumed to explain stock market performance and construct portfolios from KLD ratings data. The KLD ratings data used applies qualitative criteria (such as strength and concerns in performance on e.g. environment and human rights) and exclusionary criteria (such as company involvement in controversial business areas). Kempf and Osthoff find abnormal returns in the magnitude of an annualised alpha of around 4% with a long-short strategy in the best-in-class investment approach. At least some of the indicators applied are value-relevant and there is no risk-based explanation for the abnormal returns found. While KLD data is based on publicly available sources, the KLD rating is not costlessly and publicly available. Results are consequently not surprising in light of Fama’s original conditions for market efficiency. In order to be able to derive a judgement on market efficiency with regard to Jensen’s version of the EMH, the investment approach has to be examined in light of the transaction and information costs involved in carrying out the investment strategy. Kempf and Osthoff report an annualised alpha of 3.38% when transaction costs of up to 150 basis points are assumed. Consequently, the market is not efficient towards the underlying information in Jensen’s version of EMH, as abnormal returns can be obtained in excess of the transaction and information costs of the investment strategy.

Olsson (2007) looked at 440 US companies from the MSCI World Index in the years 2004 to 2006. He uses an environmental risk ratings from GES Investment Services, which ranks companies “along more than 60 dimensions based on international standards for environmental management and industry-specific key indicators for environmental performance, among other things“ (Olsson, 2007, p. 3). Constructing portfolios from high and low rated companies, Olsson looks at daily returns and applied the C4FM, i.e. controls for factors generally known to explain returns. He found that no portfolio produced an abnormal return. Olsson used a measure of return that is adjusted for risk and controls for factors generally thought to explain stock market performance. All criteria for judging market efficiency are fulfilled. While

GES ratings are based on publicly available information, they are not readily available to the public free of charge. Assuming that the information incorporated in GES rankings is relevant to the intrinsic value of the firm, the fact that no abnormal returns are found in excess of information and transactions costs suggest that the market is efficient towards the underlying information of CSP.

Ziegler, Busch, and Hoffmann (2011) looked at the monthly stock returns of between 447 and 1790 European and US firms in the years 2001 to 2006. They built portfolios on simple trading rules based on two binary dummy indicators for corporate climate change disclosure derived from the Asset4 data base. The indicators represent information on whether a company reports *if* “it believes that climate change can represent commercial risks and/or opportunities” (Ziegler et al., 2011, p. 1287) or not and *if* a company reports “on initiatives or new production techniques, to recycle, reduce, reuse, substitute or phase out CO_2 or CO_2 equivalents in the production process?” (Ziegler et al., 2011, p. 1287) or not. Applying a C4FM, i.e. controlling for factors generally accepted to explain stock market performance, they do not find significant out- or underperformance of any portfolio over the whole period under investigation. Ziegler et al. use Asset 4 data, which is based on publicly available data sources, but not costlessly available to market participants. From an EMH perspective the general results of Ziegler et al. hint at market efficiency in Fama’s (and Jensen’s) version of EMH, as they use a return figure that is adjusted for risk, control for factors generally argued to impact SMP and do not find abnormal returns (in excess of transaction and information costs). This perceived efficiency might however also stem from the notion, that the indicator applied by Ziegler et al. does not contain value-relevant information for market participants – whether or not a company answers a question on the expected impacts of climate change or has any initiative in place to reduce its climate change impact may not be of relevance to the intrinsic value of the firm.

Interestingly, Ziegler et al. (2011) found for the sub-period of 2004 to 2006 that a trading strategy which goes long in European companies “releasing carbon reduction measures or disclosing both responses to climate change” (Ziegler et al., 2011, page 1292) and short in companies with no disclosures generated an annualised abnormal return of almost 7%. While Ziegler et al. do not account for transaction and information costs, this abnormal return is estimated to be economically significant, even when assuming a rather high annual total expense ratio of 1.50% for carrying out the SRI investment strategy (cf. Geczy et al., 2005; Renneboog et al., 2008b; Statman, 2000).[8] These sub-results of Ziegler et al. thus hint at market inefficiency in Fama's and Jensen's version of EMH towards the underlying information on carbon disclosure in Europe in the years 2004 to 2006, either because the market is pricing information that is not relevant to the intrinsic value of the firm or – assuming that their indicator of CSP is value-relevant – the market is not pricing it correctly. In light of the short time-period under investigation (36 monthly observations) these results should however be interpreted with caution.

Reverte (2011) looks at 26 Spanish firms from 2003 to 2008 and CSR disclosure quality ratings from the Observatory on Corporate Social Responsibility reports. Reverte aims to examine the impact of the quality of CSR disclosure on the cost of equity, which is another description for expected return and represents the discount rate applied to future cash flows to arrive at current stock prices. The cost of equity is is estimated by Reverte via analyst forecasts. Reverte finds that as CSR disclosure quality increases, the cost of equity capital decreases, i.e. the rate of return required by investors decreases due to a reduction in the perceived riskiness of future cash flows. This is the case especially in environmentally sensitive industries. He concludes that "the cost of equity capital is an important channel through which the market prices CSR disclosure" (Reverte, 2011, p. 10), which may contain value-relevant information that is not included in financial reports. Reverte uses a small sample and publicly available information to assess the impact of the quality of CSR disclosure on the cost of capital, while controlling for size and book to market ratio. His study does however not allow drawing inferences on market efficiency, as he uses subjective analyst estimations of expected returns rather than measuring stock performance. Consequently, no conclusion on abnormal returns and the level of market efficiency can be derived on the basis of Reverte's study or related studies

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[8] Note that this conclusion is only an approximation. Usually annual total expense ratios are not deducted from annualised portfolio returns but split into monthly expenses and deducted from monthly portfolio returns before the regression is performed again.

measuring the cost of equity (Chava, 2010; Matsumura et al., 2011; Sharfman & Fernando, 2008).

2.2.8 Conclusions from Review of Related Studies

This chapter examined the results of related existing research in light of EMH to possibly derive a judgement on the level of semi-strong market efficiency towards CSP and disclosure of CSP. Table 2 gives an overview on the studies examined.

In conclusion, it can be summarised that while especially older studies that relate CSP to SMP argue to have identified market inefficiencies, on closer inspection it shows that the research design of these studies does not allow drawing such inferences from today's perspective. One conclusion from the review of existing studies that relate CSP to SMP is that due to their research design, a large majority of studies does not allow deriving a judgement on the level of market efficiency. No study has come to the author's attention that is exclusively devoted to the question whether the financial market is efficient with view to information on CSP. Furthermore, no study was found that allows drawing conclusive inferences on the level of market efficiency towards the market-wide financial impacts of climate change. This gap in existing research is addressed in the remainder of this thesis.

In summary, two convincing market inefficiencies towards CSP were found in this chapter (cf. Derwall et al., 2005; Kempf & Osthoff, 2007). For both of these anomalies no risk-based explanation is available. They stem from long-short strategies of a best-in-class investment approaches that relied on information that is not costlessly available to a sufficient number of market participants. The inefficiencies found are consequently not surprising given Fama's original second conditions for market efficiency. However, as the abnormal returns identified by these studies not only compensate for the transaction and information costs of carrying out the investment strategy, but generate abnormal returns even when annual total expense ratios of 1.50% are assumed, they represent market inefficiencies in Jensen's less strong but economically more reasonable definition of EMH.

Table 2: Overview of examination of related studies in light of EMH

Study	Abnormal returns	Risk-adjusted return figure	Risk-based explanation	Value-relevant CSP measure	Readily available CSP measure	Control factors	Implications for judging market efficiency
Gordon & Buchholz (1978)	No	Yes	N/A	No	Yes	No	Market efficiency cannot be judged.
Anderson & Frankle (1980)	UNK	Yes	No	No	Yes	No	Market efficiency cannot be judged.
Mahapatra (1984)	No	No	N/A	Yes	Yes	No	Market efficiency cannot be judged.
Diltz (1995)	UNK	Yes	N/A	Yes	Yes	No	Market efficiency cannot be judged.
Cohen et al. (1997)	Yes	Yes	Yes	UNK	Yes	No	Market efficiency cannot be judged.
Hughes (2000)	N/A	No	N/A	Yes	Yes	No	Market efficiency cannot be judged.
Thomas (2001)	UNK	Yes	N/A	Yes	No	No	Market efficiency cannot be judged.
Blank & Wayne (2002)	UNK	Yes	No	Yes	No	No	Market efficiency cannot be judged.
Derwall et al. (2005)	Yes	Yes	No	Yes	No	Yes	Market is inefficient. Abnormal returns in excess of costs are achieved. No risk-based explanation.
Bauer et al. (2005)	No	Yes	N/A	UNK	No	Yes	Market efficiency cannot be judged.
Hassel et al. (2005)	N/A	No	N/A	Yes	No	No	Market efficiency cannot be judged.

Notes: N/A = Not applicable, UNK = Unknown

Table 2: Overview of examination of related studies in light of EMH (cont.)

Study	Abnormal returns	Risk-adjusted return figure	Risk explanation	Value-relevant CSP measure	Readily available CSP measure	Control factors	Implications for judging market efficiency
Murray et al. (2006)	N/A	No	N/A	No	Yes	No	Market efficiency cannot be judged.
Ziegler et al. (2007)	UNK	Yes	N/A	Yes	No	Yes	Market efficiency cannot be judged.
Kempf & Osthoff (2007)	Yes	Yes	No	Yes	No	Yes	Market is inefficient. Abnormal returns in excess of costs are achieved. No risk-based explanation.
Olsson (2007)	No	Yes	N/A	Yes	No	Yes	Market is efficient. No abnormal returns in excess of costs are achieved.
Griffin et al. (2010)	N/A	No	Yes	Yes	No	No	Market efficiency cannot be judged.
Ziegler et al. (2011)	No	Yes	N/A	No	Yes	Yes	Market is efficient.
Reverte (2011)	UNK	Yes	N/A	Yes	Yes	Yes	Market efficiency cannot be judged.

Notes: N/A = Not applicable, UNK = Unknown

Recalling Fama's interest to research "the level of information at which the hypothesis breaks down" (Fama, 1970, p. 383) the review of studies relating CSP to SMP can hint at the fact that CSP information has to be costlessly available to all market participants in order for the financial market to be efficient. The weaker but economically more reasonable version of the hypothesis suggested by Jensen does not hold with regard to information on CSP. This circumstance is probably facilitated by the fact that the value-relevance of CSP information is not generally acknowledged by market participants (cf. chapter *2.1.3 Three Conditions for an Efficient Market*). As a consequence, insufficient numbers of market participants may acquire costly information and arbitrage opportunities continue to exist with regard to CSP.

Chapter 3

Hypotheses Development

As demonstrated in the previous chapter, research that allows making conclusive judgements on the level of market efficiency towards CSP is sparse and no research came to the author’s attention that allows drawing inferences on the level of market efficiency towards the financial impact of climate change on companies. To fill this gap, in this chapter, the hypotheses that allow testing market efficiency towards the market-wide financial impacts of climate change will be developed and it will be argued that the financial risk induced by climate change is of systematic nature.

Climate change is widely accepted to be a serious threat to our planet that requires urgent regulatory responses from governments around the world (IPCC, 2007; Stern, 2006). Averting the more serious consequences of climate change is expected to “be a major structural driver of economic change” (FTSE Group, 2012). In the remainder of this chapter, it is argued that the financial impact of climate change on companies in the EU constitutes a systematic risk, as various political and market initiatives for the reduction of GHG-emissions inflict unknown future costs on large parts of the economy (cf. chapter *1 Introduction*). As this climate change induced systematic risk affects a large share of all companies, it cannot be eliminated in a portfolio through diversification and should therefore be rewarded with higher returns. In this context, it is noteworthy that practitioners from the field of mainstream finance have argued for climate change to be a systematic risk that should be rewarded with a risk premium (Litterman, 2010). Academic scholars however have widely ignored the fact that the financial risks induced by climate change classifies as a new source of systematic risk. Figge (1997, p. 266) nevertheless argued very early that environmental problems might lead “to a systematization of economic risks”.

Before the hypotheses are developed that allow assessing the level of market efficiency towards climate change induced systematic risk, the important notions of EMH on which these hypotheses rest are briefly revisited: In an efficient market rational investors are rewarded with a premium for taking on systematic risk, i.e. risk that cannot be eliminated in a portfolio through diversification because it affects a large share of the economy (cf. chapter *2.1.2 Definitions and Important Notions of EMH*). Controlling for this risk and factors generally known to explain stock performance, no abnormal risk-adjusted returns can be persistently generated by investors that are trading on publicly available information in an efficient market. Consequently, it is only when the market is inefficient that stocks generate economically higher returns in the absence of higher systematic risk (cf. chapter *2.2.1 Abnormal Returns).* In chapter *2.1.3 Three Conditions for an Efficient Market,* some theoretical potential for market inefficiency concerning value-relevant information on CSP has been identified, as the theoretical conditions for market efficiency do not fully apply. Market inefficiencies towards information on CSP was subsequently evidenced in chapter *2.2 Literature linking CSP and SMP*, though only in the less strong but economically more reasonable definition of EMH of Jensen (1978). Consequently, market efficiency as much as market inefficiency towards climate change induced systematic risk is considered as a possible outcome of this research (cf. chapter *2.1.6 Application of EMH in this Research*).

To test market efficiency towards climate change induced systematic risk, hypotheses based on six publicly available proxies for the systematic risk represented by climate change are introduced and grounded in existing research in the remainder of this chapter. These proxies are a company’s affiliation with the EU ETS, the existence of disclosure of GHG-emissions by companies, the completeness of such disclosures, the absolute level GHG-emissions of companies and their GHG-efficiency, as well as their affiliation with high carbon industries.

3.1 European Emissions Trading Scheme

The first proxy for climate change induced systematic risk is a company’s affiliation with the EU ETS. To illustrate why affiliation with the EU ETS classifies as a proxy for climate change induced systematic risk, the important features and the future development of the scheme are summarized in the following paragraphs.

Launched in January 2005, the EU ETS is the world’s largest cap-and-trade system for corporate carbon dioxide emissions. It covers more than 10,000 installations of companies with energy-producing activities, companies involved in the production and processing of ferrous metals, companies from the mineral industry as well as companies with pulp, paper and board activities.[9] Together these installations are responsible for almost half of the EU's CO_2-emissions (European Commission, 2007). Under the EU ETS, EU member states currently draw up national allocation plans, which allocate allowances to each installation in the system. An allowance corresponds to the right to emit one ton of CO_2. If companies keep their emissions below the level of allocated allowances, they can sell their excess allowances at the market rate. Companies whose expected emissions surpass their allocated allowances can either take measures to reduce their emissions, obtain a limited number of Certified Emissions Reductions through investing in Clean Development Mechanism projects (Vasa, 2010) and/or buy additional EU ETS emission allowances at the market rate. Companies that do not possess the required number of allowances will be punished with a fine of € 100 per ton of CO_2.

The share of emission allowances that was distributed freely to companies in the first phase of the EU ETS, which lasted from 2005 to 2007, corresponded to almost 100% of the participating companies' emissions (and to around 90% in the second phase of the EU ETS between 2008 to 2012). The free and over-allocation of allowances in the first phase of the EU ETS invited criticism on the validity of the scheme (Carbon Retirement, 2010). Especially European utility companies, which often operate in oligopolistic markets without international competition, benefited from the lax implementation of the EU ETS in the first phase. In fact, due to basically free allocation of emission allowances in that phase and the low price of emission allowances, the profits made by utility companies from passing on at times inexistent costs to consumers compensated for the costs resulting from their affiliation with the EU ETS. Not surprisingly, with regard to the first phase of the EU ETS, Obendorfer (2009) and Veith, Werner, and Zimmermann (2009) both found that prices of emission allowances and the share price of European Utilities were positively related in many European countries in the first phase of the EU ETS.

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[9] Furthermore, airlines with flights starting from or landing in the EU are included in the EU ETS from 2012 onwards.

Evidently, the EU ETS is only slowly developing the dimension and importance it was designed to have. The free allocation of allowances will be consecutively reduced and it is estimated that about 50% of allowances will be auctioned in the third phase of the EU ETS starting in 2013, with auctioning increasing to 70-80% over time by 2020 (The World Bank, 2009). In the third phase of the EU ETS, no allowances will be allocated free of charge for electricity production while the auctioning process ensures that allowances are allocated to the highest bidder. Despite its initial deficiencies, the EU ETS has been initiated so that in the long-term companies face significant additional costs for emitting GHG-emissions. The exact magnitude of these future costs is unknown, which means that the impact of the EU ETS on the future cash flows of companies is consequently also unknown.

Future costs stemming from the EU ETS are unpredictable in magnitude as they either stem from the purchase of emissions allowances at the unknown auction or market rate or costs for the reduction of emissions within the company. In this context, Engels (2009, p. 498) found in her study of over 300 companies that participated in the first phase of the EU ETS that a “large share of companies […] up to this date do not know their own abatement costs”. In other words, a large share of the companies interviewed could not estimate the costs for CO_2-reduction within the company. These companies consequently cannot make an informed decision on when reducing emissions is more cost-effective than buying additional emissions allowances at a specific auction price or market rate. This lack of knowledge is likely to further increase the uncertainty around future costs companies incur from the EU ETS.

During the time of this study, the uncertainty concerning the magnitude of future costs of emitting CO_2 in the EU was further amplified because EU member states did not communicate their strategy for the allocation of allowances very clearly (The World Bank, 2009). For example, the chief executive of the Association of Electricity Producers suspected in early 2006 that utility companies “might be singled out for a hefty cut in emissions permits when the next allocation plan emerges” (Point Carbon, 2006). This suspicion turned out correct and as a consequence the British utility company Drax Group spent £ 107 million on emission allowances in 2008 (CO2-Handel.de, 2008), while the German RWE Group spend one billion Euro on emission allowances in 2009 (RWE Group, 2009). While, as discussed, most utility companies were able to pass on costs for allowances to consumers due to the specific conditions of the markets they operate in, these numbers are able to illustrate the potential of uncertain financial impacts that GHG-emissions can have on the intrinsic value of a company. The British consulting company Carbon Trust estimates that for example companies from the Building Materials and Bulk Commodity Chemicals sector will face severe challenges in passing on carbon costs to consumers while showing high carbon intensity. Carbon Trust (2006) therefore stipulates that under a realistic regulatory scenario these sectors are expected to be significantly impacted by the EU ETS, with a value at risk over 10% of EBIT in 2013. For other sectors, Carbon Trust does not expect the EU ETS to have a financial impact of above 5% of profit or shareholder value in 2013.

The year 2013 actually marks an important date for the EU ETS. Its impact is expected to widen significantly as a series of important changes to the way the EU ETS works will be introduced, which according to the European Commission (2008, p. 6) “will strengthen, expand and improve its functioning”. For example, from 2013 onwards, allocation plans will be determined at the EU level due to the problems of over-allocation of allowances to companies, which occurred in the first and second phase of the EU ETS. Furthermore, additional greenhouse gases and companies from the petrochemicals, ammonia and aluminium industries are to be included in the EU ETS from 2013 onwards (European Commission, 2010). In this context, for example the chemical company BASF stated that it sees a distinct cost burden stemming from the EU ETS from 2013 onwards (Carbon Disclosure Project, 2008b).

From an EMH perspective, the expected yet unknown future impact of the EU ETS on the cash flow of BASF would already be priced in today’s market valuations of BASF – and as well as in the market valuation of companies from the petrochemicals, ammonia, aluminium and mineral industry, companies with energy-producing activities, airlines, companies involved in the production and processing of ferrous metals as well as companies with pulp, paper and board activities. It thus becomes clear that while the EU ETS is limited to certain industries, it affects large segments of the economy. Already in the years 2005 to 2009, on average more than one third of the European constituents of the FTSE All World Index had installations in the EU

ETS (cf. chapter *4.3 Descriptive Sample Characteristics*). This share will rise further from 2013 onwards and illustrates that the unknown financial impact of the EU ETS on companies cannot be diversified away and therefore classifies as a proxy for the systematic risk induced by climate change.

In the long-term, the EU ETS thus inflicts unpredictable future costs on large parts of the economy through unknown fluctuations in the future price of emission allowances as well as a remaining uncertainty concerning the free allocation of allowances in the future. As a matter of fact, the future price of emission allowances is unknown and prices have shown significant fluctuation in the past. In the first phase of the EU ETS, prices for emission allowances ranged from almost € 0 to around € 27. Some companies might be able to hedge the significant risk stemming from short- to medium term fluctuations in the price of carbon. These companies however still face unknown future costs in the long-term for emitting or reducing their CO_2-emissions. The systematic risk induced by the EU ETS is consequently conceptually very similar to the systematic risk induced by oil prices (Ciner, 2001; Jones & Kaul, 1996; Sadorsky, 1999).

As it has been demonstrated, the EU ETS classifies as a proxy for climate change induced systematic risk because it inflicts unpredictable future costs on industries that present large parts of the economy. In the methodology used for this research, systematic risk is depicted by the coefficient beta, which measures the sensitivity of portfolio returns to market returns. The returns of companies that are affiliated with the EU ETS are expected to be more sensitive to the market-wide risk induced by climate change than the returns of companies that are not affiliated with the EU ETS. Ceteris paribus, affiliation with the EU ETS would increase companies’ beta, as their expected returns are more sensitive to the risk induced by climate change to the overall market, which by rule has the average beta of 1.0 (Rosenberg & Guy, 1976). In the context of EMH, the rational risk-averse investor would therefore expect to be rewarded for the increased systematic risk taken on when investing in companies that are affiliated with the EU ETS. If the financial market prices this risk correctly, no difference in risk-adjusted returns can be observed between companies that are affiliated or not affiliated with the EU ETS on a risk-adjusted basis. It is consequently hypothesized:

Hypothesis 1a: The market is efficient, i.e. there is no difference in risk-adjusted returns between portfolios constructed from companies that are affiliated and those that are not affiliated with the EU ETS.

However, as identified in chapter *2.1.3 Three Conditions for an Efficient Market*, there is a theoretical potential for market inefficiency concerning value-relevant information on CSP, as the respective conditions for market efficiency are not fulfilled. With regard to information on climate change induced systematic risk, the same arguments apply. Taking the possibility of market inefficiency[10] into account it is hypothesized:

Hypothesis 1b: The market is inefficient, i.e. there is a persistent difference in risk-adjusted returns between portfolios constructed from companies that are affiliated and those that are not affiliated with the EU ETS.

3.2 Existence of Disclosure of GHG-Emissions

The second proxy for climate change induced systematic risk in this study is the existence of corporate disclosures of absolute levels of GHG-emissions. Showing that information on absolute levels of GHG-emissions is relevant to the intrinsic value of the firm, this proxy is subsequently related to a stream of studies of estimation and information risk in mainstream finance, in which “securities for which there is relatively little information are shown to have relatively higher systematic risk” (Barry & Brown, 1985, p. 407). While there is on-going academic debate over the non-diversifiability of estimation and information risk (Artiach & Clarkson, 2011), this research builds on the theoretical and empirical contributions that have shown that estimation risk and information risk are – or should be – priced.

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[10] As described in chapter *2.1.4 Methodologies and Findings*, market inefficiency here is defined as any abnormal return, despite the existence of a risk-based explanation or not. This is due to the fact that results of one study are not sufficient to evidence shortcomings in the asset pricing models to price a specific risk correctly.

A simplified argument in this stream of literature is that higher levels of value-relevant information on a stock allow for a better and more reliable estimation of its specific future cash flow, which reduces the covariance with market returns and, ceteris paribus, its beta.[11] In this context, for example Riedl and Serafeim (2009, p. 25) summarize that various studies suggest that “insufficient firm-specific information leads market participants to infer valuation parameters based on non-firm specific (e.g. macro-economic) indicators”. In other words, if market participants do not have access to company-specific information, they have to rely on more general, non-specific information to estimate future cash flows. As a consequence, the expected returns of companies with lower levels of value-relevant firm-specific information will show a higher covariance with market returns, and consequently a higher beta. Before discussing estimation and information risk in the context of corporate disclosures of absolute levels of GHG-emissions in more depth, the value-relevance of this second proxy for climate change induced systematic risk is briefly illustrated.

Apart from the EU ETS, there are various other political and market initiatives for the reduction of GHG-emissions, which have already been or might be adopted in the future. For example, since 1990, various European countries have introduced some form of tax on carbon dioxide. The stance of remaining European countries to tax carbon is however unpredictable. To name one example, the introduction of a significant carbon tax in France was abruptly cancelled one month prior to its introduction (Kanter, 2009). The outcomes of the discussed development of national cap-and-trade programs for GHG-emissions in the US, Australia and New Zealand (Harrison, Klevnas, Nichols, & Radov, 2008) were similarly hard to predict during the period analysed in this study. Political uncertainties also exist at the level of European policy, where it is one of the policy guiding principles of the renewed EU Sustainable Development Strategy to make polluters pay, i.e. to “ensure that prices reflect the real costs to society of consumption and production activities and that polluters pay for the damage they cause to human health and the environment”

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[11] Recall that the beta of a stock can be calculated by dividing the covariance of stock and market returns by the variance of market returns. Consequently, reducing the covariance of a company’s stock with market returns, ceteris paribus, results in a reduction of beta.

(European Council, 2006, p. 5). The renewed Sustainable Development Strategy also states as one of its operational objectives to integrate climate change in all relevant European policies. During the period analysed in this study it was however unclear into which specific measures these intended policies and political guiding principles for a reduction of GHG-emissions will translate, given that they can be expected to be influenced by various actors (Ellis, 2007). Nevertheless, Sullivan (2009, p. 301) generally summarizes that “policy measures directed at reducing greenhouse gas emissions will continue to strengthen and companies across the board, not just those with significant emissions, will face increasing pressure to reduce these emissions”.

The illustrated uncertainties in national and European policy add to the financial risk induced by climate change, as the future impact of these political initiatives on the intrinsic values of companies is unknown. In the meantime, companies seem to postpone investments in the reduction of GHG-emissions until greater political clarity exits (Sullivan, 2009, p. 309), leaving them unprepared for any policy measures for the reduction of GHG-emissions that might be introduced in the future. In this context, the corporate disclosure of absolute levels of GHG-emissions is value-relevant, as it allows for a better assessment of a company’s exposure towards the discussed regulatory risks.

Interestingly, it is the discussed uncertainty from the political environment that nurtured several of the market initiatives that try to grasp or eliminate the risk induced by climate change, such as the Carbon Disclosure Project (Carbon Disclosure Project, 2008a), the Climate Principles (The Climate Group, 2012), the Investor Network on Climate Risk (Investor Network on Climate Risk, 2010) or The Institutional Investors Group on Climate Change (IIGCC, 2010). For example, to illustrate the functioning of just one market initiative, it is the aim of The Carbon Principles to “reduce the regulatory and financial risk associated with greenhouse gas emissions” (The Carbon Principles Banks, 2008). Currently restricted to utility projects, signatory banks of The Carbon Principles assure to deny financing to clients who do not provide the information required to conduct the enhanced diligence process described in the principles. In summary, these market initiatives are able to illustrate that providers of capital require information to assess climate change induced systematic risk. In fact, scholars found that not only investors, but also banks include an appraisal of environmental risk in their credit risk assessment procedures (Thompson & Cowton, 2004), even though not in every step of these procedures (Weber, Fenchel, & Scholz, 2008). The politically induced value-relevance of information on corporate climate change performance is consequently underlined by market initiatives, some of which have an impact on the certainty of a company's access to capital.

The value-relevance and risk-reduction potential of corporate disclosures of GHG-emissions is further reinforced by arguments from the context of stakeholder theory (Freeman, 1994). Stakeholder theory stipulates that "managers and entrepreneurs must take into account the legitimate interests of those groups and individuals who can affect (or be affected by) their activities" (Freeman, Wicks, & Parmar, 2004, p. 365). In the age of global warming, this relates to the legitimate interest of different stakeholders in the reduction of corporate impacts on climate change. Complying with stakeholder interests reduces the risk related to for example a company's relation with the government, customers, the media and the communities it operates in (Ambec & Lanoie, 2008). Ziegler et al. (2011) suggest that stakeholders may withdraw their support if a company does not report on responses to climate change and for example Kolk, Levy and Pinkse et al. (2008, pp. 720-721) point out that "business is under increasing pressure from investors and environmental non-governmental organizations (NGOs) to disclose information related to their GHG emissions". Waddock and Graves (1997) argue that socially irresponsible firms may face uncertain future explicit claims from stakeholders. In this context and more general terms, Herremans, Akathaporn, and McInnes (1993) found that companies with poor CSR reputation, which might indicate low levels of legitimacy from stakeholders, show a higher systematic risk.

At the same time, the existence of company-specific disclosures of GHG-emissions might indicate better management skill. In general, CSR disclosure has been argued to be an indication for good management skills (Alexander & Buchholz, 1978; Herremans et al., 1993) and scholars argue that "[i]nvestors may consider less socially responsible firms to be riskier investments because they see management skills at the firm as low" (McGuire, Alison, & Schneeweis, 1988, p. 857). Companies disclosing their absolute levels of GHG-emissions to the public may be those that are better managed and prepared to manage their climate change performance and climate change induced systematic risk. In fact, in order for companies to be able to report absolute levels of GHG-emissions, environmental management systems need to be implemented within the company. The proxy of existence of disclosure of absolute levels of GHG-emissions consequently allows distinguishing companies that are able to manage their GHG-emissions, and whose performance can be assessed and traced over time, from companies that only make “soft, unverifiable claims to be committed to the environment” (Clarkson, Li, Richardson, & Vasvari, 2008, p. 309). Generally speaking, it has been found that good management skills may insulate stock returns from market wide effects (McAlister, Raji Srinivasan, & Kim, 2007), which would reduce the covariance of stock returns with market returns and consequently systematic risk. Furthermore, it has been found that companies reporting on CSP are subject to less negative market reaction in times of intra-industry environmental crisis (Blacconiere & Patten, 1994). This reduces their covariance with market returns and thus their systematic risk. In fact, with regards to systematic risk and information on CSP, several studies find a negative relationship, i.e. companies with good environmental information practises show low systematic risk, while companies with poor environmental information practises show higher systematic risk (Sharfman & Fernando, 2008; Spicer, 1978).

In summary, there are numerous political and market initiatives, as well as arguments rooted in stakeholder theory and relating to the indicative power of environmental disclosure for better management skills, which illustrate the value-relevance of corporate disclosures of GHG-emissions and the systematic risk related to a company’s choice to disclose GHG-emissions. Having established the value-relevance of disclosures of GHG-emissions, these are now related to a stream of studies of estimation and information risk in mainstream finance.

For financial disclosures, for example Jorgensen and Kirschenheiter (2003) show that a company’s beta and risk premium is affected by its disclosure strategy choice. As discussed at the beginning of this chapter, in mainstream finance it is argued that more company-specific information reduces the covariance of returns with the market, which, ceteris paribus, in turn would reduce a company’s beta (Riedl & Serafeim, 2009). In the context of this study, it is analogously argued that companies that chose to disclose their absolute level of GHG-emissions to market participants allow for a better estimation of their specific future cash flows, as market participants do not have to infer their estimates on less specific information on exposure to climate change induced systematic risk. The returns of companies that choose to not disclose their GHG-emissions would shower higher covariance with market returns, and, ceteris paribus, a higher beta.

For example, Barry and Brown (1985) or Coles, Loewenstein, and Suay (1995) also showed “that securities for which there is little information will have higher expected returns. These securities are riskier for investors than securities about which they have more information” (Easley, Hvidkjaer, & O’Hara, 2002, p. 2188). On this note, companies that disclose their absolute levels of emission give investors the possibility to better judge the financial risk induced by climate change and thus reduce the estimation risk that may result from incomplete information. Information asymmetry between investors and managers is consequently reduced (Grossman, 1981; Milgrom, 1981).

The discussed estimation and information risk related to disclosures of GHG-emissions affects large segments of the economy. In the years 2005 to 2009, on average more than one third of the European constituents of the FTSE All World-Index (FTSE AWI) did not disclose absolute levels of GHG-emissions to market participants (cf. chapter *4.3 Descriptive Sample Characteristics*). The ratio of non-disclosing firms varies significantly among sectors, for example on average only half of the European Technology and Health Care companies in the FTSE AWI reported absolute levels of GHG-emissions between 2005 and 2009. This means that the risk induced by non-disclosure of GHG-emissions cannot easily be diversified away. Clarkson, Guedes, and Thompson (1996, p. 71) summarize that “where low information securities are a nontrivial component of the final portfolios chosen by investors, estimation risk is likely to have a meaningful, nondiversifiable element”.

In summary, companies not disclosing absolute levels of GHG-emission are argued to show a higher beta. According to the EMH, the rational risk-averse investor would consequently choose to hold stocks that allow assessing the climate change induced systematic risk through the disclosure of absolute levels of GHG-emissions or expects to be rewarded for the increased systematic risk taken on when investing in companies that do not allow assessing this risk. Adjusting for risk, no difference in returns between companies that disclose or do not disclose absolute GHG-emissions would be achievable in an efficient market. Taking the existence of corporate disclosures of absolute levels of GHG-emissions as a proxy for climate change induced systematic risk it is consequently hypothesized:

Hypothesis 2a: The market is efficient, i.e. there is no difference in risk-adjusted returns between companies that report and those that do not report GHG-emissions.

Only in an inefficient market, companies that report absolute levels of GHG-emissions would consistently generate abnormal risk-adjusted returns, as in this case value-relevant information and systematic risk would not be priced correctly. As identified in chapter *2.1.3 Three Conditions for an Efficient Market*, there is theoretical potential for market inefficiency concerning value-relevant information on CSP, and consequently climate change induced systematic risk. This potential results from, for example, the third condition for market efficiency not being fulfilled, which stipulates that all market participants agree on the implications of information to the future price of a stock. In fact, while environmental disclosure has been shown to improve analysts forecast by reducing the uncertainty concerning future cash flows (Aerts, Cormier, & Magnan, 2008), scholars found that stock brokers and mainstream analysts do not incorporate environmental information in the majority of their decision making processes or investment recommendations (Campbell & Slack, 2011; Deegan & Rankin, 1997; Hassel & Nilsson, 2006). This circumstance illustrates that not all market participants agree on the value-relevance of environmental information.

Taking the possibility of market inefficiency towards the existence of disclosure of GHG-emissions as a proxy for climate change induced systematic risk into account it is hypothesized:

Hypothesis 2b: The market is inefficient, i.e. there is a persistent difference in risk-adjusted returns between companies that report and those that do not report GHG-emissions.

3.3 Disclosure Completeness

The third proxy for climate change induced systematic risk in this study is the completeness of corporate disclosures of absolute levels of GHG-emissions, i.e. the information quality of GHG-emissions disclosure. This proxy also relates to the before discussed estimation and information risk, as well as to studies in mainstream finance that argue that information quality can be a source of systematic risk (Francis et al., 2005; Kim & Qi, 2010; Leuz & Verrecchia, 2005).

Information quality in this study is represented by the completeness of corporate disclosures of GHG-emissions, which is measured by means of a Disclosure Completeness Index. The Disclosure Completeness Index is constructed in line with the dominant reporting guidelines of the GHG Protocol (WBCSD, 2004), the Carbon Disclosure Project (CDP) (Carbon Disclosure Project, 2011) and the Global Reporting Initiative (GRI) (Global Reporting Initiative, 2000-2006) (cf. chapter *4.2.1 Collection of GHG-emissions Data*). In summary, a company is classified as reporting completely if it discloses scope 1 and scope 2 GHG-emissions for a group-wide reporting boundary. A company is classified to report incomplete if it, for example, only reports scope 1 carbon dioxide emissions for parts of its manufacturing activities, i.e. does not allow for a truthful assessment of its climate change performance and its exposure to the systematic risk induced by climate change.

Companies that disclose complete numbers of absolute levels of GHG-emissions allow investors to accurately judge their exposure to the systematic risk induced by climate change and thus reduce the estimation risk that may result from incomplete information (cf. chapter *3.2 Existence of Disclosure of GHG-Emissions*). For example, the completeness of corporate disclosures of absolute levels of GHG-emissions determines the reliability with which investors can estimate the future liability of firms under the systematic risk of the EU ETS. Complete disclosures of the level of absolute GHG-emissions thus enable investors to reduce the degree of error in estimating future cash flows (cf. Cormier & Magnan, 2007) and consequently can reduce the estimation and information risk of a stock, which in turn would reduce its beta (Barry & Brown, 1985). At the same time, referring back to the discussed signalling effect of good management practise, which might insulate company returns from market wide effects, it is stipulated that companies that disclose complete levels of GHG-emissions are better managed and represent those companies that are truly committed to managing their environmental performance (cf. Al-Tuwaijri, Christensen, & Hughes II, 2004).

The discussed estimation and information risk induced by incomplete disclosures of GHG-emissions affects large segments of the economy. In the years 2005 to 2009, on average only 15% of European constituents of the FTSE AWI disclosed complete absolute levels of GHG-emissions to market participants (cf. chapter *4.3.2 Disclosure Completeness*). This means that climate change induced systematic risk as depicted by the proxy of incomplete disclosure of GHG-emissions cannot easily be diversified away.

In summary, lower levels of completeness of GHG-emissions disclosure are expected to negatively influence the beta of a stock. According to the EMH, the rational risk-averse investor would consequently choose to hold stocks that allow correctly assessing its climate change induced systematic risk through the complete disclosure of absolute levels of GHG-emissions or expects to be rewarded for the increased level of systematic risk taken on when investing in companies that do not allow assessing the risk induced by climate change accurately. Adjusting for risk, no difference in returns between companies that disclose completely or do not disclose absolute GHG-emissions completely would be achievable in an efficient market. Taking the completeness of corporate disclosures of absolute levels of GHG-emissions as a proxy for climate change induced systematic risk it is consequently hypothesized:

Hypothesis 3a: The market is efficient, i.e. there is no difference in risk-adjusted returns between companies that report complete and those that report incomplete GHG-emissions.

Only in an inefficient market, companies that report complete GHG-emissions would consistently generate an abnormal risk-adjusted return, as in this case value-relevant information and risk are not priced correctly. As the value-relevance of the underlying proxy for climate change induced systematic risk is not generally agreed upon (cf. chapter *2.1.3 Three Conditions for an Efficient Market*) and the majority of market participants is not able to distinguish between completely and incompletely reporting companies, the possibility of market inefficiency is taken into account. The assumption that market participants are not able to differentiate between completely and incompletely disclosing companies is based on the fact that the verification of reported corporate GHG-emissions data for its completeness is a complex task. For example Kolk et al. (2008, p. 721) argue that “voluntary carbon disclosure remains inconsistent and difficult to interpret”. Furthermore, the common corporate practise of incomplete GHG-disclosure, as evidenced at a later stage in this thesis (cf. chapter *4.3.2 Disclosure Completeness*), has gone largely unnoticed and did not generate any significant public disapproval. If market participants do not take notice of the value-relevant publicly available data, the market cannot be expected to be efficient with regard to this proxy for climate change induced systematic risk. Taking the possibility of market inefficiency into account it is consequently hypothesized:

Hypothesis 3b: The market is inefficient, i.e. there is a persistent difference in risk-adjusted returns between companies that report complete and those that report incomplete GHG-emissions.

3.4 Absolute Levels of Emissions

The fourth proxy for climate change induced systematic risk in this study is the level of absolute GHG-emissions reported by companies. Arguing that the risk induced by climate change is a market wide effect, it is argued that the level of absolute GHG-emissions of a company determines its exposure and the sensitivity of its returns towards the systematic risk induced by climate change.[12] The exposure and sensitivity determine the covariance of its returns with market returns, which would,

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[12] The effect of incomplete reporting of GHG-emissions is controlled for in a test of robustness.

as discussed in chapter *3.2 Existence of Disclosure of GHG-Emissions,* impact its beta.

More specifically, the future cash flows of companies with low absolute levels of emissions are less sensitive towards external events on climate change that systematically affect firms, which would reduce the covariance of their returns with market returns and, ceteris paribus, their beta (Balabanis, Phillips, & Lyall, 1998). On the other hand, the large share of companies with comparatively high absolute levels of GHG-emissions is more exposed to, for example, the uncertain future financial liabilities under the EU ETS. Companies with comparatively high levels of GHG-emissions are furthermore more principally targeted by the discussed political and market initiatives for the reduction of GHG-emissions, which makes the future cash flows of these companies more sensitive to the unknown future impact of these initiatives.

It can further be argued that companies with lower levels of GHG-emissions are generally perceived as environmentally better performing and are thus exposed to less risk in their relation to stakeholders. From the view of stakeholder theory it can be argued that "[b]etter environmental performance may make the relations between the firm and its external stakeholders (e.g., government, ecological groups, media, communities) easier and reduce the risk associated with these relations" (Ambec & Lanoie, 2008, pp. 50-51). At the same time, low absolute levels of emissions reduce the risk related to relations with customers in the business-to-business segment. In the business-to-business segment, companies increasingly try to reduce the environmental impact along their supply chain. For example Toshiba ranks their suppliers according to their environmental performance (Toshiba, 2009) and a study commissioned by the CDP found that of the 44 companies interviewed 56% expect to deselect suppliers in the future which do not meet the carbon management criteria set by the companies (A.T. Kearney, 2010). The future cash flows of companies that do not meet certain climate change performance criteria are consequently less secure, as these companies might have to invest to meet a specific emissions threshold in the future or lose access to certain revenue streams.

Furthermore, Porter and Van der Linde (1995) argued that pollution is often associated with a waste of resources and Bloom, Genakos, Martin, and Sadun (2010) confirm this notion for absolute levels of GHG-emissions. They showed that better management practices are associated with improved energy efficiency and lower greenhouse gas emissions. As discussed in chapter *3.2 Existence of disclosure of GHG-emissions*, management skill influences the riskiness of future cash flows and may insulate stock returns from market wide effects (McAlister et al., 2007), which in turn would reduce systematic risk.

In fact, with regards to systematic risk and environmental performance of CSP, several studies find a negative relationship, i.e. companies with good environmental performance show lower systematic risk, while companies with poor environmental performance show higher systematic risk. Looking at 67 firms from six industries from 1967 to 1978, Mahapatra (1984, page 37) found that “in the long run, high pollution control expenditures result in low profitability (market returns) and low systematic risk”. Good CSP, as measured by Fortune Magazine’s MAC survey, has also been found to decrease systematic risk by Luo and Bhattacharya (2009). Salama, Anderson, and Toms (2011) also find that community and environmental responsibility rankings are marginally inversely related to systematic risk for UK companies between 1994 and 2006. This inverse relation between CSP and systematic risk is confirmed in a meta-study by Orlitzky and Benjamin (2001). Connors and Silva-Gao (2008) find that the level of chemical emissions of a company from highly polluting industries is related with the uncertainty of its future cash flows. They argue that “investors are pricing the risk associated with environmental performance because of the uncertainty of the future cash flow effects of the consequences of poor performance such as lawsuits and regulatory exposure” (Connors & Silva-Gao, 2008, p. 5). However, not only investors and banks (cf. chapter *3.2 Existence of Disclosure of GHG-Emissions)* factor in environmental performance. Different scholars found that bond markets increasingly take into account the financial impact of environmental performance (Bauer & Hann, 2010; Graham, Maher, & Northcut, 2001), which impacts the certainty of a company’s costs of capital.

To include the level of absolute GHG-emissions reported by companies as a proxy for climate change induced systematic risk in this study, absolute levels of GHG-emissions have been hand-collected from publicly available sources (cf. chapter *4.2.1 Collection of GHG-emissions Data*). Following Fama and French (1995) in their categorisation of companies' market capitalisation for the investigation of the size risk premium, companies in this study are arranged in three categories for absolute emissions levels: companies with the highest 30% of emissions are classified as high emitters, companies with the medium 40% of absolute levels of emissions are classified as medium emitters, and companies with the lowest 30% of absolute levels of emissions are categorized as low emitters (cf. chapter *5.3 Portfolio Construction*). In summary, the returns of high and medium emitters are comparatively more exposed and are more sensitive to the systematic risk induced by climate change. According to the EMH, the rational risk-averse investor would choose to hold stocks of low emitters or expects to be rewarded for the increased level of systematic risk taken on when investing in companies that have comparatively high levels of GHG-emissions. Adjusting for risk, no difference in returns between companies that have high, medium or low levels of absolute emissions should be observable. Taking absolute levels of corporate GHG-emissions as a proxy for climate change induced systematic risk it is consequently hypothesized:

Hypothesis 4a: The market is efficient, i.e. there is no difference in risk-adjusted returns between companies that have high and those have low levels of absolute GHG-emissions.

Only in an inefficient market, companies with e.g. low absolute GHG-emissions would consistently generate abnormal risk-adjusted return. As identified in chapter *2.1.3 Three Conditions for an Efficient Market*, there is a theoretical potential for a market inefficiency concerning value-relevant information on CSP and consequently climate change induced systematic risk. In this context, for example, FTSE Group argues that share prices might not fully reflect the financial risk represented by political and market initiatives for the reduction of carbon yet (FTSE Group, 2012). Taking the possibility of market inefficiency into account it is hypothesized:

Hypothesis 4b: The market is inefficient, i.e. there is a persistent difference in risk-adjusted returns between companies that have high and those have low levels of absolute GHG-emissions.

3.5 GHG-efficiency

The fifth proxy for climate change induced systematic risk in this study is the level of GHG-efficiency of a company, expressed as the net income in Euro per ton of GHG-emission.[13] It is argued that, for the reasons discussed before, the ratio of net income to GHG-emissions determines a company's exposure and the sensitivity of its returns towards the systematic risk induced by climate change, and consequently its beta.

For example, the future cash flows of companies that only generate comparatively low levels of net income per ton of GHG-emissions will be impacted more heavily by any future regulatory or market initiatives for the reduction of GHG-emissions. The future cash flows of companies with a high GHG-efficiency, on the other hand, are less sensitive towards external events on climate change. This reduced exposure and sensitivity of companies with a high GHG-efficiency would reduce the covariance of their returns with market returns and, ceteris paribus, their beta. Furthermore, a high GHG-efficiency might indicate good environmental management practices and consequently good management skills, which may insulate stock returns from market wide effects (McAlister et al., 2007). In this context, for example Clarkson, Li, and Gordon (2004) showed that relative environmental performance developed from TRI emission data serves as a good indication for future environmental liabilities of companies in the pulp and paper industry.

Again following Fama and French (1995) in their categorisation of companies' market capitalization for the investigation of the size risk premium, companies are allocated to three categories for GHG-efficiency, i.e. High GHG-efficiency, Medium GHG-efficiency and Low GHG-efficiency (cf. chapter *5.3 Portfolio Construction*). In summary, the returns of stocks from companies with a low GHG-efficiency are expected to be more exposed and more sensitive to the systematic risk induced by

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[13] The effect of incomplete reporting is controlled for in a test of robustness.

climate change. The rational risk-averse investor would consequently expect to be rewarded for the increased level of systematic risk taken on when investing in companies that have a low GHG-efficiency. Adjusting for risk, no difference in returns between companies that have a high, medium or low GHG-efficiency would be observable in an efficient market. Taking GHG-efficiency as a proxy for climate change induced systematic risk it is consequently hypothesized:

Hypothesis 5a: The market is efficient, i.e. there is no difference in risk-adjusted returns between companies that have a high GHG-efficiency and those have a low GHG-efficiency.

Only in an inefficient market stocks of companies with e.g. a high GHG-efficiency would consistently generate abnormal risk-adjusted returns, as in this case value-relevant information and risk would not be priced efficiently. Taking the possibility of market inefficiency into account it is hypothesized:

Hypothesis 5b: The market is inefficient, i.e. there is a persistent difference in risk-adjusted returns between companies that have a high GHG-efficiency and those have a low GHG-efficiency.

3.6 High Carbon Industries

The final proxy for climate change induced systematic risk in this study is a company’s affiliation with high carbon industries. Companies from high carbon industries are more likely to be targeted by the discussed political and market initiatives for the reduction of GHG-emissions. These external climate change effects are consequently expected to have a stronger impact on the future cash flows of companies from industries that are carbon intensive. It is consequently hypothesized that affiliation with a high carbon industry determines a company’s exposure and the sensitivity of its returns towards the systematic risk induced by climate change and consequently the covariance of its returns with market returns.

For example, the unknown future costs of reducing exposure to future regulation or reducing GHG-emissions are higher in high carbon industries than in low carbon industries. In this context, Konar & Cohen (2001) argued that for high polluting industries the costs of environmental preparedness and improving environmental performance are higher. Furthermore, regulatory constraints on company operations in high polluting industries affect operational uncertainty and financial performance (Semenova & Hassel, 2008). As the relation between CSP and CFP is generally thought to be much more stringent in high polluting industries, many studies have investigated this link focussing on environmental sensitive industries (cf. Clarkson et al., 2004; Hughes, 2000).

A classification of high and low carbon industries has been adopted from Stanny and Ely (2008). Stanny and Ely classify the Utilities industry, Basic Materials industry, Industrials and Oil & Gas industry as high carbon industries, which are the industries with the highest average reported GHG-emissions per company in this research. Companies from high carbon industries represent a large segment of the economy: In the years 2005 to 2009, on average 45% of European constituents of the FTSE AWI belonged to a high carbon industry (cf. chapter *4.3.4 Industry Affiliation and Affiliation with the EU ETS*). This means that climate change induced systematic risk, as depicted by the proxy of affiliation with high carbon industries, cannot easily be diversified away.

The returns of stocks of companies that are affiliated with high carbon industries are consequently expected to be more exposed and show a higher sensitivity to climate change induced systematic risk. According to the EMH, the rational risk-averse investor would expect to be rewarded for the increased level of systematic risk taken on when investing in companies from high carbon industries. Adjusting for risk, no difference in returns between companies from high or low carbon industries would be observable in an efficient market. While the proxy of absolute levels of GHG-emissions (cf. chapter *3.4 Absolute Levels of Emissions*) applied in this research examines market efficiency towards climate change induced systematic risk at company level, this proxy looks at the efficiency of the financial market to price climate change induced systematic risk at industry level. Taking affiliation with high carbon industry as a proxy for climate change induced systematic risk it is consequently hypothesized:

Hypothesis 6a: The market is efficient, i.e. there is no difference in risk-adjusted returns between companies from high carbon and those from low carbon industries.

For reasons discussed above, the possibility of market inefficiency is taken into account and it is consequently hypothesized:

Hypothesis 6b: The market is inefficient, i.e. there is a persistent difference in risk-adjusted returns between companies from high carbon and those from low carbon industries.

These six proxies for climate change induced systematic risk – affiliation with the EU ETS, the existence of disclosure of GHG-emissions, disclosure completeness, absolute levels GHG-emissions, GHG-efficiency and affiliation with high carbon industries – are used to build mutually exclusive portfolios in chapter *5.3 Portfolio Construction.* For example, all companies affiliated with the EU ETS are allocated to one portfolio, while those companies that are not affiliated with the EU ETS are put in a second portfolio. To determine whether the market is efficient or inefficient in pricing the different proxies for climate change induced systematic risk, the respective portfolios are regressed on different statistical models. Before detailing the methodology used to test the hypotheses developed in more depth in chapter *5 Methodology*, the sample construction and data collection processes for this study are now described.

Chapter 4
Sample and Data

The hypotheses developed in the previous chapter are tested with the sample and data described in the following paragraphs. After illustrating the process of sample selection in chapter *4.1 Sample Selection*, the data collected to the test the hypotheses is described in chapter *4.2 Data Collection.* The descriptive statistics for the data used are summarized in chapter *4.3 Descriptive Sample Characteristics*, before an in-depth analysis of sample characteristics concludes the chapter (cf. chapter *4.4 Understanding Sample Characteristics*).

4.1 Sample Selection

The population that served as a starting point for sample construction is the FTSE AWI as of January in each year of this study. The FTSE AWI represents an established and widely applied source for investment professionals and researchers (cf. Cao, Harris, & Shen, 2010; Chang & Lin, 2010; Lin, Strong, & Xu, 2001). The FTSE AWI covers companies with large or medium-sized market capitalisation, which in total represent between 90% and 95% of the global investable market capitalisation (FTSE Group, 2011b). Given the fact that the FTSE AWI only includes companies with large or medium-sized market capitalisation, the problem that the performance of equal-weighted portfolios is driven by micro-caps, i.e. very small companies, is significantly reduced (Fama & French, 2008).[14] This circumstance will be important for the interpretation of results in chapter *6 Regression Results.*

The decision rule for sample selection in this study is depicted in Figure 2 and described in detail in the following paragraphs. In summary, companies included in this study were selected based on the following criteria: Firstly, non-European FTSE AWI constituents were excluded from the population on account of the fact that this

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[14] No agreed upon official definition determining the size of a micro-cap exists. Only 17 companies in this sample have a market capitalisation of below € 300 million and would consequently qualify as a micro-cap by the most rigorous of definitions. 12 of these 17 companies only qualify as a micro-cap in the year 2008, i.e. during times of financial market crisis.

research focuses solely on companies from the EU. On average, 617 EU index constituents – as represented by the Stock Exchange Daily Official List (SEDOL) – formed part of FTSE AWI in the years 2005 to 2009. These 617 constituents represented on average 26% of the FTSE AWI global market capitalisation in the years 2005 to 2009. Subsequently, the FTSE Industry Classification Benchmark (ICB) (FTSE Group, 2010) was applied to classify companies according to their industry affiliation and companies from the financial service industry (ICB industry code 8000) were excluded from the sample.[15] The common practise to exclude financial service companies from the sample is applied in this study as their increased leverage and sensitivity to market developments makes financial service firms incomparable with companies from other industries (Fama & French, 1992; Foerster & Sapp, 2005; Shleifer & Vishny, 1997). On average, 358 non-financial EU index constituents formed part of the FTSE AWI in the years 2005 to 2009, which represented on average 22% of the FTSE AWI global market capitalisation in the years 2005 to 2009.

After the exclusion of financial service firms, in total 443 different index constituents formed part of the FTSE AWI in the years 2005 to 2009. Seven companies formed part of the FTSE AWI with class A and class B shares. To avoid double-weighting the performance of these companies, their class A share was excluded from the sample. Class A shares were chosen for exclusion for two reasons: Firstly, class A shares carry more voting rights and therefore show a lower liquidity. Secondly, the class B shares of the respective companies were included in the FTSE AWI for longer periods. A further three companies that were part of the index in the year 2005 had to be excluded from the sample, as no complete financial data was available. For the same reason, two companies had to be excluded in one year and another company in three years, but remained in the sample and were included in this study in the remaining years. In the end, 433 different companies from 17 European Union

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[15] The FTSE Industry Classification Benchmark (ICB) was only introduced in the year 2006. For the year 2005 industry affiliation in this study was constructed by matching companies’ industry affiliations in the years 2006 to 2009 with the year 2005. When a company was not part of the FTS AWI after the year 2005, ICB industry affiliation was derived from the most common transformation of former industry code to ICB from 2005 to 2006.

countries and eight industries form part of the sample and were included in data collection activities for this study.

These 433 different companies constitute sample A. Sample A includes companies that report absolute levels of GHG-emissions to the public as well as companies that do not disclose this information. On average 351 companies form part of sample A in each of the years 2005 to 2009 resulting in a total of 1756 firm year observations. Sample A is used to test the hypotheses concerning the EU ETS (cf. chapter *3.1 European Emissions Trading Scheme*), the existence of disclose on GHG-emissions (cf. chapter *3.2 Existence of Disclosure of GHG-Emissions*) and the affiliation with high carbon industries (cf. chapter *3.6 High Carbon Industries).*

A second sample used for this research – sample B – contains only those companies of sample A that report GHG-emissions on at least the majority of corporate activities[16] in the year preceding index inclusion, i.e. year t-1. In total 297 different companies form part of sample B. On average 206 companies reported GHG-emissions on at least the majority of corporate activities at t-1 in each of the years 2005 to 2009, resulting in a total of 1028 firm year observations. Sample B is used to test the hypotheses concerning absolute levels of GHG-emissions (cf. chapter *3.4 Absolute Levels of Emissions*), GHG-efficiency (cf. chapter *3.5 GHG-efficiency*) and disclosure completeness (cf. chapter *3.3 Disclosure Completeness*). A third sample used for this research – sample C – contains only those companies of sample A that report GHG-emissions on at least the majority of corporate activities in the year of index inclusion, i.e. at year t. In total 306 different companies form part of sample C. On average 222 companies form part of sample C in each of the years 2005 to 2009 resulting in a total of 1109 firm year observations. This sample is used for an in-depth analysis of sample characteristics (cf. chapter *4.4 Understanding Sample Characteristics*), as it allows for the inclusion of more firm year observations. The decision rule for the sample selection of sample A, B and C is depicted in Figure 2.

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[16] Only companies reporting on at the least the majority of corporate activities are included in this study based on the argument that this is the minimum level of emissions useful for drawing conclusions on a company’s exposure to climate change induced systematic risk.

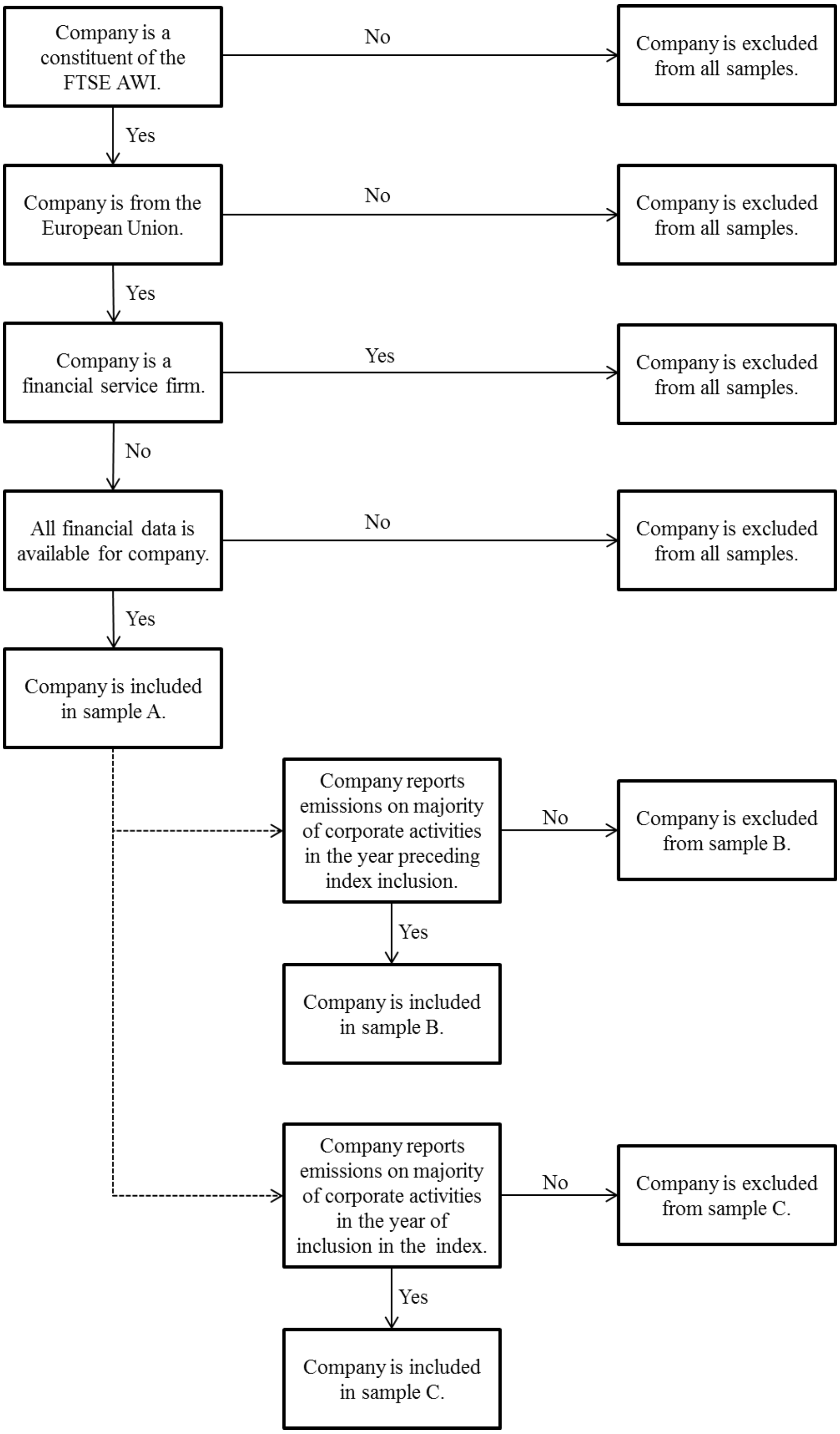

Figure 2: Decision rule for sample selection

The time period of the years 2005 to 2009 was chosen, as only from 2005 onwards a sufficient number of companies reported absolute levels of GHG-emissions for the year t-1 to facility a study of this research design. Time periods of similar or shorter lengths were chosen by various scholars applying similar research designs (cf. Gordon & Buchholz, 1978; Ziegler et al., 2011; Ziegler et al., 2007).

4.2 Data Collection

All companies in sample A were included in the data collection activities carried out for this research. The data collection at company level included the gathering of GHG-emissions data, accounting figures, market returns as well as information on a company's affiliation with the EU ETS and high carbon industries. Other information gathered for this research includes data on risk free rates of return, the price of oil and EU emissions allowances, as well as the implicit energy tax rate of countries in the EU. The process of collecting the respective data is presented in the remainder of this chapter, starting with the collection of the GHG-emissions data.

4.2.1 Collection of GHG-emissions Data

The aim of the GHG-emissions data collection activities was to gather publicly available GHG-emissions data for the 433 companies in sample A for the years that a company formed part of the FTSE AWI, as well as the year preceding inclusion in the index. The data collection process can be summarised in three steps. In a first step, corporate reports containing environmental information were collected. In a second step absolute numbers of GHG-emissions data[17] and the date of publication of GHG-emissions data were extracted from these reports, company websites or the CDP. In a third step the data gathered was classified according to its completeness in terms of the type, scope and reporting boundary of the reported emissions. The three steps of GHG-emissions data collection are summarized in Figure 3.

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[17] Companies publishing only relative levels of emissions, such as emissions per product, emissions per sales or emissions per square meter, were excluded from this study because these ratios do not allow for a standardized assessment of climate change induced systematic risk.

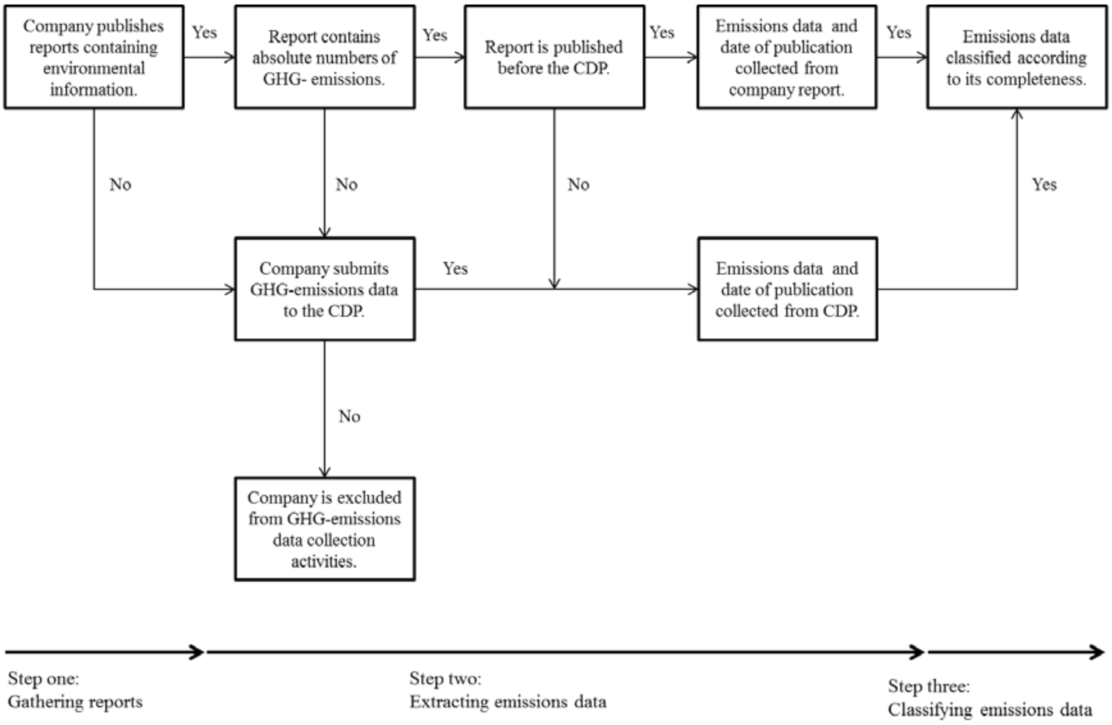

Figure 3: Three steps of GHG-emissions data collection

In the following paragraphs each step of the GHG-emissions data collection process is described. From the classification of reported emissions in terms of their type, scope and reporting boundary, a Disclosure Completeness Index is constructed, which allows testing the hypothesis concerning disclosure completeness (cf. chapter *3.3 Disclosure Completeness*).

Step one of GHG-emissions data collection: Gathering reports

In the first step of GHG-emissions data collection, corporate reports, i.e. reports published by the respective companies, were gathered from company websites and the Corporate Register website (CorporateRegister.com Limited, 2012). Corporate reports are costless and readily available to the public and consequently lend themselves for testing semi-strong market efficiency. The nature of the collected corporate reports included annual reports, integrated company reports, stand-alone reports on environmental or sustainability or CSR issues as well as dedicated company websites[18]. In total, more than 4,000 corporate reports were collected for the data collection activities of this study.

Step two of GHG-emissions data collection: Extracting emissions data

In the second step of GHG-emissions data collection, absolute numbers of quantitative GHG-emissions data and the date of publication of the data were extracted from the reports or the CDP. As depicted in Figure 3, answers of a company to the CDP were consulted as an additional source of information when a company did not publish reports containing emissions information or it was found that a company did not include absolute levels of quantitative GHG-emissions data in its reports. As shown in Figure 3, data was also extracted from the CDP when the date of publication of the company report was subsequent to the publication of the CDP data base of a specific year. In total, in terms of data sources, GHG-emissions data was extracted from corporate reports for 84% of companies who reported GHG-emissions to the public, while the for the remaining 16% of companies emissions data was extracted from the CDP in at least one year.

The emission data used for this research was collected as originally published by a company in a specific year, i.e. data corrected in retrospect was not taken into account. This has been done to account for the fact that at a specific point in time the semi-strong efficient market would have had access only to the emissions data as published at that point in time. When possible, GHG-emissions data was collected for the years that a company formed part of the FTSE AWI, as well as the year preceding inclusion in the index.

Step three of GHG-emissions data collection: Classifying emissions data

In the third step of GHG-emissions data collection, the emissions data gathered was classified according to its completeness. For example, Spalding (2010, p. 6) pointed out that corporate climate change disclosures “while more and more prevalent, are

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[18] Information published exclusively web-based during the years 2005 and 2009 was only included in the data collection activities if emissions data had not been corrected in retrospect and the original date of publication of the data was visible.

still voluntary and are by no means consistent or universal". Some scholars even argue that "climate change disclosure is still in a primitive stage of development" (Smith, Morreale, & Mariani, 2008, p. 470). To be able to control for the known limitations of GHG-emissions disclosure in this analysis of market efficiency and to construct the Disclosure Completeness Index, corporate reporting of GHG-emissions is classified according to its completeness.

In the following paragraphs, the motivation behind the classification of completeness for GHG-emissions is explained and the classification process is detailed. In summary, the classification of GHG-emissions reporting completeness builds on the three dominant guidelines for GHG-reporting, namely the GHG Protocol (WBCSD, 2004) the Carbon Disclosure Project (CDP) (Carbon Disclosure Project, 2011) and the Global Reporting Initiative (GRI) (Global Reporting Initiative, 2000-2006). The emissions data gathered was classified according to its completeness in terms of the scope and type of the emissions reported, as well as the reporting boundary applied. Table 3 summarizes the position of the three dominant reporting guidelines with view to scope, type, accounting approach[19] and the reporting boundaries of corporate GHG-emissions reporting.

Classification of the scope of emissions reported. The standard most generally applied and mutually recommended by the CDP and the GRI to define the scope of an emission is the GHG Protocol. The GHG Protocol stipulates that scope 1 GHG-emissions arise from "sources that are owned or controlled by the company" and scope 2 emissions "from the generation of purchased electricity consumed by the company" (WBCSD, 2004, p. 25). Scope 1 and 2 emissions thus give a fair summary of emissions arising as a direct result of a company's activity, which would be relevant to determine its climate change induced systematic risk.

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[19] Accounting approaches applied to emissions reporting are not taken into account for the measure of completeness of GHG-emissions reporting applied in this study, as there is no consensus among the dominant reporting guidelines (cf. Table 3) and arguing for the validity of one accounting approach over the other goes beyond the scope of this research.

Table 3: Summary of predominant reporting guidelines

	GHG Protocol	CDP	GRI	Measure of reporting completeness in this study
Scope of emission	Scopes 1 and 2 separately, scope 3 optional	Scopes 1 and scope 2 and scope 3 separately	Sum of scopes 1 and 2, scope 3 separately	Scope 1 and scope 2
Type of emissions	GHG-emissions	GHG-emissions; asking whether specific GHGs are excluded	GHG-emissions	GHG-emissions
Accounting approach applied to emissions reporting	2 choices: equity share, financial control and operational control approach.	5 choices: financial control, operational control, equity share, Climate Change Reporting Framework, other	At a minimum, entities over which the organization exercises control (for performance indicators)	N/A
Reporting boundary applied to emissions reporting	All sources and activities within the chosen inventory boundary; asking to mention any specific exclusions of sources, facilities and/or operations	All activities under the respective accounting approach; asking whether any facilities, activities and /or geographies are excluded	Entities with significant sustainability impact	Classification of activities reported on within the chosen reporting boundary

Although all three dominant reporting guidelines require the reporting of scope 1 and 2 emissions at a minimum, some companies focus their reporting on only one scope of emissions, arguing that they do not have noteworthy emissions under the other scope. At the same time, other companies from industries that usually emit significant levels of both scope 1 and scope 2 emissions only report emissions on one scope and thus give an incomplete account of their emissions. To allow for a standardized and effortless assessment of climate change induced systematic risk across company borders, the scope of the emissions reported by all companies needs to cover scope 1 and scope 2 emissions, as suggested by the dominant reporting protocols. For the classification of reporting completeness, it is therefore distinguished between companies reporting scope 1 and 2 emissions, i.e. reporting completely, and companies not reporting scope 1 and 2 emissions, i.e. reporting incompletely.

For the vast majority of the emissions data points classified for this research the scope of the emissions reported was obvious from the corporate reports. In some cases however the scope of the emissions data is not stated clearly by the reporting company. For example, some companies report an indicator in a table labelled “Greenhouse gases” that – as explained in later reports – only includes scope 1 emissions (Total, 2005, p. 8). Other companies report an indicator labelled “CO_2 emissions” in a table without ever explaining the scope in their reports (Tullow Oil plc., 2009, 2010). When in doubt about the scope of the emissions reported, the CDP was consulted for further information and usually allowed for a clear classification of the scope of emissions reported. In few cases a company did not report to the CDP and no information could be found that allowed for a clear determination of which scope of emissions a company reports on. In these few cases the classification had to be derived from key words and key phrases in the report. In these rare cases, the terms “total emissions", "Total" or indicators labelled “GHG” or "CO_2" were classified as reporting scope 1 and scope 2 emissions.

Classification of the type of emission reported. Given the comparatively high global warming potential of Greenhouse gases other than carbon dioxide and the fact that other gases than carbon dioxide are included in the EU ETS from 2013 onwards, a comprehensive analysis of climate change induced systematic risk cannot be limited to carbon dioxide emissions, but must include other Greenhouse gases. All three dominant reporting guidelines ask for the reporting of not just carbon dioxide but also the five other main Greenhouse gases. Nevertheless, many companies focus their reporting on carbon dioxide, as they do not emit noteworthy levels of other Greenhouse gases. At the same time, some companies from industries that usually emit significant levels Greenhouse gases other than CO_2 only report on CO_2 and thus give an incomplete record of their climate change performance. To allow for a standardized comparison of a company’s exposure to climate change induced systematic risk across industry borders, the reporting of GHG-emissions and not just carbon dioxide is necessary. For the classification of the type of emissions reported in this research it is therefore distinguished between companies reporting on Greenhouse gases other than carbon dioxide, i.e. reporting completely, and companies only reporting CO_2-emissions, i.e. reporting incompletely.

For the vast majority of the emissions data points classified for this research the type of emissions reported was obvious from corporate reports. Some companies however do not state in a sufficiently clear way whether they are reporting on carbon emissions or Greenhouse gases. For example, companies refer to “CO_2” in the text (Ahold N.V., 2009) or label their emissions indicator “carbon emissions” (Delhaize Group, 2009), although these companies include other Greenhouse gases than carbon dioxide in their emissions reporting. Other companies label an indicator “Greenhouse gas emission” although only reporting on carbon dioxide (Assa Abloy AB, 2010). Yet other companies seem to use the terms carbon and CO_2-equivalents – usually used to measure GHG-emissions – interchangeably (Ericsson, 2009). When in doubt about the completeness of the emissions reported, the CDP was consulted for further information and allowed for a clear classification of the type of emissions reported. In few cases a company did not report to the CDP and in these few cases the classification had to be derived from key words and key phrases in the corporate report. The terms “CO_2-equivalents" and “GHG” were classified as reporting on Greenhouse gas emissions, while key words such as “Carbon dioxide” and "CO_2" were classified as reporting only carbon dioxide emissions.

Classification of reporting boundary. Unfortunately, with regard to reporting boundaries, GRI, CDP and the GHG Protocol are incoherent with view to the activities which are to be included within the boundary of emissions reporting. The GRI allows setting the boundaries of a sustainability report to entities that “generate significant sustainability impacts” (Global Reporting Initiative, 2000-2006, p. 18). GRI specifies that “[g]enerally speaking, significant impacts are those that change a performance measured under a quantitative indicator by a noticeable amount” (Global Reporting Initiative, 2005, p. 11). In contrast to the GRI, the CDP requires reporting on all corporate activities that generate GHG-emissions (Carbon Disclosure Project, 2010b). Likewise, the GHG Protocol requires users to “[a]ccount for and report on all GHG emission sources and activities” (WBCSD, 2004, p. 7). Both, the CDP and

GHG Protocol require companies to specify any exclusion made to the reporting boundary in terms of sources, facilities and/or operations, which are not included in the emissions reported.

While companies do not follow the general requirements of the GHG Protocol and the CDP to report GHG emission from *all* activities, the vast majority of companies adhere to the guidelines by specifying which sources and activities are excluded from their reporting boundary. For this study, the completeness of reporting boundaries is therefore classified on the basis of the activities included in the GHG-emissions reporting of a company. Although the thresholds of five categories developed for the classification of the completeness of reporting boundaries had to be set subjectively, these categories are probably the first of their kind to allow for an objective and meaningful comparison of the completeness of reporting boundaries across company borders. The five categories for the classification of reporting boundaries defined for this research are as follows:

- **Group-wide**: emissions data covering all or almost all corporate activities; or expressed as a percentage figure more than 90% of manufacturing activities and more than 90% of all other activities.
- **All manufacturing operations**: emissions data covering all manufacturing operations; or expressed as a percentage figure more than 95% of manufacturing activities but no other activities.
- **Majority of manufacturing operations**: emissions data covering at least the majority of manufacturing activities; or expressed as a percentage figure more than 85% of manufacturing activities.
- **Majority of activities**: emissions data covering all activities with significant sustainability impact; or expressed as a percentage figure: more than 50% of all activities.
- **Insufficient reporting**: emissions data not covering all activities with significant sustainability impact; or expressed as a percentage figure: less than 50% of all activities. The company is consequently excluded from sample B and C.

Of the 1109 firm year observations in sample B, the reporting boundaries of 16% were defined with a percentage figure by the reporting company in terms of the activities covered, for example as a percentage coverage in terms of turnover, corporate activity or manufacturing operations. These emissions were consequently classified with regard to the completeness of reporting boundaries based on the percentage figure given (cf. Table 4). For the remaining emission data points included in this research, the completeness of reporting boundaries had to be classified based on the frequently used key words or key phrases utilized by companies to define reporting boundaries. Some examples for the classification of reporting boundaries used in this research based key words or key phrases are shown in Table 4. For 11% of the firm year observations in sample B no information defining the reporting boundary could be found in the reports or the CDP. The classification of these data points was based exclusively on the information given by a company in previous or later years and the company was excluded in case there were major changes in company structure from one year to the other.

Table 4 illustrates the fact that reporting boundaries are not standardized across company borders. There are consequently limitations with regard to the classification of the unstandardized terminology used by companies to explain their reporting boundary. For example, the key word "operations" is used by some companies to describe all types of activities and by other companies to describe only manufacturing activities. In order to minimise subjectivity a reporting boundary that contained only this key word was classified as including only manufacturing activities, unless it could be asserted that the information given includes other activities than manufacturing activities. The finding that reporting boundaries are neither complete nor set in a standardized manner is in line with Sullivan (2009) and Archel, Fernández, and Larrinaga (2008, p. 115), who also found in their study of triple bottom line (TBL) reports that “the voluntary nature of TBL reporting leads to a lack of quality in boundary setting and boundary disclosure”.

Table 4: Classification of completeness of reporting boundaries

	Examples of classification based on reporting boundary defined with a percentage	Examples for classification based on reporting boundary defined with key words or key phrases
Group-wide	“98% of group's revenues”, “100% of group operations”, “97.3% of corporate activity”, “covering 96% of employees worldwide”, “94% of the consolidated company”, “94.7% of corporate activity”, “94.4% of corporate activity”, “95% of turnover”, “92% of turnover”, “94% of sales”, “7 % of the Group’s entities did not communicate GHG-emissions”	“group-wide”, “company-wide “, “all consolidated subsidiaries”, “our global activities”, “all business divisions and sites”, “extrapolated to cover all employees”, “stores, owned vehicle fleet, production and transport”, “large offices and all factories”, “all sites and major offices”, “excluding small subsidiaries”, the number of reporting companies
All manufacturing operations	“98% of production”, “96% of production sites”, “98% of emissions from manufacturing sites”, “97% of the total production activities”	“all manufacturing activities”, “all manufacturing activities over which the Group exercises operational control”, “global manufacturing operations”, “for our total of […] production units”, “all sites where the Group owns more than a 50% stake”, “all manufacturing sites”
Majority of manufacturing operations	“88% of industrial activities”, “95% of manufacturing, 80% of engineering centers”, “95% of our manufacturing operations", “86% of sales […] data covers production sites”	“major manufacturing sites”, “major facilities”, “all relevant production sites”, “manufacturing of core products”, the number of manufacturing sites, a list of divisions or countries from which manufacturing data is reported
Majority of activities	“81% of global workforce covered”, “81% of production”, “100% of all activities that have impact”, “84% of sales”, “89% of group”, “72% of sales covered”, “72.5% of total workforce”, “75% of UK facilities and UK turnover”, “more than 75% of our facilities which account for greater than 75% of our business turnover”	“companies which meet specified threshold criteria in terms of environmental impact”, “significant activities in terms of environmental impact”, “from processes covered under the EU ETS”, “all installations participating in EU ETS”, a list of divisions or countries from which data is reported
Insufficient reporting	“40% of headcount”, “38% of sales”	“from transport fleet”, “from business travel”, “our head office”, a list of divisions or countries from which data is reported

Disclosure Completeness Index

In summary, companies should report scope 1 and 2 GHG-emissions for a group-wide reporting boundary to allow for a reliable and standardized assessment of its exposure to climate change induced systematic risk. To assess the overall completeness of corporate GHG-emissions reporting, an equal-weighted Disclosure Completeness Index is built based on the measures for completeness of scope, type and reporting boundary introduced above. For the construction of this index, a company that reports scope 1 and 2 emissions is scored ‘1’ (and ‘0’ otherwise). Furthermore, a company that reports GHG-emissions is scored ‘1’ (and ‘0’ otherwise). Finally, a company that reports on group-wide activities is scored ‘1’ (and ‘0’ otherwise). In the equal-weighted index, companies thus can receive a score between ‘0’ and ‘3’. A company reporting group-wide scope 1 and 2 GHG-emissions scores ‘3’, whereas a company reporting scope 2 CO_2-emissions on the majority of manufacturing activities would score ‘0’.

Results of the GHG-emissions data collection activities and the construction of the Disclosure Completeness Index are detailed in chapter *4.3 Descriptive Sample Characteristics*.

4.2.2 Collection of Other Data

Various data other than GHG-emissions has been gathered for this research from different sources. The collection of other data is detailed in the following paragraphs.

Datastream

The necessary monthly and yearly data for accounting figures, market returns and carbon prices have been extracted from the Thomson Reuters Datastream (Datastream) data base for the years 2003 to 2005. Table 5 summarizes the data extracted from Datastream that has been used in this test of market efficiency, the in-depth analysis of sample characteristics (cf. chapter *4.4 Understanding Sample Characteristics*) and/or the tests of robustness (cf. chapter *5.4 Tests of Robustness*) carried out in this research.

Table 5: Overview on data gathered from Datastram

Indicator	Mnemonic	Datastream Description (shortened)
Market capitalization	MV	Share price multiplied by the number of ordinary shares in issue.
Net income	WC01651	Income after all operating and non-operating income and expenses, reserves, income taxes, minority interest and extraordinary items.
Total assets	WC02999	Sum of total current assets, long term receivables, investment in unconsolidated subsidiaries, net property plant and equipment and other assets.
Common equity	WC03501	Common shareholders' investment in a company.
Debt to common equity ratio	WC08231	Total debt to common equity.
Debt to assets	WC08236	Total debt to assets.
Return on total assets ratio	WC08326	(Net income + ((Interest expense on debt-interest capitalized) * (1-tax rate))) / average of last year's and current year’s total assets * 100.
Return on equity	WC08301	(Net income before preferred dividends - preferred dividend requirement) / last year's common equity * 100.
Return index	RI	A theoretical growth in value of a share holding over a specified period, assuming that dividends are re-invested to purchase additional units of an equity. $RI_t = \quad RI_{t-1} * \frac{PI_t}{PI_{t-1}} * \left(1 + \frac{DY_t}{100} * \frac{1}{N}\right)$ Where: RI_t = return index on day t, RI_{t-1}= return index on previous day, PI_t = price index, DY_t= dividend yield %, N = number of working days in the year.
Carbon price	EEXEUAS	European Union CO_2 Emissions Allowance (European Energy Exchange).

For a total of nine companies it was not possible to extract information from Datastream on the return on total assets (Datastream mnemonic WC08326). This information was consequently approximated via the ratio of net income (WC01651) and total assets (WC02999), while accounting for differences in the reported return on total assets ratio (WC08326) and the ratio of return to total assets calculated for preceding and/or following years. For a total of thirteen companies no information was available on the return on equity, which was consequently estimated via the ratio of net income (WC01651) and common equity (WC03501), while accounting for differences in the reported return on equity ratio (WC08301) and the ratio of return on equity calculated for preceding and/or following years. A price for carbon was only available from end of May 2005 onwards. The time period of the regression that includes the price of carbon as a test of robustness is consequently shortened by five months (cf. chapter *5.4.3 Carbon Price*).

Risk free rate of return

To define the return of a risk free asset in the CAPM and the C4FM (cf. chapter *5 Methodology*), monthly data on Euro Interbank Offered Rate, the so called Euribor, for the years 2005 to 2009 has been obtained from www.euribor-rates.eu (Triami Media, 2011). The three months Euribor rate has been transformed into the logarithm of the continuously compounded monthly risk free rate of return as described in chapter *5.1 CAPM*.

Affiliation with EU ETS

To determine which companies owned installations that were part of the EU ETS in the years 2005 to 2009, the respective publicly available data base of Carbon Market Data (Carbon Market Data, 2011) was used. This indicator is used in in this research in two ways. Affiliation with the EU ETS is used in chapter *4.4 Understanding Sample Characteristics* to determine whether companies that have installations in the EU ETS are more likely to report (complete) GHG-emissions to the public in their voluntary reporting. Furthermore, affiliation with the EU ETS is used in the construction of portfolios that allow testing hypothesis 1a and 1b (cf. chapter *5.3 Portfolio Construction).*

Implicit tax rate on energy

The implicit tax rate on energy of a country was extracted from the publications of the European Commission (Eurostat, 2011b) to determine whether companies headquartered in countries with comparatively high ambitions to reduce global warming through national fiscal policy are more likely to report GHG-emissions (cf. chapter *4.4 Understanding Sample Characteristics*). The implicit tax rate on energy is calculated as energy tax revenues of a country in relation to its final energy consumption in Euro per ton oil equivalent (Eurostat, 2011b). For two countries the data for the year 2008 was not yet available on the date of data collection and was consequently set to the level of the preceding year.

Oil price

Price data for Brent crude oil in Euro per Barrel has been extracted from Index Mundi (Index Mundi, 2012). Brent crude is an oil refined in Europe and used to price two thirds of internationally traded crude oil. The natural logarithm of the change in the monthly oil price as of the first of each month at t-1 from January 2005 to December 2009 is included in this study as a test of robustness of results (cf. chapter *5.4 Tests of Robustness*).

High Carbon Industries

A classification of high and low carbon industries has been adopted from Stanny and Ely (2008). Stanny and Ely classify the Utilities industry, Basic Materials industry, Industrials and Oil & Gas industry as high carbon industries. The classification of Stanny and Ely is based on carbon intensity. Based on their classification, high carbon industries represent the four industries with the highest average reported GHG-emissions per company in this research. The indicator of affiliation with high carbon industries is used in chapter *4.4 Understanding Sample Characteristics* to determine whether companies from high carbon industries are more likely to report, and also in the creation of the portfolios used to test hypotheses 6a and 6b (cf. chapter *5.3 Portfolio Construction).*

4.3 Descriptive Sample Characteristics

In the following, the outcome of the data collection activities described and the descriptive statistics of companies in samples A and B and C are briefly summarized. Due to the nature of this study, special emphasis is placed on descriptive statistics concerning the existence and completeness of GHG-emissions disclosure.

4.3.1 Existence of Disclosure of GHG-emissions

Table 6 summarizes the outcome of the data collection efforts concerning the existence of disclosure of absolute levels of GHG-emissions. In total, absolute numbers of GHG-emissions data covering at least the majority of company activities were collected for a total of 306 different companies (sample C). On average over five years 59% of the companies from sample A, i.e. companies that were part of the FTSE AWI between 2005 and 2009 and for which the necessary financial data is available, reported GHG-emissions in the year preceding index inclusion (sample B). Table 6 illustrates that over time, the number of companies reporting GHG-emissions on at least the majority of corporate activities increased. While only 52% of companies that were part of the FTSE AWI reported GHG-emissions for the year 2005 (sample C), this share increased to 71% in the year 2009.

Table 6: Results of data collection activities

	Number of companies							% Share of reporting companies					
	Total	Mean	2005	2006	2007	2008	2009	Mean	2005	2006	2007	2008	2009
Sample A: All companies	433	351	348	352	353	360	343						
Sample B: Reporting emissions at t-1	300	206	148	185	204	242	249	59%	43%	53%	58%	67%	73%
Sample C: Reporting emissions at t	306	222	181	199	229	255	245	63%	52%	57%	65%	71%	71%

Notes: This table shows the outcome of the GHG-emissions data collection process. The first row shows the number of non-financial EU companies that were part of the FTSE AWI between 2005 and 2009 and for which the necessary financial data was available (sample A). The second row shows sample B, i.e. companies from Sample A reporting GHG-emissions covering at least 50% of company activities in the year preceding index inclusion (year t-1). The third row shows sample C, i.e. companies from Sample A reporting GHG-emissions covering at least 50% of company activities in the years of index inclusion (year t). The first column shows the number of different companies in each sample, followed by the number of companies on average and in each of the specific years 2005 to 2009. The following columns show the percentage share of companies in sample B and sample C.

4.3.2 Disclosure Completeness

Table 7 summarizes the completeness of the GHG-emissions data reported by companies in sample B and C in terms of the scope and type of the emissions reported, as well as the reporting boundaries applied. Results of the constructed Disclosure Completeness Index are also presented.

In summary, most of the companies included in sample B and C were classified to report scope 1 and 2 emissions. In fact, on average over five years 80% of the emissions reported for the year preceding index inclusion (sample B) were classified to be complete in terms of the scope of emissions reported. In general, a positive trend can be observed in the reporting of scope 1 and 2 emissions: While in 2005 only 74% of the companies reported GHG-emission for the preceding year (sample B) that were classified to cover scope 1 and 2 emissions, this percentage was up to 87% in 2008 and 2009.

In contrast to the encouraging results in terms of reporting completeness of scope 1 and 2 emissions, the majority of companies included in this analysis were classified to report incomplete with regard to the type of emissions disclosed, i.e. to report only CO_2-emissions as compared to GHG-emissions. In fact, on average over five years only 37% of companies reported emissions that were classified to cover other Greenhouse gases than CO_2 for the year preceding index inclusion (sample B). This is a surprising finding in the light of the fact that the GHG Protocol, the CDP and the GRI all ask for reporting of Greenhouse gas emissions and not just of carbon dioxide. Nevertheless, in general, a slow but positive trend can be observed with regard to the type of emissions reported by the companies included in this analysis. While in 2005 only 36% of the companies were classified to reporting on other emissions than carbon dioxide in the year of inclusion in the index (sample C), this percentage is up to 52% in 2009. Only in 2009 the majority of companies included in this analysis followed the requirements of dominant reporting guidelines to report on Greenhouse gas emissions and not just carbon dioxide.

The results of the classification of completeness of GHG-emissions in terms of the reporting boundaries applied by companies are similarly discouraging. On average over five years only 34% of companies reported emissions for group-wide activities for the year preceding inclusion in the index (sample B). Nevertheless, it is possible to derive a slow but positive trend towards a more complete reporting in terms of reporting boundaries. In 2005, equal shares of roughly 25% of companies reported emissions for a group-wide reporting boundary, for all manufacturing operations, for the majority of manufacturing operations and the majority of activities respectively for the year preceding inclusion in the index (sample B).

Table 7: Descriptive statistics on disclosure completeness

	Number of companies						% Share					
	Mean	2005	2006	2007	2008	2009	Mean	2005	2006	2007	2008	2009
Sample B: Reporting GHG-emissions at t-1												
Scope of emission reported												
Scope 1 and 2	167	110	142	166	199	216	80%	74%	77%	81%	82%	87%
Not scope 1 and 2	39	38	43	38	43	33	20%	26%	23%	19%	18%	13%
Type of emission reported												
GHG-emissions	78	51	65	61	99	114	37%	34%	35%	30%	41%	46%
Only CO_2-emissions	128	97	120	143	143	135	63%	66%	65%	70%	59%	54%
Reporting boundary												
Group-wide activities	73	39	55	69	92	111	34%	26%	30%	34%	38%	45%
All manufacturing	46	35	40	46	57	53	23%	24%	22%	23%	24%	21%
Majority of manufacturing operations	48	34	52	48	53	51	23%	23%	28%	24%	22%	20%
Majority of activities	39	40	38	41	40	34	20%	27%	21%	20%	17%	14%
Disclosure Completeness Index												
0 scores	17	23	22	14	16	12	9%	16%	12%	7%	7%	5%
1 scores	81	63	81	89	94	76	40%	43%	44%	44%	39%	31%
2 scores	82	49	65	78	100	118	39%	33%	35%	38%	41%	47%
3 scores	26	13	17	23	32	43	12%	9%	9%	11%	13%	17%
Sample C: Reporting GHG-emissions at t												
Scope of emission reported												
Scope 1 and 2	185	139	164	188	222	215	83%	77%	82%	82%	87%	88%
Not scope 1 and 2	36	42	35	41	33	30	17%	23%	18%	18%	13%	12%
Type of emission reported												
GHG-emissions	95	65	77	96	112	126	42%	36%	39%	42%	44%	52%
Only CO_2-emissions	126	116	122	133	143	119	58%	64%	61%	58%	56%	48%
Reporting boundary												
Group-wide activities	88	54	64	89	112	122	39%	30%	32%	39%	44%	50%
All manufacturing	49	40	46	51	55	53	22%	22%	23%	22%	22%	22%
Majority of manufacturing operations	48	48	48	50	52	44	22%	27%	24%	22%	20%	18%
Majority of activities	36	39	41	39	36	26	17%	22%	21%	17%	14%	11%
Disclosure Completeness Index												
0 scores	14	21	14	14	12	9	7%	12%	7%	6%	5%	4%
1 scores	80	79	87	88	79	66	37%	44%	44%	38%	31%	27%
2 scores	95	64	76	96	125	113	42%	35%	38%	42%	49%	46%
3 scores	33	17	22	31	39	57	15%	9%	11%	14%	15%	23%

Notes: This table summarizes the characteristics of both sample B and sample C. Rows show the scope, type and reporting boundaries of the emissions reported, as well as the Disclosure Completeness Index built from these classifications. The first columns show the number of companies each sample on average and in each of the years 2005 and 2009. The following columns represent the percentage share of companies in each classification of the scope, type, reporting boundary, as well as the Disclosure Completeness Index.

In 2009, already 50% of companies reported emissions for group-wide activities for the year of inclusion in the index (sample C). Despite this positive trend towards more complete reporting of GHG-emissions in terms of reporting boundaries, this fact also illustrates that in the year 2009 only half of the companies that reported emissions did so for the whole company.

The three measures of reporting completeness discussed are merged in the constructed Disclosure Completeness Index. Results of the Disclosure Completeness Index are also summarized in Table 7 and illustrate that for the year preceding index inclusion (sample B), on average over five years only 12% of companies that reported emissions followed the requirements of the established reporting guidelines to report scope 1 and 2 GHG-emissions for a group-wide reporting boundary. The percentage of companies reporting completely for the year t-1 (sample B) is up from 9% in 2005 to 17% in 2009, i.e. in 2009 only roughly every fifth company that reports emissions followed the established reporting guidelines. These descriptive results on the incompleteness of reported absolute levels of GHG-emission suggest that the estimation and information risk resulting from incomplete information concerning this proxy for climate change induced systematic risk affects large shares of the economy (cf. chapter *3.3 Disclosure Completeness*).

Furthermore, these descriptive results show that the incompleteness of GHG-emissions data must be controlled for when relating financial performance to climate change performance. Especially when accounting measures of financial performance are applied, studies relating group-wide financial performance to emissions reported only for a selective share of the company would suffer from distorted results. In the context of EMH and tests of semi-strong market efficiency, it is noticeable that the semi-strong efficient market would incorporate the publicly available information on incomplete GHG-emissions and the resulting estimation risk. Information on complete GHG-emissions for all companies is – if at all – only privately available and would thus be only of interest in tests of strong market efficiency.[20] Nevertheless, in a test of semi-strong market efficiency toward climate change induced systematic risk, the incompleteness of GHG-emissions data may be controlled for to ensure that the generated results are not distorted by the different levels of completeness of reported emissions data. This is done in this research as a test of robustness of results (cf. chapter *5.4.1 Incompleteness of GHG-emissions Data*).

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[20] Complete emissions for all companies require an informed extrapolation for all companies that report incomplete emissions to emissions data that covers scope 1 and 2 GHG-emissions for group-wide activities.

4.3.3 Timeliness of GHG-emissions Reporting

Unlike with financial data, where annual reports are legally required to be published on an annual basis, there are still substantial discrepancies regarding the time companies take to voluntarily publish their emissions data. For example, in 2006 one company took the maximum of 38 months to publish its emissions data for the respective year. In the year 2009 the earliest company published its emissions data one month after the end of the financial year, while eleven companies took the maximum time of ten months to publish their emissions. On average over five years, in total 73% of all companies in sample C reported emissions within six month from the end of the financial year.

The discrepancies in the timeliness of GHG-emissions data are accounted for in a test of robustness of results, where a two year time-lag for emissions data is applied (cf. chapter *5.4 Tests of Robustness*). The date of publication of absolute levels of emissions data is however not expected to have a significant impact on creation of portfolios used for this research, as emissions levels, in contrast to financial performance data, are rather constant over time. Furthermore, absolute levels of emissions in this research are only used to allocate companies to portfolios of high, medium and low levels of absolute emissions and GHG-efficiency (cf. chapter *3.4 Absolute Levels of Emissions* and chapter *3.5 GHG-efficiency*). During the five year period studied for this research only 37 companies, i.e. 12% of the reporting companies, migrate from one portfolio of absolute levels of emissions to another one. The remaining 88% of companies do not change from one portfolio to another in any of the years under analysis, illustrating that the timeliness of GHG-emissions data cannot be expected to have a strong impact on the creation of portfolios used for this research.

4.3.4 Industry Affiliation and Affiliation with the EU ETS

Table 8 illustrates the descriptive statistics of samples A, B and C in terms of industry affiliation, affiliation with the EU ETS as well as affiliation with high carbon industries. Every sample contains companies that are (not) part of the EU ETS and (not) affiliated with high carbon industries, as well as companies from the following industries: Oil & Gas (ICB 0001), Basic Materials (ICB 1000), Industrials (ICB

2000), Consumer Goods (ICB 3000), Health Care (ICB 4000), Consumer Services (ICB 5000), Telecommunications (ICB 6000), Utilities (ICB 7000) and Technology (ICB 9000).

As it can be seen from Table 8, sample A, B and C show a different composition of the respective industries and the respective industries show different levels of GHG-emissions reporting. For example, while sample A has an average share of companies from the Consumer Service industry of 22%, the share of companies from the Consumer Service industry reporting GHG-emissions at t-1 (sample B) only corresponds to 14%. Furthermore, while on average over five years 83% of companies in the Oil & Gas industry and 75% of Basic Materials companies report absolute levels of GHG-emissions on at least the majority of corporate activities for the year t-1 (sample C), only 41% of companies from the Technology sector report emissions. These descriptive findings suggest that the samples of reporting companies (sample B and C) might be concentrated in heavy industries. This notion is confirmed when comparing the share of reporting companies affiliated with high carbon industries (71% on average over five years at t-1) to the share of companies reporting that are affiliated low carbon industries (48% on average over five years at t-1). With regard to affiliation with the EU ETS Table 8 shows that the samples of reporting companies (sample B and C) show a higher share of companies affiliated with the EU ETS. On average over five years, 81% of companies that have installations in the EU ETS report absolute levels of GHG-emissions on at least the majority of corporate activities for the year t-1 (sample B). In contrast, only 48% of companies that are not affiliated with the EU ETS reported.

To better understand the sample characteristics and to examine whether, for example, the dissimilarities in reporting practices between companies from differing industries are statistically significant an in-depth analysis of determinants of the existence and completeness of reporting is carried out in chapter *4.4 Understanding Sample Characteristics.* Furthermore, to avoid that results obtained with sample B are driven by the specific industry affiliations of reporting companies, potentially inefficiently priced industry effects are controlled for in the testing of the hypotheses as described in chapter *5.2.1 Controlling for Industry Effects*.

Table 8: Descriptive statistics on affiliation wiht industries and EU ETS

	Number of companies						% Share of companies						% Share of reporting companies					
	Mean	2005	2006	2007	2008	2009	Mean	2005	2006	2007	2008	2009	Mean	2005	2006	2007	2008	2009
Sample A	351	348	352	353	360	343												
Industry affiliation																		
Oil & Gas	19	15	16	18	21	24	5%	5%	4%	5%	5%	6%						
Basic Materials	34	30	31	35	36	37	9%	10%	9%	9%	10%	10%						
Industrials	76	72	74	75	79	80	21%	22%	21%	21%	21%	22%						
Consumer Goods	57	56	58	60	57	53	16%	16%	16%	16%	17%	16%						
Health Care	22	23	23	21	20	21	6%	6%	7%	7%	6%	6%						
Consumer Services	76	82	79	77	79	65	22%	22%	24%	22%	22%	22%						
Telecommunications	21	22	23	20	20	19	6%	6%	6%	7%	6%	6%						
Utilities	31	30	32	32	32	31	9%	9%	9%	9%	9%	9%						
Technology	16	18	16	15	16	13	5%	4%	5%	5%	4%	4%						
Affiliation with																		
High carbon industries	160	147	153	160	168	172	45%	46%	42%	43%	45%	47%						
Low carbon industries	191	201	199	193	192	171	55%	54%	58%	57%	55%	53%						
EU ETS	109	102	105	111	114	113	31%	31%	29%	30%	31%	32%						
Not EU ETS	242	246	247	242	246	230	69%	69%	71%	70%	69%	68%						
Sample B	206	148	185	204	242	249							59%	43%	53%	58%	67%	73%
Industry affiliation																		
Oil & Gas	16	11	14	14	19	21	7%	8%	7%	8%	7%	8%	83%	73%	88%	78%	90%	88%
Basic Materials	26	19	24	25	29	31	13%	12%	13%	13%	12%	12%	75%	63%	77%	71%	81%	84%
Industrials	47	28	37	46	62	62	22%	23%	19%	20%	23%	26%	61%	39%	50%	61%	78%	78%
Consumer Goods	33	29	35	35	36	32	17%	16%	20%	19%	17%	15%	59%	52%	60%	58%	63%	60%
Health Care	10	9	9	11	11	11	5%	5%	6%	5%	5%	5%	48%	39%	39%	52%	55%	52%
Consumer Services	29	20	26	28	34	38	14%	14%	14%	14%	14%	14%	39%	24%	33%	36%	43%	58%
Telecommunications	13	9	13	14	14	15	6%	6%	6%	7%	7%	6%	63%	41%	57%	70%	70%	79%
Utilities	25	18	23	27	29	29	12%	12%	12%	12%	13%	12%	80%	60%	72%	84%	91%	94%
Technology	6	5	4	4	8	10	3%	3%	3%	2%	2%	3%	41%	28%	25%	27%	50%	77%
Affiliation with																		
High carbon industries	114	76	98	112	139	143	54%	55%	51%	53%	55%	57%	71%	52%	64%	70%	83%	83%
Low carbon industries	92	72	87	92	103	106	46%	45%	49%	47%	45%	43%	48%	36%	44%	48%	54%	62%
EU ETS	89	75	85	88	98	97	45%	43%	51%	46%	43%	40%	81%	74%	81%	79%	86%	86%
Not EU ETS	117	73	100	116	144	152	55%	57%	49%	54%	57%	60%	48%	30%	40%	48%	59%	66%
Sample C	222	181	199	229	255	245							63%	52%	57%	65%	71%	71%
Industry affiliation																		
Oil & Gas	17	13	14	17	19	20	7%	7%	7%	7%	7%	7%	88%	87%	88%	94%	90%	83%
Basic Materials	26	24	21	26	31	28	12%	12%	13%	11%	11%	12%	76%	80%	68%	74%	86%	76%
Industrials	53	37	46	56	65	62	24%	24%	20%	23%	24%	25%	69%	50%	62%	74%	81%	78%
Consumer Goods	35	34	36	36	35	34	16%	16%	19%	18%	16%	14%	61%	60%	62%	59%	60%	63%
Health Care	10	9	10	10	10	12	5%	5%	5%	5%	4%	4%	51%	41%	43%	53%	56%	63%
Consumer Services	33	26	26	34	41	36	15%	15%	14%	13%	15%	16%	43%	32%	33%	44%	52%	55%
Telecommunications	15	12	16	15	15	15	7%	7%	7%	8%	7%	6%	71%	55%	70%	75%	75%	79%
Utilities	26	22	26	27	29	28	12%	12%	12%	13%	12%	11%	84%	73%	81%	84%	91%	90%
Technology	7	4	4	8	10	10	3%	3%	2%	2%	3%	4%	51%	24%	25%	57%	67%	83%
Affiliation with																		
High carbon industries	122	96	107	126	144	138	55%	55%	53%	54%	55%	56%	76%	65%	70%	79%	86%	80%
Low carbon industries	100	85	92	103	111	107	45%	45%	47%	46%	45%	44%	52%	42%	46%	53%	58%	63%
EU ETS	91	84	84	94	97	96	42%	41%	46%	42%	41%	38%	83%	82%	80%	85%	85%	85%
Not EU ETS	131	97	115	135	158	149	58%	59%	54%	58%	59%	62%	54%	39%	47%	56%	64%	65%

Notes: This table summarizes the characteristics of sample A, B and sample C in terms of industry affiliation, affiliation with high and low carbon industries, as well as affiliation with the EU ETS. Absolute numbers of companies, as well as the share of companies and the share of reporting companies within the respective affiliations is presented on average and in each of the years 2005 and 2009.

4.3.5 Other Indicators

For the remaining indicators as used in the respective samples of this study, a summarizing Table 9 shows their mean and standard deviation (SD). Market capitalization in million €, book to market ratio (calculated by dividing common equity (Datastream mnemonic WC03501) in December at year t-2 by market capitalisation (Datastream mnemonic MV) in December at year t-1 (cf. *5.2 C4FM*), reported GHG-emissions in million t, GHG-efficiency in €/t (calculated by dividing the net income (Datastream mnemonic WC01651) by the amount of reported GHG-emissions), debt to common equity ratio (Datastream mnemonic WC08231) and the return on total assets ratio (Datastream mnemonic WC08326) are presented.

Table 9 illustrates that the average market capitalization of reporting companies (sample B and C) is comparatively higher than the average market capitalization of companies in sample A. To find out if the difference in size between reporting and non-reporting companies is statistically significant, size, as measured by market capitalization, is included in the in-depth analysis of sample characteristics in chapter *4.4 Understanding Sample Characteristics.* Company size is also controlled for in the subsequent testing of market efficiency, as it has been found to determine risk and stock performance (cf. chapter *2.1.4 Methodologies and Findings*).

With regard to the average book to market ratio, Table 9 shows almost no difference between the companies in sample A and sample B. It is noticeable that the average book to market ratio of companies in both samples approaches 1.00 in 2008, i.e. during the financial crisis the average book value of companies in sample A and sample B almost entirely explained the market value of its equity. With regard to the debt to common equity ratio (“financial leverage”), which in in Datastream is inflated by 100% (cf. chapter *4.2.2 Collection of Other Data),* companies in sample A show a slightly higher financial leverage than companies in sample C in the majority of years. With regard to the average return on total assets ratio (“profitability), Table 9 shows that it is slightly higher for all companies (sample A) than reporting companies (sample C) in the majority of years. Interestingly, the return on assets ratio reduces more significantly in times of crisis for reporting companies.

Table 9: Descriptive statistics of samples

	2004		2005		2006		2007		2008	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sample A: All companies										
Market cap in million €	10,683	17,589	13,034	20,275	14,721	20,644	15,710	23,456	9,531	15,305
Book to market ratio	0.49	0.39	0.43	0.47	0.39	0.36	0.45	0.38	0.98	1.08
Debt to common equity ratio	124	524	108	293	127	249	125	504	59	1,297
Return on total assets ratio	7.39	7.10	8.85	7.99	9.87	9.07	9.93	9.45	7.42	8.00
Sample B: Reporting GHG-emissions at t-1										
Market cap in million €	17,097	24,224	18,619	25,472	20,210	24,918	20,431	27,187	11,750	17,282
Book to market ratio	0.53	0.37	0.47	0.57	0.41	0.38	0.46	0.40	0.96	0.96
GHG-emissions in million t	12.13	26.09	10.70	23.91	10.37	22.76	10.57	26.07	10.53	26.20
GHG-efficiency in €/t	1,497	4,870	2,742	6,510	3,524	9,143	5,733	37,642	1,726	6,822
Sample C: Reporting GHG-emissions at t										
Market cap in million €	15,248	22,225	18,143	24,974	19,472	24,181	19,337	26,594	11,928	17,407
Debt to common equity ratio	116	303	101	329	117	182	136	345	10	1,479
Return on total assets	6.66	5.43	8.09	5.66	9.80	9.06	10.22	9.44	6.94	7.12

Notes: This table summarizes descriptive characteristics of sample A, B and C. Average and standard deviation (SD) for all companies in the respective samples in each of the specific years from 2005 to 2009 are shown. Where applicable, market capitalization (Market cap) in million €, book to market ratio, debt to common equity ratio, return on total assets ratio, GHG-emissions in million t and GHG-efficiency in €/t are presented.

These descriptive results thus suggest that (1) there might be differences in the profitability and financial leverage between companies that report GHG-emissions and companies that do not and (2) that the impact of financial market crisis might be different on reporting as compared to non-reporting firms. To control for the latter possibility, the impact of financial market crisis is included in the tests of robustness of the results obtained from testing the hypotheses developed (cf. chapter *5.4.4 Financial Market Crisis*). To examine whether there is a statistically significant difference in the profitability and financial leverage of reporting and non-reporting companies the return on total assets ratio and the debt to common equity ratio are included in the in-depth examination of sample characteristics in chapter *4.4 Understanding Sample Characteristics.*

Interestingly, as also displayed in Table 9, the average GHG-emissions of companies in sample B have significantly reduced from 2004 to 2005 and kept relatively constant from 2005 to 2008. At the same time, the average GHG-efficiency of companies in sample B has steadily increased from 2005 to 2007, showing that companies in the sample increased their average net income generated with a rather steady amount of GHG-emissions. As a result of the fact that the depicted increase in GHG-efficiency is mainly due to an increase in net income, the average GHG-efficiency of companies in sample B almost reduces to the level observed in 2004 in the year 2008, probably as a result of the financial market crisis.

Descriptive statistics on the monthly changes in prices of oil and carbon, which are used in the tests of robustness of this research (cf. chapter *5.4 Tests of Robustness*) are displayed in Table 10. It is noticeable that during the financial crisis in 2008, the natural logarithm of mean monthly changes in oil prices shows a significant reduction and an elevated standard deviation. The price of carbon reduces on average in 2006 and 2007, halts on average in 2008 and increases again in 2009. In 2009, the standard deviation of mean monthly changes in carbon prices is particularly high, suggesting that carbon prices fluctuated significantly in 2009. The mean annualised risk free rate of return shows almost no standard deviation, as to be expected. The mean annualised risk free rate of return increases between 2005 and 2008 and then significantly reduces in 2009.

Table 10: Descriptive statistics of other indicators

	2005		2006		2007		2008		2009	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ln change in Oil price	0.040	0.071	-0.001	0.070	0.024	0.061	-0.059	0.136	0.042	0.066
Ln change in carbon price	0.010	0.117	-0.098	0.234	-0.483	0.413	0.000	0.246	0.536	1.757
Annualised risk free rate	2.17%	0.000	3.03%	0.001	4.21%	0.001	4.69%	0.001	1.32%	0.002

Notes: This table summarizes descriptive statistics of the natural logarithm of the monthly change in oil prices and carbon prices, as well as the annualised risk free rate (EURIBOR) in %. Average and standard deviation (SD) in each of the specific years from 2005 to 2009 are presented.

Table 11 shows the implicit tax rate on energy of the 17 countries of origin of companies included in this study. While some countries have reduced the implicit tax rate on energy in the years under analysis, other countries have increased this measure between 2005 and 2009. The indicator is included in the in-depth analysis of sample characteristics to determine if companies coming from countries with a comparatively higher level of ambition to reduce global warming are more likely to report GHG-emissions to the public (cf. chapter *4.4 Understanding Sample Characteristics*).

Table 11: Descriptive statistics on implicit tax rate on energy

	2004	2005	2006	2007	2008
BELG	104 €/t	107 €/t	103 €/t	112 €/t	97 €/t
CZE	79 €/t	94 €/t	99 €/t	109 €/t	127 €/t
DEN	307 €/t	290 €/t	280 €/t	273 €/t	268 €/t
GER	213 €/t	207 €/t	202 €/t	204 €/t	194 €/t
IRE	159 €/t	155 €/t	151 €/t	153 €/t	153 €/t
GRC	103 €/t	100 €/t	96 €/t	102 €/t	102 €/t
SP	125 €/t	119 €/t	120 €/t	118 €/t	115 €/t
FRA	169 €/t	163 €/t	163 €/t	161 €/t	161 €/t
ITA	214 €/t	208 €/t	210 €/t	200 €/t	187 €/t
HUN	84 €/t	87 €/t	86 €/t	98 €/t	98 €/t
NETH	170 €/t	182 €/t	193 €/t	178 €/t	190 €/t
OEST	156 €/t	150 €/t	141 €/t	150 €/t	150 €/t
POL	67 €/t	84 €/t	88 €/t	101 €/t	108 €/t
PTL	142 €/t	149 €/t	148 €/t	149 €/t	143 €/t
FIN	111 €/t	112 €/t	105 €/t	103 €/t	115 €/t
SWED	199 €/t	197 €/t	200 €/t	197 €/t	190 €/t
UK	221 €/t	213 €/t	211 €/t	218 €/t	180 €/t

Notes: This table summarizes the implicit energy tax per country, which is calculated by Eurostat as energy tax revenues of a country in relation to its final energy consumption in Euro per ton of oil equivalent.

Finally, it should be noted that the sample used for the test of market efficiency shows a survivorship bias. This is due to the fact that companies can only be included in the analysis until the months of a merger or bankruptcy. However, as the sample used for this research does not includes micro-caps (cf. chapter *4.1 Sample Selection*), the effect of a survivorship bias is estimated to be comparatively small in this study (Elton, Gruber, & Blake, 1996). Furthermore, as some of the hypotheses developed can only be tested with the sample of reporting companies, it must be determined that the results obtained from testing these hypotheses are not driven by a *green* bias, i.e. determined by the specific characteristics of companies that report emissions. To that end, an in-depth analysis of the important characteristics of reporting versus non-reporting companies is carried out in the following chapter.

4.4 Understanding Sample Characteristics

As discussed in chapter *3 Hypotheses Development*, six proxies for climate change induced systematic risk are used to build portfolios to test market efficiency towards the hypotheses developed (cf. chapter *5 Methodology*). Several of these hypotheses can only be tested with portfolios constructed from companies that report GHG-emissions (cf. chapter *3.3 Disclosure Completeness*, chapter *3.4 Absolute Levels of Emissions* and chapter *3.5 GHG-efficiency*). At the same time, descriptive statistics (cf. chapter *4.3 Descriptive Sample Characteristics*) showed differences in important characteristics between all companies (sample A) and the sub-samples of reporting companies (sample B and C).

The following in-depth analysis of sample characteristics makes two contributions: First, it serves to better understand whether companies that disclose GHG-emissions show exposure to other proxies of climate change induced systematic risk. For example, for the analysis of results obtained with the sample of reporting companies, it is important to know if affiliation with the EU ETS affects (1) the decision of a company to disclose GHG-emissions and (2) the completeness of the reported emissions. The second contribution of this analysis is to allow determining that results obtained from testing hypotheses are not driven by statistically significant difference in important company characteristics between reporting and non-reporting companies. For example, if companies that report their GHG-emissions showed a statistically significant higher or lower financial leverage, this could impact their stock performance (Fama & French, 1992; Foerster & Sapp, 2005; Shleifer & Vishny, 1997) and the level of financial leverage would have to be controlled for in the subsequent analysis of market efficiency. Otherwise, financial leverage might be a distorting factor in the results obtained from testing the hypotheses introduced concerning the existence of disclosures of GHG-emissions. The same is valid for financial leverage and the hypotheses introduced concerning the completeness of reported emissions.

Two in-depth analyses are consequently carried out in this chapter with regard to the following research questions: First, do companies that report GHG-emissions differ in important characteristics from companies that do not report GHG-emissions? And second: Do companies that report complete GHG-emissions differ in important characteristics from companies that report incomplete GHG-emissions? The aim of the following in-depth analysis of sample characteristics is thus not to fully explain determinants of the existence and completeness of corporate GHG-emissions disclosure, but to better understand the characteristics and potentially important differences in the characteristics of companies that report GHG-emissions as opposed to companies that do not.

In this context it is worth noting that the idea that corporate non-financial reporting practices are determined by variables such as size, country or industry affiliation has been researched for decades (Belkaoui & Karpik, 1989; Gray, Kouhy, & Lavers, 1995; Hackston & Milne, 1996; Patten, 2002). The following analyses however represent the first comprehensive investigation of the existence and completeness of quantitative GHG-emissions disclosure by companies in Europe. An overview over dominant studies from the field and studies that informed the indicator selection of this analysis is displayed in Table 12. The characteristics of companies that are analysed for in research are affiliation with the EU ETS, the implicit energy tax level of the originating country, financial leverage, size, industry affiliation and profitability. In the following paragraphs each of the indicators is briefly introduced and motivated.

EU ETS

Regulatory influences were found to be a determinant of environmental disclosure in various studies (Holland & Foo, 2003; Luo, Lan, & Tang, 2010; Patten, 2000; Reid & Toffel, 2009). In fact, with regard to the EU ETS, descriptive results suggested that companies having installation in the EU ETS, who are legally required to build up the systems necessary for carbon accounting (Engels, 2009), are also more frequently reporting their GHG-emissions to the public compared to companies that are not affiliated with the EU ETS (cf. chapter *4.3.4 Industry Affiliation and Affiliation with the EU ETS*). The EU ETS is consequently included in this analysis to determine whether the a portfolio constructed from reporting companies is significantly biased towards companies that have installations in the EU ETS and consequently is more exposed to the financial risk induced by climate change (cf. chapter *3.1 European Emissions Trading Scheme*).

Table 12: Overview over related studies

Study	Thematic focus	Sample	Data source	Indicators / Proxies					
				Size	**Industry**	**Leverage**	**Profit**	**Country**	**Other indicators**
Brammer & Pavelin (2006)	Existence and quality of environmental disclosures	450 large UK companies, years 2000	Survey: PIRC Environmental Reporting 2000	Total assets	12 sectors	Total debt to total assets	Return on assets	N/A	Ownership concentration, Non-executive directors, No. of news articles, environmental fines
Cormier & Magnan (2005)	Quality of environmental disclosure	55 German companies, years 1992-1998	Annual and environmental reports, own disclosure quality index	Total assets	6 industries	Long-term debt to book value of equity	Market returns	N/A	Beta, trading volume, change in financial leverage, fixed asset age, ownership concentration , SEC registration, No. of news stories
Stanny & Ely (2008)	Scrutiny as a determinant of the existence of answers to the CDP	287 SP500 companies, year 2006	CDP	Total assets	10 industries, classify-cation of high carbon industries	Debt to total assets	Income, Tobin's Q	% of sales outside of USA	Previous answers to CDP, equipment age, membership FT500, capital spending divided by total sales, ownership concentration
Clarkson et al. (2008)	Environmental performance and the level of environmental disclosures	191 US firms, year 2003	Environmental disclosures, TRI, own disclosure quality index	Total assets	5 industries	Total debt to total assets	Return on assets, Tobin's Q	N/A	Beta, debt or equity capital raised, asset newness, capital intensity, Janis–Fadner coefficient, TRI

Table 12: Overview over related studies (cont.)

Study	Thematic focus	Sample	Data source	Indicators / Proxies					
				Size	**Industry**	**Leverage**	**Profit**	**Country**	**Other indicators**
Freedman & Jaggi (2005)	Disclosures of pollution and GHG-emissions in countries that have ratified the Kyoto Protocol as compared to other countries	120 world largest companies from specific industries, years 2000-2002	Annual reports, websites, own disclosure index	Total assets	5 industries	Debt to equity	Return on assets	Kyoto Protocol countries, regulatory enforcement level, legal system	N/A
Reid & Toffel (2009)	Proposed regulation and shareholder resolutions as determinants for the existence of CDP disclosure	S&P 500 companies, years 2006-2007	CDP	Net sales employment	12 industries	N/A	N/A	N/A	Shareholder resolutions (targeted against other companies in industry), regulatory threat, ownership concentration, TRI
Dawkins & Fraas (2010)	Environmental performance and media visibility as determinants of the existence and extent of answers to the CDP	344 SP500 companies, 2006-2008	CDP, KLD and Trucost ratings	Revenue, employment	9 industries	N/A	Return on assets, return on equity	N/A	No. of times company mentioned (along with term “climate change”) in 5 US newspapers and Google News Archive, KLD and Trucost ratings

Table 12: Overview over related studies (cont.)

Study	Thematic focus	Sample	Data source	Indicators / Proxies					
				Size	Industry	Leverage	Profit	Country	Other indicators
Cho & Patten (2007)	Monetary and non-monetary environmental disclosure in environmentally sensitive and not environmentally sensitive industries	100 companies, year 2002	KLD, own disclosure score, 10k filings	Size effects removed through matching	Classification of environmentally sensitive industries	N/A	N/A	N/A	KLD rating
Prado-Lorenzo et al. (2009)	Determinants of the extent of online climate change disclosure	101 Fortune 500 companies, year 2007	Company websites, own climate change disclosure index	Total revenues	11 industries	Total debt to equity	Return on assets, return on equity	Operations mainly in Kyoto Protocol countries	Market to book ratio, Inclusion in Dow Jones Sustainability Index

Furthermore, as currently under the EU ETS companies are only expected to report CO_2-emissions from specific processes and installations, it must be detected for this study whether companies in the EU ETS are more likely to report incomplete GHG-emissions. If incompletely reporting companies tend to be those that have installations in the EU ETS, this would further increase the climate change induced systematic risk of incompletely reporting companies, as well as that of companies with installations in the EU ETS, as market participants would not be able to infer future liabilities stemming from the climate change induced systematic risk proxied by the EU ETS (cf. chapter *3.3 Disclosure Completeness*).

Implicit Energy Tax Level

As a second indicator for regulatory influences, the implicit energy tax of the originating country is included in this in-depth analysis of sample characteristics. In this context it is noteworthy that emissions arising from energy use account for a total of 79% of GHG-emissions in the EU (Eurostat, 2011a). The implicit energy tax level can thus be taken as an indicator of a country’s level of implicit ambition to reduce GHG-emissions through national fiscal policies. The implicit energy tax level of a country is calculated as energy tax revenues of a country divided by its final energy consumption (Eurostat, 2011b) (cf. chapter *4.2.2 Collection of Other Data*). Companies that are under more fiscal pressure for the reduction of GHG-emissions and consequently the improvement of climate change performance in their home country, but do not respond to this stakeholder request by communicating their climate change performance, might increase their risk in relations with the government as an important stakeholder (cf. chapter *3.2 Existence of disclosure of GHG-emissions*). On the other hand, companies that report their GHG-emissions to the public can be expected to be in a position to actually manage their climate change performance, and, as a consequence, are also in a better position to respond to increases in national fiscal pressure for the reduction of GHG-emissions.

With regard to the completeness of the reported emissions, it can be argued that companies that report complete GHG-emissions i.e. make an effort to accurately disclose and be in a position to manage its climate change performance, have responded to stakeholder interests to reduce GHG-emissions and are better equipped to respond to possible future regulation with regard to climate change. Companies that report (complete) GHG-emissions consequently have reduced the risk associated with relations with the government as an important stakeholder (Ambec & Lanoie, 2008).

Financial Leverage

Descriptive results (cf. chapter *4.3.5 Other Indicators*) suggested that non-reporting companies show a slightly higher debt to common equity ratio on average than companies in sample A. In fact, financial leverage was found to be a determinant of environmental and sustainability disclosure by some scholars (Clarkson et al., 2008; Peters & Romi, 2011; Simnett, Vanstraelen, & Wai Fong, 2009) but not by others (Cormier & Magnan, 2005; Freedman & Jaggi, 2005). Financial leverage, as measured by the ratio of debt to common equity, is generally accepted to impact stock performance (Fama & French, 1992; Foerster & Sapp, 2005; Shleifer & Vishny, 1997) and included in this analysis to ensure that companies that report GHG-emissions do not have a significant differently capital structure as non-reporting companies, which might impact their beta (Beaver, Kettler, & Scholes, 1970; Gahlon & Gentry, 1982) and consequently might also influence the results obtained from testing the hypotheses in this research. Furthermore, it must be established whether completely reporting companies differ in their capital structure from incompletely reporting companies, which would impact stock performance and consequently the results obtained from testing hypotheses concerning disclosure completeness (cf. chapter *3.3 Disclosure Completeness*).

Size

Company size is generally accepted to influence financial market performance (Banz, 1981; Fama & French, 1992). At the same time, descriptive statistics suggested that reporting and non-reporting companies might differ in size (cf. chapter *4.3.5 Other Indicators*). In fact, different scholars have shown that the extent and quality of environmental disclosure depends on company size (Brammer & Pavelin, 2006; Gray et al., 1995; Luo et al., 2010; Patten, 2002) and among others Prado-Lorenzo et al. confirmed this relation for GHG-emissions (Freedman & Jaggi, 2005; Prado-Lorenzo, Rodriguez-Dominguez, Gallego-Alvarez, & Garcia-Sanchez, 2009). Size in terms of market capitalization is included in this in-depth analysis of sample characteristics to determine whether reporting companies are statistically significantly bigger in terms of size than non-reporting companies, which would impact financial market performance. Furthermore, it must be established whether larger companies are more or less likely to report complete GHG-emissions for the testing of hypothesis concerning the disclosure completeness (cf. chapter *3.3 Disclosure Completeness).*

Profitability

The fact that the reporting of GHG-emissions is a complex and expensive undertaking for companies invites the assumption that predominantly companies that have above-average financial resources tend to report GHG-emissions. Interestingly, descriptive results suggested that in the majority of years companies that invest the necessary financial resources to build up the systems to report GHG-emissions are slightly less profitable than companies in sample A (cf. chapter *4.3.5 Other Indicators*). To detect whether there is a statistically significant difference in the profitability of reporting as compared to non-reporting firms, which could impact the results obtained from testing the hypotheses in this research, a measure of profitability is included in this in-depth analysis of sample characteristics. Different measures of profitability have been found to determine environmental disclosure in some studies (Cormier & Magnan, 1999; Stanny & Ely, 2008) but not in others (Archel et al., 2008; Brammer & Pavelin, 2006; Cormier & Magnan, 2005; Prado-Lorenzo, Rodríguez-Domínguez, Gallego-Álvarez, & García-Sánchez, 2009). With regard to the completeness of the reported emissions, it will be determined if completely reporting companies are primarily those that have the financial resources necessary to report scope 1 and 2 GHG-emissions for a group-wide reporting boundary. Therefore, a potential relation between profitability and the completeness of GHG-emissions reporting is examined to make sure results obtained from the testing of hypotheses concerning disclosure completeness are not driven by important company characteristics not controlled for (cf. chapter *3.3 Disclosure completeness).*

Industry Affiliation

Descriptive results further suggested that different industries show different levels of GHG-emissions disclosure (cf. chapter *4.3.4 Industry Affiliation and Affiliation with the EU ETS*). Industry affiliation is generally accepted to influence stock market performance (Campbell et al., 2001; Fama & French, 1997) as well as environmental disclosure practices. Industry affiliation was for example found to be a determinant of environmental disclosure in Dawkins and Fraas (2010), Brammer and Pavelin (2006) and Prado-Lorenzo et al. (2009). Stanny and Ely however found that affiliation with a "high carbon industry is not positively associated with disclosure" (Stanny & Ely, 2008, p. 344). Industry affiliation, as classified by the FTSE Industry Classification Benchmark (ICB), as well as affiliation with high carbon industries, is included in this research to find out whether a portfolio constructed from reporting companies is statistically different in terms of industry composition to a portfolio constructed from companies that do not report GHG-emissions. If this was the case, industry affiliation would have to be controlled for in the subsequent tests of the hypotheses developed concerning market efficiency.

In the following, two sets of logistic regressions are carried out. The first investigates if companies that report GHG-emissions differ in important characteristics from companies that do not report GHG-emission. A second set of logistic regressions examines if companies that report complete GHG-emissions differ in important characteristics from companies that report incomplete GHG-emissions.

4.4.1 Existence of Corporate GHG-disclosure

In order to determine if companies that report GHG-emissions differ in important characteristics from companies that do not report, a binary logistic regression analysis is carried out with all companies in sample A. A binary response variable is coded one for companies reporting GHG-emissions on at least the majority of corporate activities and zero otherwise. Logistic regression applies maximum likelihood estimation, as the more commonly known ordinary least squares (OLS) regression cannot resolve the problems of nonlinearity and non-additivity that arise when the dependent variable can only take the values one or zero (Pampel, 2000). Maximum likelihood estimation "aims to find those coefficients that have the greatest likelihood of producing the observed data" (Pampel, 2000, p. 44). The full model specification for examining the characteristics of reporting versus non-reporting companies is:

$$\begin{aligned} \text{EXIST} = {} & \beta_0 + \beta_1\,(\text{EU\_ETS}) + \beta_2\,(\text{EN\_TAX}) + \beta_3\,(\text{LEV}) + \beta_4\,(\text{PROF}) \\ & + \beta_5\,(\text{MA\_CAP}) + \beta_6\,(\text{OIL\_GAS}) + \beta_7\,(\text{BASIC\_MAT}) \\ & + \beta_8\,(\text{INDUST}) + \beta_9\,(\text{CONS\_GOODS}) + \beta_{10}\,(\text{HEALTH}) \\ & + \beta_{11}\,(\text{CONS\_SERV}) + \beta_{12}\,(\text{TELECOMM}) + \beta_{13}\,(\text{UTIL}) \\ & + \beta_{14}\,(\text{TECH}) \end{aligned} \tag{1}$$

Where:

β_0	is the intercept.
$\beta_1 \dots \beta_{14}$	are the logistic regression coefficients referred to as logged odds. A positive logged odd means that independent variable increases the probability of the outcome.
EXIST	is a binary dummy variable coded 1 for companies disclosing GHG-emissions on at least the majority of activities, 0 otherwise.
EU_ETS	is a binary dummy variable coded 1 for companies that have installations in the EU ETS, 0 otherwise.
EN_TAX	is a continuous variable representing the logarithm of the implicit energy tax level of a country at year t-1.
LEV	is a continuous variable representing the ratio of total debt to common equity at year t-1.
PROF	is a continuous variable representing the ratio of return to total assets at year t-1.
MA_CAP	is a continuous variable representing the logarithm of market capitalization in million € at year t-1.
OIL_GAS	is a binary dummy variable coded 1 for companies from the Oil & Gas industry (ICB 0001), 0 otherwise
BASIC_MAT	is a binary dummy variable coded 1 for companies from the Basic Materials industry (ICB 1000), 0 otherwise
INDUST	is a binary dummy variable coded 1 for companies from the Industrials industry (ICB 2000), 0 otherwise.

CONS_GOODS	is a binary dummy variable coded 1 for companies from the Consumer Goods industry (ICB 3000), 0 otherwise
HEALTH	is a binary dummy variable coded 1 for companies from the Health Care industry (ICB 4000), 0 otherwise.
CONS_SERV	is a binary dummy variable coded 1 for companies from the Consumer Services industry (ICB 5000), 0 otherwise.
TELECOMM	is a binary dummy variable coded 1 for companies from the Telecommunications industry (ICB 6000), 0 otherwise.
UTIL	is a binary dummy variable coded 1 for companies from the Utilities industry (ICB 7000), 0 otherwise.
TECH	is a binary dummy variable coded 1 for companies from the Technology industry (ICB 9000), 0 otherwise.

For the sake of brevity, the 468 Pearson pair-wise correlation coefficients for the years 2005 to 2009 and the pooled regression are not presented here. In summary, no correlation between independent variables surpassed the 0.50 level in any of the five years of the study. In order to detect potential problems with multicollinearity, Variance inflation factor (VIF) analyses for the 10 correlations of independent variables with Pearson correlation coefficients above 0.30 were performed. These 10 correlations concerned companies with installations under the EU ETS and specific industry affiliation. In general terms, VIF measures the impact of collinearity on the variance of an estimated regression coefficient. At a maximum VIF of 1.73 no serious problems of multicollinearity have been detected (Marquardt, 1970). Factors are below the cut-off level for logistic regressions of 2.00 (Neter, Wasserman, Nachtsheim, & Kutner, 1996; Peters & Romi, 2011).

Table 13 displays the results of the year-specific and pooled logistic regressions taking the existence of GHG-emissions disclosure as a dependent variable. Results show that companies with installations in the EU ETS (EU_ETS) were more likely to report emission to the public in the years 2005 to 2007 and 2009, but not in the year 2008. In fact, having installations in the EU ETS multiplied the odds of a company to report GHG-emissions by 3.22 ($p<0.01$) in 2005.[21] It can be deduced that a portfolio constructed from reporting companies shows a statistically significant bias towards companies that carry an additional financial risk induced by climate change as proxied by the EU ETS (cf. chapter *3.1 European Emissions Trading Scheme)*. This climate change induced systematic risk as proxied by the EU ETS is however contrasted by the reduced information and estimation risk of companies that report GHG-emissions (cf. chapter *3.2 Existence of Disclosure of GHG-Emissions*).

Results further show that in the years 2005 to 2008, companies coming from countries with high implicit energy tax levels (EN_TAX) were more likely to report GHG-emissions. For example, an increase in the logarithm of the implicit energy tax level of a country by 1 multiplied the odds of a company to report GHG-emissions by 3.98 ($p<0.01$) in the year 2008. These significant results are confirmed by the pooled regression. It can therefore be deduced that reporting companies have responded to increased national fiscal pressure in their home countries for the reduction of GHG-emissions by disclosing their emissions. In the context of stakeholder theory this measure can be interpreted as reducing the risk relating to relations with the government as an important stakeholder (cf. chapter *3.2 Existence of Disclosure of GHG-Emissions*).

Leverage (LEV) is only found to be a determining characteristic of the existence of corporate GHG-emissions reporting in the year 2009. The negative coefficient implies that higher leverage reduces the likelihood of a company to report GHG-emissions. The pooled regression confirms that leverage is not a significant determinant of the existence of GHG-emissions disclosure by companies for the overall sample period. It is consequently deduced that, generally speaking, there is no statistically significant difference between reporting and non-reporting companies in

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[21] Logistic regression coefficients are logged odds and have little intuitive meaning (Pampel, 2000). To allow for a more intuitive interpretation the exponent (or antilogarithm) of the logistic regression coefficients is discussed in the text, i.e. EXP(1.169) = 3.218.

terms of the ratio of total debt to common equity and leverage does not have to be controlled for in the subsequent testing of the developed hypotheses.[22]

Profitability (PROF) is only found to be a determining characteristic of the existence of corporate GHG-emissions reporting in the years 2005 and 2009. The negative coefficient implies that higher profitability reduces the likelihood of a company to report GHG-emissions. The pooled regression shows that profitability is generally not a significant determinant of the existence of GHG-emissions disclosure by companies for the overall sample period. It is consequently deduced that, generally speaking, there is no difference between reporting and non-reporting companies in terms of the ratio of return to total assets. Consequently profitability does not have to be controlled for in the testing of the developed hypotheses.[23]

A strong determinant for the existence of GHG-emissions reporting is company size (MA_CAP). In all years under analysis, companies that are bigger in terms of their market capitalization are more likely to report GHG-emissions ($p<0.01$). In other words, the bigger the company, the higher the likelihood of it reporting GHG-emissions that cover at least 50% of corporate activity.[24] In fact, in the year 2007, an increase in the logarithm of market capitalisation by 1 increases the odds of a company to report GHG-emissions by 3.45 ($p<0.01$). These results indicate that there is a statistically significant difference in the size of reporting and non-reporting companies, which must be controlled for in the subsequent testing of the developed hypothesis.

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[22] As a test of robustness of these results, the ratio of debt to assets has been used as an indicator. Results remain the same, except in year 2009, where the total debt to assets ratio is not a significant determinant.

[23] As a test of robustness of these results the ratio of return to equity as well as net income have been used as an indicator. Results remain the same, except in year 2009, where the ratio of return to equity as well as net income are not a significant indicator.

[24] As a test of robustness of these results the logarithm of total assets has been used as an indicator for company size. Results remain the same.

Table 13: Results of logistic regression on existence of disclosure

	2005	2006	2007	2008	2009	Pooled
C	-14.791 ***	-14.976 ***	-16.877 ***	-14.139 ***	-11.266 ***	-12.640 ***
EU_ETS	1.169 ***	0.709 *	0.940 **	0.386	0.711 *	0.812 ***
EN_TAX	0.929 *	0.904 *	1.101 **	1.382 ***	0.944	1.015 ***
LEV	0.000	-0.001	0.000	0.000	-0.001 *	0.000
PROF	-0.049 **	-0.023	0.010	0.011	-0.030 *	-0.009
MA_CAP	1.023 ***	1.027 ***	1.237 ***	0.807 ***	0.863 ***	0.939 ***
OIL_GAS	2.599 **	2.749 **	2.556 **	1.655 *	0.830	1.599 ***
BASIC_MAT	3.064 ***	2.083 **	0.726	1.448 **	0.400	1.081 ***
INDUST	1.445 **	2.025 ***	1.228 ***	1.321 ***	1.040 **	1.034 ***
CONS_GOOD	1.362 *	1.616 **	-0.090	-0.290	-0.341	0.109
HEALTH	1.088	1.404 *	0.141	-0.387	-0.213	0.026
CONS_SERV	0.738	0.884	Note 1	Note 1	Note 1	Note 1
TELECOMM	1.077	1.951 **	0.992	0.640	0.730	0.689 **
UTIL	1.458 *	2.522 ***	1.155 *	1.515 *	1.060	1.165 ***
TECH	Note 1	Note 1	0.353	0.807	1.050	0.047
Year 2005	-	-	-	-	-	-1.296 ***
Year 2006	-	-	-	-	-	-1.245 ***
Year 2007	-	-	-	-	-	-0.940 ***
Year 2008	-	-	-	-	-	-0.557 ***
Observations	348	352	353	360	343	1,756
Pseudo R-squared	0.25	0.23	0.25	0.18	0.19	0.21
Chi Square	121 ***	112 ***	114 ***	80 ***	77 ***	493 ***
% Correctly predicted	72%	71%	74%	77%	74%	72%

Notes: This table reports results of year-specific and pooled binary logistic regressions carried out with sample A. The binary dependent variable EXIST refers to the existence of GHG-emissions disclosure and is coded 1 for companies reporting GHG-emissions on at least the majority of corporate activities in the year of index inclusion. Logistic regression coefficients are represented. Independent variables are lagged one year to t-1, except those which are constant over time (EU ETS, Industry). ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Note 1: Industry serves as a reference group as it shows the lowest ratio of reporting firms. Year 2009 serves as a reference year for the pooled regression. At the bottom of the table, the number of observations, McFadden R-squared, Log likelihood Chi Square and the % of correctly predicted dependent variable are presented. The cut-off value is 0.50.

Industry affiliation is also a statistically significant determinant of the existence of corporate GHG-disclosure. For example, compared to the reference group, which in these regressions is the industry with the lowest ratio of reporting firms, the odds that a company from the basic materials industry (BASIC_MAT) reports its GHG-emissions for the year 2005 are multiplied by 21.41 (p<0.01). Overall, the likelihood of a company to report GHG-emissions is significantly higher when it comes from high carbon industries, such as the Oil & Gas (OIL_GAS) industry, Basic Materials (BASIC_MAT), Industrials (INDUST) or Utilities (UTIL) industry. In one year under analysis, companies from the Consumer Goods industry (CONS_GOODS) and in two years from the Health Care (HEALTH) and the Telecommunications (TELECOMM) industry were also more likely to report GHG-emissions. In the latter years of the analysis, industry affiliation is not as strong as a determining factor of the existence of GHG-emissions disclosure by companies as it is in the early years. Nevertheless, results show that a portfolio constructed from reporting companies would show a statistically significant different composition with regard to specific industries than a portfolio constructed from non-reporting companies, which impacts its exposure to climate change induced systematic risk. As industry affiliation is known to influence stock performance, industry effects are controlled for when testing the hypotheses developed.

Concerning the model fit, the Log Likelihood chi-square presented at the bottom of Table 13 confirms that the model as a whole is statistically significant in all years under analysis. At a McFadden Pseudo R-squared of between 0.18 and 0.25 the model correctly predicts more than 71% of dependent variables in any given year under analysis.[25] The pooled regression shows a McFadden R-squared of 0.21 and, at a cut-off level of 0.50 in line with Neter et al (1996) and Pampel (2000), correctly predicts 72% of dependent variables. While the model thus does not – and did not aim to – entirely explain the determinants of corporate disclosure of GHG-emissions, it gives sufficient reliability for a meaningful interpretation of the important characteristics of companies reporting or not reporting GHG-emissions. In 2008 the McFadden R-squared drops to 0.18, which is still superior to Pseudo R-squares of other similar studies from the field of environmental reporting (cf. Reid & Toffel, 2009).

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[25] A Pseudo R-squared cannot be analogously interpreted to an OLS R-squared, as logistic regression does not aim to minimize variance. A McFadden Pseudo R-squared of 0.02 to 0.04 is considered highly satisfactory and illustrates the improvement in the log likelihood relative to the baseline log likelihood.

In summary, the analysis showed that companies that report GHG-emissions on at least 50% of corporate activities are bigger in terms of market capitalization. In terms of stock market performance, a portfolio built from reporting companies would thus be expected to underperform a portfolio from non-reporting companies due to the size-effect. This fact supports the necessity to control for size effects in the later analysis. Also, reporting companies are more likely to come from high carbon industries and tend to be affiliated with the EU ETS. A portfolio constructed from reporting companies thus carries increased climate change induced systematic risk. This increased risk is however contrasted by the reduced information and estimation risk of reporting companies (cf. chapter *3.2 Existence of disclosure of GHG-emissions*) and the fact that reporting companies have responded to high implicit energy tax levels and thus reduced the risk related to stakeholder relations. These findings concerning important characteristics of reporting as compared to non-reporting firms are taken into account when analysing results of the hypotheses tested.

4.4.2 Completeness of Corporate GHG-disclosure

In order to determine if companies that report complete GHG-emissions differ in terms of important company characteristics from companies that report incomplete GHG-emissions, an ordered logistic regression analysis is carried out with all companies in sample C. For this analysis, the Disclosure Completeness Index developed in chapter *4.2.1 Collection of GHG-emissions data* is taken as an ordinal dependent variable. Industry dummy variables are not included in this model due to the low number of companies from a specific industry in each category of the ordinal dependent variable (“frequency of events”). To rule out the methodological problems that can arise from low frequencies of events in ordered logistic regression (Peduzzi, Concato, Kemper, Holford, & Feinstein, 1996), industries are merged into a binary dummy variable for affiliation with high carbon industries.

The full model specification for examining the characteristics of complete as compared to incomplete reporting companies is:

$$\mathrm{COMP} = \beta_1\,(\mathrm{EU\_ETS}) + \beta_2\,(\mathrm{EN\_TAX}) + \beta_3\,(\mathrm{LEV}) + \beta_4\,(\mathrm{PROF}) + \beta_5\,(\mathrm{MA\_CAP}) + \beta_6\,(\mathrm{IND\_HC}) \qquad (2)$$

Where:

COMP	is an ordinal variable that can take values from 0 to 3 based on the score of a company on the Disclosure Completeness Index.
IND_HC	is a binary dummy variable coded 1 for companies belonging to high carbon industries, 0 otherwise.

Other variables as defined earlier.

Table 14 displays the results of the year-specific and the pooled logistic regressions taking the score of a company on the Disclosure Completeness Index (COMP) as a dependent variable. It is noticeable that the model fit is extremely low, with a McFadden R-squared of as low as 0.02 in the year 2009. Nevertheless, the Log Likelihood chi-square presented at the bottom of the table confirms that the model as a whole is statistically significant in all years under analysis, i.e. not all indicators in the model are insignificant. However, only in the year 2008 the model correctly predicts the majority of dependent variable scores. While the indicators chosen for this analysis thus do not serve to entirely explain the levels of completeness of GHG-emissions disclosure by companies, the model allows for an interpretation of results with regard to important characteristics of complete versus incomplete reporting companies.

For example, results show that companies with installations in the EU ETS (EU_ETS) were significantly less likely to report complete GHG-emissions in the years 2006 to 2009. The odds for those companies that have installations in the EU ETS to have been classified in a higher category of the Disclosure Completeness Index versus a lower one are about 0.30 ($p <= 0.01$) as high as for those who did not have installations in the EU ETS. This is not a surprising finding in light of the fact that he EU ETS currently only requires reporting of carbon dioxide on specific processes and installations, and not the reporting of group-wide scope 1 and 2 GHG-emissions. From these results, it can be deduced that companies that report incomplete GHG-emissions are more likely to carry climate change induced systematic risk not only proxied by the EU ETS, but also with regard to higher information and estimation risk.

Furthermore, in the years 2005 to 2008, companies coming from countries with high implicit energy tax levels (EN_TAX) were more likely to be classified in a higher category of the Disclosure Completeness Index. For example, in 2006 the odds of being classified in a higher category of the Disclosure Completeness Index versus a lower one were 3.27 times higher ($p<0.05$) with a one-unit increase in the logarithm of the implicit energy tax level of the respective home country. For the years 2005 to 2008, it can be deduced that companies that report complete GHG-emissions have responded to the increased national fiscal pressure by reporting GHG-emissions and thus reduced their risk related to relations with the government as an important stakeholder, while also reducing their estimation risk, as market participants can make an informed estimate based on completely reported GHG-emissions data (cf. chapter *3.3 Disclosure completeness*).

Leverage (LEV) and profitability (PROF) are only found to be a determining characteristic of the completeness of corporate GHG-emissions reporting in one out of five years under analysis. The pooled regression confirms that leverage and profitability are not significant determinants of the completeness of GHG-emissions disclosure by companies for the overall sample period. It is consequently deduced that, generally speaking, there is no difference between companies that report complete GHG-emissions and companies that report incomplete levels of GHG-emissions in terms of the ratio of total debt to common equity or the ratio of return to total assets.[26] Leverage and profitability can consequently be neglected when testing the hypotheses concerning disclosure completeness.

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[26] As a test of robustness of these results the ratio of return to equity, net income and the ratio of debt to assets have been used as indicators. Results remain the same, except in year 2008, where net income is not a significant indicator, and year 2006, where the total debt to assets ratio is not a significant indicator.

Table 14: Results of logistic regression on disclosure completeness

	2005	2006	2007	2008	2009	Pool
EU_ETS	-0.334	-0.820 ***	-0.700 **	-1.137 ***	-0.944 ***	-0.812 ***
EN_TAX	0.926 *	1.184 **	1.318 **	0.836 *	0.492	0.966 ***
LEV	0.000	-0.001 *	0.000	0.000	0.000	0.000
PROF	-0.033	-0.028	-0.001	0.027 **	0.007	0.005
MA_CAP	0.382 ***	0.337 **	0.212 *	0.239 **	0.070	0.217 ***
IND_HC	0.019	0.364	0.279	0.502 *	0.342	0.326 ***
Year 2005	-	-	-	-	-	-1.256 ***
Year 2006	-	-	-	-	-	-1.075 ***
Year 2007	-	-	-	-	-	-0.850 ***
Year 2008	-	-	-	-	-	-0.560 ***
Observations	181	199	229	255	245	1,109
Pseudo R-squared	0.03	0.04	0.03	0.05	0.02	0.04
Chi-Square	13.89 **	19.16 ***	16.12 **	28.52 ***	14.28 **	113.95 ***
% Correctly predicted	48%	49%	46%	52%	46%	48%

Notes: This table reports results of year-specific and pooled ordinal logistic regressions carried out with sample C. The ordinal dependent variable COMP refers to the Disclosure Completeness Index for GHG-emissions. Logistic regression coefficients are represented for each of the years 2005 to 2009 and the pooled regression. All independent variables are lagged one year to t-1, except those which are constant over time (EU ETS, Industry). The Year 2009 serves as a reference year for the pooled regression. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. At the bottom of the table the number of observations, McFadden R-squared, the Log Likelihood Chi Square as well as the % of correctly predicted depentend variables are presented.

A small yet consistently significant determinant for the completeness of GHG-emissions reporting is company size (MA_CAP). In the years 2005 to 2008, larger companies are slightly more likely to report complete GHG-emissions.[27] In contrast to that, affiliation with high carbon industries (IND_HC) generally does not influence the completeness of corporate GHG-disclosure. Only in the year 2008, the likelihood of a company to report complete GHG-emissions is higher when it belongs to a high carbon industry. These companies are consequently not only exposed to climate

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[27] As a test of robustness of these results the logarithm of total assets has been used as an indicator for company size. Total assets is not a significant indicator in year 2005, 2006, 2007, prompting the conclusion that market based measures of size are a better determinant for the completeness of GHG-emissions reporting than book values.

change induced systematic risk as proxied by affiliation with high carbon industries (cf. chapter *3.6 High Carbon Industries*) but also as proxied by the information and estimation risk resulting from incomplete disclosures of GHG-emissions (cf. chapter *3.3 Disclosure Completeness*).

With regard to differences in specific important characteristics of companies that report complete levels of GHG-emissions as compared to companies that tend to report incomplete levels of GHG-emissions, it can be summarized that larger companies in terms of market capitalization are more likely to report complete GHG-emissions. Company size consequently has to be controlled for when testing the hypotheses concerning disclosure completeness (cf. chapter *3.3 Disclosure Completeness*). The finding that comparatively larger companies tend to report complete GHG-emissions also implies that larger companies, which tend to show higher levels of emissions due to their size, report comparatively higher – since complete – emissions. As a result, disclosure completeness has to be controlled for when testing hypotheses concerning absolute levels of emissions and GHG-efficiency, as otherwise lower absolute levels of emissions and higher levels of GHG-efficiency may stem from incomplete emissions reporting by medium and small-cap companies. Reporting incompleteness is consequently controlled for in a test of robustness when testing the hypotheses developed (cf. chapter *5.4.1 Incompleteness of GHG-emissions Data*).

Furthermore, companies affiliated with EU ETS are found to be more likely to report incomplete GHG-emissions and thus further increase their climate change induced systematic risk, as their estimation risk is rises (cf. chapter *3.3 Disclosure Completeness*). In contrast to that, companies from countries with relatively high implicit energy tax levels are found to be more likely to report complete GHG-emissions. Completely reporting companies thus reduce their climate change induced systematic risk by responding to national fiscal pressure and their estimation risk by allowing market participants to correctly assess the climate change induced systematic risk through the complete disclosure of absolute levels of GHG-emissions.

The results obtained from his in-depth analysis of sample characteristics are taken into account when analysing the results of the hypotheses tested in the remainder of this thesis. They are also reflected in the methodology applied to test the hypotheses, which is introduced in detail in the following chapter.

Chapter 5
Methodology

In this chapter, the methodology applied to test the hypotheses developed in chapter *3 Hypotheses Development* is motivated and explained. As discussed in chapter *2.1.4 Methodologies and Findings*, test of market efficiency suffer from a Joint Hypothesis Problem, as market efficiency cannot be tested without simultaneously testing the underlying model used for the estimation of expected returns. While this circumstance cannot be removed, its effect is minimised through the use of two of the most established asset pricing models for test of market efficiency, the CAPM and the C4FM, in this research.

The CAPM is the traditional model applied in tests of market efficiency, as it stipulates that portfolio returns can be explained exclusively by systematic risk. It thus relates to the basic notion of the EMH, in which investors are rewarded only for taking systematic risk (cf. chapter *2.1.2 Definitions and Important Notions of EMH*). After the emergence of different risk premiums over time (cf. chapter *2.1.4 Methodologies and Findings*), the C4FM has become a standard model for testing market efficiency (Fama & French, 2010). Applying the C4FM ensures that any potential market inefficiency found is not in fact driven by factors other than beta, which are however already known to determine abnormal stock performance.

After the two models are introduced in chapter *5.1 CAPM* and chapter *5.2 C4FM* respectively, additional control variables are motivated and added to the C4FM in chapter *5.2.1 Controlling for Industry Effects* and chapter *5.4 Tests of Robustness*. These control variables represent industry effects, changes in the price of carbon and oil, as well as a control variable for the impact of financial market crisis. Further tests of robustness include portfolio creation in June of each respective year, as well as the construction of portfolios with GHG-emissions data from year t-2.

In chapter *5.3 Portfolio Construction*, portfolios are formed based on the six proxies for climate change induced systematic risk introduced in chapter *3 Hypotheses*

Development, which will allow testing market efficiency towards the respective proxies. Portfolios, rather than individual stocks, are used in this research as the precision of their estimated betas is known to be higher (Fama & French, 2004). CAPM and C4FM are estimated using OLS regression and the software Eviews. Coefficient covariances and standard errors in all following regressions are made heteroscedasticity and autocorrelation consistent based on the approach of Newey & West (1987).

5.1 CAPM

The first model applied in this study is the CAPM, which was created by Sharpe (1964), Lintner (1965) and Mossin (1966). CAPM conceptually implies that portfolio returns can be explained by systematic risk, which is represented by the coefficient beta. The alpha coefficient in the CAPM describes the return of a portfolio in excess of the compensation for the systematic risk borne. As discussed, in an efficient market investors would not be able to persistently achieve returns in excess of the return rewarded for the systematic risk borne, i.e. alpha would correspond to zero. CAPM thus lends itself very well to testing market efficiency and is defined as (Brooks, 2008):

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \varepsilon_{it} \tag{3}$$

Where:

R_{it}	is the logarithm of the continuously compounded return of portfolio i at month t.
R_{ft}	is the logarithm of the continuously compounded risk-free return rate.
α_i	is the alpha coefficient.
β_i	is the beta coefficient.
R_{mt}	is the logarithm of the continuously compounded return of the market.
ε_{it}	is the error term that captures the return variation that cannot be explained by the model.

Each variable of the model is briefly explained in the following paragraphs.

As described above, R_{it} is the logarithm of the continuously compounded return of a portfolio i. Portfolio i is the respective portfolio formed based on one of the six proxies for climate change induced systematic risk (cf. chapter *5.3 Portfolio Construction*). R_i is calculated for each month t in the study based on the Return Index extracted from Datastream (cf. chapter *4.3.5 Other Indicators*), which stipulates that dividends are reinvested to purchase additional units of stocks.[28] R_{it} in this research is calculated for equal- and value-weighted portfolios. To calculate R_{it} for an equal-weighted portfolio, the Return Index at month t of each share in the portfolio is divided by the Return Index at month t-1 of each share in the portfolio. The continuously compounded monthly return of an equal-weighted portfolio is then generated by computing the natural logarithm of the average equal-weighted return of all shares in the portfolio. To calculate R_{it} for value-weighted portfolios, the market capitalizations of all shares in the portfolio at month t are summed and the market capitalization of a share is divided by the total market capitalization of the portfolio. The resulting market weight is multiplied with the return of each share, which again is calculated by dividing the Return Index at month t by the Return Index at month t-1. The continuously compounded monthly return of a value-weighted portfolio is then generated by computing the natural logarithm of the sum of all value-weighted returns of all shares in the portfolio.

R_{ft} is the logarithm of the continuously compounded risk-free return rate. As described in chapter *4.2.2 Collection of Other Data*, the three months Euribor-rate is used as risk-free rate of return. In order to convert the three months Euribor-rate into the monthly continuously compounded risk free return an investor would receive, each per annum stated return is transformed into a 91 days return by multiplying it with 91/365.25. Subsequently, one is added to the result and the sum is taken to the power of 30.4375/91, whereby 30.4375 is one twelfth of 365.25 days, i.e. one month. The continuously compounded monthly risk free return is then obtained by computing the natural logarithm of the result (cf. Hoepner, Rezec, & Siegl, 2011b). In

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[28] Ignoring dividend payments would result in underestimating the total returns that arise to investors (Brooks, 2008) and can lead to an overestimation of growth stocks, which usually have large capital gains, compared to income stocks, which pay high dividends.

this study, the annualised average risk free return corresponds to 3.08% at a mean standard deviation of 0.004.

α_i in the CAPM is the alpha coefficient, which represents the portfolio's return in excess of the compensation for the systematic risk borne. As described, in an efficient market, the alpha of a portfolio equals zero as investors are not able to persistently generate abnormal returns in excess of the return rewarded for the systematic risk borne. Systematic risk is represented in the CAPM by the coefficient β_i. As discussed before, beta represents the non-diversifiable risk of a portfolio and measures the sensitivity of portfolio returns to market returns.

R_{mt} is the logarithm of the continuously compounded return of the market at month t. In this study, the return of the market is depicted by the return of all non-financial European constituents of the FTSE AWI, i.e. all companies in sample A. The equal- and value-weighted R_{mt} is obtained by putting all shares of sample A in a market portfolio and following the calculation of the equal- and value-weighted returns of portfolio R_{it} described above. The mean annualised equal-weighted return of the market portfolio in excess of the risk free return (R_m - R_f) over the period studied corresponds to 3.10% at a mean SD of 0.19 (see Table 15).

Finally, ε_{it} corresponds to the error term, which captures the variation in portfolio returns that is not explained by the model. As no model can fully represent the relationship between the independent variables and the dependent variable, the error term captures the remaining inaccuracy of a model.

5.2 C4FM

Almost 30 years after the emergence of the CAPM and as a response to the emerging evidences of patterns in stock returns based on size and book to market ratios (cf. chapter *2.1.4 Methodologies and Findings*), the model was extended by Fama and French (1993). They introduced a control factor into the CAPM for the size effect, i.e. the continuously observed excess returns of small-cap over large-cap stocks (SMB factor). Furthermore, Fama and French (1993) added a control factor for the excess returns of value stocks over growth stocks into the model (HML factor). The inclusion of these two factors in the CAPM reduced the significance and importance of the beta coefficient and created the so called Fama and French Three Factor Model. Shortly afterwards, Carhart (1997) added the momentum factor (UMD factor) (cf chapter *2.1.4 Methodologies and Findings)* to the Fama and French Three Factor Model. The momentum factor controls for the effect that past winners (losers) continue to perform well (poorly), which was evidenced by Jegadeesh and Titman (1993). The resulting Carhart 4 Factor Model (C4FM)f is the dominant asset pricing model currently applied in tests of market efficiency (Fama & French, 2010) and one of the prevailing models in studies examining the performance of SRI portfolios (cf. Derwall et al., 2005; Kempf & Osthoff, 2007; Ziegler et al., 2011).

The controversy over the correct explanation of factors such as size or momentum is discussed in chapter *2.1.4 Methodologies and Findings* and is not further elaborated in the remainder of this research. The factors included in the C4FM have been proven to persistently determine returns in many markets and are consequently controlled for in the methodology applied in this research to ensure that any potential market inefficiency identified cannot be explained by factors generally known to explain stock performance.

The C4FM is defined as:

$$R_{it} - R_{ft} = \alpha_i + \beta_i\left(R_{mt} - R_{ft}\right) + s_i SMB_t + h_i HML_t + p_i UMD_t + \varepsilon_{it} \tag{4}$$

Where:

s_i	is the coefficient that measures the sensitivity of the portfolio's return to the SMB factor.
SMB_t	is the measure for the historic excess returns of small-cap over large-cap stocks.
h_i	is the coefficient that measures the sensitivity of the portfolio's return to the HML factor.
HML_t	is the measure for the historic excess returns of value stocks over growth stocks.

p_i	is the coefficient that measures the sensitivity of the portfolio's return to the UMD factor.
UMD_t	is the measure for the historic excess returns of winner-stocks over loser-stock.

Other variables as defined earlier.

Explanations of those variables in the C4FM that are identical to the CAPM are not repeated here. The calculation of SMB_t (small-minus-big factor), HML_t (high-minus-low factor) and UMD_t (up-minus-down factor) in line with Fama and French (1992) and Carhart (1997) respectively is explained in the following.

First, the stocks included in this study are ranked in descending order based on their market capitalisation in December of year t-1. The stocks are then divided into two portfolios, which are re-formed on a yearly basis: The small-cap portfolio (S) contains the stocks with a market capitalisation below the median market capitalisation of the companies included in this research. The large-cap portfolio (B) contains the stocks with a market capitalisation above the median market capitalisation of the companies included in this research.

Subsequently, the stocks included in this research are divided into three portfolios depending on their book to market ratio. As described in chapter *4.3.5 Other Indicators*, the book to market ratio is calculated by dividing common equity in December at year t-2 by market capitalisation in December of year t-1.[29] Stocks with a book to market ratio below the 30th percentile of book to market ratios of firms in this sample are placed in the “low” portfolio (L). Stocks with a book to market ratio that is in the middle 40 % of book to market ratios of firms in this research are put in the “medium” portfolio (M). Stocks with a book to market ratio in the top 30 % of

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[29] As portfolios are created in January, book values from t-2 are taken to make sure the information used is known to the market. As a test of robustness, portfolios are created in June and for this test of robustness book values are taken from year t-1 (cf. chapter *5.4.5 Portfolio Creation in June*).

book to market ratios of firms in this sample are placed in the “high” portfolio (H). The resulting L, M and H portfolios are re-formed on a yearly basis. In line with Fama and French (1995), firms with a negative book to market ratio are excluded when calculating the percentage breakpoints for the L/M/H portfolio construction or when forming the respective portfolios. Firm with negative book to market ratio correspond to less than 2.5% of the yearly observations in sample A.

Next, six cross sectional portfolios (SL, SM, SH, BL, BM, and BH) are formed, where for example the SL portfolio contains stocks categorized as small-cap (S) and having a low book to market ratio (L). The monthly returns on the six portfolios are calculated for the 12 months following portfolio formation analogously to the calculation of return of R_{it} described in chapter *5.1 CAPM*. This process is repeated for all years and carried out for equal and value-weighted portfolio returns. Subsequently the SMB factor can be calculated. SMB_t is the difference between the returns on the three small stock portfolios and the three big stock portfolios at month t, while adjusting for the difference in returns of stock with differing book to market ratios. SMB factors are calculated for every month t in this study with equal- and value-weighted portfolios. The formula used to calculate SMB_t is defined as:

$$SMB_t = \ln\left(1 + \frac{SH_t + SM_t + SL_t}{3} - \frac{BH_t + BM_t + BL_t}{3} \right) \tag{5}$$

Following the same procedure, the HML_t factor can be calculated by deducting the returns of a portfolio constructed from stocks with a high book to market ratio at month t from the returns of a portfolio constructed from stocks with a low book to market ratio, while adjusting for the difference in returns of stock with differing size. HML factors are calculated for every month t in this study with equal- and value-weighted portfolios. The formula used to calculate HML is defined as:

$$HML_t = \ln\left(1 + \frac{BH_t + SH_t}{2} - \frac{BL_t + SL_t}{2} \right) \tag{6}$$

The UMD factor, which is also referred to as MOM or PR1YR (Carhart, 1997), is constructed by allocating those 30% of the stocks with the highest average return in the 12 months period preceding portfolio construction in to “winner” or “up” portfolio (U). The “loser” or “down” portfolio (D) contains those 30% of the stocks with the lowest average prior performance in the 12 months period preceding portfolio construction. The UMD_t factor is updated monthly and calculated as the returns on the U portfolio at month t minus the returns on the D portfolio at month t:

$$UMD_t = \ln\,(1 + U_t - D_t) \qquad (7)$$

The market capitalisation at the end of each year and the number of companies in each of the respective portfolios is depicted in Table 15. Furthermore, the mean annualised returns in excess of the risk free rate of return of the portfolios used to construct the respective SMB, HML and UMD factors are detailed in Table 15. It is noticeable that over the five year period of this study, two of the portfolios constructed from small-cap companies (SH, SM) underperform portfolios constructed from large-cap companies (BH, BM) on the basis of equal-weighted mean annualised returns. The performance of these two portfolios is against the prediction of the size premium, which would stipulate that portfolios constructed from small-cap companies outperform portfolios constructed from large-cap companies. The extraordinary performance is probably attributable to the effect of the crisis of the financial market in the second half of the period under analysis, which had a stronger negative impact on smaller firms (Campello, Graham, & Harvey, 2010).

Table 15: Annualised excess returns of cross-sectional portfolios

Portfolio	Annualised excess returns EW Mean	EW SD	VW Mean	VW SD	No. of stocks in portfolio 2005	2006	2007	2008	2009	MV of portfolio in trillion € 2005	2006	2007	2008	2009
R_m-R_f	3.10%	0.19	2.50%	0.16	348	351	353	360	342	4.19	4.94	5.61	3.39	3.83
SH-R_f	4.65%	0.26	5.62%	0.23	58	59	53	68	67	0.20	0.25	0.23	0.12	0.18
SM-R_f	3.11%	0.21	3.92%	0.20	60	60	66	66	61	0.21	0.28	0.27	0.15	0.20
SL-R_f	0.83%	0.19	1.22%	0.18	48	54	52	42	39	0.16	0.23	0.22	0.10	0.11
BH-R_f	5.48%	0.19	6.06%	0.17	44	45	52	40	36	0.75	0.96	1.39	0.60	0.64
BM-R_f	5.14%	0.18	4.24%	0.17	75	77	71	75	73	1.61	1.96	2.13	1.39	1.51
BL-R_f	0.18%	0.15	-1.64%	0.14	53	50	52	65	62	1.22	1.24	1.34	1.03	1.18
U-R_f	1.78%	0.17	2.22%	0.14	104	105	106	108	103	1.78	2.06	2.29	1.58	1.69
D-R_f	2.60%	0.21	2.42%	0.18	104	106	106	108	103	0.82	0.97	1.26	0.72	0.85

Notes: This table reports the annualised returns of the SL, SM, SH, BL, BM, BH, U and D portfolios, as well as the market portfolio, in excess of the risk free rate of return R_f. The first column depicts the mean and standard deviation (SD) of the equal-weighted (EW) and value-weighted (VW) annualised excess returns respectively. The following columns show the number of stocks, as well as the market value (MV) in trillion € of each portfolio at the end of each respective year.

The remaining variables in the C4FM, s_i, h_i and p_i, are coefficients that measure the sensitivity of a portfolio concerning the respective factors SMB, HML and UMD. s_i is the coefficient that measures the sensitivity of the portfolio's return to the SMB factor. Large-cap portfolios load negatively on SMB, i.e. s_i is statistically significant and negative. Small-cap portfolios have a statistically significant and positive value for s_i. h_i is the coefficient that measures the sensitivity of the portfolio's return to the HML factor. Portfolios of value stocks have a statistically significant and positive value for h_i. p_i is the coefficient that measures the sensitivity of the portfolio's return to the UMD factor. Portfolios constructed from winner-stocks have a statistically significant and positive value for p_i.

C4FM forms one of the base models for this research. However, the in-depth analysis of sample characteristics in chapter *4.4 Understanding Sample Characteristics* evidenced that additional control variables are necessary to ensure that results are not driven by, for example, industry effects. Additional control variables are consequently included in the C4FM in chapter *5.2.1 Controlling for Industry Effects* and chapter *5.4 Tests of Robustness*.

5.2.1 Controlling for Industry Effects

Among others, Fama and French showed that different industries display significant differences in risk exposure (Campbell et al., 2001; Fama & French, 1997). If this risk is not efficiently priced by financial markets, the different industry composition of the various portfolios i would distort results. In fact, industry composition is generally thought to impact portfolio returns and not controlling for these effects can result in a misleading interpretation of results (Dess, Ireland, & Hitt, 1990). DiBartolomeo and Kurtz (1999) showed that SRI portfolio returns posit no exception in this context. For example Lewellen, Nagel, and Shanken (2010) suggest that therefore portfolios sorted by industry must be included in asset pricing models. Furthermore, Hsu, Kalesnik, and Wermers (2011) argue that investment practitioners tend to focus more heavily on industry factors than academia traditionally has in models of asset pricing. Industry effects are consequently controlled for in this research, to make sure the results obtained with the C4FM are not driven by differences in industry composition of the respective portfolios i and possibly incorrectly priced industry performance.[30] At the same time, controlling for industry effects potentially raises the interest for results of this study from investment practitioners.

To illustrate the potentially distorting effect of industry composition on portfolio returns, returns of industry-specific portfolios in the C4FM are shown in Table 16. Industries are sorted according to their ICB codes (cf. chapter *4.1 Sample Selection*). Table 16 shows that for example a portfolio constructed from all Utilities (ICB 7000) in sample A generates a significant annualised alpha of 5.5%, i.e. according to the C4FM the market was inefficient in pricing Utilities companies from 2005 to 2009. As evidenced in chapter *4.4.1 Existence of Corporate GHG-disclosure*, companies from the Utility industry are more likely to report GHG-emissions. Consequently, the performance of a portfolio constructed from GHG-reporting companies could be

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[30] Industry effects are not controlled for when portfolio formation is based or loosely based on industry affiliation, as it is the case for portfolios formed based on the affiliation of companies with high carbon industries or the EU ETS. Controlling for industry effects in the respective regressions would cancel out the climate change induced systematic risk at industry level, which is of interest in the context of these two portfolios.

driven by its higher share of companies from the Utility industry. At the same time, as shown in chapter *4.3.4 Industry Affiliation and Affiliation with the EU ETS*, companies from the Health Care (ICB 4000), Consumer Services (ICB 5000) and Technology (ICB 9000) industries show a low share of reporting companies. To eliminate the possibility that a portfolio constructed from companies that do not report GHG-emissions is driven by the performance of these inefficiently priced industries, industry effects are controlled for.

Table 16: Regression results: Industry portfolios

Portfolio	ICB	α	(Rm-Rf)	SMB	HML	UMD	Adj. R^2
Oil & Gas	0001	5.99%	1.090 ***	-0.343	-0.563 **	-0.572 **	0.713
Basic Materials	1000	9.10%	1.249 ***	0.235	-0.267	-0.696 ***	0.837
Industrials	2000	-0.10%	1.139 ***	0.221	0.014	0.099	0.962
Consumer Goods	3000	1.74%	0.910 ***	0.014	0.237 *	0.094	0.904
Health Care	4000	7.59% **	0.733 ***	-0.299	-0.277	0.208	0.676
Consumer Services	5000	-9.88% ***	0.942 ***	0.309 **	0.220 *	0.423 ***	0.941
Telecommunications	6000	-1.73%	0.733 ***	-1.071 ***	0.115	-0.207	0.670
Utilities	7000	5.50% *	0.926 ***	-0.597 ***	-0.343 **	-0.173	0.793
Technology	9000	-10.90% **	1.129 ***	0.155	0.273	-0.275	0.846

Notes: This table reports C4FM regression results for industry-specific portfolios from January 2005 to December 2009 using monthly equal-weighted returns and equal-weighted SMB, HML and UMD factors. Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

To be able to control the returns of portfolio i in the C4FM for industry-effects, orthogonalised industry performance variables are added to the model (cf. Derwall et al., 2005; Geczy et al., 2005; Hoepner et al., 2011a). Othogonalisation is “[a] statistical technique that makes two or several factors […] independent of each other” (Drummen & Zimmermann, 1992, p. 16). Orthogonalised industry returns in this study represent the share of the return of an industry that cannot be explained by market developments and constitute purely industry-specific return characteristics. Variables representing industry performance that were made orthogonal to the market thus allow controlling for industry effects in the model, while avoiding the problems of multicollinearity that may arise from including market and industry returns in the same model. The definition of the C4FM that has been extended with orthogonalised industry returns is:

$$\begin{aligned} R_{it} - R_{ft} = \; & \alpha_i + \beta_i\left(R_{mt} - R_{ft}\right) + s_i SMB_t + h_i HML_t + p_i UMD_t + m_i 0001_t \\ & + n_i 1000_t + o_i 2000_t + r_i 3000_t + u_i 4000_t + v_i 5000_t \\ & + w_i 6000_t + x_i 6000_t + y_i 7000_t + z_i 9000_t + \varepsilon_{it} \end{aligned} \tag{8}$$

Where:

0001_t	is the orthogonalised return of a portfolio constructed from companies from the Oil & Gas industry (ICB 0001).
1000_t	is the orthogonalised return of a portfolio constructed from companies from the Basic Materials industry (ICB 1000).
2000_t	is the orthogonalised return of a portfolio constructed from companies from the Industrials industry (ICB 2000).
3000_t	is the orthogonalised return of a portfolio constructed from companies from the Consumer Goods industry (ICB 3000).
4000_t	is the orthogonalised return of a portfolio constructed from companies from the Health Care industry (ICB 4000).
5000_t	is the orthogonalised return of a portfolio constructed from the Consumer Services industry (ICB 5000).
6000_t	is the orthogonalised return of a portfolio constructed from companies from the Telecommunication industry (ICB 6000).
7000_t	is the orthogonalised return of a portfolio constructed from companies from the Utilities industry (ICB 7000).
9000_t	is the orthogonalised return of a portfolio constructed from companies from the Technology industry (ICB 9000).
m_i, n_i, o_i, r_i, u_i, v_i, w_i, x_i, y_i, z_i	are the coefficients that measure the sensitivity of the portfolio's return to the respective orthogonalised industry returns.

Other variables as defined earlier.

The orthogonalised industry returns 0001 to 9000 for month t are obtained by forming portfolios with all companies from a respective industry and regressing the returns of the respective industry portfolio in month t on the returns of the market in the CAPM. Subsequently, the intercept and the residuals of that regression are summed up to obtain the orthogonalised industry return for month t (Elton, Gruber, Das, & Hlavka, 1993). As a result, there is zero correlation between industry and market returns and no problem of multicollinearity exists in a model that includes market returns and controls for industry performance.

The Pearson correlation matrix for equal-weighted orthogonalised industry returns is shown in Table 17 below. Interestingly, orthogonalised returns of the Consumer Services industry (ICB 5000) show a medium negative correlation of -0.55 with the Oil & Gas (ICB 0001) and Basic Materials sector (ICB 1000) respectively. In order to detect potential problems with multicollinearity between the orthogonalised industry returns, a VIF analysis was performed. At a maximum VIF of 1.74 no serious problems of multicollinearity have been detected (Marquardt 1970).

Table 17: Pearson correlation matrix for orthogonalised industry returns

ICB	0001	1000	2000	3000	4000	5000	6000	7000	9000
0001	1								
1000	0.43	1							
2000	-0.39	-0.31	1						
3000	-0.36	-0.26	-0.03	1					
4000	0.22	-0.11	-0.19	-0.23	1				
5000	-0.55	-0.55	0.10	0.02	-0.22	1			
6000	0.03	-0.21	-0.15	-0.17	0.03	-0.06	1		
7000	0.30	-0.11	-0.18	-0.30	0.32	-0.31	0.10	1	
9000	-0.07	-0.05	-0.20	-0.05	-0.04	0.05	0.01	-0.26	1

Notes: This table reports Pearson correlation coefficients for orthogonalised equal-weighted industry returns.

5.3 Portfolio Construction

In the following paragraphs, the construction of portfolios i is detailed, which allow testing the level of market efficiency toward climate change induced systematic risk based on the six proxies introduced in chapter *3 Hypotheses Development*. For every hypothesis a set of mutually exclusive portfolios for two trading strategies is formed. First, a simple buy-and-hold strategy is pursued, i.e. mutually exclusive portfolios are constructed and updated once per year. Second, a long-short trading strategy is pursued, which allows determining whether active investors can generate economically significant abnormal returns by taking advantage of performance differences between the mutually exclusive portfolios. The construction of portfolios for both trading strategies is detailed in the remainder of this chapter.

5.3.1 Buy and Hold Strategy

To test the hypothesis concerning affiliation with the European Emissions Trading Scheme as a proxy for climate change induced systematic risk (cf. chapter *3.1 European Emissions Trading Scheme*) with a buy-and-hold trading strategy, two portfolios are constructed. The first portfolio (EU ETS) contains all companies in sample A that are affiliated with the trading scheme. The second portfolio (Not in EU ETS) contains all companies in sample A that are not affiliated with the scheme. The composition of both portfolios is detailed in Table 18. Table 18 shows that in terms of market capitalisation at the end of the year, the EU ETS portfolio is very similar to the Not EU ETS portfolio, although the latter includes twice the number of companies, i.e. on average companies in the EU ETS are much bigger in terms of market capitalization. This fact again underlines the need to control portfolio performance for company size.

Table 18 also shows the mean annualised returns in excess of the risk free rate of the respective portfolios. On the basis of these excess returns the EU ETS portfolio strongly outperforms the portfolio constructed from companies that are not affiliated with the EU ETS. However, as these returns are not adjusted for risk, and factors generally known to explain stock market performance are not controlled for, no preliminary conclusion should be drawn with regard to market efficiency or the hypotheses developed. To adjust returns for risk and control for factors generally accepted to explain stock market performance, portfolio returns are regressed on the CAPM and C4FM, as described in chapter *5.1 CAPM* and chapter *5.2 C4FM.*

Table 18: Annualised excess portfolio returns

Portfolio	Annualised excess returns				No. of stocks in portfolio					MaV of portfolio in trillion €				
	EW		VW											
	Mean	SD	Mean	SD	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Affiliation to European Emissions Trading Scheme														
EU ETS -R_f	7.02%	0.20	4.93%	0.17	103	105	111	113	112	1.95	2.45	2.87	1.80	1.93
Not in EU ETS -R_f	1.33%	0.19	0.40%	0.16	245	247	242	247	231	2.24	2.49	2.74	1.60	1.90
Existence of Disclosure														
Reporting GHG -R_f	5.18%	0.19	2.95%	0.16	148	185	204	242	249	2.91	3.73	4.50	3.03	3.37
Not Reporting GHG -R_f	0.34%	0.20	1.59%	0.19	200	167	149	118	94	1.29	1.21	1.11	0.36	0.45
Disclosure Completeness														
0 Score -R_f	2.02%	0.20	2.10%	0.17	23	22	14	16	12	0.37	0.31	0.19	0.11	0.12
1 Score -R_f	5.36%	0.19	3.14%	0.15	63	81	89	94	76	0.94	1.37	1.93	1.27	1.04
2 Score -R_f	4.61%	0.20	2.23%	0.16	49	65	78	100	118	1.43	1.71	1.86	1.21	1.59
3 Score -R_f	7.49%	0.18	5.80%	0.17	13	17	23	32	43	0.17	0.35	0.52	0.45	0.62
Absolute levels of GHG-emissions														
High GHG -R_f	8.75%	0.20	5.36%	0.18	44	56	61	73	75	1.16	1.66	2.05	1.48	1.47
Medium GHG -R_f	4.83%	0.19	0.76%	0.14	59	74	82	97	100	1.25	1.51	1.86	1.16	1.33
Low GHG -R_f	1.89%	0.19	2.91%	0.16	44	56	61	73	75	0.50	0.56	0.60	0.39	0.57
Level of GHG-efficiency														
High GHG-efficiency -R_f	2.37%	0.17	1.31%	0.14	44	56	61	73	75	1.01	1.09	1.28	0.91	1.16
Medium GHG-efficiency -R_f	5.54%	0.18	3.95%	0.16	59	74	82	97	100	1.13	1.65	1.84	1.23	1.46
Low GHG-efficiency -R_f	7.17%	0.23	4.00%	0.20	44	56	61	73	75	0.77	0.99	1.38	0.89	0.75
Affiliation to high carbon industries														
High Carbon Industry -R_f	6.98%	0.21	5.28%	0.19	147	152	160	168	172	1.83	2.38	2.89	1.74	1.98
Low Carbon Industry -R_f	-0.08%	0.18	0.30%	0.14	201	200	193	192	171	2.29	2.56	2.72	1.66	1.85

Notes: This table reports the annualised returns of the respective portfolios in excess of the risk free rate of return R_f. The first column depicts the mean and standard deviation (SD) of the equal-weighted (EW) and value-weighted (VW) annualised average excess returns respectively. The following columns show the number of stocks in each portfolio in each year of the study. The remaining columns show the market value (MaV) of each portfolio at the end of each respective year in trillion €.

To be able to test the hypothesis concerning the existence of GHG-emissions disclosure as a proxy for climate change induced systematic risk (cf. chapter *3.2 Existence of Disclosure of GHG-Emissions*), two mutually exclusive portfolios are constructed. The first portfolio (Reporting GHG) contains all companies of sample A that disclose GHG-emissions on at least the majority of corporate activities. The second portfolio (Not reporting GHG) is constructed from all companies in sample A that do not report their GHG-emissions to the public. Table 18 illustrates that on the basis of mere mean annualised equal-weighted returns in excess of the risk free rate of return, the portfolio constructed from reporting companies significantly outperforms the portfolio of non-reporting companies.

To test the hypothesis concerning the completeness of GHG-emissions disclosure as a proxy for climate change induced systematic risk (cf. chapter *3.3 Disclosure completeness*), four mutually exclusive portfolios are constructed from companies in sample B. Companies are allocated to these four portfolios based on their respective score on the Disclosure Completeness Index (cf. chapter *4.2.1 Collection of GHG-emissions data*), where a score of 0 corresponds to incomplete GHG-emissions reporting and a score of 3 corresponds to complete reporting of scope 1 and 2 GHG-emissions for a group-wide reporting boundary. The mean annualised returns in excess of the risk-free rate of return of each of the four portfolios (0 Score, 1 Score, 2 Score, 3 Score) are illustrated in Table 18. It is noticeable that these basic return statistics suggest that the portfolio of completely reporting companies (Score 3) strongly outperforms the portfolio constructed from incomplete reporting companies (Score 0). As can be seen from Table 18, the number of companies in these two portfolios is low, yet still sufficiently high to ensure that equal-weighted portfolio results are not driven by individual companies’ performance.

As described in chapter *3.4 Absolute Levels of Emissions,* portfolios constructed to test the hypothesis concerning absolute levels of GHG-emissions as a proxy for climate change induced systematic risk follow the portfolio categorization rules of Fama and French (1995). Based on their absolute emission levels, companies in sample B are arranged in three portfolios: The first portfolio consists of companies with the highest 30% of reported absolute levels of GHG-emissions in sample B (High GHG). Companies reporting absolute levels of reported GHG-emissions that fall within the medium 40% of GHG-emissions reported are classified as medium emitters and allotted to the second portfolio (Medium GHG). The final portfolio (Low GHG) consists of those companies in sample B with the lowest 30% of absolute levels of reported emissions. It is noticeable form Table 18 that based on mean annualised returns in excess of the risk-free rate of return, the High GHG-portfolio strongly outperforms the Low GHG-portfolio, with regard to both equal- and value-weighted returns. It is of further interest to note that with an equal amount of companies, the market capitalisation of the High GHG portfolio is more than twice as big, thus underlining the need to control portfolio performance for company size.

Following the same rule for portfolio formation, three portfolios based on GHG-efficiency, expressed as the ratio of net income to absolute amounts of reported emissions (cf. chapter *4.3.5 Other Indicators*), are created to test the respective hypothesis (cf. chapter *3.5 GHG-efficiency*). The first portfolio (High GHG-efficiency) consists of companies with a GHG-efficiency that falls within the highest 30% of reported levels of GHG-efficiency in sample B. A second portfolio (Medium GHG-efficiency) consists of those companies with a reported GHG-efficiency that is in the medium 40% of reported levels of GHG-efficiency, while a third portfolio is formed with those companies that reported a GHG-efficiency that falls within the lowest 30% of GHG-efficiency in sample B (Low GHG-efficiency). Table 18 indicates that based on mean annualised returns in excess of the risk-free rate of return, the High GHG-efficiency portfolio strongly outperforms the Low GHG-efficiency portfolio, in terms of both equal- and value-weighted returns.

The final proxy for climate change induced systematic risk is affiliation with high carbon industries (cf. chapter *3.6 High Carbon Industries*). To test the hypothesis concerning affiliation with high carbon industries, again, two mutually exclusive portfolios are constructed. Companies in sample A that are affiliated with a high carbon industry are allocated to one portfolio (High carbon industry) and companies that are not affiliated with a high carbon industry to another one (Low carbon industry). Based on mean annualised excess returns the High carbon industry portfolio strongly outperforms the Low carbon industry portfolio, in terms of both equal- and value-weighted returns (see Table 18). However as discussed, no preliminary conclusion should be drawn with regard to market efficiency or the hypotheses developed, as these portfolio returns are not adjusted for risk and factors generally accepted to explain stock market performance are not controlled for.

5.3.2 Long-short Trading Strategy

A supplementary trading strategy is applied in the testing of all hypotheses. This trading strategy consists of buying the stocks in one of the mutually exclusive portfolios (going long) while selling the stocks in the other portfolio (going short). These so called long-short portfolios are constructed by subtracting the monthly returns (cf. chapter *5.1 CAPM*) of the portfolio that is bought, e.g. Reporting GHG, from the excess return of the portfolio which is sold, e.g. Not reporting GHG (John & Miller, 1996). The result of this subtraction is regressed on the C4FM extended with industry effects. As a result, it is possible to obtain the performance of portfolios based on a long-short trading strategy while controlling for factors generally known to explain stock performance and industry effects.

Long-short trading allows illustrating whether an active investor taking advantage of performance differences between the mutually exclusive portfolios can generate abnormal returns. As hypothesised for the buy-and-hold strategy discussed above, in an efficient market, long-short trading should not result in economically significant risk-adjusted abnormal returns.

5.4 Tests of Robustness

Different tests of robustness are carried out to verify the validity of results obtained. First, additional portfolios are formed that allow excluding the possibility that results obtained with absolute levels of GHG-emissions are driven by incompletely reported GHG-emissions data. Second, the C4FM extended with industry variables is complemented with factors that allow controlling for changes in the price of oil and carbon, as well as the impact of the financial crisis. These additional control variables (ACV) are included in the analysis to determine whether results are driven by exposure to these variables rather than climate change induced systematic risk. Furthermore, to eliminate the possibility that the timeliness of reported data significantly impacts results, portfolios are created in June of each year and, in a final test of robustness, with GHG-emissions data from year t-2. Each of the tests of robustness is briefly described in the following paragraphs.

5.4.1 Incompleteness of GHG-emissions Data

As described in chapter *4.4.2 Completeness of Corporate GHG-disclosure*, controlling for the incompleteness of reported emissions data is important to ensure that results obtained from testing the hypotheses concerning absolute levels of GHG-emissions and GHG-efficiency are not driven by incompletely reporting companies. To that end, the score of a company on the Disclosure Completeness Index (cf. chapter *4.2.1 Collection of GHG-emissions Data*) is divided by the sum of all scores of companies on the Disclosure Completeness Index in a respective portfolio at month t. The resulting disclosure completeness weight is multiplied with the returns of the respective stocks in the portfolio. The continuously compounded monthly return of an equal-weighted portfolio is then generated by computing the natural logarithm of the sum of the disclosure-weighted returns of all stocks in the portfolio.

As a result, the returns of stocks in the respective portfolio are weighted according to the completeness of their GHG-emissions reporting. The higher the score of a company on the Disclosure Completeness Index, the more weight its returns are given in the construction of the respective portfolio returns. Consequently, the returns of a portfolio constructed from absolute levels of GHG-emissions and weighted by disclosure completeness in the C4FM, as well as the returns of portfolios constructed from different levels of GHG-efficiency and weighted by disclosure completeness, cannot be primarily driven by companies that report GHG-emissions in an incomplete manner. The mean annualised excess returns of the portfolios constructed with absolute levels of GHG-emissions and GHG-efficiency shown in Table 18 and the corresponding portfolios that have been weighted according to disclosure completeness respectively (see Table 19) show few differences. Mean annualised excess returns thus suggest that incompletely reporting companies do not primarily drive the returns of the respective portfolios.

Table 19: Annualised excess portfolio returns weighted by completeness

Portfolio	Annualised excess returns			
	EW		VW	
	Mean	SD	Mean	SD
Absolute levels of GHG-emissions				
High GHG / weighted -R_f	9.53%	0.20	7.51%	0.19
Medium GHG / weighted -Rf	2.59%	0.19	1.74%	0.17
Low GHG / weighted -Rf	1.76%	0.19	2.37%	0.18
Level of GHG-efficiency				
High GHG-efficiency / weighted -Rf	2.46%	0.17	1.92%	0.15
Medium GHG-efficiency / weighted -Rf	5.81%	0.18	4.95%	0.17
Low GHG-efficiency / weighted -Rf	7.25%	0.23	5.69%	0.21

Notes: This table reports the annualised returns of the respective portfolios weighted by disclosure completeness and in excess of the risk free rate of return R_f. The first column depicts the mean and standard deviation (SD) of the equal weighted (EW) and value-weighted (VW) annualised average excess returns respectively.

5.4.2 Oil Price

As discussed in chapter *4.4 Understanding Sample Characteristics*, GHG-emissions mainly stem from energy use. Consequently, an additional control variable representing changes in the price of oil is introduced in the extended C4FM to determine if results are driven by a portfolios exposure to changes in oil prices, rather than climate change induced systematic risk. As a test of robustness, the natural logarithm of the change in the monthly crude oil price (cf. chapter *4.2.2 Collection of other data*) in Euro per barrel as of the first of each month at t-1 from January 2005 to December 2009 is included in the C4FM that has been extended with industry effects. If the exposure on the resulting factor (Oil) is insignificant in the regression, portfolio results are not significantly affected by oil price changes. If the exposure on the resulting factor is significant and positive (negative), portfolio returns are positively (negatively) correlated with changes in the price of oil.

5.4.3 Carbon Price

As discussed in chapter *3.1 European Emissions Trading Scheme*, changes in the price of carbon have been found to impact the stock performance of specific companies. Consequently, to ensure results are driven by proxies of climate change induced systematic risk rather than changes in the price of carbon, a corresponding additional control variable is introduced in the extended C4FM. More specifically, the natural logarithm of the change in the monthly price of EU ETS emissions allowances as of the end of each month at t-1 is included in the C4FM that has been extended with industry effects. If the exposure on the resulting factor (Carbon) is insignificant in the regression, portfolio results are not significantly affected by changes in the price of carbon. If the exposure on the resulting factor is significant and positive (negative), portfolio returns are positively (negatively) correlated with changes in the price of carbon. Due to data availability (cf. chapter *4.2.2 Collection of Other Data*) the respective regressions only cover the time period from June 2005 to December 2009, which reduces the statistical power of the regressions and shifts the period of analysis into comparatively more months of financial market crisis.

5.4.4 Financial Market Crisis

In an additional test of robustness, the effect of financial market crisis is controlled for. Following Hoepner and Zeum (2009) an additional control variable for financial market crisis is included in the extended C4FM, which corresponds to the accumulated drawdown of the stock market at month t. This control variable is coded zero in each month in which the market return R_{mt} is above the risk free return R_{ft}. If the market return R_{mt} is below the risk free return R_{ft}, the respective month is defined as a month of financial market crisis and the control variable corresponds to the absolute value of accumulated continuously compounded stock market excess return since the last month coded zero. The resulting factor is multiplied by -1 for ease of interpretation and introduced in the C4FM that has been extended with industry effects. If the exposure on the resulting factor (Crisis) is insignificant in the regression, portfolio results are not significantly affected by months of financial market crisis. If the exposure on the resulting factor is significant and positive (negative), the portfolio outperforms (underperforms) the market in months of financial market crisis.

5.4.5 Portfolio Creation in June

In this study, portfolios are formed in January of each respective year. Fama and French built portfolios in June of year t with the motivation to be sure that all accounting data for the year ending in December of year t-1 has been published in June of year t. While this rule of thumb applies to American companies, it does not apply accordingly to European companies. For example, the financial year of almost half of the TOP 500 UK companies does not correspond to the calendar year (FTSE Group, 2011a). Nevertheless, to eliminate the possibility that the timeliness of reported data strongly impacts results of this study, portfolios are created in June of each year t and regressed on the extended C4FM. For the construction of the HML factor in the C4FM for this test of robustness, book values are taken from year t-1 instead of year t-2. Unfortunately, results of these regressions are consequently also likely to be influenced by this change in the calculation of HML and the fact that the time period under investigation is shortened to 55 months (June 2005 – December 2009), i.e. is consequently proportionally more prone to the months of financial market crisis. Furthermore, results are likely to be impacted by changes in the composition of the portfolios, as some of the FTSE AWI constituents, as gathered according to the constituents list of January of each year, are no longer in existence in June of the respective year.

5.4.6 Portfolio Creation with GHG-emissions from t-2

The final test of robustness relates to the timeliness of GHG-emissions data. As this research has shown, there are huge discrepancies among companies with regard to the time they take to publish GHG-emissions data for a respective year (cf. chapter *4.3.3 Timeliness of GHG-emissions reporting*). To account for this circumstance, portfolios constructed on the basis of absolute levels of GHG-emissions and GHG-efficiency are formed with GHG-emissions data from year t-2 in this test of robustness. This reduces the period under investigation to 48 months from January 2006 to December 2009. As discussed in chapter *4.3.3 Timeliness of GHG-emissions reporting*, the date of publication of absolute levels of emissions data is not expected to have a significant impact on results, as GHG-emission levels are fairly stable. For example, during the five year period studied for this research only 37 companies, i.e. 12% of the reporting companies, migrated from one portfolio of absolute levels of emissions to another one. Unfortunately, results of this test of robustness are also likely to be influenced by the accompanying changes in portfolio composition and the shortened period of analysis, which shifts the period under investigation to longer periods of financial market crisis.

Chapter 6
Regression Results

In this chapter, regression results are presented for the portfolios constructed in chapter *5.3 Portfolio construction* using the methodology and the corresponding tests of robustness introduced in chapter *5 Methodology*. Regression result are presented and discussed with regard to the respective portfolios constructed based on proxies of climate change induced risk, i.e. affiliation with the EU ETS (chapter *6.1 European Emissions Trading Scheme*), the existence of disclosure of GHG-emissions (chapter *6.2 Existence of Disclosure of GHG-emissions*), the completeness of such disclosures (chapter *6.3 Disclosure Completeness*), the absolute level GHG-emissions of companies (chapter *6.4 Absolute Levels of GHG-emissions*) and their GHG-efficiency (6.5 *GHG-efficiency*), as well as affiliation with high carbon industries (chapter *6.6 High Carbon Industries*). The aim of this chapter is to accept or reject the hypotheses developed in chapter *3 Hypotheses Development* based on the results of the regressions performed.

The discussion of results in the remainder of this chapter focusses on regression results obtained with equal-weighted portfolio returns, which have been regressed on equal-weighted market returns and control variables, as well as equal-weighted SMB, HML and UMD factors. The focus is laid on results obtained with equal-weighted portfolio returns for several reasons: For example, equal-weighted portfolio returns are not tilted toward the larger companies in the sample, whose performance is considered as more relevant when portfolio returns are value-weighted. Thus, using equal-weighted returns ensures that portfolio returns are not driven by the performance and specific risk-characteristics of a few large companies in the portfolio. When investigating market efficiency, it appears reasonable to attribute the same relevance to every company in the portfolio irrespective of company size.

A common argument for using value-weighted returns is that any abnormal return found with equal-weighted returns may be driven by micro-caps and model problems relating to micro-caps (Fama, 1998). This argument does however not apply in the context of this study, as the sample used only includes mid-size and large-cap companies (cf. chapter *4.1 Sample Selection*). Consequently, this common argument, together with the notion that micro-caps hamper market efficiency as they suffer from information shortage and reduced analyst following, do not apply for this research. Furthermore, Loughran and Ritter (2000) evidenced that in some cases multifactor models, such as the C4FM, may actually underestimate abnormal returns when value-weighted returns are used. Finally, the arguments that value-weighted returns are more commonly used by investors (Derwall et al., 2005) and better reflect the “total wealth effects experienced by investors” (Fama, 1998, p. 296) can be neglected in the context of this study, as it is not primarily focussed on investor habits or wealth effects, but the level of market efficiency towards the climate change induced systematic risk of companies. Nevertheless, in order to be transparent with regard to the effect of alternative weighting procedures, all regressions have also been performed with value-weighted returns (cf. *Appendix A Regression Results: Value-weighted Returns*). Furthermore, equal-weighted portfolio returns have been regressed on value-weighted market returns and industry control variables, as well as value-weighted SMB, HML and UMD factors (cf. *Appendix B Regression Results: Equal-weighted Returns on Value-weighted Factors*). Reference is made in the text to these alternative weighting procedures to illustrate their effect on results.

In the remainder of this chapter, regression result are presented and discussed with respect to each of the hypotheses developed. To allow for an effortless comprehensibility of results, all regression models and tests of robustness for a respective portfolio are summarized in one table and the consolidated presentation of these results follows Kempf and Osthoff (2007).

6.1 European Emissions Trading Scheme

With regard to the EU ETS as a proxy for climate change induced systematic risk, it was hypothesised in chapter *3.1 European Emissions Trading Scheme* that in an efficient market there is no difference in risk-adjusted returns between portfolios constructed from companies that are affiliated and those that are not affiliated with the EU ETS (Hypothesis 1a).

6.1.1 Regression Results

In the CAPM, as illustrated in Table 20, a portfolio constructed from companies that are part of the EU ETS generates an abnormal annualised risk-adjusted alpha of 3.92% (at a significance level of 10%, i.e. $p<0.10$). At the same time, the Not in EU ETS portfolio generates an annualised risk-adjusted loss of -1.77% ($p<0.10$). At an adjusted R-squared of 96% and 99% respectively, these results are deemed highly reliable. As there is a difference in risk-adjusted returns, these initial results suggest that the market might be inefficient in pricing climate change induced systematic risk as proxied by the EU ETS. Interestingly, the systematic risk of both portfolios, depicted in the table by the caption ($R_m - R_f$), is essentially identical. This fact supports the notion that the market does not incorporate an increased level of systematic risk of companies affiliated with the EU ETS into the traditional beta coefficient. At the same time, however, as the EU ETS portfolio outperforms the market on a risk-adjusted basis, these initial results also hint at the fact that market participants take note of the value-relevance of information on a company's affiliation with the EU ETS. Nevertheless, before making any conclusion on the level of market efficiency, factors generally known to explain abnormal financial market performance must be controlled for by means of the C4FM.

Table 20 shows that results obtained in the C4FM are very similar to results obtained in the CAPM. In the C4FM the EU ETS portfolio generates a slightly reduced annualised alpha of 3.53% ($p<0.10$, adjusted R-squared of 96%).[31] At the same time, the loss of the Not in EU ETS portfolio slightly reduces to -1.59% ($p<0.10$, adjusted R-squared of 99%). The EU ETS shows a significant negative exposure on the SMB factor, suggesting that it contains companies with large market capitalization (as evidenced in chapter *5.3 Portfolio Construction*). The exposure on the SMB factor of the Not in EU ETS portfolio is significant and positive, suggesting that it contains

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[31] When returns are value-weighted the EU ETS portfolio also generates an annualised alpha of 2.92% ($p<0.10$, adjusted R-squared of 97%). See Appendix *A.1 European Emission Trading Scheme*. When equal-weighted portfolio returns are regressed on value-weighted factors the EU ETS portfolio generates an annualised alpha of 3.62% ($p<0.10$, adjusted R-squared of 97%). See Appendix *B.1 European Emission Trading Scheme.*

Table 20: Regression results: European Emissions Trading Scheme

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	ACV	Adj. R^2
EU ETS							
CAPM	3.916% *	1.004 ***					0.957
C4FM	3.529% *	1.046 ***	-0.304 **	-0.017	-0.181 **		0.964
C4FM / June	1.103%	0.988 ***	-0.430 ***	0.198 ***	-0.139 ***		0.973
C4FM + Carbon	1.536%	1.001 ***	-0.402 ***	0.201 *	-0.151 **	-0.000	0.965
C4FM + Oil	3.026% *	1.025 ***	-0.320 **	0.025	-0.153 **	0.036 ***	0.967
C4FM + Crisis	6.401% ***	0.986 ***	-0.193 *	-0.056	-0.195 ***	-0.034 **	0.967
Not in EU ETS							
CAPM	-1.768% *	0.999 ***					0.991
C4FM	-1.590% *	0.979 ***	0.143 **	0.008	0.082 **		0.992
C4FM / June	-0.348%	0.974 ***	0.312 ***	-0.038	-0.011		0.992
C4FM + Carbon	-0.667%	0.975 ***	0.309 ***	-0.042	-0.014	0.000	0.987
C4FM + Oil	-1.360%	0.989 ***	0.150 **	-0.011	0.069 **	-0.017 ***	0.993
C4FM + Crisis	-2.929% ***	1.007 ***	0.091 **	0.026	0.089 ***	0.016 **	0.993
Long EU ETS - Short Not in EU ETS	5.119% *	0.067	-0.447 **	-0.025	-0.264		0.155

Notes: This table reports regression results for EU ETS and Not in EU ETS portfolios using monthly equal-weighted returns and equal-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, as well as the tests of robustness of results. Tests of robustness include portfolio creation in June (/ June) and the inclusion of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors and ACV, as well as the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

companies with a smaller market capitalization. These significant exposures on the SMB factor illustrate that the performance of both portfolios was corrected for the historical return differences between small-cap and large-cap companies (cf. chapter *5.2 C4FM*). The HML factor is insignificant for both portfolios, i.e. none of the portfolios shows significant exposure to the difference in returns between companies with a high book to market ratio and those with a low book to market ratio. The EU ETS portfolio shows a significant negative loading on the UMD factor. Companies affiliated with the EU ETS thus performed poorly with regard to their historical stock performance. The coefficient on the UMD factor is significant and positive for the Not in EU ETS portfolio, suggesting that these companies performed well historically. The significant exposures to the UMD factor illustrate that the returns of both portfolios were corrected for the known return differences between winner and loser stocks (cf. chapter *5.2 C4FM*).

The persistent outperformance of the EU ETS portfolio in a buy-and-hold strategy of 3.53%, on the basis of risk-adjusted returns after controlling for factors generally known to explain stock performance, confirms that the market is not efficiently pricing this proxy for climate change induced systematic risk. If an investor applies a long-short trading strategy (cf. chapter *5.3.1 Long-short trading strategy*), the inefficiency established becomes even more obvious. As shown at the bottom of Table 20, a trading strategy that goes long in (i.e. buys) companies affiliated with the EU ETS and short in (i.e. sells) companies not affiliated with the EU ETS generates an annualised alpha of 5.12% (p<0.10).[32] In these long-short portfolio regressions, the coefficients on beta, SMB, HML and UMD show the differences of exposure of the long versus the short portfolio. For example, the *Long EU ETS – Short Not in EU ETS* portfolio shows significant positive exposure on the SMB factor, as the Not in EU ETS portfolio contains smaller companies. Furthermore, the adjusted R-squared of long-short portfolio regressions cannot be interpreted analogously to those of the previous models. All long-short portfolios presented in this study show an F-test probability of under 0.05, i.e. the models are statistically significant as a whole.

As discussed in chapter *4.2 Data Collection*, the information used in this research was obtained costlessly from publicly available sources. Nevertheless, analogously to Ball (1994) it is argued that there are costs involved in the gathering of information for this proxy for climate change induced systematic risk, which relate to the time invested in producing the information for each of the companies in the sample of this study. These information costs, as well as hypothetical transaction costs, are accounted for in this test of market efficiency by assuming a rather high annual total expense ratio of 1.50% for carrying out the investment strategy (cf. Geczy et al., 2005; Renneboog et al., 2008b; Statman, 2000). As described in chapter *2.2.7 Review of Studies*, to that end the annual total expense ratio is split into monthly expenses and deducted from the monthly portfolio returns of the EU ETS portfolio and the Not in EU ETS portfolio. Subsequently an updated long-short portfolio is constructed (cf.

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[32] Annualised returns of 5.52% (p<0.01) for the *Long EU ETS – Short Not in EU ETS* portfolio are found when portfolio returns are value-weighted (see Appendix *A.1 European Emission Trading Scheme*) and 6.75% (p<0.05) when equal-weighted portfolio returns are regressed on value-weighed factors (see Appendix *B.1 European Emission Trading Scheme*) respectively.

chapter *5.3.2 Long-short Trading Strategy*) and the regression is repeated. As expenses are deducted from both portfolios used to construct the updated long-short portfolio, the effect of the expense ratio on long-short portfolios is irrelevant in economic terms, but might impact the statistical significance of the results obtained.

The annualised alpha of the long-short portfolio of 5.12% found is statistically significant even when an annual total expense ratio of 1.50% is accounted for. The persistent risk-adjusted abnormal returns identified thus not only cover transaction and information costs and consequently represent a market inefficiency not only in the original version of EMH of Fama (1970), but also in Jensen’s less strong but economically more reasonable definition of EMH. As discussed in chapter *2.1.3 Three Conditions for an Efficient Market*, the market is argued to be efficient in Jensen’s version of EMH when the expected risk-adjusted returns of an investment strategy for individuals are consumed by its transaction and information costs (Fama, 1991; Jensen, 1978). In summary, it is consequently deduced that between January 2005 and December 2009 the financial market was inefficient in pricing climate change induced systematic risk of European companies as proxied by a company’s affiliation with the EU ETS. This result is obtained at a rather low yet conventional confidence level of 10%, but confirmed at higher statistical significance levels in regressions with alternative weighting procedures of portfolio returns (see Appendices *A.1 European Emission Trading Scheme* and *B.1 European Emission Trading Scheme*). Hypothesis 1a is consequently rejected, as the regression evidenced differences in risk-adjusted returns between portfolios constructed from companies that are affiliated and those that are not affiliated with the EU ETS. At a statistical power level of 0.96 at all relevant significance levels and a medium effect size of 0.30 (Cohen, 1988) the possibility that wrong conclusions are derived for the interpretation of results with regard to any of the hypotheses under examination in this study is regarded as small. A post-hoc analysis of statistical power was carried out using Faul, Erdfelder, Buchner, and Lang (2009).

It was argued in chapter *3.1 European Emissions Trading Scheme* that companies that are affiliated with the EU ETS show higher climate change induced systematic risk. Consequently, there is a risk-based explanation for the outperformance of the EU ETS portfolio evidenced here. As discussed in chapter *2.1.4 Methodologies and*

Findings, opponents of the EMH tend to interpret any abnormal risk-adjusted returns as evidence for market inefficiencies, while advocates of the EMH are inclined to point towards the Joint Hypothesis Problem and search for a risk-based explanation of the abnormal returns identified. If there is a risk-based explanation, and the abnormal returns exist in different markets and periods, the abnormal returns can be attributed to shortcomings in the underlying asset pricing model to price the respective risk correctly and may therefore be consistent with the basic notion of the EMH according to which returns compensate for risk (Bodie et al., 2008). Consequently, if the abnormal risk-adjusted returns found here were to continue to exist outside of this sample and the period studied in this research, the increased systematic risk related to the EU ETS might qualify as an additional risk premium at some point in the future. Results found in this research could then be aligned with the EMH, according to which investors are rewarded for taking risk. However, as discussed in chapter *2.1.4 Methodologies and findings*, further research is needed before any conclusion of this magnitude can be made and consequently any abnormal risk-adjusted return found in this study is interpreted as market inefficiency (cf. chapter *2.1.6 Application of EMH in this Research*). In fact, based on the following test of robustness, the possibility that the abnormal risk-adjusted returns found may not occur outside of the period analysed in this study cannot be excluded.

6.1.2 Tests of Robustness

The first test of robustness refers to the creation of the respective portfolios in June instead of January of each respective year. When the EU ETS and Not in EU ETS portfolios are formed in June, no significant abnormal returns are identified (see Table 20).[33] This finding may be due to the timeliness of financial data, the different composition of the portfolio or the shortened period of analysis to 55 month (cf. chapter *5.4.5 Portfolio Creation in June*). The shortened period shifts the period under investigation into a comparatively longer period of financial market crisis. The significant negative loading on the control variable for financial crisis suggest that the

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[33] Note that when this regression is performed with equal-weighted returns on value-weighted factors (see Appendix *B.1 European Emission Trading Scheme*), alpha is almost significant at $p = 0.104$ (unreported) and an adjusted R-squared of 97%.

EU ETS portfolio underperforms the market in months of financial market crisis (cf. chapter *5.4.4 Financial Market Crisis*). Consequently, it is not surprising that the EU ETS portfolio loses its outperformance when months of financial market crisis represent a larger share of the period analysed. The Not in EU ETS portfolio shows a significant positive loading on the crisis factor, i.e. it outperforms in months of financial market crisis. Consequently, the underperformance of the Not in EU ETS portfolio is reduced when the period of analysis is shifted towards more months of financial crisis. In conclusion, while the crisis factor gives some explanation for the disappearance of the out- and underperformance when portfolios are constructed in June, the possibility that the timeliness of financial data and the period under analysis impacts results cannot be excluded.

The additional control variable of changes in the price of carbon is not significant for the EU ETS or the Not in EU ETS portfolio, i.e. there is no significant exposure of portfolio returns to the changes in the price of carbon. As this regression is also shortened to a period of 55 months (cf. chapter *5.4.3 Carbon Price*), the disappearance of the significance of alpha can probably be attributed to the shift of the period under analysis towards more months of financial market crisis. The fact that the adjusted R-squared of this regression is lower compared to that of the regression when both portfolios are created in June confirms that the change in carbon prices does not help explaining the performance of the portfolios. When the change in monthly oil prices is included in the regression, it shows that the exposure on this additional control variable is significant and positive (negative) for the EU ETS (Not in EU ETS) portfolio. Controlling for the effect of changes in oil prices does however not significantly affect the out- or underperformance of the respective portfolios.[34] In summary, with regard to the additional control variables of changes in the price of carbon and oil, results are consequently argued to be robust.

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[34] Note that the alpha coefficient of the Not in EU ETS portfolio in the respective regression is almost significant at $p = 0.1047$ (unreported), i.e. the addition of the control factor does not significantly influence portfolio performance.

6.2 Existence of Disclosure of GHG-emissions

The second proxy of climate change induced systematic risk applied in this study is the existence of disclosure of GHG-emissions on at least the majority of corporate activities. With regard to this proxy, it was hypothesised in chapter *3.2 Existence of Disclosure of GHG-Emissions* that in an efficient market there is no difference in risk-adjusted returns between portfolios constructed from companies that disclose GHG-emissions and those that do not disclose GHG-emissions (Hypothesis 2a).

6.2.1 Regression Results

As shown in Table 21, in the CAPM a portfolio constructed from companies that report GHG-emissions (Reporting GHG) outperforms the portfolio constructed from companies that do not report GHG-emissions (Not reporting GHG). The Reporting GHG portfolio generates an annualised equal-weighted return of 2.15%, while the Not reporting GHG portfolio generates a loss of -2.89%. Both results are deemed highly reliable at a statistically significance level of 1% ($p<0.01$) and an adjusted R-squared of over 99%. The beta coefficient of the Not reporting GHG portfolio is higher, i.e. companies that do not report GHG-emissions to the public show an elevated level of systematic risk, in line with the arguments presented earlier (cf. chapter *3.2 Existence of Disclosure of GHG-Emissions)*. However, given the fact that there is a difference in risk-adjusted returns, these initial results hint at the fact that the market may not be pricing the existence of disclosure of GHG-emissions as a proxy for climate change induced systematic risk efficiently. Nevertheless, before any conclusion can be drawn, factors generally accepted to impact returns, as well as the impact of the industry compositions of the respective portfolios, have to be controlled for.

In the C4FM, the results of the GHG reporting portfolio are very similar to those in the CAPM. The Reporting GHG portfolio generates an annualised alpha of 2.15% ($p<0.01$, adjusted R-squared of over 99%). The significant exposure to the SMB factor is slightly negative for this portfolio, suggesting that the Reporting GHG portfolio contains companies with a larger market capitalization (as also evidenced in chapter *4.4.1 Existence of Corporate GHG-disclosure*). In the C4FM the loss of the Not reporting GHG portfolio increases to -3.08% ($p<0.01$, adjusted R-squared of over

99%).[35] The Not reporting GHG portfolio shows a significant positive exposure to the SMB factor, i.e. returns of this portfolio were also corrected for the historical return differences between small-cap and large-cap companies (cf. chapter *5.2 C4FM).* The portfolio also shows a small significant and positive exposure on the UMD factor, which implies that companies that did not report GHG-emissions performed slightly better historically and portfolio returns were corrected for the return differences between winner and loser stocks.

As the two portfolios show differences in industry composition (cf. chapter *5.2.1 Controlling for Industry Effects*) and reporting companies are more likely to be affiliated with high carbon industries (cf. chapter *4.4.1 Existence of corporate GHG-disclosure)*, industry effects are controlled for by means of the C4FM extended for industry effects. As it can be seen in Table 21, the abnormal annualised return of the Reporting GHG portfolio reduces to 1.72% (p<0.01) when industry effects are controlled for. For example, as to be expected (cf. chapter *5.2.1 Controlling for industry effects*), the returns of Reporting GHG portfolio are corrected for its significant positive exposure to the outperforming Utilities industry (ICB 7000), which is a high carbon industry with 76% of companies being affiliated with the EU ETS. When controlled for industry effects, the Not reporting GHG portfolio generates a slightly reduced annualised loss of -2.62% (p<0.01). The adjusted R-squared of both models remains stable when industry variable are added. This fact supports the notion that the industry variables have explanatory power for the regression, as the adjusted R-squared is a measure of model fit that punishes for the inclusion of additional variables in a model, i.e. it would reduce if the additional eight industry variables would not have significant explanatory power.

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[35] Note that an investment strategy that goes long in reporting companies and short in companies that do not disclosure GHG-emissions generates an annualised alpha of 5.23% (p<0.01) in the traditional C4FM when portfolio returns are equal-weighted (unreported).

Table 21: Regression results: Existence of disclosure of GHG-emissions

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	0001	1000	2000	3000	4000	5000	6000	7000	9000	ACV	Adj. R^2
Reporting GHG																
CAPM	2.148% ***	0.980 ***														0.996
C4FM	2.152% ***	1.008 ***	-0.102 ***	-0.026	-0.023											0.997
C4FM + Industry	1.722% ***	0.995 ***	-0.051	-0.008	0.002	0.060 **	0.085	0.174 *	0.149 *	0.043	0.151	0.067 **	0.093 **	0.017		0.997
C4FM + Industry / GHG t-2	2.130% ***	0.931 ***	-0.022	0.094 ***	0.026	0.127 ***	0.138 **	0.286 **	0.281 ***	0.139 ***	0.284 **	0.115 ***	0.188 ***	0.039		0.996
C4FM + Industry / June	1.262% **	0.977 ***	0.046	0.037	0.023	0.053 **	0.082 ***	0.154 **	0.127 **	0.068 **	0.134 ***	0.088 ***	0.113 **	-0.003		0.996
C4FM + Industry + Carbon	0.836%	0.945 ***	0.049	0.076	0.037	0.065 ***	0.098 **	0.195 **	0.228 ***	0.126 ***	0.198 ***	0.092 ***	0.144 ***	-0.009	0.000	0.994
C4FM + Industry + Oil	1.714% ***	0.997 ***	-0.044	-0.011	0.005	0.065 **	0.090	0.176	0.158 *	0.043	0.152	0.069 **	0.100 **	0.020	-0.005	0.997
C4FM + Industry + Crisis	1.830% ***	0.993 ***	-0.049	-0.010	0.000	0.060 **	0.082	0.171	0.144 *	0.042	0.147	0.066 *	0.089 *	0.016	-0.001	0.997
Not reporting GHG																
CAPM	-2.887% ***	1.044 ***														0.992
C4FM	-3.078% ***	0.977 ***	0.178 ***	0.078	0.005 ***											0.995
C4FM + Industry	-2.615% ***	0.995 ***	0.101 **	0.064 **	-0.021	-0.079 *	-0.098	-0.226	-0.191	-0.063	-0.183	-0.103 *	-0.094	-0.021		0.995
C4FM + Industry / GHG t-2	-2.119% **	1.072 ***	0.034	-0.072	-0.057	-0.131 ***	-0.149 *	-0.309 *	-0.320 **	-0.165 ***	-0.314 **	-0.134 **	-0.201 **	-0.042		0.995
C4FM + Industry / June	-0.983%	1.082 ***	-0.069	-0.043	-0.074	0.057 *	0.198 ***	0.381 ***	0.293 ***	0.058	0.454 ***	0.028	0.104 *	0.141 ***		0.992
C4FM + Industry + Carbon	-0.526%	1.119 ***	-0.131	-0.059	-0.144	0.010	0.129 *	0.257 **	0.102	-0.061	0.317 ***	-0.012	0.024	0.121 **	0.001	0.989
C4FM + Industry + Oil	-2.596% ***	0.990 ***	0.085 *	0.070 **	-0.029	-0.090 *	-0.110	-0.230	-0.213	-0.062	-0.187	-0.107 *	-0.111	-0.028	0.012	0.995
C4FM + Industry + Crisis	-2.615% ***	0.995 ***	0.101 **	0.064 **	-0.021	-0.079 *	-0.098	-0.226	-0.191	-0.063	-0.183	-0.103	-0.094	-0.021	-0.000	0.995
Long Reporting GHG - Short Not Reporting GHG	4.338% ***	-0.000	-0.151 **	-0.073 *	0.022	0.140 **	0.183	0.401	0.340	0.107	0.334	0.171 **	0.187	0.037		0.461

Notes: This table reports regression results for Reporting GHG and Not reporting GHG portfolios, as well as the respective long-short portfolio, using monthly equal-weighted returns and equal-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, C4FM controlled for industry effects, as well as the tests of robustness of results. Tests of robustness include portfolio creation with GHG-data from t-2 (/ GHG t-2) and in June (/ June) and the introduction of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as on orthogonalised industry returns represented by their respective ICB code. The remaining columns show coefficient exposure on ACV and the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

The persistent difference in risk adjusted returns of the Reporting GHG portfolio and Not reporting GHG portfolio in the C4FM extended for industry effects suggests that the market is not efficiently pricing this proxy for climate change induced systematic risk. In fact, as depicted in Table 21, an investor that goes long in companies reporting GHG-emissions and short in companies not reporting GHG-emissions (cf. chapter *5.3.1 Long-short trading strategy*) generates an annualised alpha of 4.34% ($p<0.01$).[36] The annualised alpha of 4.34% is statistically significant even when a total expense ratio of 1.50% for carrying out the investment strategy is accounted for (cf. Geczy et al., 2005; Renneboog et al., 2008b).[37] The total expense ratio accounts for hypothetical information and transaction costs (Ball, 1994). It is consequently deduced that between January 2005 and December 2009 the financial market did not price the climate change induced systematic risk of European companies as proxied by the existence of GHG-emissions disclosure by companies in an efficient way. This conclusion is valid for Fama's original version, as well as Jensen's less strong but economically more reasonable version of EMH, as risk-adjusted abnormal returns in excess of transaction and information costs can be obtained (cf. chapter *2.1.3 Three Conditions for an Efficient Market*). Hypothesis 2a is consequently rejected.

It was argued in chapter *3.2 Existence of disclosure of GHG-emissions* that companies that do not report GHG-emissions show higher estimation and information risk. Consequently, there is no risk-based explanation for the outperformance of the Reporting GHG portfolio evidenced here. Since companies that report GHG-

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[36] These results are also found when equal-weighted returns are regressed on value-weighted factors (see Appendix *B.2 Existence of Disclosure of GHG-emissions*), but not when both returns and factors are value-weighted (see Appendix *A.2 Existence of Disclosure of GHG-emissions*).

[37] To that end, as explained above in chapter *6.1.1 Regression Results*, the annual total expense ratio is split into monthly expenses and deducted from the monthly portfolio returns of the Reporting GHG and the Not reporting GHG portfolio. Subsequently an updated long-short portfolio is constructed and the regression is repeated. As expenses are deducted from both portfolios used to construct the long-short portfolio, the effect on long-short portfolios is economically irrelevant, but might have impacted the statistical significance of the results obtained.

emissions show positive abnormal returns, the market seems to value the positive effects of GHG-emissions in an inefficient way while disregarding the additional risk that non-reporting companies are exposed to. Investors in companies not reporting GHG-emissions are consequently not only *not* rewarded for taking on additional risk, but in fact penalised with a persistent financial loss.

6.2.2 Tests of Robustness

Tests of robustness largely confirm the results found in the main regressions. Results of the Reporting GHG portfolio are robust with regard to both the construction of the portfolio with GHG-emissions from year t-2 (cf. chapter *5.4.6 Portfolio creation with GHG-emissions from t-2*) and in June of respective years. In both regressions, the Reporting GHG portfolio shows a significant positive outperformance in the range of the original results. Of the additional control variables none are significant, i.e. results of none of the portfolios are significantly exposed to changes in the price of carbon or oil, or the impact of the financial market crisis. However, when the Not reporting GHG portfolio is constructed in June of each of the respective years, no abnormal performance is identified. This effect is attributable to the timeliness of financial data and/or changes in portfolio composition (cf. chapter *5.4.5 Portfolio Creation in June*).

6.3 Disclosure Completeness

With regard to the completeness of disclosures of GHG-emissions as a proxy for climate change induced systematic risk, it was hypothesised in chapter *3.3 Disclosure Completeness* that in an efficient market there is no difference in risk-adjusted returns between portfolios constructed from companies that report complete and those that report incomplete GHG-emissions (Hypothesis 3a).

As illustrated in chapter *4.2.2 Collection of Other Data*, the completeness of GHG-emissions reporting was classified according the score of a company on the Disclosure Completeness Index developed. Companies were allocated to four mutually exclusive portfolios (cf. chapter *5.3 Portfolio Construction*) based on their respective score on the Disclosure Completeness Index. The 0 Score portfolio consequently contains companies with incomplete GHG-emissions reporting, for example a company reporting only scope 1 CO_2-emissions for parts of manufacturing activities. The 3 Score portfolio is constructed with companies that report complete GHG-emissions, i.e. scope 1 and 2 GHG-emissions for a group-wide reporting boundary.

6.3.1 Regression Results

As illustrated in Table 22, in the CAPM the 0 Score and the 2 Score portfolios do not show any significant outperformance. The 1 Score and 3 Score portfolios show a risk-adjusted annualised alpha of 2.34% ($p<0.05$, adjusted R-squared of 98%) and 4.70% ($p<0.05$, adjusted R-squared of 92%) respectively. These initial results thus suggest that companies with higher reporting completeness tend to generate positive abnormal returns, i.e. the market does not price this information efficiently.

Results obtained with the C4FM confirm these results. Again, the 0 Score and 2 Score portfolios do not show any out- or underperformance at conventional significance levels, whereas 1 Score portfolio shows a minimally reduced risk-adjusted annualised return of 2.29% ($p<0.05$, adjusted R-squared of 98%). The annualised alpha of the 3 Score portfolio increases to 5.37% ($p<0.05$, adjusted R-squared of 93%) in the C4FM. The 3 Score portfolio shows a large significant negative exposure on the HML factor, suggesting that it contains growth stocks and that its performance was corrected for the historical performance differences between growth and value stocks. Interestingly, other portfolios show very little exposure to the size, value and momentum effect, suggesting that companies within the respective portfolios show little similarity in terms of size, book to market ratio and historical performance.

When industry effects are controlled for, the 1 Score portfolio no longer generates abnormal returns (see Table 22). The initial results that companies with higher reporting completeness tend to generate positive abnormal returns are however reinforced. The 3 Score portfolio still shows a slightly reduced significant annualised return of 4.90% ($p<0.05$, adjusted R-squared of 94%). The outperformance of the 3 Score portfolio is reduced, as this portfolio shows significant positive exposure to the Health Care industry (ICB 4000), an industry that performed exceptionally well in the

Table 22: Regression results: Disclosure completeness

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	0001	1000	2000	3000	4000	5000	6000	7000	9000	ACV	Adj. R^2
0 Score																
CAPM	-1.097%	1.005 ***														0.913
C4FM	-1.336%	1.067 ***	-0.262	0.011	0.018											0.912
C4FM + Industry	-8.148% ***	1.035 ***	-0.160	0.200 **	0.287 *	0.021	0.231	0.396	0.375	0.072	-0.202	-0.108	0.494 **	0.135		0.955
C4FM + Industry / GHG t-2	-11.312% ***	0.725 ***	0.553 **	0.693 ***	0.221 **	-0.623 ***	-1.174 ***	-2.424 ***	-1.655 ***	-0.538 ***	-3.163 ***	-0.656 ***	-0.456	-0.500 **		0.944
C4FM + Industry / June	-6.404% ***	1.104 ***	-0.020	0.119	0.228	0.253 **	0.862 ***	1.547 ***	1.364 ***	0.485 ***	1.098 ***	0.293 ***	1.101 ***	0.369 ***		0.950
C4FM + Industry + Carbon	-5.930% *	1.062 ***	-0.039	0.085	0.029	0.181	0.757 **	1.353 ***	1.307 **	0.435 *	1.030 **	0.234	1.062 ***	0.340 **	0.000	0.929
C4FM + Industry + Oil	-8.108% ***	1.024 ***	-0.191	0.213 **	0.271	-0.001	0.206	0.390	0.333	0.074	-0.209	-0.114	0.460 *	0.120	0.023	0.955
C4FM + Industry + Crisis	-5.172%	0.991 ***	-0.113	0.159	0.249	0.004	0.159	0.293	0.253	0.034	-0.295	-0.159	0.403	0.106	-0.030 *	0.956
1 Score																
CAPM	2.352% **	0.970 ***														0.984
C4FM	2.285% **	0.965 ***	-0.015	0.003	-0.035											0.984
C4FM + Industry	2.033%	0.964 ***	-0.014	0.005	-0.038	0.027	-0.022	0.009	0.114	-0.019	0.010	-0.041	0.076	0.014		0.984
C4FM + Industry / GHG t-2	4.640% ***	0.916 ***	-0.122	0.094 *	0.132 **	0.259 ***	0.332 **	0.659 *	0.674 ***	0.266 **	0.811 ***	0.165	0.391 ***	0.148		0.981
C4FM + Industry / June	2.668% ***	0.919 ***	0.147 **	0.024	0.058	-0.034	-0.106 *	-0.306 **	-0.111	-0.069	-0.180 *	-0.042	-0.022	-0.057		0.989
C4FM + Industry + Carbon	2.809% **	0.935 ***	0.191 *	-0.037	0.075	-0.016	-0.057	-0.193	-0.151	-0.070	-0.170	-0.002	-0.014	-0.059	-0.000	0.981
C4FM + Industry + Oil	2.020%	0.967 ***	-0.004	0.001	-0.033	0.034	-0.014	0.011	0.128	-0.019	0.013	-0.039	0.087	0.019	-0.007	0.983
C4FM + Industry + Crisis	3.247%	0.946 ***	0.005	-0.012	-0.054	0.020	-0.052	-0.033	0.064	-0.034	-0.028	-0.062	0.039	0.002	-0.012	0.984
2 Score																
CAPM	1.474%	1.014 ***														0.978
C4FM	1.201%	1.044 ***	-0.188 **	0.015	-0.047											0.979
C4FM + Industry	1.506%	1.020 ***	-0.085	0.023	-0.034	0.047	-0.026	0.120	-0.052	-0.031	0.010	0.119	-0.023	-0.039		0.982
C4FM + Industry / GHG t-2	0.316%	0.934 ***	-0.041	0.129 *	-0.095	0.118	-0.010	0.207	0.018	0.063	0.137	0.132	-0.002	-0.039		0.983
C4FM + Industry / June	0.292%	1.005 ***	-0.009	0.076	-0.096	0.097 **	0.069	0.359 **	0.132	0.081	0.259 **	0.186 **	0.105	-0.011		0.982
C4FM + Industry + Carbon	0.227%	0.905 ***	-0.010	0.208 *	-0.082	0.128 ***	0.037	0.322 *	0.320 **	0.219 **	0.411 ***	0.169 **	0.140	-0.034	-0.000	0.971
C4FM + Industry + Oil	1.499%	1.022 ***	-0.079	0.021	-0.031	0.050	-0.022	0.121	-0.045	-0.032	0.011	0.120	-0.017	-0.036	-0.004	0.981
C4FM + Industry + Crisis	1.123%	1.026 ***	-0.091	0.028	-0.029	0.049	-0.017	0.133	-0.037	-0.027	0.022	0.125	-0.011	-0.035	0.004	0.981
3 Score																
CAPM	4.690% **	0.903 ***														0.922
C4FM	5.366% ***	0.992 ***	-0.118	-0.172 **	0.022											0.925
C4FM + Industry	4.902% **	0.979 ***	-0.105	-0.113	0.071	0.146	0.326	0.179	0.211	0.241 *	0.523	0.139	0.049	0.038		0.939
C4FM + Industry / GHG t-2	6.108% **	1.117 ***	-0.102	-0.335 ***	-0.045	0.243	0.677	0.783	0.770	0.273	0.976	0.320	0.362	0.210		0.938
C4FM + Industry / June	3.317%	0.974 ***	-0.040	-0.022	0.200	0.148	0.279	0.225	0.129	0.203	0.243	0.104	0.074	0.008		0.924
C4FM + Industry + Carbon	0.718%	1.068 ***	-0.059	-0.095	0.331	0.158	0.489 *	0.529	0.325	0.221	0.270	0.172	0.212	0.098	0.001	0.879
C4FM + Industry + Oil	4.889% **	0.983 ***	-0.094	-0.118	0.076	0.153	0.334 *	0.182	0.226	0.240 *	0.525	0.141	0.060	0.043	-0.008	0.937
C4FM + Industry + Crisis	3.610%	0.998 ***	-0.126	-0.095	0.087	0.154	0.357 *	0.224	0.264	0.257 **	0.563	0.161	0.088	0.051	0.013	0.938
Long 3 Score - Short 0 Score	13.050% ***	-0.055	0.055	-0.314 **	-0.217	0.125	0.095	-0.217	-0.164	0.169	0.725	0.247	-0.445 *	-0.097		0.403

Notes: This table reports regression results for the four portfolios constructed from levels of GHG-emissions disclosure completeness, as well as the long-short portfolio, using monthly equal-weighted returns and equal-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, C4FM controlled for industry effects, as well as the tests of robustness of results. Tests of robustness include portfolio creation with GHG-data from t-2 (/ GHG t-2) and in June (/ June) and the introduction of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as on orthogonalised industry returns represented by their respective ICB code. The remaining columns show coefficient exposure on ACV and the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

period under investigation (cf. chapter *5.2.1 Controlling for Industry Effects*). Furthermore, the 0 Score portfolio shows a significant annualised loss of -8.15% (p<0.01, adjusted R-squared of 96%), after being corrected for its exposure to the outperforming Utility industry (ICB 7000) (cf. chapter *5.2.1 Controlling for Industry Effects*).

These persistent differences in risk-adjusted returns suggest that the market is inefficient in pricing the quality of disclosure, as measured by the Disclosure Completeness Index. The long-short portfolio confirms this conclusion. A trading strategy that goes long in companies reporting completely (3 Score) and short in companies reporting incompletely (0 Score) generates an annualised alpha of 13.05% (p<0.01). This is a particularly high outperformance, which confirms the discussed finding of market inefficiency.[38] While the information used in this research was obtained costlessly from publicly available sources, hypothetical information and transaction costs (Ball, 1994) are accounted for in this test of market efficiency by assuming a rather high annual total expense ratio of 1.50% for carrying out the investment strategy (cf. Geczy et al., 2005; Renneboog et al., 2008b; Statman, 2000). The annualised outperformance of 13.05% found is statistically significant even when an annual total expense ratio of 1.50% is accounted for.[39] The persistent risk-adjusted abnormal returns identified thus not only cover transaction and information costs and consequently represent a market inefficiency not only in the original version of EMH of Fama (1970), but also in Jensen's less strong but economically more reasonable definition of EMH (cf. chapter *2.1.3 Three Conditions for an Efficient Market).*

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[38] Similar results are also found when equal-weighted returns are regressed on a value-weighted factors (see Appendix *B.2 Existence of Disclosure of GHG-emissions*), but not when both returns and factors are value-weighted (see Appendix *A.2 Existence of Disclosure of GHG-emissions*). As the number of companies in the respective portfolios is rather low, the possibility that results of value-weighted portfolio returns are driven by a few large companies is elevated.

[39] To that end the annual total expense ratio is split into monthly expenses and deducted from the monthly portfolio returns of the 0 Score and the 3 Score portfolio. Subsequently a renewed long-short portfolio is constructed and the regression is repeated. As expenses are deducted from both portfolios used to construct the long-short portfolio, the effect on long-short portfolios is economically irrelevant, but might impact the statistical significance of the results obtained.

The annualised alphas of both the Score 0 and the Score 3 portfolio are economically significant for a buy-and-hold and a long-short trading strategy. As it was hypothesised that incomplete reporting increases the information and estimation risk of a company, there is no risk-based explanation for the abnormal returns of a portfolio constructed from companies that are reporting completely (3 Score). The significant abnormal returns show that the market rewards completely reporting companies and thus does not price the positive effect of complete reporting of GHG-emissions correctly. At the same time, the market does not reward investors for the additional risk taken on when investing in incompletely reporting companies, which not only have higher estimation and information risk, but – as evidenced in chapter *4.4.2 Completeness of corporate GHG-disclosure* – are also more likely to be affiliated with the EU ETS and consequently would be even more exposed to climate change induced systematic risk. In conclusion, it is consequently deduced that the market is not efficiently pricing this proxy for climate change induced systematic risk and hypothesis 3a is rejected.

As discussed in chapter *5.3 Portfolio construction*, the number of companies in these two portfolios is low, yet still sufficiently high to ensure that portfolio results are not driven by the individual performance of a few companies. Using equal-weighted returns further reduces the possibility that portfolio results are driven by the individual performance of a few large companies in the portfolio.

6.3.2 Tests of Robustness

The performance of the equal-weighted 0 Score portfolio is robust to portfolio creation with GHG-emissions data from year t-2, portfolio creation in June, as well as changes in the price of oil and carbon. In other words equal-weighted portfolio returns are not severely affected by the timeliness of data or changes in the price of carbon and oil (see Table 22). The additional control variable for financial market crisis is significant and negative, suggesting that the 0 Score portfolio underperforms the market in months of financial market crisis. However, at $p = 0.102$ (unreported) the alpha of the corresponding regression is almost significant, i.e. portfolio results are interpreted to be robust to the effect of the financial market crisis. Noticeably, the 0 Score portfolio shows an even stronger underperformance when the portfolio is constructed with GHG-emissions from year t-2. This effect can be attributed to the fact that the time period of this regression is shortened to 48 months and thus, among other things, shifts the period of analysis into months of financial market crisis. As discussed, the significant negative exposure to the crisis factor suggests that the portfolio underperformed the market in months of financial market crisis.

The 3 Score portfolio is also robust to the creation of the portfolio with GHG-emissions data from year t-2. However, when the 3 Score portfolio is created in June of each respective year under analysis, the risk-adjusted outperformance disappears. This effect is due to the availability of financial data and/or the difference in portfolio composition. All additional control variables are insignificant, i.e. there is no significant exposure of the returns of the 3 Score portfolio to changes in the price of oil or carbon, or the effect of financial market crisis. The same conclusion is valid for the 1 Score portfolio, for which all additional control variables are also insignificant. Interestingly, the 1 Score portfolio shows an outperformance when the portfolio is created with GHG-emissions data from year t-2, when the portfolio is created in June and when changes in the price of carbon are controlled for. As there is no significant exposure on the crisis factor, these results are attributable to the timeliness of the respective data and/or changes in portfolio composition. The results of the 2 Score portfolio are robust to every test of robustness performed.

6.4 Absolute Levels of GHG-emissions

With regard to absolute levels of GHG-emissions as a proxy for climate change induced systematic risk, it was hypothesised in chapter *3.4 Absolute Levels of Emissions* that in an efficient market there is no difference in risk-adjusted returns between portfolios constructed from companies with high absolute levels of GHG-emissions and those that have low levels of absolute GHG-emissions (Hypothesis 4a). Three mutually exclusive portfolios, including companies with high, medium or low absolute levels of reported emissions respectively (cf. chapter *5.3 Portfolio Construction*), were constructed to test this hypothesis. To ensure that results obtained from testing this hypothesis are not driven by incompletely reporting companies, an additional test of robustness is performed that controls for the incompleteness of reported emissions data (cf. chapter *5.4.1 Incompleteness of GHG-emissions Data*).

6.4.1 Regression Results

Table 23 illustrates that in the CAPM an equal-weighted portfolio constructed from companies with high absolute levels of GHG-emissions generates an annualised alpha of 5.63% (p<0.05, adjusted R-squared of 93%). Portfolios built from companies with medium levels of GHG-emissions outperform the market with an annualised return of 1.84% (p<0.10, adjusted R-squared of 98%), while portfolios built form companies with the lowest 30% of emissions levels do not show a significant out- or underperformance in the CAPM. It is noticeable that, in line with the argument in chapter *3.4 Absolute Levels of Emissions*, the High GHG portfolio has a higher beta than the Medium GHG portfolio and the Low GHG portfolio. However, given the fact that there is a difference in risk-adjusted returns, these initial results hint at the fact that the market may not be pricing absolute levels of GHG-emissions as a proxy for climate change induced systematic risk efficiently.

The performance of the three portfolios is similar when factors generally known to determine stock performance are controlled for in the C4FM: The High GHG portfolio generates a slightly reduced annualised alpha of 5.11% (p<0.10, adjusted R-squared of 94%). The Medium GHG portfolio generates an annualised return of 1.80% (p<0.10, adjusted R-squared of 98%). As in the case of the CAPM, the Low GHG portfolio does not show a significant out- or underperformance. Both, the High GHG and the Medium GHG portfolio load significantly and negatively on the SMB factor. This large significant negative exposure, especially in the case of the High GHG portfolios, suggests that these portfolios contain companies with a larger market capitalisation, which in turn confirms the notion that larger companies tend to have higher levels of GHG-emissions (cf. chapter *4.4.2 Completeness of Corporate GHG-disclosure).*

Portfolios constructed based on absolute levels of GHG-emissions can be expected to show significant differences industry composition. As to be expected, controlling for industry effects strongly impacts results. When industry effects are controlled for, the High GHG and the Medium GHG portfolios no longer outperform the market. In the case of the High GHG portfolio, this effect can be attributed to the significant positive exposure of the portfolio to the comparatively well-performing industries Oil & Gas (ICB 0001), Basic Materials (ICB 1000), Industrials (ICB 2000) and Utilities (ICB

7000) (cf. chapter *5.2.1 Controlling for Industry Effects*), which eliminates the outperformance identified in the basic C4FM.[40] The Medium GHG portfolio shows significant exposure to the Utilities (ICB 7000) industry and, when this industry effect is controlled for, the Medium GHG portfolio no longer shows a significant outperformance. The Low GHG portfolio persistently outperforms the market when industry effects are corrected for. The Low GHG portfolio generates an annualised alpha of 3.61% (p<0.10, adjusted R-squared of 98%).[41] This result suggests that the market does not efficiently price climate change induced systematic risk as proxied by the level of absolute GHG-emissions in Fama's original version of EMH. However, when hypothetical information and transaction costs are accounted for in the economically more reasonable version of EMH of Jensen (1978) (cf. chapter *2.1.3 Three Conditions for an Efficient Market)*, the alpha becomes statistically insignificant. In other words, when a rather high total expense ratio of 1.50% for carrying out the investment strategy is assumed (cf. Geczy et al., 2005; Renneboog et al., 2008b; Statman, 2000) no statistically significant outperformance is found. Only when the hypothetical total expense ratio of the investment strategy is as low as 0.35%, the low GHG portfolio generates a statistically significant abnormal return of 3.26% (p<0.01).

As also shown in Table 23, there is no outperformance of the long-short portfolio based on equal-weighted returns. However, when portfolio returns are value-weighted (see Appendix *A.4 Absolute Levels of GHG-emissions*), a trading strategy that goes long in companies with low absolute levels of GHG-emissions and short in companies with high absolute levels of GHG-emissions generates an annualised alpha of 5.59% (p<0.01). This outperformance is statistically significant, even when a total expense ratio of 1.50% for carrying out the investment strategy is assumed (cf. Geczy et al., 2005; Renneboog et al., 2008b; Statman, 2000). In other words, when portfolio returns are value-weighted, the market is inefficient not only in Fama's original

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[40] When returns are value-weighted the High GHG portfolio generates a significant annualised loss of -2.08% (p<0.01, adjusted R-squared of 99%). See Appendix *A.4 Absolute Levels of GHG-emissions*.

[41] When returns are value-weighted the Low GHG portfolio also generates an annualised alpha of 3.51% (p<0.01, adjusted R-squared of 97%). See Appendix *A.4 Absolute Levels of GHG-emissions*.

version of EMH (1970), but also in Jensen's adaption (1978) with regard to transaction and information costs (cf. chapter *2.1.4 Methodologies and Findings*).

Results based on value-weighted returns might be stronger in these regressions, as the criteria for portfolio creation relates to the size of a company. Consequently, the importance and effect of company size in the creation of the portfolio is reinforced in two ways: by value-weighing returns based on company size and constructing portfolios based on a rule that is related to company size. In summary, the persistent outperformance of the equal-weighted Low GHG portfolio suggests that the market is inefficient in pricing the absolute level of GHG-emissions as a proxy for climate change induced systematic risk in Fama's version of EMH. In Jensen's less strong but economically more reasonable version of EMH, the market is inefficient when portfolio returns are value-weighted. In this case, as a trading strategy that goes long in companies with low absolute levels of GHG-emissions and short in companies with high absolute levels of GHG-emissions generates an economically significant alpha even when transaction and information costs are accounted for. As it was hypothesised that high absolute levels of GHG-emissions result in higher exposure towards the systematic risk induced by climate change, there is no risk-based explanation for the abnormal returns found. The market rewards companies with low GHG-emissions and thus does not price the positive effect of low absolute levels of GHG-emissions correctly. Hypothesis 4a is consequently rejected.

Table 23: Regression results: Absolute levels of GHG-emissions

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	0001	1000	2000	3000	4000	5000	6000	7000	9000	ACV	Adj. R^2
High GHG																
CAPM	5.632% **	1.009 ***														0.930
C4FM	5.107% *	1.044 ***	-0.322 **	0.010	-0.187											0.936
C4FM + Industry	0.739%	0.971 ***	-0.143 *	0.275 ***	0.094	0.247 **	0.409 **	0.639 **	0.375	0.148	0.429	0.066	0.634 ***	0.154 *		0.979
C4FM + Industry / Weighted	0.953%	0.973 ***	-0.118	0.271 ***	0.084	0.298 ***	0.509 ***	0.748 **	0.451 *	0.197 **	0.531 *	0.132	0.635 ***	0.155 **		0.979
C4FM + Industry / GHG t-2	-0.667%	0.875 ***	-0.189 **	0.495 ***	0.095	0.344 ***	0.400 ***	0.719 **	0.416	0.188 **	0.427	0.088	0.685 ***	0.162 **		0.980
C4FM + Industry / June	0.492%	0.928 ***	-0.118	0.267 ***	-0.005	0.183 ***	0.244 **	0.290	0.173	0.060	0.245	0.023	0.505 ***	0.083		0.975
C4FM + Industry + Carbon	1.820%	0.947 ***	-0.147	0.274 ***	-0.086	0.135 **	0.081	0.140	-0.178	-0.065	0.039	-0.069	0.300 **	-0.029	-0.002 **	0.978
C4FM + Industry + Oil	0.778%	0.962 ***	-0.172 *	0.287 ***	0.079	0.226 **	0.386 **	0.633 **	0.335	0.150 *	0.422	0.060	0.602 ***	0.140 *	0.021	0.979
C4FM + Industry + Crisis	3.631% **	0.929 ***	-0.097	0.235 ***	0.057	0.230 **	0.339 *	0.539	0.257	0.111	0.339	0.017	0.546 ***	0.126	-0.030 **	0.981
Medium GHG																
CAPM	1.840% *	0.964 ***														0.977
C4FM	1.802% *	1.012 ***	-0.172 ***	-0.025	-0.006											0.978
C4FM + Industry	0.911%	1.035 ***	-0.239 ***	-0.068	-0.039	-0.116	-0.247	-0.452	-0.296	-0.123	-0.560	-0.113	-0.380 **	-0.147		0.982
C4FM + Industry / Weighted	-0.425%	1.063 ***	-0.231 **	-0.098	-0.043	-0.040	0.031	-0.106	0.081	0.029	0.033	0.073	-0.173	-0.082		0.976
C4FM + Industry / GHG t-2	2.138% **	0.981 ***	-0.193 ***	-0.009	-0.050	-0.096	-0.182	-0.351	-0.083	-0.001	-0.327	-0.055	-0.212	-0.099		0.989
C4FM + Industry / June	0.768%	0.986 ***	-0.123	-0.012	-0.045	-0.025	-0.029	-0.033	0.012	0.063	-0.080	0.035	-0.175 **	-0.084 *		0.982
C4FM + Industry + Carbon	0.139%	0.931 ***	-0.093	-0.006	-0.099	-0.037	-0.018	-0.044	0.256 **	0.127 **	-0.015	0.038	-0.082	-0.047	0.001 *	0.985
C4FM + Industry + Oil	0.864%	1.047 ***	-0.203 ***	-0.082 *	-0.020	-0.091	-0.218	-0.445	-0.247	-0.125	-0.552	-0.105	-0.341 **	-0.130	-0.026 **	0.984
C4FM + Industry + Crisis	-0.361%	1.054 ***	-0.259 ***	-0.050	-0.023	-0.109	-0.216	-0.408	-0.245	-0.106	-0.520	-0.091	-0.341 *	-0.135	0.013	0.982
Low GHG																
CAPM	-1.121%	0.972 ***														0.957
C4FM	-0.552%	0.968 ***	0.204	-0.060	0.123											0.959
C4FM + Industry	3.611% *	0.968 ***	0.281 **	-0.211 **	-0.035	0.111 *	0.203 *	0.552 **	0.518 **	0.158 *	0.825 ***	0.308 ***	0.182 *	0.096		0.977
C4FM + Industry / Weighted	3.640% *	0.966 ***	0.300 **	-0.204 **	-0.035	0.104	0.114	0.424	0.347	0.119	0.712 **	0.275 ***	0.117	0.045		0.976
C4FM + Industry / GHG t-2	4.675% **	0.920 ***	0.364 **	-0.163 ***	0.057	0.206 **	0.298 *	0.701 **	0.627 **	0.273 **	0.958 ***	0.362 ***	0.226	0.096		0.981
C4FM + Industry / June	2.419%	1.015 ***	0.427 *	-0.124	0.145	0.023	0.067	0.267	0.232	0.083	0.310	0.224 **	0.104	0.014		0.966
C4FM + Industry + Carbon	0.716%	0.964 ***	0.423	-0.013	0.351 **	0.133 **	0.273 *	0.573 **	0.591 **	0.322 ***	0.647 ***	0.328 ***	0.293 **	0.069	0.001	0.964
C4FM + Industry + Oil	3.606% *	0.969 ***	0.285 **	-0.212 **	-0.033	0.113 *	0.206 *	0.552 **	0.522 **	0.157 *	0.825 ***	0.309 ***	0.185	0.097	-0.002	0.976
C4FM + Industry + Crisis	2.772%	0.980 ***	0.268 **	-0.199 **	-0.024	0.116 *	0.224 *	0.581 **	0.552 **	0.168 *	0.851 ***	0.322 ***	0.208 *	0.104	0.009	0.976
Long Low GHG - Short High GHG	2.872%	-0.004	0.424 ***	-0.486 ***	-0.129	-0.136	-0.206	-0.087	0.143	0.010	0.396	0.242 *	-0.452 *	-0.058		0.678

Notes: This table reports regression results for the three portfolios contructed from absolute levels of GHG-emissions, as well as the long-short portfolio, using monthly equal-weighted returns and equal-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, C4FM controlled for industry effects, as well as the tests of robustness of results. Tests of robustness include weighting by disclosure completeness (/ weighted), portfolio creation with GHG-data from t-2 (/ GHG t-2) and in June (/ June) and the introduction of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as on orthogonalised industry returns represented by their respective ICB code. The remaining columns show coefficient exposure on ACV and the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

6.4.2 Tests of Robustness

As a first test of robustness, to ensure that results obtained from testing hypothesis 4a are not driven by incompletely reporting companies, returns are weighted by the completeness of GHG-emissions reporting (cf. chapter *5.4.1 Incompleteness of GHG-emissions Data*). There is essentially no difference in the performance of portfolios constructed from high, medium and low levels of GHG-emissions and those portfolios in which the returns of the respective companies are weighted by their score on the Disclosure Completeness Index (see Table 23). This test of robustness illustrates that results of the low GHG portfolio are not driven by incompletely reporting companies. The Low GHG portfolio generates an annualised return of 3.64% ($p<0.10$, adjusted R-squared of 98%) when reporting completeness is controlled for.

Results obtained are also stable with regard to the construction of the portfolios with GHG-emissions data from year t-2. Interestingly, the Medium GHG portfolio generates an annualised return of 2.14% ($p<0.05$, adjusted R-squared of 99%), when portfolios are created with GHG-emissions from year t-2. As this portfolio does not show significant exposure to the crisis factor, this effect can be related to the timeliness of GHG-emissions data and/or differences in portfolio composition. Other portfolios do not change their performance when constructed with GHG-emissions data from year t-2, i.e. results obtained are robust to the timeliness of GHG-emissions data and the accompanying differences in portfolio composition.

Results of the High GHG and the Medium GHG portfolio are also robust to the creation of the respective portfolios in June of each year under analysis. The outperformance of the Low GHG portfolio however disappears. As the portfolio shows no exposure to the crisis factor, which would allow explaining the insignificant performance with a shift of the period under analysis to more months of financial market crisis, this performance can be related to the timeliness of financial data and/or differences in portfolio composition.

The Low GHG portfolio is not significantly exposed to any of the additional control variables. As to be expected, the High GHG and Medium GHG portfolio show a significant, yet small, exposure to changes in the price of carbon. Only the Medium GHG portfolio shows exposure to the changes in the price of oil. However, neither one of these additional control variables significantly impact portfolio performance. The final control variable, crisis, is only significant in the High GHG portfolio, where the negative exposure suggests that the portfolio underperforms the market in months of financial market crisis.

6.5 GHG-efficiency

With regard to GHG-efficiency as a proxy for climate change induced systematic risk, it was hypothesised in chapter *3.5 GHG-efficiency* that in an efficient market there is no difference in risk-adjusted returns between portfolios constructed from companies that have a high GHG-efficiency and those that have a low GHG-efficiency (Hypothesis 5a). Three mutually exclusive portfolios were constructed to test this hypothesis, based on companies with high, medium or low levels of GHG-efficiency respectively (cf. chapter *5.3 Portfolio Construction*). To ensure that results obtained from testing this hypothesis are not driven by incompletely reporting companies, the additional test of robustness that controls for the incompleteness of reported emissions data is also performed for these regressions (cf. chapter *5.4.1 Incompleteness of GHG-emissions Data*).

6.5.1 Regression Results

Table 24 illustrates that in the CAPM portfolios constructed from companies with a high and a low GHG-efficiency do not generate any significant out- or underperformance. The Medium GHG-efficiency portfolio generates an annualised alpha of 2.63% ($p<0.10$, adjusted R-squared of 97%). It is noticeable that the Low GHG-efficiency shows the highest beta among all portfolios with equal-weighted returns, suggesting that low GHG-efficiency might be related to higher systematic risk, as argued in chapter *3.5 GHG-efficiency*. However, given the fact that there is a difference in risk-adjusted returns, these initial results also hint at the fact that the market may not be pricing GHG-efficiency as a proxy for climate change induced systematic risk efficiently.

When factors generally accepted to impact stock performance are controlled for in the C4FM, the outperformance of the Medium GHG-efficiency portfolio increases to 3.04% annually ($p<0.05$, adjusted R-squared of 97%). The Medium GHG-efficiency portfolio loads negatively on SMB and HML, suggesting that it contains rather large companies with a low book-to-market-ratio. Performances of the High GHG-efficiency and Low GHG-efficiency portfolio remain unchanged in the C4FM.

As these three portfolios can be expected to show differences in industry composition, industry effects are controlled for. Results of equal-weighted GHG-efficiency portfolios change when controlled for industry effects: For example, the High GHG-efficiency generates an annualised alpha of 3.04% ($p<0.05$, adjusted R-squared of 97%), when its exposure to the comparatively poor performing Telecommunications industry (ICB 6000) is controlled for.[42] The outperformance of the Medium GHG-efficiency portfolio is reduced to an annualised return of 2.59% ($p<0.10$, adjusted R-squared of 98%). This reduction is due to the significant positive exposure of the Medium GHG-efficiency portfolio to the comparatively well-performing Oil & Gas industry (ICB 0001). The Low GHG-efficiency portfolio has a negative alpha, which however is not statistically significant at any conventional significance level.[43] Though these portfolios are only significantly exposed to few industry variables, the adjusted R-squared of the C4FM extended with industry effects increases significantly compared to the traditional C4FM, for example from 94% to 97% in the case of the High GHG-efficiency portfolio. This increase in adjusted R-squared suggests that controlling for industry effects increases the fit of the model and that controlling for industry effects thus enhances the explanatory power of the regression. In summary, these results obtained with the C4FM extended

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[42] When returns are value-weighted the High GHG-efficiency portfolio also generates an annualised return of 2.74% ($p<0.05$, adjusted R-squared of 96%). See Appendix *A.5 GHG-efficiency*.

[43] When returns are value-weighted the Low GHG-efficiency portfolio generates a statistically significant annualised loss of -2.72% ($p<0.10$, adjusted R-squared of 98%). See Appendix *A.5 GHG-efficiency*.

with industry effects suggest that portfolios constructed from companies with a comparatively high GHG-efficiency generate abnormal returns.

As also shown in Table 24, a trading strategy that goes long in companies with a high GHG-efficiency and short in companies with a low GHG-efficiency generates an annualised alpha of 4.10% (p<0.10). These abnormal returns of 4.10% not only cover transaction and information costs, but remain statistically and economically significant even when a rather high annual total expense ratio of 1.50% for carrying out the investment strategy is assumed (cf. Geczy et al., 2005; Renneboog et al., 2008b; Statman, 2000). Results thus indicate market inefficiency not only in Fama's original version of EMH, but also in Jensen's adaption of EMH (cf. chapter *2.1.3 Three Conditions for an Efficient Market)*, which accounts for transaction and information costs. The outperformance identified is even higher when a long-short trading strategy is applied under complementary weighting procedures: Annualised returns of 5.46% (p<0.01) and 5.48% (p<0.01) are obtained when returns are value-weighted (see Appendix A.5 GHG-efficiency) and when equal-weighted portfolio returns are regressed on value-weighted factors (see Appendix B.5 GHG-efficiency) respectively.

In summary, the persistent differences in the risk-adjusted returns between the portfolios suggest that the market is inefficient in pricing GHG-efficiency as a proxy for climate change induced systematic risk. As it was argued that low GHG-efficiency hints at high exposure towards the systematic risk induced by climate change (cf. chapter *3.5 GHG-efficiency*), there is no risk-based explanation for the abnormal returns of portfolios constructed from companies with high and medium levels of GHG-efficiency. The market rewards companies with higher levels of GHG-efficiency and thus does not price the positive effect of comparatively high levels of GHG-efficiency correctly. Hypothesis 5a is consequently rejected.

Table 24: Regression results: GHG-efficiency

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	0001	1000	2000	3000	4000	5000	6000	7000	9000	ACV	Adj. R^2
High GHG-efficiency																
CAPM	-0.278%	0.857 ***														0.943
C4FM	-0.305%	0.923 ***	-0.178	0.012	0.141											0.944
C4FM + Industry	3.035% **	0.932 ***	-0.133	-0.162 **	-0.043	-0.031	-0.056	0.132	0.216	0.066	0.261	0.168 **	-0.066	0.025		0.972
C4FM + Industry / Weighted	3.370% **	0.948 ***	-0.145	-0.167 **	-0.033	-0.020	-0.045	0.154	0.175	0.051	0.287	0.181 **	-0.056	0.023		0.967
C4FM + Industry / GHG t-2	3.209% *	0.885 ***	-0.165	-0.102	0.076	-0.076	-0.223	-0.222	-0.136	0.007	-0.089	0.093	-0.232	-0.078		0.958
C4FM + Industry / June	2.220%	0.933 ***	0.229	-0.113	0.114	-0.011	0.042	0.203	0.279	0.147	0.305	0.287 ***	0.082	0.027		0.960
C4FM + Industry + Carbon	0.704%	0.871 ***	0.423	-0.122	0.355 *	0.119 *	0.307 *	0.579 **	0.839 ***	0.462 ***	0.672 ***	0.419 ***	0.362 *	0.152	-0.002	0.950
C4FM + Industry + Oil	3.019% *	0.936 ***	-0.121	-0.167 **	-0.037	-0.023	-0.047	0.134	0.232	0.065	0.264	0.170 **	-0.054	0.031	-0.009	0.972
C4FM + Industry + Crisis	2.119%	0.946 ***	-0.147	-0.149 **	-0.032	-0.026	-0.034	0.164	0.254	0.078	0.290	0.183 **	-0.038	0.034	0.009	0.972
Medium GHG-efficiency																
CAPM	2.632% *	0.940 ***														0.969
C4FM	3.035% **	1.012 ***	-0.150 *	-0.127 **	-0.025											0.973
C4FM + Industry	2.594% *	1.030 ***	-0.222 ***	-0.136 **	-0.033	0.139 ***	0.098	0.012	0.270	0.045	0.225	0.001	-0.073	-0.048		0.984
C4FM + Industry / Weighted	3.059% **	1.000 ***	-0.186 ***	-0.131 **	-0.038	0.121 *	0.073	-0.040	0.218	0.096	0.228	0.029	-0.104	-0.061		0.981
C4FM + Industry / GHG t-2	3.701% **	1.001 ***	-0.289 ***	-0.052	-0.075	0.158 **	0.107	0.057	0.350 *	0.080	0.278	-0.006	-0.012	-0.047		0.985
C4FM + Industry / June	2.494% *	1.001 ***	-0.162 **	-0.036	0.019	0.116 ***	0.042	0.024	0.185	0.065	0.079	-0.053	-0.098	-0.084 **		0.987
C4FM + Industry + Carbon	0.713%	0.997 ***	-0.188	-0.023	0.021	0.112 ***	0.113	0.101	0.333 **	0.089	0.137	-0.031	-0.024	-0.074	0.002 **	0.981
C4FM + Industry + Oil	2.558% **	1.040 ***	-0.195 ***	-0.147 ***	-0.019	0.159 ***	0.121	0.018	0.308 *	0.043	0.232	0.007	-0.043	-0.035	-0.020 *	0.985
C4FM + Industry + Crisis	1.646%	1.044 ***	-0.237 ***	-0.123 **	-0.021	0.145 ***	0.121	0.045	0.309	0.057	0.255	0.018	-0.044	-0.039	0.010	0.984
Low GHG-efficiency																
CAPM	3.596%	1.154 ***														0.955
C4FM	3.084%	1.089 ***	0.024	0.073	-0.182 *											0.957
C4FM + Industry	-1.067%	1.012 ***	0.244 ***	0.315 ***	0.090	0.050	0.215	0.451	-0.068	0.024	-0.040	0.058	0.477 **	0.095		0.984
C4FM + Industry / Weighted	-0.889%	1.042 ***	0.233 *	0.302 ***	0.072	0.070	0.280	0.528	-0.065	0.001	0.015	0.100	0.455 *	0.096		0.981
C4FM + Industry / GHG t-2	-1.444%	0.887 ***	0.464 ***	0.476 ***	0.107	0.292 ***	0.553 ***	1.118 ***	0.625 *	0.353 ***	0.689 *	0.304 **	0.885 ***	0.273 ***		0.985
C4FM + Industry / June	-1.642%	0.990 ***	0.131	0.289 ***	-0.061	0.030	0.174	0.275	-0.106	-0.004	0.042	0.079	0.425 ***	0.071		0.982
C4FM + Industry + Carbon	0.894%	0.949 ***	-0.017	0.406 ***	-0.259 ***	-0.050	-0.137	-0.071	-0.525 **	-0.156	-0.188	-0.070	0.149	-0.084	-0.001	0.978
C4FM + Industry + Oil	-1.034%	1.003 ***	0.219 **	0.325 ***	0.077	0.032	0.195	0.446	-0.103	0.025	-0.046	0.053	0.449 **	0.083	0.019	0.984
C4FM + Industry + Crisis	1.488%	0.974 ***	0.284 **	0.279 ***	0.058	0.035	0.153	0.363	-0.172	-0.009	-0.120	0.015	0.399 *	0.071	-0.026 *	0.985
Long Low GHG-efficiency - Short High GHG-efficiency	4.102% *	-0.080	-0.377 ***	-0.477 ***	-0.134	-0.081	-0.271	-0.319	0.284	0.043	0.302	0.109	-0.543 *	-0.070		0.795

Notes: This table reports regression results for the portfolios contructed from three levels of GHG-efficiency, as well as the long-short portfolio, using monthly equal-weighted returns and equal-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, C4FM controlled for industry effects, as well as the tests of robustness of results. Tests of robustness include weighting by disclosure completeness (/ weighted), portfolio creation with GHG-data from t-2 (/ GHG t-2) and in June (/ June) and the introduction of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as on orthogonalised industry returns represented by their respective ICB code. The remaining columns show coefficient exposure on ACV and the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

6.5.2 Tests of Robustness

The results obtained are robust to a weighting of portfolio returns according to disclosure completeness (cf. chapter *5.4.1 Incompleteness of GHG-emissions Data*). The performance of equal-weighted portfolios constructed from high, medium and low levels of GHG-efficiency is slightly higher to those portfolios in which the returns of the respective companies are weighted by their score on the Disclosure Completeness Index (see Table 24). For example, the disclosure weighted Medium GHG-efficiency portfolio generates an annualised return of 3.01% ($p<0.05$, adjusted R-squared 98%), as compared to an annualised return of 2.59% ($p<0.10$, adjusted R-squared of 98%) for the original Medium GHG-efficiency portfolio. This difference in risk-adjusted returns of 0.46% suggests that the returns of the original Medium GHG-efficiency portfolio are driven by more completely reporting companies. Consequently, it is ensured that incompletely reporting companies are not driving the results of the Medium GHG-efficiency portfolio.

Results obtained are also robust to the construction of the portfolios with GHG-emissions data from year t-2, i.e. no significant change in portfolio performance takes place when portfolios are constructed with returns from year t-2. Results of the Medium GHG-efficiency and the Low GHG-efficiency portfolios are robust to the construction of portfolios in June of each respective year. Results of the High GHG-efficiency portfolio are however not robust to portfolio creation in June, suggesting that the timeliness of financial performance data and/or differences in portfolio composition (cf. chapter *5.4.5 Portfolio Creation in June*) might be important here, as the portfolio shows no exposure to the crisis factor, which would allow explaining the insignificant performance with a shift of the period under analysis to more months of financial market crisis.

The additional control variables for the changes in the price of carbon and oil, as well as financial market crisis are insignificant for the High GHG-efficiency portfolio. The Medium GHG-efficiency portfolio shows a significant, yet small, exposure to changes in the price of carbon and oil. While portfolio returns are robust to the changes in the price of oil, changes in the price of carbon significantly affect portfolio returns of the Medium GHG-efficiency portfolio. The final control variable, crisis, is only significant in the Low GHG-efficiency portfolio, where the negative exposure suggests that the Low GHG-efficiency portfolio underperforms the market in months of financial market crisis.

6.6 High Carbon Industries

With regard to the affiliation with high carbon industries as a proxy for climate change induced systematic risk, it was hypothesised in chapter *3.6 High carbon industries* that in an efficient market there is no difference in risk-adjusted returns between portfolios constructed from companies from high carbon and those from low carbon industries (Hypothesis 6a).

6.6.1 Regression Results

In the CAPM, as illustrated in Table 25, the High carbon industries portfolio generates an annualised alpha of 3.60% while the Low Carbon Industries portfolio generates an annualised loss of -2.92% (both at $p<0.10$ and an adjusted R-squared of 97%). The increased beta coefficient of the High carbon industries portfolio suggests that this portfolio is more exposed to systematic risk than the Low carbon industries portfolio. However, given the fact that there is a difference in risk-adjusted returns, these initial results hint at the fact that the market may not incorporate climate change induced systematic risk in beta.

When factors generally accepted to explain financial market performance are controlled for in the C4FM, the outperformance of the High carbon industries portfolio increases to 4.17% ($p<0.05$, adjusted R-squared of 98%) annually.[44] The loss of the Low carbon industries portfolio grows to -3.42% on an annual basis ($p<0.05$, adjusted R-squared of 98%). Both portfolios show significant exposure to the HML and UMD factors. The performance of the High carbon industries portfolio was consequently corrected for the fact that it contains predominantly stocks with a low book to market ratio which performed poor historically. In contrast, the performance of the Low carbon industries portfolio shows positive exposure to the

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[44] Similar results are obtained for the High carbon industries portfolio when returns are value-weighted (see Appendix A.6 High Carbon Industries) and when equal-weighted portfolio returns are regressed on value-weighted factors (see Appendix B.6 High Carbon Industries).

HML and UMD factors, i.e. it contains predominantly stocks with a high book to market ratio (value stocks) which performed well historically. As discussed in chapter *5.2.1 Controlling for industry effects*, these portfolios are not controlled for industry effects, as doings so would cancel out the climate change induced systematic risk at industry level, which is of interest in this context.

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	ACV	Adj. R^2
High carbon industries							
CAPM	3.596% *	1.094 ***					0.973
C4FM	4.170% **	1.112 ***	0.009	-0.185 *	-0.202 ***		0.977
C4FM / June	2.952% *	1.112 ***	-0.205 **	-0.023	-0.139 ***		0.977
C4FM + Carbon price	4.016% **	1.043 ***	-0.091	0.049	-0.109 *	0.000	0.972
C4FM + Oil price	3.803% **	1.097 ***	-0.003	-0.155 *	-0.181 ***	0.026 **	0.978
C4FM + Crisis	4.642% **	1.103 ***	0.027	-0.192 *	-0.204 ***	-0.006	0.977
Low carbon industries							
CAPM	-2.924% *	0.918 ***					0.971
C4FM	-3.416% **	0.904 ***	-0.012	0.159 *	0.176 ***		0.976
C4FM / June	-2.452%	0.902 ***	0.170 **	0.028	0.127 ***		0.975
C4FM + Carbon price	-3.358% **	0.961 ***	0.060	-0.025	0.102 *	-0.000	0.974
C4FM + Oil price	-3.106% **	0.917 ***	-0.003	0.133 *	0.159 ***	-0.022 *	0.977
C4FM + Crisis	-3.791% **	0.912 ***	-0.026	0.164 *	0.178 ***	0.004	0.976
Long High carbon industries - Short Low carbon industries	7.586% **	0.209 ***	0.021	-0.344 *	-0.378 ***		0.339

Notes: This table reports regression results for the High carbon indstries and the Low carbon industries portfolios, as well as the long-short portfolio, using monthly equal-weighted returns and equal-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, as well as the tests of robustness of results. Tests of robustness include portfolio creation in June (/ June) and the inclusion of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors and ACV, as well as the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

Table 25: Regression results: Affiliation to high carbon industries

When a long-short trading strategy is applied, an investor that goes long in companies from high carbon industries and short in companies from low carbon industries generates an annualised return of 7.59% ($p<0.05$).[45] Results thus suggest that the financial market was not efficiently pricing this proxy for climate change induced systematic risk between January 2005 and December 2009 in Fama's (1970) original

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[45] Similar results are obtained when equal-weighted portfolio returns are regressed on value-weighted factors (see Appendix *B.6 High Carbon Industries*), but not returns are value-weighted (see Appendix *A.6 High Carbon Industries*).

version of the EMH. When assuming a rather high annual total expense ratio of 1.50% for carrying out the investment strategy (cf. Geczy et al., 2005; Renneboog et al., 2008b; Statman, 2000), the alpha of 7.59% remains statistically significant. The persistent risk-adjusted abnormal returns identified consequently not only cover transaction and information costs. The market is thus inefficiently pricing this proxy for climate change induced systematic risk also in Jensen’s (1978) less strong but economically more reasonable definition of EMH (cf. chapter *2.1.3 Three Conditions for an Efficient Market)*. Consequently, hypothesis 6a is rejected.

As it was argued that affiliation with high carbon industries hints at higher exposure towards the systematic risk induced by climate change, there is a risk-based explanation for the abnormal returns of a portfolio constructed from companies affiliated with high carbon industries. If there is a risk-based explanation, and the abnormal returns exist in different markets and time periods, the abnormal returns can be attributed to shortcomings in the underlying asset pricing model to price the respective risk correctly. If the abnormal risk-adjusted returns identified here were to continue to exist outside of this sample and the period studied, the increased systematic risk related to high carbon industries might qualify as an additional risk premium in the future. This interpretation of the results can then be aligned with the EMH. However, as discussed in chapter *2.1.4 Methodologies and Findings*, further research is needed before a conclusion of this magnitude can be drawn and therefore any risk-adjusted abnormal returns found in this research is interpreted as market inefficiency (cf. chapter *2.1.6 Application of EMH in this Research*). It must further be acknowledged in this context that the differences of risk-adjusted performance at the industry level might have other explanations than climate change induced systematic risk. Nevertheless, as the Utilities industry, Basic Materials industry, Industrials and Oil & Gas industry are more likely to be targeted by political and market initiatives for the reduction of GHG-emissions (cf. chapter *3.6 High Carbon Industries*) and represent the industries with the highest average reported GHG-emissions per company in this research, climate change induced systematic risk can be identified as one common characteristic of the out- and underperformance found.

6.6.2 Tests of Robustness

Results obtained are robust to all tests of robustness (see Table 25), i.e. the creation of portfolios in June of each year under analysis, as well as the additional control variables. When portfolios are constructed in June, the alpha of the Low carbon industries portfolio is almost significant at p = 0.1085 (unreported). Consequently results are interpreted to be robust for the creation of the portfolio in June as well. Both portfolios show significant exposure to the additional control variables of changes in the price of oil. The High carbon industries portfolio shows a significant positive exposure, while the low carbon industries portfolio shows a significant negative exposure. These exposures do however not strongly affect portfolio results. Other additional control variables are insignificant, i.e. there is no significant exposure of portfolio returns to the changes in the price of carbon or months of financial market crisis.

In the following final chapter of this thesis, the results presented are summarised and critically discussed in the light of the EMH. The relevance and contribution of this research to both academia and investors are illustrated. Finally, limitations of this research and its implications for future research are shown.

Chapter 7
Conclusions and Discussion

The objective of this research was to assess the level of market efficiency towards climate change induced systematic risk. In summary, the results obtained in chapter *6 Regression Results* suggest that the market was inefficient in pricing climate change induced systematic risk of companies from the European Union in the years 2005 to 2009.

Results obtained with regard to the each of the six proxies for climate change induced systematic risk are briefly summarised and discussed in the light of their implications from the perspective of EMH in chapter *7.1 Summary of Results in Light of EMH*. Subsequently, the implications for the investment community of the results obtained, as well as the contribution of this research to knowledge are illustrated in chapter *7.2 Relevance and Contribution to Knowledge*. Finally, limitations of this study and suggestions for future research are discussed in chapter *7.3 Limitations and Avenues for Future Research*.

7.1 Summary of Results in Light of EMH

With regard to the first proxy for climate change induced systematic risk in this research, it was found that a trading strategy that goes long in companies affiliated with the EU ETS and short in companies not affiliated with the EU ETS generates an annualised alpha of 5.12% ($p<0.10$) (see Table 20), when portfolio returns are equal-weighted. Even higher persistent and significant abnormal returns were found when supplementary weighting procedures of returns were applied (see Appendices *A.1 European Emission Trading Scheme* and *B.1 European Emission Trading Scheme*). Hypothesis 1a, which stipulated that the market is efficient, i.e. there is no difference in risk-adjusted returns between portfolios constructed from companies that are affiliated and those that are not affiliated with the EU ETS, was consequently rejected.

It was argued in chapter *3.1 European Emissions Trading Scheme* that the returns of companies that are affiliated with the EU ETS are more sensitive to the market-wide risk induced by climate change due to the unpredictability of future costs related to emitting GHG-emissions under the EU ETS. Following this line of argument, there is a risk-based explanation for the persistently risk-adjusted abnormal returns found for the portfolio constructed from companies affiliated with the EU ETS. As discussed in chapter *2.1.4 Methodologies and Findings,* opponents of the EMH tend to interpret any abnormal risk-adjusted returns as evidence for market inefficiencies. Advocates of the EMH argue that, if abnormal returns for which there is a risk-based explanation exist in different markets and time periods, these abnormal returns can be attributed to shortcomings in the underlying asset pricing model to price the respective risk correctly (cf. chapter *6.1.1 Regression Results).*

Consequently, if the risk-adjusted abnormal returns found here were to continue to exist outside of this sample and the period studied, the increased climate change induced systematic risk related to the EU ETS might qualify as an additional risk premium at some point in the future. Results of this research could then be attributed to the inability of beta to grasp climate change induced systematic risk as proxied by affiliation to the EU ETS correctly. In this case, results obtained could be aligned with the EMH, according to which investors are rewarded for taking risk. However, as discussed in chapter *2.1.4 Methodologies and findings*, further research is needed before any conclusion of this magnitude can be made and consequently the abnormal risk-adjusted return found in this study is interpreted as market inefficiency (cf. chapter *2.1.6 Application of EMH in this Research*).

In fact, the tests of robustness performed in this study cannot exclude the possibility that the risk-adjusted abnormal returns identified occurs only in the period analysed in this study (cf. chapter *6.1.2 Tests of robustness*) and that consequently the inefficiency found cannot be attributed to a shortcoming in the underlying asset pricing model. If risk-adjusted abnormal returns were to occur only in the period analysed in this study, a reasonable explanation for the abnormal returns found in this research would be that the financial market took time to efficiently incorporate the new phenomenon that the EU ETS represented during the period analysed in this study. Such an explanation however cannot be aligned with the notion of an efficient market, as prices that are only slowly adjusting to reflect available information are not consistent with the EMH. EMH stipulates that prices at every time represent good estimates of intrinsic value.

With regard to the second proxy of climate change induced systematic risk, i.e. the existence of disclosure of GHG-emissions, the financial market was also found to be inefficient. It was argued in chapter *3.2 Existence of Disclosure of GHG-Emissions* that companies that disclose their absolute levels of GHG-emissions to market participants reduce their estimation and information risk by facilitating better and more reliable estimations of their specific future cash flows, which reduces the covariance of their returns with market returns and, ceteris paribus, their beta. As shown at the bottom of Table 21 in chapter *6.2.1 Regression Results*, a trading strategy that goes long in companies reporting GHG-emissions and short in companies not reporting GHG-emissions generates an annualised alpha of 4.34% ($p<0.01$) in the C4FM extended for industry effects. These results confirm findings of Ziegler et al. (2011) who reported for a short sub-period of their study that an investment strategy that goes long in companies disclosing a general responses to climate change and short in non-disclosing companies generated an annualised abnormal return of almost 7% between 2004 and 2006 in Europe (cf. chapter *2.2.7 Review of Studies*).

The significant persistent difference in portfolio returns shows that the market is inefficient in pricing this second proxy for climate change induced systematic risk. Tests of robustness confirm these results (cf. chapter *6.2.2 Tests of Robustness*). Hypothesis 2a, which stipulated that the market is efficient, i.e. there is no difference in risk-adjusted returns between portfolios constructed from companies that report and those that do not report GHG-emissions, is consequently rejected. In the absence of a risk-based explanation for the abnormal returns found, there is no possibility to align the outperformance of GHG-disclosing firms with the EMH. In this context it is worth mentioning that some scholars discuss the possibility that committing financial resources to environmental disclosure or an improvement of environmental performance increases the risk of a company (Salama et al., 2011). This conclusion does not apply to the results of this research as the interpretation of risk in the mentioned argument refers to downside risk and is consequently different to the notion of systematic risk applied in this study. Furthermore, the in-depth analysis of sample characteristics carried out in chapter *4.4 Understanding Sample Characteristics* showed that there are no significant differences in the profitability of companies disclosing GHG-emissions and those not disclosing, or companies that report complete GHG-emissions as opposed to incompletely reporting companies.

The completeness of corporate disclosures on absolute levels of GHG-emissions was the third proxy for climate change induced systematic risk applied in this study. It was argued in chapter *3.3 Disclosure Completeness* that incomplete disclosure of GHG-emissions results in higher non-diversifiable estimation and information risk. In chapter *6.3.1 Regression Results*, a trading strategy that goes long in companies reporting complete GHG-emissions (3 Score) and short in companies reporting incomplete GHG-emissions (0 Score) was identified to generate an annualised alpha of 13.05% ($p<0.01$) in the C4FM extended for industry effects. Tests of robustness largely confirm these results (cf. chapter *6.3.2 Tests of Robustness*). There is no risk-based explanation for the significant abnormal returns of completely reporting companies, i.e. companies that report scope 1 and 2 GHG-emissions for group-wide activities in line with the requirements of dominant reporting guidelines. At the same time, incompletely reporting companies (0 Score) not only have higher estimation and information risk, but – as evidenced in chapter *4.4.2 Completeness of Corporate GHG-disclosure* – are also more likely to be affiliated with the EU ETS and consequently are even more exposed to climate change induced systematic risk. Despite this increased risk, the 0 Score portfolios generate an annualised loss of 8.15% ($p<0.01$). Consequently, the financial market is concluded to be inefficient towards this proxy for climate change induced systematic risk between January 2005 and December 2010. Hypothesis 3a, which stipulated that the market is efficient, i.e. there is no difference in risk-adjusted returns between companies that report complete and those that report incomplete GHG-emissions, is consequently rejected.

With regard to the fourth proxy for climate change induced systematic risk, i.e. absolute levels of GHG-emissions, the market was also found to be inefficient. It was argued in chapter *3.4 Absolute Levels of Emissions* that the returns of companies that emit comparatively high levels of GHG-emissions are more exposed to the systematic risk induced by climate change and that in an efficient market there is no difference in risk-adjusted returns between companies that have high and those have low levels of absolute GHG-emissions (Hypothesis 4a). In chapter *6.4.1 Regression Results* it was evidenced that the Low GHG portfolio generates a risk-adjusted annualised alpha of 3.61% (p<0.10) when portfolio returns are equal-weighted and regressed on the C4FM extended for industry effects. When portfolio returns are value-weighted (see Appendix *A.4 Absolute Levels of GHG-emissions*), a trading strategy that goes long in companies with low absolute levels of GHG-emissions and short in companies with high absolute levels of GHG-emissions generates an annualised alpha of 5.59% (p<0.01).

These results suggest that the financial market was inefficient in pricing the absolute level of GHG-emissions as a proxy for climate change induced systematic risk of European companies between January 2005 and December 2009. Hypothesis 4a is consequently rejected. In an additional test of robustness of these results, company returns were weighted according to the completeness of their GHG-emissions disclosure (cf. chapter *5.4.1 Incompleteness of GHG-emissions Data*) to make sure that incompletely reporting companies are not driving the results obtained with portfolios constructed from absolute levels of GHG-emissions. Results obtained in this tests of robustness confirmed results of the original regression (cf. chapter *6.3.2 Tests of Robustness*). As it was argued in this research that higher absolute levels of GHG-emissions result in higher exposure towards the systematic risk induced by climate change, no risk-based explanation for the abnormal returns of a portfolio constructed from companies with low levels of GHG-emissions is available. Results cannot be aligned with the EMH, in which investors are rewarded for taking risk.

With regard to the fifth proxy of climate change induced systematic risk in this study, it was argued that the ratio of net income to GHG-emissions, i.e. its GHG-efficiency, impacts a company’s exposure and the sensitivity of its returns towards the systematic risk induced by climate change (cf. chapter *3.5 GHG-efficiency).* In chapter *6.5.1 Regression Results* it was found that a trading strategy that goes long in companies with a high GHG-efficiency and short in companies with a low GHG-efficiency generates an annualised alpha of 4.10% (p<0.10) when portfolio returns are equal-weighted and regressed on the C4FM extended for industry effects. This outperformance increases to 5.46% (p<0.01) and 5.48% (p<0.01) when returns are value-weighted (see Appendix *A.5 GHG-efficiency*) and when equal-weighted portfolio returns are regressed on value-weighted factors (see Appendix *B.5 GHG-efficiency*) respectively. The results obtained are robust to a weighting of portfolio returns according to the completeness of GHG-emissions disclosure (cf. chapter *5.4.1 Incompleteness of GHG-emissions Data*), i.e. incomplete reporting companies are not driving the results obtained. Results are also reasonably robust to other tests of robustness (cf. chapter *6.5.2 Tests of Robustness*).

As it was argued that low levels of GHG-efficiency results in higher exposure towards the systematic risk induced by climate change, there is no risk-based explanation for the persistent abnormal returns of portfolios constructed from companies with high and medium levels of GHG-efficiency (see Table 24). The differences in risk-adjusted returns between the portfolios evidenced with the long-short investment strategy suggest that the market is inefficient in pricing GHG-efficiency as a proxy for climate change induced systematic risk. Consequently, hypothesis 5a, which stipulated that the market is efficient, i.e. there is no difference in risk-adjusted returns between companies that have a high GHG-efficiency and those have a low GHG-efficiency, is also rejected.

With regard to the final proxy of climate change induced systematic risk in this study, affiliation with high carbon industries, it was argued in *3.6 High Carbon Industries* that the returns of companies affiliated with high carbon industries show a higher exposure and the sensitivity towards the systematic risk induced by climate change. Results of regressions in chapter *6.6.1 Regression Results* showed that an investor that goes long in companies from high carbon industries and short in companies from low carbon industries generates an annualised alpha of 7.59% ($p<0.05$). This persistent difference in equal-weighted risk-adjusted portfolio returns illustrated by the long-short investment strategy suggests that the financial market was not efficiently pricing this proxy for climate change induced systematic risk between 2005 and 2009. The results obtained are robust to all tests of robustness (cf. chapter *6.6.2 Tests of Robustness*). Consequently, hypothesis 6a, which stipulated that the market is efficient, i.e. there is no difference in risk-adjusted returns between companies from high carbon and those from low carbon industries, is also rejected.

As there is a risk-based explanation for the outperformance found, advocates of the EMH would argue that they might be due to a shortcoming in the underlying asset pricing model, i.e. the inability of beta to grasp climate change induced risk correctly. Results obtained could then be aligned with the basic notion of the EMH according to which investors are rewarded for taking risk. However, as discussed in chapter *2.1.4 Methodologies and findings*, further research is needed before any conclusion of this magnitude can be made and consequently any abnormal risk-adjusted return found in this study is interpreted as market inefficiency (cf. chapter *2.1.6 Application of EMH in this Research*). Also, while the Utilities industry, Basic Materials industry, Industrials and Oil & Gas industry share the characteristic that they are more likely to be targeted by political and market initiatives for the reduction of GHG-emissions and contain the highest average reported GHG-emissions per company, this research cannot exclude the possibility that factors other than climate change induced systematic risk might be responsible for the outperformance found.

Overall, the financial market was concluded to be inefficient with regard to the six proxies for the climate change induced systematic risk of European companies between 2005 and 2009. As discussed in chapter *2.1.3 Three Conditions for an Efficient Market*, the inefficiencies identified do not come as a complete surprise, given that conditions for an efficient market are not entirely fulfilled in the context of CSP and proxies for climate change induced systematic risk. While the market may be efficient even if these conditions are not met, the potential for market inefficiency increases when the conditions are not fulfilled (Fama, 1970). In this context, results of this study are especially interesting with regard to the third condition for market efficiency, which stipulates that all market participants agree on the implications of information to the future price of a stock. On one hand, the abnormal returns found in this study clearly indicate that the information underlying the different proxies for climate change induced systematic risk used in this study are relevant to the intrinsic value of the firm. At the same time, findings confirm the circumstance that not all market participants agree on the implications of information on CSP and climate change induced systematic risk to the future price of a stock (cf. chapter *2.1.3 Three Conditions for an Efficient Market*). If all market participants agreed and consequently had acted on the value-relevance of the six proxies for climate change induced systematic risk applied in this study, no arbitrage opportunities would exist.

In fact, results of this research thus indicate that in retrospect a large share of market participants was wrong not to incorporate information on a company's affiliation to the EU ETS and high carbon industries, its GHG-emissions disclosure strategy or its climate change performance into their assessment of the intrinsic value of a firm during the period analysed in this study. While this is a bold statement, it would not be the first time the majority of market participants were homogeneously wrong (Malkiel, 2003a).

Violations of the first and second condition for market efficiency, which state that there are no transaction costs and all available information is costless available to all market participants (cf. chapter *2.1.3 Three Conditions for an Efficient Market*), are fully accounted for in this research. As discussed in chapter *4.2 Data Collection*, information used in this research comes from publicly available sources, which were available at no cost during the time analysed in this study. Nevertheless, some scholars would argue that there are costs involved in the gathering of information for the six proxies for climate change induced systematic risk used in this study, which relate to the time invested in producing the information for each of the companies in the sample of this study (Ball, 1994). These information costs, as well as hypothetical transaction costs, are accounted for in this test of market efficiency by means of a total expense ratio of 1.5%, which corresponds to a rather high level of transaction and information costs for SRI mutual funds (cf. Geczy et al., 2005; Renneboog et al., 2008b; Statman, 2000). In summary, all conclusions on market inefficiency discussed above hold even when approximated costs for transactions and information are deducted (cf. chapter *chapter 6 Regression* Results).[46] Consequently, the market is inefficient not only in Fama's original version of the EMH (1970), but also in the less strong but economically more reasonable version of the EMH suggested by Jensen (1978) with regard to the first and second condition for market efficiency. Jensen's adaption of EMH stipulates that in an efficient market an investment strategy cannot generate abnormal risk-adjusted returns in excess of its transaction and information costs.

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[46] With regard to the fourth proxy for climate change induced systematic risk, i.e. absolute levels of GHG-emissions, this conclusion is only valid when portfolio results are value-weighted (cf. chapter *6.4.1 Regression Results*).

In the light of EMH, results of this study are furthermore interesting with regard to the existence of risk-based explanations for the abnormal results found. As discussed before, further research is necessary before abnormal returns for which there is a risk-based explanation can be related to shortcomings in the underlying asset pricing model and consequently be aligned with the EMH (cf. chapter *2.1.4 Methodologies and Findings)*. Keeping this constraint in mind, it is nevertheless interesting to theoretically discuss the implications of these results from an EMH perspective under the assumption that (1) they will be validated by future research and (2) the outperformance at the industry level is related to climate change induced systematic risk:

Risk-based explanations are only available in this study for proxies for market-wide climate change risk that refer to the industry level, i.e. company affiliation with the EU ETS and high carbon industries. In the remaining regressions, which examine market efficiency towards climate change induced systematic risk via proxies that refer to the company level, results do not imply risk-based explanations. Results of this research thus hint at the circumstance that the market was able to grasp climate change induced systematic risk at industry level but not at company level. As discussed in chapter *1 Introduction*, investors have been slow to incorporate the risks related to climate change into their investment strategies. In fact, one driver for market inefficiency is that market participants do not make use of available information, as a result of the fact that they do not regard it as value relevant (cf. chapter *2.1.3 Three Conditions for an Efficient Market*). In summary, results of this research thus suggest that investors were able to grasp climate change induced systematic risk on industry level, but did not make the effort to properly analyse and take into account climate change induced systematic risk at the company level during the time of this study. Referring to Fama’s interest to research “the level of information at which the hypothesis breaks down” (Fama, 1970, p. 383), results point towards the circumstance that it might be the lacking effort of market participants to analyse information on climate change induced systematic risk at company level at which the EMH breaks down.

Results of this study furthermore show that the market inefficiently priced the positive effects of (complete) GHG-disclosure or good corporate climate change performance, as portfolios constructed from (completely) reporting companies or companies with a good climate change performance generate abnormal risk-adjusted returns. In this context, results support the findings and observation of other scholars (Derwall et al., 2005; Herremans et al., 1993; Renneboog et al., 2008b) that the risk-adjusted returns of companies with good CSP will only be constantly higher than those of companies with poor CSP when the financial market does not price information on CSP accurately. Nevertheless, in this study the Not reporting GHG portfolio, as well as the 0 Score portfolio and – when returns are value-weighted – the High GHG portfolio and the Low GHG-efficiency portfolio (cf. chapter *6 Regression Results*) at the same time generate significant abnormal losses. Assuming that these latter portfolios show higher levels of climate change induced systematic risk (cf. chapter *3 Hypotheses Development*), the market is not only *not* rewarding investors for taking on additional risk but is in fact penalising them financially. The market was consequently particularly inefficient from an EMH perspective in pricing the stipulated higher exposure to climate change induced systematic risk of companies that do not disclose GHG-emissions, report incompletely or show high absolute levels of GHG-emissions or a low GHG-efficiency.

As discussed in chapter *2.1.2 Definitions and Important Notions of EMH*, Fama did not conceptualize the efficient market to be able to perfectly predict the intrinsic value of a stock correctly all of the time. Nevertheless, the fact that the abnormal returns found in this study are persistent over a five year period suggests that they constitute market inefficiency. With regard to the expected future persistence of these abnormal returns two cases must be distinguished. Where there is no risk-based explanation for an inefficiency found, the abnormal returns are expected to be “erased with the knowledge of its existence” (Fama, 1991, p. 1593). As discussed in chapter *2.1.4 Methodologies and Findings*, stock markets are made efficient by market participants believing it is inefficient and acting on arbitrage opportunities until prices have adjusted to reflect information (Dimson & Mussavian, 1998; Grossmann & Stiglitz, 1980; Lee, 2001). This process ensures that stock prices fully reflect information again and consequently give accurate signals for resource allocation, which allows the stock market to fulfil its task to correctly allocate ownership of the economy’s capital stock (Fama, 1970).

In the evidenced inefficient state, the stock market does not sufficiently take into account the climate change induced systematic risk of European companies when allocating ownership of capital stock. The inefficient allocation of capital comes at a cost not only to investors but to the whole economy, given that investments in real assets are heavily influenced by the valuation of financial assets (Barro, 1990; Bodie et al., 2008). If stock prices do not accurately reflect the intrinsic value of the firm and climate change induced systematic risk, the beta calculated under consideration of these stock prices is incorrect. Consequently, the cost of equity, which is often calculated based on historic betas, is also incorrect and in turn the overall cost of capital of all companies in the sample cannot be expected to be estimated correctly. This cost of capital however is important to various corporate decisions, “[f]rom determining the hurdle rate for investment projects to influencing the composition of the firm’s capital structure” (Easley & O'Hara, 2004, p. 1553). If incorrect rates for the cost of capital of companies are used for investment decisions, the capital in the economy is not allocated efficiently, as companies do not know their respective opportunity costs and therefore cannot correctly determine the profitability of capital investment decisions. As a result, all companies in the sample can be expected to pursue value-destroying projects and/or incorrectly reject value-enhancing projects, which would impede economic growth (Hayek, 1941).

At the same time, inefficient markets allow companies to raise additional capital at an overvalued price (Lin & Wu, 2010). Among others, Spiess and Affleck-Graves (1995) and Loughran and Ritter (1995) evidenced that overvalued firms are more likely to raise additional capital on financial markets in order to exploit the temporary market inefficiency. In the context of this study, this means that the outperforming (completely) reporting companies, as well as companies with comparatively good climate change performance, can be expected to be more likely to raise additional capital on financial markets. This increase in financial capital would entail an increase of their investments in real assets and thus support the general growth of these companies in the real economy (cf. Wurgler, 2000). Therefore, ironically and unwanted from the perspective of EMH, the aimed-at transition to a low carbon economy might in fact be supported by the current inefficiency of the market to price climate change induced systematic risk at the company level efficiently.

According to the EMH, investors making use of the arbitrage opportunities evidenced would however soon change the evidenced state of market inefficiency. These arbitrage forces would eliminate the abnormal returns of companies that report GHG-emissions, the abnormal returns of completely reporting companies, the abnormal returns of companies with low GHG-emissions and finally the abnormal returns of companies with a high and medium GHG-efficiency. After this exploitation of the abnormal risk-adjusted returns found, no outperformance on the basis of risk-adjusted returns can be expected from investing in companies with (complete) GHG-disclosure or good corporate climate change performance. In this state of market efficiency the lower levels of climate change induced systematic risk of these companies would, ceteris paribus, result in a lower beta (cf. chapter *3 Hypotheses Development)*. As beta, despite its shortcomings, is used to calculate the cost of equity (Fama & French, 1997), these companies, ceteris paribus, would also show lower cost of equity. This lower cost of equity results in a lower cost of capital, which in turn fosters the real investments of companies with (complete) GHG-disclosure or good corporate climate change performance, as the opportunity costs for investment projects of these companies are comparatively low. Thus, once the presumed state of market efficiency is achieved, the lower systematic risk and resulting lower cost of equity of companies with (complete) GHG-disclosure or good corporate climate change performance would encourage growth of these companies in the real economy and thus support the aimed-at transition to a low-carbon economy. At the same time, the stipulated higher climate change induced systematic risk of companies that, for example, show high levels of absolute GHG-emissions would, ceteris paribus, result in a higher beta (cf. chapter *3.4 Absolute Levels of Emissions*) in an efficient market. This higher beta would manifest itself in increased cost of capital for such companies and consequently, as the opportunity costs for investment projects of these companies are comparatively high, impede their economic growth.

With regard to the expected future persistence of the risk-adjusted abnormal returns found at industry level for the EU ETS and the High Carbon portfolios, these “abnormal” returns might persist in the future given that there is a risk-based explanation. As discussed, abnormal returns for which there is a risk-based explanation may be attributable to a shortcoming in the underlying asset pricing models to correctly price the systematic risk induced by climate change. As indicated before, a conclusion of this magnitude however requires further research. It is nevertheless interesting to theoretically discuss a scenario where these abnormal returns are a rational compensation for the additional risk investors take on when investing in companies that show higher exposure to climate change induced systematic risk. In this scenario, returns of the EU ETS and High carbon industries portfolios would persist in future and traditional asset pricing models applied to test market efficiency would need to be extended for a factor that controls for climate change induced systematic risk. In this scenario, these returns do not constitute "abnormal" returns but can be aligned with the basic notion of the EMH that investors are rewarded for taking non-diversifiable risk. The relevance and practical implications of these and other discussed findings are illustrated in the following chapter.

7.2 Relevance and Contribution to Knowledge

The findings of this study are relevant and constitute a contribution to knowledge in several ways. First and foremost, this research represents the first assessment of market efficiency dedicated towards climate change induced systematic risk. Results of this research thus add to the sparse literature that allows drawing conclusions on market efficiency towards CSP (cf. chapter *2.2 Literature linking CSP and SMP).* Furthermore, as briefly discussed above in the context of EMH, this research is expected to contribute to raising the level of market efficiency. Schwert (2003) showed that inefficiencies disappear once they are published, i.e. research causes the market to become more efficient because market participants act on the inefficiencies evidenced. This research may consequently make a contribution to raising the level of market efficiency towards climate change induced systematic risk of European companies by having evidenced the arbitrage opportunities discussed.

While not targeted towards investment practitioners, the arbitrage opportunities evidenced are expected to be of interest to mainstream and SRI investors. This was ensured to be the case in this research by applying a C4FM extended for industry effects, as investment practitioners tend to focus more heavily on industry factors than academia traditionally has done in models of asset pricing (Hsu et al., 2011). Interestingly, when exploiting the arbitrage opportunities evidenced in this research, the interests of SRI and mainstream investors are aligned. The value-driven SRI investor (Derwall, Koedijk, & Ter Horst, 2011) would tend to invest in companies reporting (complete) GHG-emissions and showing a comparatively good climate change performance for ethical reasons. The mainstream investor, out of purely financial motivation, would also invest in these companies in order to benefit from the inefficiency of the financial market to correctly price the positive effect of (complete) GHG-emissions reporting and good climate change performance. During this period of exploiting the market inefficiency identified, the interests of both types of investors are consequently aligned, while simultaneously resulting in a reduction of the exposure of their portfolios towards climate change induced systematic risk.

In this context, it is interesting to refer to an argument of Heinkel, Kraus and Zechner (2001), who proposed that if a sufficiently large number of investors refuse to hold shares of polluting firms, the price of these shares falls and as a consequently the cost of capital of the respective firms would rise. They argue that polluting firms will become greener if the increased cost of capital surpasses the cost of switching to less polluting business practices and show that theoretically “roughly 25% green investors are necessary to overcome a firm's cost of reforming” (Heinkel et al., 2001, p. 447). Theoretically speaking, if, during the time of exploiting the anomalies evidenced in this research, the share of market participants investing in companies with low GHG-emissions and a high GHG-efficiency surpasses this threshold, the economy might be changed towards greener business practises in the long term.

According to the EMH, market participants will erase inefficiencies by acting on arbitrage opportunities and, as a result, the financial market at some point will correctly reflect the information concerning (complete) GHG-emissions reporting and good climate change performance. In this scenario of market efficiency, investors will no longer be able to generate an abnormal return by investing in companies that report (complete) GHG-emissions and show a comparatively good climate change performance. Relating this argument to studies gathering evidence on whether *it pays to be green* illustrates that it can only be financially rewarding – in the sense of abnormal risk-adjusted returns – for investors to be *green* in the short term, i.e. until market participants have erased the inefficiencies evidenced. In an efficient market, investors would only be rewarded for taking on higher levels of climate change induced systematic risk. As argued in *chapter 3 Hypotheses Development*, companies that do not report GHG-emission, report incomplete GHG-emissions, show comparatively high absolute levels of GHG-emissions and a comparatively low GHG-efficiency would consequently generate higher returns, while no difference in risk-adjusted returns between portfolios would be obtainable by market participants. In this scenario of market efficiency, mainstream investors with a higher taste for risk would – at the unknown point in time when the market becomes efficient – switch to companies that do not report GHG-emissions (completely) or have a poor climate change performance. They would do so because in an efficient market, ceteris paribus, these latter companies would generate higher returns as a compensation for the additional climate change induced systematic risk assumed. This type of investor would also invest in companies affiliated with the EU ETS and high carbon industries. The value-driven SRI investor on the other hand would continue investing in companies with good climate change performance and, ceteris paribus, receive a lower return in light of his or her reduced exposure to climate change induced systematic risk. If, in this scenario of market efficiency, investors do not actively optimise their portfolios according to their specific taste for climate change induced systematic risk, they are exposing themselves to unidentified levels of systematic risk.

Interestingly, in this scenario of an efficient market and in the context of the presumed climate change induced systematic risk, the value-driven SRI investor does not act irrationally by investing in companies that, for example, show a good climate change performance, given that the portfolio is reasonable diversified. As described in chapter *2.1.2 Definitions and Important Notions of EMH*, Fama and French believe that socially responsible investors trade in parts of their risk-adjusted return for knowledge that their investments do not violate their social or environmental conscience (Fama & French, 2007). If however, lower returns stem from lower systematic climate change induced risk, the socially responsible investor is not irrational and does not receive lower levels of risk-adjusted returns. In this scenario, the assessment of Fama and French (2007, p. 673) that “the world is a better place (prices are more rational)” when socially responsible investors switch to a passive market portfolio strategy requires the following footnote: When lower returns in an efficient market stem from lower levels of climate change induced systematic risk, green investors are not acting irrationally, do not trade in risk-adjusted return for ethical values and consequently do not hamper market efficiency.

In addition to this implication and the implications of results for investment practice discussed, this research makes a contribution to knowledge with regard to the on-going debate on the value-relevance of information on corporate climate change performance. Identifying economically significant abnormal risk-adjusted returns in a large European sample over five years, this research gives strong evidence that the existence and quality of corporate disclosures on climate change performance, as well as the information on the actual levels of absolute GHG-emissions and GHG-efficiency, is regarded as relevant to the intrinsic value of the firm by financial markets. On a related note, findings of this research should consequently also motivate companies to report (complete) GHG-emissions to the public, given that the current inefficiency of the market results in significant annualised abnormal returns of e.g. 4.90% ($p<0.05$) for companies that report complete GHG-emissions in line with the GHG Protocol and the CDP. At the same time, results suggest that incompletely reporting companies were severely penalised by financial markets during the time of this study (cf. chapter *6.3.1 Regression Results*). If, at some point in the future, the market efficiently prices climate change induced systematic risk at the company level, companies should also be motivated to report (completely) on their climate change performance in order to reduce their systematic risk, as discussed in chapter *3 Hypotheses Development*.

Furthermore, as it represents the first comprehensive analysis of the completeness of quantitative corporate GHG-emissions reporting in Europe, this study makes a more general contribution to knowledge with regard to the state of corporate GHG-emissions reporting. By means of the constructed Disclosure Completeness Index, descriptive results suggested that on average over the five years under analysis, only 15% of companies strictly follow the recommendations of the GHG Protocol and the CDP (cf. chapter *4.3.2 Disclosure Completeness*). In other words, on average between 2005 and 2009 only 15% of the European constituents of the FTSE AWI reported scope 1 and 2 GHG-emissions for group-wide corporate activities. Consequently, results of this study also show that while the GHG Protocol and the CDP give companies useful tools for the reporting of GHG-emissions, these reporting guidelines are not applied in a precise manner without regulatory enforcement.

Finally, to be able to control for the incompleteness of reported GHG-emissions data evidenced, this research made a methodological contribution: By weighting company returns according to the completeness of its GHG-emission reporting (cf. chapter *5.4.1 Incompleteness of GHG-emissions Data*), it suggested a methodology that allows ensuring that incompletely reported emissions data is not driving the returns of portfolios constructed from specific levels of absolute GHG-emissions or GHG-efficiency. Given that the quality of environmental data represents a general problem in SRI, this methodological innovation should constitute an interesting test of robustness for other studies. As long as the environmental performance data reported by companies is not complete and reliable, this test of robustness is necessary as it allows eliminating the possibility that the performance of a socially responsible investment strategy is driven by incompletely reported data.

In summary, this test of financial market efficiency evidenced that the market was inefficient in pricing the climate change induced systematic risk of European companies between 2005 and 2009. However, leaving aside the ideology of EMH, this research has also produced a lot of insight into the behaviour of stock prices towards the affiliation of companies with the EU ETS and high carbon industries, the existence and completeness of corporate disclosure on GHG-emissions, as well as climate change performance, as measured by absolute levels of GHG-emissions and GHG-efficiency. As such, and as illustrated above, the findings of this research have implications for investment practise, the choice of companies to disclosure (complete) GHG-emissions, the discussion on the value-relevance of such disclosures, as well as methodologies applied in SRI research that allow controlling for incomplete environmental data. At the same time, the findings of this research open up interesting avenues for future research, which are discussed in the remaining paragraphs of this thesis.

7.3 Limitations and Avenues for Future Research

The findings of this study are limited to the sample and period under analysis, i.e. mid- and large cap non-financial companies from the European Union in the years 2005 to 2009. Further research, analysing the six proxies for climate change induced systematic risk introduced in this study outside of the sample and period of this research, is required to generalise or contrast the results found. For example, this future research would be able to verify whether the outperformance found at the industry level for portfolios constructed from companies affiliated with the EU ETS and high carbon industries is in fact related to climate change induced systematic risk and is persistent in other markets and periods. If this was the case, climate change induced systematic risk would qualify as an additional risk premium in the future. On the other hand, repeating this test of market efficiency with the sample examined in this study in the years after 2009 would allow examining whether the arbitrage opportunities evidenced at the company level for (complete) reporting companies and companies with a good climate change performance are being erased by market participants, as stipulated by the EMH, or continue to exist.

As it has been evidenced in this test of semi-strong market efficiency, complete information on corporate GHG-emissions is not readily available to the market (cf. chapter *4.3.2 Disclosure Completeness*). Consequently, GHG-emissions data actually lends itself for a rarely possible large-scale test of strong market efficiency (i.e. a market in which even private information is accounted for in a stock price (cf. chapter *2.1.1 The Short History of EMH*)). Though tests of robustness performed in this study confirmed that the incompleteness of GHG-emissions data is not driving the returns of portfolios constructed from different dimensions of GHG-emissions, it would nevertheless be conceptually interesting to contrast these results with a test of strong market efficiency on company level based on privately held information on complete GHG-emissions data.

Making the necessary informed extrapolations for such a test of strong market efficiency of incomplete GHG-emissions data to cover scope 1 and 2 GHG-emissions for group-wide corporate activities for all companies in a sufficiently large sample would be a challenging task. The resulting complete GHG-emissions data would however also allow relating this data to accounting measures of financial performance as a return figure. An assessment of whether it is financially rewarding in accounting terms for companies to have a good climate change performance would then be possible. Furthermore, the specific characteristics of companies with different levels of complete GHG-emissions could then be investigated and – more importantly – the specific characteristics of companies reducing their GHG-emissions could be determined. If drivers for the reduction of absolute levels of corporate GHG-emissions were known, the transition to a low carbon economy could be expedited via political and market initiatives focussing on these drivers.

Finally, while the Joint Hypothesis Problem in tests of market efficiency cannot be eliminated (cf. chapter *2.1.4 Methodologies and Findings*), this research made an effort to minimise this limitation by using the most advanced yet established C4FM extended for industry effects. With regard to the discussed potential shortcoming of prevailing asset pricing models to price climate change induced systematic risk at the industry level further research is required, as discussed before. Overall, this study thus opens up some interesting avenues for future research.

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Appendix A
Regression Results: Value-weighted Returns

A.1 European Emission Trading Scheme

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	ACV	Adj. R^2
EU ETS							
CAPM	2.318%	1.045 ***					0.946
C4FM	2.915% *	1.148 ***	-0.145 ***	-0.064	0.212 ***		0.965
C4FM / June	1.249%	1.107 ***	-0.255 ***	0.076	0.151 ***		0.972
C4FM + Carbon	1.512%	1.089 ***	-0.220 ***	0.137	0.201 ***	-0.000	0.961
C4FM + Oil	2.412% *	1.113 ***	-0.155 ***	-0.041	0.176 ***	0.037 ***	0.969
C4FM + Crisis	4.294% **	1.112 ***	-0.122 **	-0.068	0.215 ***	-0.022 **	0.965
Not in EU ETS							
CAPM	-1.993%	0.959 ***					0.930
C4FM	-2.603%	0.849 ***	0.163 ***	0.064	-0.222 ***		0.956
C4FM / June	-1.889%	0.880 ***	0.263 ***	-0.059	-0.186 ***		0.965
C4FM + Carbon	-2.148%	0.908 ***	0.200 ***	-0.106	-0.201 ***	-0.000	0.955
C4FM + Oil	-2.074%	0.886 ***	0.174 ***	0.039	-0.184 ***	-0.039 ***	0.961
C4FM + Crisis	-4.091% **	0.888 ***	0.138 **	0.068	-0.225 ***	0.024 *	0.957
Long EU ETS - Short Not in EU ETS	5.516% *	0.299 ***	-0.309 ***	-0.128	0.434 ***		0.368

Notes: This table reports regression results for EU ETS and Not in EU ETS portfolios using monthly value-weighted returns and value-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, as well as the tests of robustness of results. Tests of robustness include portfolio creation in June (/ June) and the inclusion of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors and ACV, as well as the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

A.2 Existence of disclosure of GHG-emissions

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	0001	1000	2000	3000	4000	5000	6000	7000	9000	ACV	Adj. R^2
Reporting GHG																
CAPM	0.492%	0.983 ***														0.995
C4FM	0.587%	1.012 ***	-0.089 ***	-0.005	0.023 *											0.997
C4FM + Industry	-0.289%	0.998 ***	-0.065 ***	0.006	-0.000	0.098 ***	0.060 ***	0.094 ***	0.084 ***	0.083 ***	0.004	0.059 ***	0.076 ***	-0.005		0.998
C4FM + Industry / GHG t-2	-0.316%	0.948 ***	-0.079 ***	0.082 ***	-0.022	0.094 **	0.014	0.038	0.061	0.069 **	-0.027	0.027	0.023	-0.022 *		0.997
C4FM + Industry / June	-0.494%	0.980 ***	-0.044	0.012	-0.022	0.128 ***	0.073 ***	0.095 ***	0.112 ***	0.109 ***	0.028	0.087 ***	0.090 ***	-0.000		0.998
C4FM + Industry + Carbon	-0.608%	0.974 ***	-0.033	0.019	-0.019	0.104 ***	0.065 ***	0.076 **	0.077 **	0.106 ***	-0.009	0.073 ***	0.078 **	-0.017	0.000	0.997
C4FM + Industry + Oil	-0.304%	0.999 ***	-0.064 **	0.006	0.001	0.100 ***	0.062 ***	0.096 ***	0.087 ***	0.084 ***	0.003	0.060 ***	0.078 ***	-0.004	-0.002	0.998
C4FM + Industry + Crisis	-0.620% *	1.003 ***	-0.062 ***	0.007	0.004	0.101 ***	0.065 ***	0.098 ***	0.092 ***	0.087 ***	0.002	0.067 ***	0.087 ***	-0.004	0.004 *	0.998
Not reporting GHG																
CAPM	-1.225%	1.126 ***														0.914
C4FM	-1.657%	0.953 ***	0.543 ***	0.007	-0.137 ***											0.979
C4FM + Industry	1.073%	1.018 ***	0.418 ***	-0.034	-0.038	-0.246 ***	-0.108 *	-0.180 *	-0.172 *	-0.217 ***	0.030	-0.111 *	-0.227 ***	0.042		0.986
C4FM + Industry / GHG t-2	0.216%	1.199 ***	0.310 ***	-0.195 ***	0.081	-0.109	0.125	0.166	-0.039	-0.106	0.148	0.050	0.031	0.117 **		0.985
C4FM + Industry / June	-1.133%	1.114 ***	0.171	0.035	-0.000	-0.109	0.031	0.121	-0.021	-0.163 *	0.123	-0.025	-0.065	0.068		0.978
C4FM + Industry + Carbon	0.594%	1.077 ***	-0.031	0.120	-0.095	0.046	0.070	0.172	0.211	-0.065	0.412 **	0.001	0.008	0.169 ***	-0.001	0.971
C4FM + Industry + Oil	1.243%	1.006 ***	0.403 ***	-0.030	-0.049	-0.276 ***	-0.137 **	-0.199 *	-0.208 **	-0.232 ***	0.039	-0.127 **	-0.253 ***	0.039	0.019 *	0.986
C4FM + Industry + Crisis	1.200%	1.016 ***	0.417 ***	-0.035	-0.040	-0.248 ***	-0.110 *	-0.181 *	-0.175 *	-0.219 ***	0.031	-0.113 *	-0.231 ***	0.042	-0.001	0.986
Long Reporting GHG - Short Not Reporting GHG	-1.362%	-0.020	-0.483 ***	0.040	0.038	0.344 ***	0.168 **	0.274 **	0.256 **	0.300 ***	-0.026	0.169 **	0.303 ***	-0.047		0.840

Notes: This table reports regression results for Reporting GHG and Not reporting GHG portfolios, as well as the long-short portfolio, using monthly value-weighted returns and value-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, C4FM controlled for industry effects, as well as the tests of robustness of results. Tests of robustness include portfolio creation with GHG-data from t-2 (/ GHG t-2) and in June (/ June) and the introduction of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as on orthogonalised industry returns represented by their respective ICB code. The remaining columns show coefficient exposure on ACV and the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

A.3 Disclosure Completeness

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	0001	1000	2000	3000	4000	5000	6000	7000	9000	ACV	Adj. R^2
0 Score																
CAPM	-0.391%	0.999 ***														0.834
C4FM	1.440%	1.038 ***	0.190	-0.321 **	0.060											0.850
C4FM + Industry	-2.119%	0.974 ***	0.351	-0.157	0.124	-0.654 ***	-0.266 *	-0.531 **	-0.511 **	-0.301 **	-0.612 ***	-0.470 ***	-0.123	-0.189 **		0.885
C4FM + Industry / GHG t-2	-1.332%	0.948 ***	0.690 **	0.178	0.587 *	-0.949 ***	-0.444 **	-0.573	-0.673 ***	-0.398 **	-1.120 ***	-0.427 **	-0.182	-0.131		0.903
C4FM + Industry / June	-3.818%	1.007 ***	0.419	-0.042	0.204	-0.737 ***	-0.212 *	-0.346	-0.557 **	-0.179	-0.844 ***	-0.440 ***	-0.136	-0.219 **		0.876
C4FM + Industry + Carbon	-0.637%	0.934 ***	-0.225	0.123	-0.264	-0.409	-0.121	0.047	-0.101	0.044	-0.287	-0.409 **	0.042	-0.136	0.005 *	0.821
C4FM + Industry + Oil	-1.368%	0.924 ***	0.286	-0.141	0.078	-0.786 ***	-0.392 **	-0.614 **	-0.670 **	-0.367 **	-0.572 ***	-0.544 ***	-0.236	-0.204 ***	0.084 ***	0.904
C4FM + Industry + Crisis	0.172%	0.937 ***	0.329	-0.166	0.096	-0.679 ***	-0.302 *	-0.560 **	-0.568 **	-0.334 **	-0.597 ***	-0.523 ***	-0.198	-0.193 **	-0.027	0.884
1 Score																
CAPM	0.797%	0.940 ***														0.937
C4FM	0.834%	1.016 ***	-0.110 **	0.028	0.224 ***											0.959
C4FM + Industry	0.223% ***	1.059 ***	0.003	-0.008 **	0.004	-0.001	-0.001	-0.003	0.309 ***	0.113 ***	0.394 ***	0.111 ***	-0.006 *	0.079 ***		1.000
C4FM + Industry / GHG t-2	0.266%	0.892 ***	-0.180 **	0.119 ***	-0.073	0.078	-0.107	-0.224 *	0.093	-0.025	0.102	-0.136	0.020	-0.029		0.980
C4FM + Industry / June	-0.076%	0.929 ***	-0.051	-0.001	0.007	0.178 **	0.003	-0.100	0.193 **	0.026	0.141	-0.012	0.171 **	0.023		0.975
C4FM + Industry + Carbon	0.418%	0.895 ***	-0.169	0.052	-0.097	0.209 *	-0.011	-0.083	0.281	0.064	0.250 *	-0.055	0.174 *	0.036	-0.001	0.963
C4FM + Industry + Oil	-0.200%	0.965 ***	-0.034	0.004	0.058	0.156	-0.013	-0.046	0.187	0.026	0.012	-0.046	0.197 **	0.022	-0.005	0.973
C4FM + Industry + Crisis	1.826%	0.930 ***	-0.058	-0.002	0.030	0.126	-0.053	-0.076	0.128	-0.007	0.028	-0.096	0.125	0.017	-0.023	0.974
2 Score																
CAPM	-0.314%	1.020 ***														0.965
C4FM	-0.424%	1.007 ***	-0.113 **	0.012	-0.163 **											0.968
C4FM + Industry	-1.060%	1.056 ***	-0.248 **	0.015	-0.103	0.184 *	0.177 **	0.416 ***	0.182	0.205 ***	0.103	0.183 *	0.075	0.003		0.975
C4FM + Industry / GHG t-2	-2.432% *	0.963 ***	-0.108	0.142 ***	-0.111	0.291 **	0.168 *	0.386 ***	0.187	0.224 ***	0.042	0.214 **	0.080	-0.000		0.976
C4FM + Industry / June	-2.022%	1.021 ***	-0.171	0.023	-0.168	0.311 ***	0.232 ***	0.459 ***	0.331 ***	0.303 ***	0.138	0.278 ***	0.203 **	0.032		0.975
C4FM + Industry + Carbon	-2.503%	1.014 ***	0.057	0.021	0.001	0.197 *	0.189	0.289 *	0.093	0.260 ***	-0.085	0.263 **	0.126	-0.029	-0.001	0.971
C4FM + Industry + Oil	-1.117%	1.059 ***	-0.243 **	0.014	-0.100	0.194 *	0.186 **	0.422 ***	0.194	0.210 ***	0.100	0.188 *	0.084	0.004	-0.006	0.975
C4FM + Industry + Crisis	-4.451% **	1.110 ***	-0.215 ***	0.027	-0.061	0.220 *	0.230 **	0.459 ***	0.265	0.254 ***	0.080	0.261 **	0.186	0.009	0.040 ***	0.978
3 Score																
CAPM	3.260%	1.016 ***														0.882
C4FM	4.207% *	1.076 ***	0.011	-0.148 *	0.119											0.882
C4FM + Industry	2.488%	1.043 ***	0.258	-0.056	0.337	0.341	0.334	0.170	0.128	0.195	0.132	0.435 **	0.279	0.106		0.914
C4FM + Industry / GHG t-2	3.922%	1.105 ***	-0.024	-0.256 ***	0.052	0.432	0.459 *	0.346	0.326	0.291	0.102	0.389 *	0.292	0.049		0.890
C4FM + Industry / June	5.624% *	1.096 ***	0.184	-0.011	0.508 *	0.089	0.177	0.081	-0.207	-0.062	-0.059	0.205	0.032	0.054		0.885
C4FM + Industry + Carbon	2.599%	1.256 ***	0.348	-0.251	0.654	0.020	0.294	0.234	-0.221	-0.182	-0.302	0.338	0.120	0.060	0.004	0.816
C4FM + Industry + Oil	2.256%	1.058 ***	0.278 *	-0.060	0.351	0.381	0.373 *	0.196	0.177	0.215	0.120	0.458 **	0.314	0.111	-0.026	0.914
C4FM + Industry + Crisis	3.917%	1.020 ***	0.244	-0.061	0.319	0.325	0.312	0.152	0.093	0.174	0.141	0.402 *	0.232	0.104	-0.017	0.913
Long 3 Score - Short 0 Score	4.606%	0.069	-0.093	0.102	0.213	0.995 ***	0.601 **	0.701 **	0.639	0.496 **	0.744 ***	0.905 ***	0.402	0.295 **		0.283

Notes: This table reports regression results for the four portfolios constructed from levels of GHG-emissions disclosure completeness, as well as the long-short portfolio, using monthly value-weighted returns and value-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, C4FM controlled for industry effects, as well as the tests of robustness of results. Tests of robustness include portfolio creation with GHG-data from t-2 (/ GHG t-2) and in June (/ June) and the introduction of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as on orthogonalised industry returns represented by their respective ICB code. The remaining columns show coefficient exposure on ACV and the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

A.4 Absolute Levels of GHG-emissions

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	0001	1000	2000	3000	4000	5000	6000	7000	9000	ACV	Adj. R^2
High GHG																
CAPM	2.634%	1.094 ***														0.901
C4FM	3.007%	1.201 ***	-0.232 ***	-0.022	0.179 **											0.920
C4FM + Industry	-2.080% ***	1.106 ***	-0.254 ***	0.139 ***	-0.090	0.441 ***	0.238 ***	0.150	0.263 ***	0.066	0.004	-0.044	0.359 ***	-0.004		0.988
C4FM + Industry / Weighted	-1.200%	1.107 ***	0.019	0.197 ***	-0.032	0.517 ***	0.387 ***	0.364 ***	0.426 ***	0.154 ***	0.111	0.121 **	0.529 ***	0.044		0.991
C4FM + Industry / GHG t-2	-3.174% ***	1.036 ***	-0.272 ***	0.263 ***	-0.043	0.295 **	0.126	0.006	0.072	-0.007	-0.160	-0.154	0.212 **	-0.053 *		0.980
C4FM + Industry / June	-2.633% ***	1.041 ***	-0.277 ***	0.218 ***	-0.178 ***	0.561 ***	0.294 ***	0.213 *	0.404 ***	0.151 **	0.144 *	0.042	0.456 ***	0.035		0.986
C4FM + Industry + Carbon	-2.591% **	1.060 ***	-0.294 **	0.183 **	-0.231 **	0.637 ***	0.337 ***	0.322 **	0.468 **	0.177 *	0.223 **	0.088	0.492 ***	0.046	0.001	0.981
C4FM + Industry + Oil	-2.035% ***	1.103 ***	-0.257 ***	0.140 ***	-0.093	0.433 ***	0.230 ***	0.145	0.253 **	0.063	0.006	-0.048	0.352 ***	-0.005	0.005	0.988
C4FM + Industry + Crisis	-1.435%	1.095 ***	-0.260 ***	0.136 ***	-0.099 *	0.434 ***	0.227 ***	0.142	0.247 ***	0.057	0.008	-0.059	0.338 ***	-0.006	-0.008	0.988
Medium GHG																
CAPM	-1.392%	0.861 ***														0.907
C4FM	-1.717%	0.842 ***	-0.080	0.050	-0.120 **											0.906
C4FM + Industry	0.628%	0.877 ***	0.023	-0.098 ***	-0.003	-0.039	-0.032	0.135	0.098	0.194 ***	0.067	0.249 ***	-0.104	0.002		0.975
C4FM + Industry / Weighted	0.772%	0.989 ***	0.208 ***	-0.067 **	0.060	-0.058	0.012	0.132	0.097	0.093	0.089	0.188 **	-0.105	0.016		0.978
C4FM + Industry / GHG t-2	0.980%	0.843 ***	0.018	-0.069 *	-0.118	0.184 *	0.076	0.245 *	0.343 **	0.311 ***	0.246 **	0.357 ***	0.054	0.037		0.976
C4FM + Industry / June	0.798%	0.900 ***	0.051	-0.140 ***	0.029	-0.065	-0.065	0.099	0.033	0.170 ***	0.028	0.218 ***	-0.163 **	-0.019		0.979
C4FM + Industry + Carbon	0.293%	0.871 ***	0.107	-0.121 *	0.082	-0.155	-0.087	0.014	-0.050	0.157 **	-0.134 *	0.191 **	-0.176	-0.062	0.001	0.977
C4FM + Industry + Oil	0.506%	0.885 ***	0.033	-0.101 ***	0.004	-0.018	-0.012	0.148	0.124	0.205 ***	0.061	0.261 ***	-0.085	0.004	-0.013	0.976
C4FM + Industry + Crisis	-0.766%	0.899 ***	0.036	-0.093 ***	0.014	-0.024	-0.010	0.152	0.132	0.215 ***	0.058	0.281 ***	-0.058	0.004	0.016	0.976
Low GHG																
CAPM	0.461%	0.981 ***														0.893
C4FM	0.521%	0.867 ***	0.364 ***	-0.060	-0.142 *											0.936
C4FM + Industry	3.508% ***	0.990 ***	0.179	-0.175 **	0.062	0.066	0.084	0.299 *	0.181	0.097	0.326 **	0.199	0.110	0.123 **		0.967
C4FM + Industry / Weighted	2.279% **	0.972 ***	0.410 ***	-0.114 *	0.001	0.248 *	0.143	0.335 **	0.325 *	0.198 **	0.463 ***	0.295 **	0.206	0.157 ***		0.979
C4FM + Industry / GHG t-2	4.688% ***	0.962 ***	0.128	-0.106	0.130	-0.185	-0.168	0.030	-0.123	-0.097	0.091	-0.015	-0.219	0.048		0.956
C4FM + Industry / June	4.667% ***	0.989 ***	0.367 ***	-0.244 **	0.153 *	-0.148	-0.020	0.111	-0.048	-0.020	0.042	0.097	-0.061	0.063		0.965
C4FM + Industry + Carbon	4.343% ***	0.953 ***	0.297 *	-0.023	0.241 **	-0.480 ***	-0.237 **	-0.301 **	-0.485 **	-0.143	-0.154	-0.187	-0.337 **	-0.043	-0.002	0.958
C4FM + Industry + Oil	3.598% **	0.984 ***	0.171	-0.173 **	0.056	0.050	0.069	0.290 *	0.162	0.089	0.331 **	0.190	0.097	0.121 **	0.010	0.967
C4FM + Industry + Crisis	3.364% *	0.992 ***	0.180	-0.174 **	0.064	0.068	0.087	0.301 *	0.185	0.099	0.325 **	0.202	0.115	0.123 **	0.002	0.967
Long Low GHG - Short High GHG	5.587% ***	-0.116 *	0.432 **	-0.313 ***	0.152	-0.375 *	-0.153	0.149	-0.081	0.031	0.322 **	0.243	-0.249	0.127 *		0.846

Notes: This table reports regression results for the three portfolios contructed from absolute levels of GHG-emissions, as well as the long-short portfolio, using monthly value-weighted returns and value-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, C4FM controlled for industry effects, as well as the tests of robustness of results. Tests of robustness include weighting by disclosure completeness (/ weighted), portfolio creation with GHG-data from t-2 (/ GHG t-2) and in June (/ June) and the introduction of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as on orthogonalised industry returns represented by their respective ICB code. The remaining columns show coefficient exposure on ACV and the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

A.5 GHG-efficiency

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	0001	1000	2000	3000	4000	5000	6000	7000	9000	ACV	Adj. R^2
High GHG-efficiency																
CAPM	-0.674%	0.795 ***														0.845
C4FM	-0.696%	0.772 ***	-0.004	-0.007	-0.105											0.840
C4FM + Industry	2.740% **	0.861 ***	-0.059	-0.204 ***	0.018	0.109	0.084	0.311 **	0.317 **	0.296 ***	0.339 ***	0.318 ***	0.108	0.133 **		0.957
C4FM + Industry / Weighted	3.156% ***	0.912 ***	0.139	-0.170 ***	0.028	0.133	0.075	0.310 **	0.293 **	0.239 ***	0.370 ***	0.301 ***	0.112	0.148 ***		0.97
C4FM + Industry / GHG t-2	2.892%	0.795 ***	-0.008	-0.158 **	-0.013	-0.048	-0.080	0.097	0.123	0.209 *	0.170	0.198	-0.119	0.062		0.947
C4FM + Industry / June	2.701% *	0.845 ***	0.129	-0.224 ***	0.068	-0.044	0.002	0.142	0.181	0.218 **	0.119	0.259 ***	0.011	0.096		0.955
C4FM + Industry + Carbon	2.707%	0.775 ***	0.214	-0.096	0.133	-0.179	-0.091	-0.134	0.014	0.235 *	0.005	0.121	-0.101	0.044	-0.004 ***	0.956
C4FM + Industry + Oil	2.759% **	0.860 ***	-0.061	-0.203 ***	0.017	0.105	0.081	0.309 **	0.313 **	0.295 ***	0.340 ***	0.316 ***	0.105	0.133 **	0.002	0.956
C4FM + Industry + Crisis	1.334%	0.884 ***	-0.046	-0.199 ***	0.036	0.124	0.106	0.329 **	0.352 **	0.316 ***	0.330 ***	0.350 ***	0.154	0.135 **	0.016	0.957
Medium GHG-efficiency																
CAPM	1.544%	0.964 ***														0.899
C4FM	0.821%	1.048 ***	-0.194 ***	0.174 **	0.309 ***											0.952
C4FM + Industry	-1.037%	0.970 ***	-0.298 ***	0.174 ***	-0.132 **	0.429 ***	0.130 *	0.110	0.336 ***	0.097	0.157	-0.017	0.036	-0.031		0.985
C4FM + Industry / Weighted	1.144%	0.995 ***	-0.023	0.040	-0.138 **	0.419 ***	0.199 **	0.183 *	0.430 ***	0.130	0.310 ***	0.097	0.089	0.029		0.986
C4FM + Industry / GHG t-2	-1.906%	0.932 ***	-0.364 ***	0.242 ***	-0.155	0.506 ***	0.185	0.234	0.427 ***	0.150	0.190	0.022	0.145	-0.041		0.980
C4FM + Industry / June	-0.445%	0.940 ***	-0.317 ***	0.120 ***	-0.159 **	0.530 ***	0.124 *	0.162 **	0.427 ***	0.144 **	0.241 **	0.027	0.084	-0.012		0.984
C4FM + Industry + Carbon	-2.087% *	1.043 ***	-0.259 **	-0.009	-0.087	0.445 ***	0.154 **	0.214 ***	0.285 **	0.042	0.101	0.051	0.060	-0.039	0.002 ***	0.984
C4FM + Industry + Oil	-1.184%	0.980 ***	-0.285 ***	0.171 ***	-0.123 **	0.455 ***	0.155 **	0.126	0.367 ***	0.110	0.150	-0.002	0.058	-0.028	-0.016 **	0.985
C4FM + Industry + Crisis	-1.316%	0.974 ***	-0.295 ***	0.175 ***	-0.128 **	0.432 ***	0.134 *	0.114	0.343 ***	0.101	0.156	-0.011	0.045	-0.031	0.003	0.984
Low GHG-efficiency																
CAPM	0.932%	1.230 ***														0.922
C4FM	1.571%	1.196 ***	-0.026	-0.138	-0.302 ***											0.936
C4FM + Industry	-2.717% *	1.153 ***	0.272 ***	0.092 **	0.057	-0.321 **	-0.052	-0.127	-0.432 **	-0.093	-0.524 ***	-0.101	0.198	-0.094 *		0.976
C4FM + Industry / Weighted	-2.606% *	1.144 ***	0.505 ***	0.265 ***	0.102	-0.099	0.091	0.159 *	-0.194	0.015	-0.362 ***	0.007	0.287 **	-0.045		0.987
C4FM + Industry / GHG t-2	-1.980% *	1.104 ***	0.267 ***	0.272 ***	0.046	-0.176	-0.049	-0.162	-0.363 *	-0.078	-0.451 **	-0.107	0.211	-0.061 *		0.985
C4FM + Industry / June	-3.466% **	1.133 ***	0.192	0.193 ***	0.007	-0.143	0.127	-0.014	-0.297 **	0.028	-0.249 *	0.049	0.314 **	-0.047		0.973
C4FM + Industry + Carbon	-1.681%	1.063 ***	-0.034	0.288 **	-0.192	-0.041	0.114	0.103	-0.176	0.111	-0.074	0.031	0.346 **	-0.044	0.002	0.953
C4FM + Industry + Oil	-2.627%	1.147 ***	0.264 ***	0.094 **	0.052	-0.337 *	-0.067	-0.137	-0.451 **	-0.101	-0.519 ***	-0.110	0.185	-0.096 *	0.010	0.975
C4FM + Industry + Crisis	-0.768%	1.121 ***	0.253 **	0.085 *	0.033	-0.342 **	-0.083	-0.152	-0.480 **	-0.121	-0.511 ***	-0.146	0.134	-0.098 *	-0.023	0.976
Long Low GHG-efficiency - Short High GHG-efficiency	5.458% ***	-0.292 ***	-0.331 **	-0.296 ***	-0.039	0.430 **	0.136	0.439 **	0.750 ***	0.389 ***	0.863 ***	0.419 ***	-0.090	0.227 ***		0.836

Notes: This table reports regression results for the portfolios contructed from three levels of GHG-efficiency, as well as the long-short portfolio, using monthly value-weighted returns and value-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, C4FM controlled for industry effects, as well as the tests of robustness of results. Tests of robustness include weighting by disclosure completeness (/ weighted), portfolio creation with GHG-data from t-2 (/ GHG t-2) and in June (/ June) and the introduction of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as on orthogonalised industry returns represented by their respective ICB code. The remaining columns show coefficient exposure on ACV and the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

A.6 High Carbon Industries

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	ACV	Adj. R^2
High carbon industries							
CAPM	2.336%	1.179					0.946
C4FM	3.329% *	1.197 ***	0.065	-0.176 *	-0.021		0.949
C4FM / June	2.152%	1.175 ***	-0.096	-0.053	-0.122 *		0.946
C4FM + Carbon price	2.510%	1.102 ***	-0.056	0.167	0.029	0.000	0.942
C4FM + Oil price	2.707%	1.154 ***	0.053	-0.147 *	-0.066	0.046 *	0.953
C4FM + Crisis	3.184%	1.201 ***	0.062	-0.176 *	-0.022	0.002	0.948
Low carbon industries							
CAPM	-1.740%	0.816 ***					0.880
C4FM	-3.004%	0.787 ***	-0.056	0.222 *	0.031		0.890
C4FM / June	-1.748%	0.810 ***	0.126	0.079	0.138 *		0.881
C4FM + Carbon price	-2.274%	0.901 ***	0.057	-0.148	-0.015	-0.000	0.908
C4FM + Oil price	-2.376%	0.831 ***	-0.044	0.193 *	0.077	-0.046 **	0.899
C4FM + Crisis	-2.744%	0.781 ***	-0.052	0.221 *	0.032	-0.004	0.888
Long High carbon industries - Short Low carbon industries	6.332%	0.410 ***	0.121	-0.398 *	-0.052		0.322

Notes: This table reports regression results for the High carbon indstries and the Low carbon industries portfolios, as well as the long-short portfolio, using monthly value-weighted returns and value-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, as well as the tests of robustness of results. Tests of robustness include portfolio creation in June (/ June) and the inclusion of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors and ACV, as well as the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

Appendix B
Regression Results: Equal-weighted Returns on Value-weighted Factors

B.1 European Emission Trading Scheme

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	ACV	Adj. R^2
EU ETS							
CAPM	4.001% *	1.211 ***					0.941
C4FM	3.616% *	1.089 ***	0.458 ***	0.023	0.006		0.970
C4FM / June	3.048%	1.093 ***	0.345 ***	0.121	-0.084		0.966
C4FM + Carbon	4.643% ***	1.045 ***	0.350 ***	0.253 **	0.072	-0.001	0.963
C4FM + Oil	3.156% *	1.058 ***	0.449	0.044	-0.028 ***	0.034 ***	0.973
C4FM + Crisis	5.501% ***	1.040 ***	0.490 ***	0.017	0.010	-0.031 *	0.972
Not in EU ETS							
CAPM	-1.546%	1.150 ***					0.885
C4FM	-3.134% **	0.909 ***	0.741 ***	0.196 ***	-0.020		0.977
C4FM / June	-0.056%	1.017 ***	0.832 ***	-0.003	-0.025		0.971
C4FM + Carbon	0.023%	0.992 ***	0.845 ***	-0.062	-0.143 *	0.002 **	0.959
C4FM + Oil	-2.982% **	0.920 ***	0.744 ***	0.189 ***	-0.009	-0.011	0.977
C4FM + Crisis	-3.868% **	0.929 ***	0.729 ***	0.198 **	-0.022	0.012	0.977
Long EU ETS - Short Not in EU ETS	6.750% **	0.180 ***	-0.283 **	-0.174	0.026		0.153

Notes: This table reports regression results for EU ETS and Not in EU ETS portfolios using monthly equal-weighted returns and value-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, as well as the tests of robustness of results. Tests of robustness include portfolio creation in June (/ June) and the inclusion of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors and ACV, as well as the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

B.2 Existence of Disclosure of GHG-emissions

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	0001	1000	2000	3000	4000	5000	6000	7000	9000	ACV	Adj. R^2
Reporting GHG																
CAPM	2.296%	1.156 ***														0.937
C4FM	1.441% **	0.985 ***	0.557 ***	0.088 *	-0.030											0.991
C4FM + Industry	1.296% *	1.034 ***	0.439 ***	0.042 *	0.002	0.262 ***	0.205 ***	0.332 ***	0.353 ***	0.163 ***	0.251 ***	0.206 ***	0.242 ***	0.091 ***		0.995
C4FM + Industry / GHG t-2	2.185% ***	1.005 ***	0.428 ***	0.094 ***	0.022	0.271 ***	0.209 ***	0.305 ***	0.369 ***	0.162 ***	0.255 ***	0.209 ***	0.266 ***	0.099 ***		0.997
C4FM + Industry / June	2.947% **	1.065 ***	0.517 ***	0.000	-0.032	0.078	0.112 *	0.161 **	0.131 *	0.090	0.066	0.051	0.078	0.059 **		0.991
C4FM + Industry + Carbon	3.233% ***	1.055 ***	0.500 ***	-0.025	-0.059	0.119	0.131	0.251 **	0.167	0.094	0.063	0.102	0.119	0.054	0.002 ***	0.986
C4FM + Industry + Oil	1.385% **	1.028 ***	0.431 ***	0.044 **	-0.003	0.247 ***	0.190 ***	0.322 ***	0.334 ***	0.156 ***	0.256 ***	0.197 ***	0.229 ***	0.089 ***	0.010 *	0.995
C4FM + Industry + Crisis	1.084%	1.037 ***	0.441 ***	0.043 *	0.005	0.265 ***	0.208 ***	0.335 ***	0.358 ***	0.166 ***	0.249 ***	0.211 ***	0.249 ***	0.092 ***	0.002	0.995
Not reporting GHG																
CAPM	-2.651%	1.200 ***														0.884
C4FM	-4.610% ***	0.936 ***	0.812 ***	0.256 ***	0.014											0.983
C4FM + Industry	-3.338% ***	0.995 ***	0.600 ***	0.209 ***	-0.011	0.095	0.112	0.140	0.189 *	0.056	0.257 ***	0.030	0.094	0.111 ***		0.989
C4FM + Industry / GHG t-2	-2.292% *	1.097 ***	0.562 ***	0.085 **	0.121	0.277 *	0.269 **	0.398 **	0.384 **	0.123	0.434 ***	0.204 *	0.258	0.170 ***		0.987
C4FM + Industry / June	-1.124%	1.102 ***	0.478 ***	0.158	0.013	0.216	0.269	0.333	0.329	0.110	0.383 **	0.100	0.190	0.180		0.963
C4FM + Industry + Carbon	-0.043%	1.119 ***	0.435	0.040	-0.102	0.530	0.437	0.673 *	0.739	0.238	0.658 **	0.318	0.416	0.294 *	0.001	0.942
C4FM + Industry + Oil	-3.112% ***	0.980 ***	0.580 ***	0.214 ***	-0.024	0.056	0.073	0.115	0.141	0.036	0.269 ***	0.008	0.060	0.106 ***	0.025 **	0.990
C4FM + Industry + Crisis	-2.224% *	0.977 ***	0.589 ***	0.205 ***	-0.025	0.083	0.094	0.126	0.161 *	0.040	0.265 ***	0.004	0.057	0.109 ***	-0.013	0.989
Long Reporting GHG - Short Not Reporting GHG	4.636% ***	0.039 *	-0.161 ***	-0.167 ***	0.013	0.167 **	0.093	0.192 *	0.164 *	0.108 *	-0.007	0.176 ***	0.148 *	-0.019		0.519

Notes: This table reports regression results for Reporting GHG and Not reporting GHG portfolios, as well as the long-short portfolio, using monthly equal-weighted returns and value-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, C4FM controlled for industry effects, as well as the tests of robustness of results. Tests of robustness include portfolio creation with GHG-data from t-2 (/ GHG t-2) and in June (/ June) and the introduction of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as on orthogonalised industry returns represented by their respective ICB code. The remaining columns show coefficient exposure on ACV and the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

B.3 Disclosure Completeness

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	0001	1000	2000	3000	4000	5000	6000	7000	9000	ACV	Adj. R^2
0 Score																
CAPM	-0.995%	1.206 ***														0.888
C4FM	-1.457%	1.087 ***	0.527 ***	0.040	0.110											0.917
C4FM + Industry	-5.626% **	1.080 ***	0.470 **	0.143	0.116	-0.221	-0.002	0.095	0.025	0.016	-0.389 **	-0.230	0.156	-0.074		0.945
C4FM + Industry / GHG t-2	-2.238%	0.882 ***	1.050 ***	0.577 ***	0.198	-0.420	-0.183	-0.212	-0.110	-0.019	-0.880 ***	-0.274	0.143	-0.058		0.931
C4FM + Industry / June	-3.623%	1.079 ***	0.755 ***	0.270	-0.022	-0.354	0.006	-0.129	-0.150	0.113	-0.562 **	-0.327 *	0.150	-0.067		0.905
C4FM + Industry + Carbon	-2.688%	1.141 ***	0.374	0.117	-0.332	-0.132	0.177	0.279	0.107	0.214	-0.237	-0.242	0.299	0.012	0.004	0.855
C4FM + Industry + Oil	-5.263% **	1.056 ***	0.439 **	0.151	0.094	-0.285	-0.062	0.055	-0.052	-0.016	-0.370 **	-0.266	0.101	-0.081	0.040	0.948
C4FM + Industry + Crisis	-3.535%	1.046 ***	0.450 **	0.135	0.089	-0.244	-0.034	0.068	-0.026	-0.014	-0.375 **	-0.279	0.088	-0.077	-0.024	0.945
1 Score																
CAPM	2.521%	1.135 ***														0.910
C4FM	1.277%	0.953 ***	0.622 ***	0.158 **	0.059											0.970
C4FM + Industry	1.153%	0.995 ***	0.527 ***	0.075	0.056	0.364 ***	0.240 **	0.328 ***	0.523 ***	0.178 **	0.341 ***	0.244 ***	0.398 ***	0.157 ***		0.979
C4FM + Industry / GHG t-2	3.496% **	0.955 ***	0.428 ***	0.088 *	0.076	0.308 ***	0.190 **	0.169 **	0.412 ***	0.130 **	0.406 ***	0.199 ***	0.332 ***	0.111 ***		0.983
C4FM + Industry / June	3.664% ***	0.996 ***	0.633 ***	-0.018	0.008	0.088	0.105	-0.019	0.162	0.054	0.183 *	0.071	0.146	0.082 **		0.985
C4FM + Industry + Carbon	5.122% ***	0.941 ***	0.715 ***	-0.003	0.048	0.052	0.011	-0.077	0.038	0.005	0.083	0.060 *	0.085	0.044	0.000	0.985
C4FM + Industry + Oil	1.240%	0.990 ***	0.519 ***	0.077	0.051	0.348 ***	0.226 **	0.318 ***	0.504 ***	0.170 **	0.346 ***	0.235 **	0.385 ***	0.156 ***	0.010	0.979
C4FM + Industry + Crisis	2.342%	1.198 ***	-0.173	0.002	0.117 *	0.067 **	0.121 **	0.298 ***	0.251 ***	0.016	0.198 ***	0.077 *	0.214 ***	0.065 *	-0.006	0.986
2 Score																
CAPM	1.632%	1.194 ***														0.916
C4FM	0.803%	1.000 ***	0.531 ***	0.072	-0.172 ***											0.976
C4FM + Industry	0.688%	1.063 ***	0.407 ***	0.026	-0.085	0.309 **	0.228 *	0.491 ***	0.345 **	0.251 ***	0.249	0.288 **	0.229	0.067 *		0.981
C4FM + Industry / GHG t-2	-0.410%	1.009 ***	0.396 ***	0.098 **	-0.112	0.355 ***	0.239 **	0.478 ***	0.387 **	0.251 ***	0.281 **	0.293 ***	0.241	0.096 ***		0.984
C4FM + Industry / June	1.744%	1.111 ***	0.502 ***	-0.030	-0.131	0.199 *	0.159 *	0.423 ***	0.228 **	0.227 ***	0.023	0.155	0.125	0.072		0.975
C4FM + Industry + Carbon	2.000%	1.101 ***	0.488 ***	-0.045	-0.141	0.264	0.200	0.523 **	0.306	0.246 **	0.034	0.235	0.197	0.084	0.003 *	0.955
C4FM + Industry + Oil	0.754%	1.059 ***	0.401 ***	0.028	-0.089	0.297 **	0.217 *	0.484 ***	0.331 *	0.245 ***	0.252	0.282 **	0.219	0.066 *	0.007	0.981
C4FM + Industry + Crisis	0.180%	1.071 ***	0.412 ***	0.028	-0.078	0.314 **	0.236 *	0.498 ***	0.358 **	0.258 ***	0.245	0.300 **	0.245	0.068 *	0.006	0.981
3 Score																
CAPM	4.751% *	1.095 ***														0.916
C4FM	4.615% **	1.009 ***	0.442 ***	-0.007	0.107											0.942
C4FM + Industry	6.560% ***	1.073 ***	0.234 *	0.002	0.161	0.076	0.126	0.057	0.000	-0.084	0.223	0.055	-0.109	0.109 *		0.953
C4FM + Industry / GHG t-2	7.169% ***	1.254 ***	0.072	-0.192 ***	0.103	0.358	0.430 **	0.542 *	0.403 *	0.110	0.355	0.254 *	0.111	0.182 ***		0.951
C4FM + Industry / June	7.307% ***	1.134 ***	0.083	0.032	0.200	0.092	0.128	0.211	-0.009	-0.153	0.221	-0.011	-0.157	0.092		0.947
C4FM + Industry + Carbon	4.823%	1.244 ***	0.006	-0.137	0.109	0.204	0.331	0.539	0.162	-0.109	0.269	0.134	0.012	0.099	0.005 **	0.919
C4FM + Industry + Oil	6.562% ***	1.073 ***	0.234 *	0.002	0.161	0.076	0.125	0.057	0.000	-0.084	0.223	0.054	-0.109	0.109 *	0.000	0.952
C4FM + Industry + Crisis	6.020% **	1.082 ***	0.239 *	0.004	0.168	0.082	0.134	0.064	0.014	-0.076	0.219	0.067	-0.091	0.110 *	0.006	0.952
Long 3 Score - Short 0 Score	12.186% ***	-0.006	-0.236	-0.141	0.045	0.297	0.127	-0.038	-0.025	-0.100	0.612 **	0.285	-0.265	0.183 *		0.382

Notes: This table reports regression results for the four portfolios constructed from levels of GHG-emissions disclosure completeness, as well as the long-short portfolio, using monthly equal-weighted returns and value-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, C4FM controlled for industry effects, as well as the tests of robustness of results. Tests of robustness include portfolio creation with GHG-data from t-2 (/ GHG t-2) and in June (/ June) and the introduction of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as on orthogonalised industry returns represented by their respective ICB code. The remaining columns show coefficient exposure on ACV and the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

B.4 Absolute Levels of GHG-emissions

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	0001	1000	2000	3000	4000	5000	6000	7000	9000	ACV	Adj. R^2
High GHG																
CAPM	5.700% **	1.223 ***														0.926
C4FM	4.745% *	1.091 ***	0.410 ***	0.123	0.003											0.949
C4FM + Industry	-0.726%	1.089 ***	0.331 **	0.254 ***	0.037	0.492 ***	0.438 ***	0.476 ***	0.512 ***	0.200 ***	0.184 *	0.213 **	0.688 ***	0.081		0.983
C4FM + Industry / Weighted	-0.439%	1.111 ***	0.293 ***	0.245 ***	0.025	0.604 ***	0.546 ***	0.588 ***	0.603 ***	0.248 ***	0.226 **	0.297 ***	0.709 ***	0.094 **		0.986
C4FM + Industry / GHG t-2	-1.278%	1.030 ***	0.331 ***	0.363 ***	0.031	0.395 ***	0.368 ***	0.403 ***	0.378 **	0.171 **	0.040	0.135	0.609 ***	0.069		0.984
C4FM + Industry / June	0.750%	1.056 ***	0.486 ***	0.240 ***	-0.046	0.286 **	0.336 ***	0.195 *	0.275 **	0.167 **	-0.009	0.107	0.529 ***	0.068		0.977
C4FM + Industry + Carbon	2.376% **	1.018 ***	0.455 ***	0.244 **	-0.166 *	0.338 *	0.278 *	0.283	0.225	0.168 *	0.048	0.095	0.482 ***	0.033	0.001	0.975
C4FM + Industry + Oil	-0.462%	1.072 ***	0.308 ***	0.260 ***	0.021	0.446 ***	0.394 ***	0.447 ***	0.456 ***	0.177 **	0.198 *	0.187 **	0.648 ***	0.076 *	0.029 *	0.985
C4FM + Industry + Crisis	-0.650%	1.088 ***	0.330 ***	0.254 ***	0.036	0.492 ***	0.437 ***	0.475 ***	0.510 ***	0.199 ***	0.184 *	0.211 **	0.685 ***	0.081	-0.001	0.983
Medium GHG																
CAPM	1.982%	1.138 ***														0.920
C4FM	1.438%	0.987 ***	0.541 ***	0.040	-0.014											0.968
C4FM + Industry	3.070% **	1.053 ***	0.392 ***	-0.037	0.032	-0.065	-0.015	0.153	0.073	-0.003	0.016	0.035	-0.172	0.010		0.977
C4FM + Industry / Weighted	0.805%	1.104 ***	0.394 ***	-0.043	0.124	-0.073	0.060	0.133	0.100	-0.007	0.114	0.133	-0.102	0.031		0.971
C4FM + Industry / GHG t-2	3.911% ***	1.009 ***	0.323 ***	0.016	-0.083	0.097	0.087	0.196	0.300 *	0.104	0.191	0.110	0.016	0.064 *		0.986
C4FM + Industry / June	3.175% **	1.083 ***	0.369 ***	-0.067	-0.009	-0.055	0.020	0.156	0.030	0.022	0.017	-0.004	-0.178 *	-0.010		0.977
C4FM + Industry + Carbon	3.013% **	1.049 ***	0.344 ***	-0.128 **	-0.059	0.131	0.184	0.356 **	0.363 **	0.150	0.112	0.167	0.047	0.059	0.002 ***	0.982
C4FM + Industry + Oil	2.947% **	1.062 ***	0.402 ***	-0.039	0.039	-0.043	0.005	0.166	0.099	0.007	0.009	0.047	-0.154	0.013	-0.014	0.977
C4FM + Industry + Crisis	2.268%	1.066 ***	0.400 ***	-0.034	0.042	-0.056	-0.002	0.163	0.093	0.008	0.010	0.053	-0.146	0.012	0.009	0.976
Low GHG																
CAPM	-0.890%	1.113 ***														0.847
C4FM	-2.058%	0.879 ***	0.725 ***	0.120	-0.087											0.940
C4FM + Industry	0.809%	0.956 ***	0.604 ***	-0.065	-0.071	0.460 ***	0.260 **	0.423 **	0.558 ***	0.341 ***	0.630 ***	0.422 ***	0.344 **	0.208 ***		0.976
C4FM + Industry / Weighted	1.004%	0.955 ***	0.639 ***	-0.056	-0.060	0.433 ***	0.203	0.373 **	0.471 **	0.300 ***	0.603 ***	0.394 ***	0.303 *	0.192 ***		0.975
C4FM + Industry / GHG t-2	3.098% *	0.976 ***	0.661 ***	-0.067	0.151	0.369 ***	0.205 *	0.344 **	0.441 ***	0.219 ***	0.556 ***	0.406 ***	0.255 *	0.177 ***		0.981
C4FM + Industry / June	4.584% **	1.050 ***	0.742 ***	-0.150 **	-0.043	0.051	0.014	0.140	0.127	0.104	0.216	0.077	-0.022	0.142 **		0.960
C4FM + Industry + Carbon	4.369% *	1.098 ***	0.746 ***	-0.154	0.050	-0.115	-0.088	0.075	-0.157	-0.054	0.018	0.024	-0.142	0.072	0.003 **	0.935
C4FM + Industry + Oil	1.000%	0.944 ***	0.587 ***	-0.061	-0.082	0.427 ***	0.228 *	0.402 **	0.518 ***	0.324 ***	0.641 ***	0.403 ***	0.315 *	0.204 ***	0.021 *	0.977
C4FM + Industry + Crisis	1.139%	0.951 ***	0.600 ***	-0.066	-0.075	0.456 ***	0.254 **	0.419 **	0.550 ***	0.336 ***	0.633 ***	0.414 ***	0.333 *	0.208 ***	-0.004	0.975
Long Low GHG - Short High GHG	1.536%	-0.133 **	0.273 **	-0.319 ***	-0.107	-0.032	-0.179	-0.053	0.046	0.140	0.447 **	0.209	-0.344 *	0.127 **		0.740

Notes: This table reports regression results for the three portfolios contructed from absolute levels of GHG-emissions, as well as the long-short portfolio, using monthly equal-weighted returns and value-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, C4FM controlled for industry effects, as well as the tests of robustness of results. Tests of robustness include weighting by disclosure completeness (/ weighted), portfolio creation with GHG-data from t-2 (/ GHG t-2) and in June (/ June) and the introduction of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as on orthogonalised industry returns represented by their respective ICB code. The remaining columns show coefficient exposure on ACV and the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

B.5 GHG-efficiency

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	0001	1000	2000	3000	4000	5000	6000	7000	9000	ACV	Adj. R^2
High GHG-efficiency																
CAPM	-0.118%	0.998 ***														0.864
C4FM	-0.799%	0.841 ***	0.462 ***	0.060	-0.104											0.915
C4FM + Industry	3.097% ***	0.951 ***	0.347 ***	-0.135 ***	0.046	0.186	0.092	0.346 **	0.347 **	0.202 **	0.403 **	0.315 ***	0.145	0.170 ***		0.972
C4FM + Industry / Weighted	3.512% ***	0.966 ***	0.335 ***	-0.142 ***	0.038	0.161	0.071	0.314 **	0.274 *	0.183 **	0.405 **	0.290 ***	0.120	0.164 ***		0.969
C4FM + Industry / GHG t-2	4.868% ***	0.927 ***	0.375 ***	-0.113 *	0.185	-0.063	-0.091	0.075	0.039	0.009	0.214	0.200	-0.076	0.092 *		0.966
C4FM + Industry / June	5.345% ***	0.990 ***	0.597 ***	-0.213 ***	-0.024	-0.125	-0.126	-0.015	-0.029	0.046	0.032	0.042	-0.160	0.105 *		0.961
C4FM + Industry + Carbon	5.480% ***	0.988 ***	0.696 ***	-0.263 **	0.025	-0.228	-0.172	-0.086	-0.179	-0.006	-0.150	0.006	-0.216	0.070	0.000	0.930
C4FM + Industry + Oil	3.179% ***	0.945 ***	0.340 ***	-0.133 ***	0.041	0.172	0.079	0.337 **	0.330 **	0.195 **	0.407 **	0.307 ***	0.133	0.168 ***	0.009	0.972
C4FM + Industry + Crisis	3.536% **	0.944 ***	0.343 ***	-0.137 ***	0.040	0.181	0.086	0.340 **	0.337 **	0.196 **	0.406 **	0.305 ***	0.130	0.169 ***	-0.005	0.972
Medium GHG-efficiency																
CAPM	2.742%	1.122 ***														0.932
C4FM	2.645%	1.014 ***	0.496 ***	-0.024	0.061											0.969
C4FM + Industry	2.458%	1.043 ***	0.261 ***	-0.113 ***	-0.157 **	0.424 ***	0.296 ***	0.281 **	0.572 ***	0.154	0.457 ***	0.205 **	0.174	0.088 **		0.982
C4FM + Industry / Weighted	3.146% *	1.024 ***	0.258 ***	-0.103 ***	-0.144 **	0.422 ***	0.281 ***	0.271 **	0.542 ***	0.170	0.470 ***	0.225 **	0.155	0.093 **		0.981
C4FM + Industry / GHG t-2	3.312% *	1.017 ***	0.143	-0.062	-0.278 **	0.549 ***	0.388 ***	0.404 ***	0.725 ***	0.229 **	0.563 ***	0.235 *	0.270 *	0.094		0.981
C4FM + Industry / June	4.214% ***	1.054 ***	0.280 ***	-0.104 **	-0.166 **	0.194 **	0.156 **	0.175 *	0.311 ***	0.028	0.207 **	-0.023	-0.064	0.026		0.985
C4FM + Industry + Carbon	3.001% **	1.076 ***	0.244 ***	-0.128 *	-0.137 **	0.181	0.212 **	0.244	0.319 **	0.004	0.155	0.034	-0.011	0.017	0.004 ***	0.986
C4FM + Industry + Oil	2.429%	1.045 ***	0.264 ***	-0.114 ***	-0.155 **	0.429 ***	0.301 ***	0.285 **	0.578 ***	0.156	0.455 ***	0.208 **	0.178	0.089 **	-0.003	0.981
C4FM + Industry + Crisis	1.240%	1.063 ***	0.273 ***	-0.109 ***	-0.142 **	0.437 ***	0.315 **	0.297 **	0.602 ***	0.171	0.449 ***	0.233 **	0.214	0.090 **	0.014	0.982
Low GHG-efficiency																
CAPM	3.779%	1.358 ***														
C4FM	1.763%	1.092 ***	0.727 ***	0.263 ***	-0.080	0.965										0.894
C4FM + Industry	-2.380%	1.108 ***	0.756 ***	0.423 ***	0.172	0.124	0.199 **	0.391 ***	0.068	0.138	-0.169	0.101	0.434 ***	0.016		0.986
C4FM + Industry / Weighted	-2.586%	1.137 ***	0.735 ***	0.430 ***	0.147	0.128	0.237 ***	0.449 ***	0.051	0.124	-0.194 *	0.121	0.381 ***	0.004		0.988
C4FM + Industry / GHG t-2	-2.486%	1.071 ***	0.854 ***	0.502 ***	0.263 *	0.238	0.280 **	0.409 ***	0.231	0.229 **	-0.105	0.191	0.614 ***	0.113 **		0.987
C4FM + Industry / June	-1.469%	1.154 ***	0.750 ***	0.352 ***	0.133	0.124	0.288 ***	0.312 **	0.047	0.218 ***	-0.081	0.159	0.509 ***	0.053		0.979
C4FM + Industry + Carbon	1.003%	1.092 ***	0.642 ***	0.352 ***	-0.042	0.377	0.322 *	0.585 **	0.305	0.314 **	0.156	0.286	0.629 ***	0.087	0.002	0.972
C4FM + Industry + Oil	-2.141%	1.092 ***	0.735 ***	0.428 ***	0.158	0.082	0.159 **	0.365 ***	0.017	0.117	-0.156	0.077	0.398 ***	0.011	0.027 **	0.987
C4FM + Industry + Crisis	-1.894%	1.100 ***	0.751 ***	0.421 ***	0.166	0.119	0.191 **	0.385 ***	0.056	0.131	-0.166	0.090	0.418 ***	0.015	-0.006	0.986
Long Low GHG-efficiency - Short High GHG-efficiency	5.476% ***	-0.158 **	-0.409 ***	-0.558 ***	-0.127	0.062	-0.106	-0.045	0.280	0.064	0.572 ***	0.215	-0.289	0.154 ***		0.836

Notes: This table reports regression results for the portfolios contructed from three levels of GHG-efficiency, as well as the long-short portfolio, using monthly equal-weighted returns and value-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, C4FM controlled for industry effects, as well as the tests of robustness of results. Tests of robustness include weighting by disclosure completeness (/ weighted), portfolio creation with GHG-data from t-2 (/ GHG t-2) and in June (/ June) and the introduction of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors, as well as on orthogonalised industry returns represented by their respective ICB code. The remaining columns show coefficient exposure on ACV and the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).

B.6 High Carbon Industries

Portfolio	α	(Rm-Rf)	SMB	HML	UMD	ACV	Adj. R^2
High carbon industries							
CAPM	3.758%	1.292 ***					0.916
C4FM	3.637% **	1.118 ***	0.709 ***	-0.048	-0.010		0.981
C4FM / June	4.267% *	1.166 ***	0.570 ***	-0.029	-0.109 *		0.967
C4FM + Carbon price	5.885% ***	1.065 ***	0.600 ***	0.155	0.033	0.000	0.966
C4FM + Oil price	3.151% **	1.085 ***	0.700 ***	-0.025	-0.045	0.036 *	0.983
C4FM + Crisis	3.619% **	1.119 ***	0.709 ***	-0.048	-0.010	0.000	0.981
Low carbon industries							
CAPM	-2.731%	1.061 ***					0.876
C4FM	-4.864% **	0.835 ***	0.598 ***	0.303 ***	-0.011		0.952
C4FM / June	-2.189%	0.932 ***	0.701 ***	0.035	0.029		0.958
C4FM + Carbon price	-2.244%	0.941	0.656	-0.081	-0.111	0.001	0.958
C4FM + Oil price	-4.519% ***	0.859 ***	0.604 ***	0.286 ***	0.014	-0.025	0.954
C4FM + Crisis	-4.636% *	0.830 ***	0.602 ***	0.302 *	-0.011	-0.004	0.952
Long High carbon industries - Short Low carbon industries	8.500% **	0.283 ***	0.111	-0.350 **	0.001		0.332

Notes: This table reports regression results for the High carbon indstries and the Low carbon industries portfolios, as well as the long-short portfolio, using monthly equal-weighted returns and value-weighted SMB, HML and UMD factors. Rows represent the different models used, i.e. CAPM, C4FM, as well as the tests of robustness of results. Tests of robustness include portfolio creation in June (/ June) and the inclusion of additional control variables (ACV) for changes in the price of carbon (Carbon) and oil (Oil), as well as financial market crisis (Crisis). Columns show the annualised alpha in per cent, beta estimations (Rm - Rf), coefficient exposure on the SMB, HML and UMD factors and ACV, as well as the adjusted R-squared. ***, ** and * indicate the 1%, 5% and 10% significance level respectively. Coefficient covariances and standard errors are made heteroscedasticity and autocorrelation consistent based on Newey and West (1987).