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Essays on Sustainable Finance

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Abstract

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This thesis contributes to the field of sustainable finance by studying some critical sustainability challenges through three distinct research avenues. First, it examines greenwashing in sustainable investments, offering a comprehensive analysis to detect greenwashing practices by environmental mutual funds. Second, it introduces a novel greenwashing index, providing a valuable tool to evaluate the effectiveness of the Sustainable Finance Disclosure Regulation (SFDR) in combating greenwashing. Finally, the thesis employs a quasi-natural experimental design to investigate shifts in herding behavior across various investment fund types, shedding light on whether the SFDR influences investor behavior and improves the transparency of sustainable investing practices.

We provide evidence that environmental funds fail to reduce their carbon footprints compared to a matched group of conventional funds, despite a significant increase in inflows driven by sustainability commitments. This combination of underperformance in carbon reduction and increased inflows suggests greenwashing, raising concerns about the fiduciary duty of these funds. Using a novel greenwashing index, we find that after implementing the SFDR, Article 9 funds exhibit a lower greenwashing index relative to unclassified funds. Our analysis also reveals that Article 9 funds decarbonise their portfolios primarily by tilting toward low carbon-intensive holdings. Additionally, Article 9 funds show a significant decline in herding behavior, while Article 8 and Article 6 funds experience an insignificant reduction compared to unclassified funds. These findings highlight the differential impact of SFDR regulations on fund behavior.

The results of this thesis have important policy implications. First, given the growing concerns around greenwashing, our findings can help regulators evaluate the gap between sustainability claims and actual performance, ensuring that investment funds fulfill their fiduciary duties. Furthermore, introducing a greenwashing index offers regulators an effective tool to assess the credibility of sustainability claims, reducing the risk of misleading investors. Finally, the observed reduction in herding behavior among Article 9 funds post-SFDR highlights the regulation's role in promoting independent and responsible investment decisions, which can help foster more diverse sustainable investing strategies.

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Declaration of Authorship

I, Rabab Abouarab, declare that this thesis and the work presented in it is my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. Parts of this work have been published as:

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Signed:..... Date:.....

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To My Family . . .

Chapter 1

Introduction

1.1 Preamble

This thesis aims to provide new insights into the field of sustainable finance. To this end, this thesis encompasses three distinct papers focusing on key sustainability issues and their effects on investment management. First, this thesis examines greenwashing practices in investment funds by investigating whether these funds engage in misleading behaviour or genuinely make efforts to align their portfolios with environmental sustainability objectives. Second, the thesis proposes a novel measure of greenwashing practices and uses it to examine the impact of sustainable finance regulations on the behaviour of investment funds. Finally, the thesis examines the effects of sustainable finance regulations on herding behaviour in sustainable investments.

1.2 Thesis Background

The main inquiry of this thesis stems from the growing global emphasis on sustainable investing and its profound influence on financial markets. Sustainable investing has emerged as a powerful force in today's era of increased environmental awareness and growing recognition of businesses' social and governance responsibilities. The urgent need to address climate change has reshaped recent economic policies and investment strategies. This comes in the wake of the 2015 Paris Agreement and the 2021 special report from the Intergovernmental Panel on Climate Change (IPCC) on the impact of global warming of 1.5°C (The Institutional Investors Group on Climate Change (IIGCC), 2021), which set a clear international mandate for mitigating climate change and promoting sustainable development. By the early 2020s, the finance industry began to respond with unprecedented force, integrating sustainability considerations into investment strategies and risk management frameworks. This rapid growth has led to a wave of regulatory initiatives, such as the European Commission's dedication to developing a set of regulations for

sustainable investment. The commission produced an action plan called “Financing Sustainable Growth” in March 2018, based on the recommendations of the specialist panel on Sustainable Finance, which asks for additional labelling and transparency measures (EU Commission,2018).

Sustainable investment refers to "integrating environmental, social, and governance factors in the investment decision process" (PRI, 2017). To achieve this goal, the frameworks specifically require investors to set concrete targets in terms of investment management to alter corporate issuers' access to capital by allocating capital in relation to the issuers' own Net-Zero alignment (Ng and Rezaee, 2015), as well as engagement with companies to influence them through dialogue and the exercise of ownership rights (Appel et al., 2016). In line with the development of these frameworks, sustainable investing has seen substantial growth in recent years, driven by increasing awareness of environmental, social, and governance (ESG) issues. According to the Global Sustainable Investment Alliance (GSIA), assets invested in sustainable funds reached $30.3 trillion by 2022. This marks a 20% increase in sustainable assets under management outside the U.S (Global Sustainable Investment Alliance (GSIA), 2022). In addition, Morningstar highlighted that global sustainable fund assets, reaching about $2.74 trillion at the end of the first quarter of 2023, Europe remains dominant in the sustainable fund landscape, accounting for most global sustainable fund assets, totalling 84% of the market share. While the United States secured the second-largest portion of global sustainable fund assets, representing approximately 11% of fund assets (Morningstar Research, 2023a). As a result, asset managers are under high pressure to integrate ESG investing into their investment objectives to align their portfolios with sustainability goals. For example, a recent report from Morgan Stanley finds that 85% of institutional investors are interested in sustainable investing (Morgan Stanley, 2022). This surge in sustainable investing reflects broader efforts within the financial industry to promote responsible investment, as institutions globally adopt stricter disclosure and transparency requirements.

However, sustainable investing has raised significant concerns, particularly regarding the

motivations behind investors' choices. A key debate centers on whether investors choose sustainable investments primarily due to their nonpecuniary preferences for sustainability or because they view sustainability as a signal of future financial performance. This ambiguity complicates the relationship between sustainability and financial returns (Amel-Zadeh and Serafeim, 2018; Starks, 2023; Riedl and Smeets, 2017). Moreover, there is increasing diversity in approaches to providing clear and predictable incentives for investors regarding companies' genuine efforts to improve sustainability performance (Liang and Renneboog, 2020; Berg et al., 2022; Edmans, 2023). There is growing diversity in how incentives for genuine sustainability efforts are provided, varying notably between the US and EU. In the US, market-driven mechanisms and voluntary ESG disclosures often prevail, while in the EU, regulatory directives such as the SFDR impose stricter standardized guidelines. These differing frameworks affect transparency and the credibility of sustainability commitments, ultimately shaping how investors, regulators, and financial institutions approach sustainable finance across regions. A major concern is that the ESG data used to assess companies must reliably reflect their actual impact on the ESG issues that investors seek to address (Ng and Rezaee, 2020). Many studies highlight the divergence in ESG ratings and the lack of transparency in the methodologies used by rating providers, raising doubts about the genuine efforts made by funds to fulfill their sustainability commitments (Berg et al., 2022; Gibson Brandon et al., 2021). As regulators and investors push for sustainable practices, some companies may resort to unethical behaviour, such as superficial compliance with environmental regulations or misleading claims to meet investor expectations about corporate responsibility (Marquis et al., 2016). For example, OECD (2020) find that companies with good environmental scores are often associated with high emissions, making their ESG ratings counterproductive for climate mitigation efforts. This lack of transparency in ESG methodologies and metrics complicates the assessment of sustainable funds, potentially opening a window of opportunity for misleading behaviour. As a result, the promised decarbonisation goals may turn out to be superficial exercises rather than meaningful contributions to real-world emissions reductions.

In this new era of sustainable investing, the prevalence of behaviours such as greenwashing and herding has become a serious concern. Greenwashing refers to the selective disclosure of information by firms, where they mislead shareholders about the true extent of their sustainability efforts (Connelly et al., 2011). This practice is not only ethically problematic but also poses significant risks to investors, especially when sustainable investments underperform due to insufficient adherence to ESG standards (Friede et al., 2015). For instance, some funds falsely claim to integrate sustainability criteria into their investment strategies, raising ethical concerns about their commitment to sustainable investing (e.g., Marquis et al., 2016; Berrone et al., 2017). Additionally, greenwashing is often used as a manipulative marketing strategy to attract investor inflows, even when a firm's actual practices fail to meet the sustainability expectations of investors. Studies show that funds take cosmetic actions to exploit investor sentiment. For example, Cooper et al. (2005) found that mutual funds often renamed themselves to align with popular market trends, which led to significant increases in fund inflows. Furthermore, greenwashing thrives in environments with information asymmetry, where investors struggle to verify the authenticity of a company's sustainability claims (e.g., Delmas and Burbano, 2011; Torelli et al., 2020; Berrone et al., 2017). Additionally, in such contexts, herding behaviour emerges, with companies imitating others' environmental claims to align with industry trends rather than out of a genuine commitment to sustainability, further diluting true sustainability efforts (Lyon and Maxwell, 2011).

Thus, there remains a need for comprehensive examination of greenwashing and herding practices stemming from the complex interactions between companies, investment managers, investors, and regulatory bodies in the financial markets. An important aspect of this ambitious objective is to evaluate the effectiveness of the newly introduced sustainability regulations, which aim to mitigate misleading sustainability claims that can distort market perceptions and influence investment decisions. The roots of understanding greenwashing and herding in this context trace back to early work on information

asymmetry and agency theory, with a focus on revealing the cascading effects of misleading environmental claims to mitigate their detrimental influence on investor confidence and sustainability goals.

1.3 Thesis Aims

The main aim of this thesis is to investigate greenwashing and herding behaviour in sustainable investing. The first core chapter investigates greenwashing practices in environmental fund portfolios by identifying whether environmental funds mislead investors to attract their money. Particularly, this chapter aims to answer two main questions. (1) Do environmental funds decrease their carbon footprint post the announcements about their commitments to decarbonisation? (2) Do environmental funds' announcements about their commitment to decarbonisation lead to abnormal flows from investors? To address these questions, this chapter utilises a unique dataset of US equity mutual fund holdings between 2012 and 2021 to calculate the funds' carbon footprints.

In the same vein, this thesis examines the impact of the Sustainable Finance Disclosure Regulation (SFDR) on greenwashing practice in the EU sustainable funds industry. Chapter 3 proposes a new measure called the Greenwashing Index, based on a fund's decarbonisation effort relative to its flows, to quantify the level of greenwashing. This greenwashing index represents a unique measure of the fund's real outcomes using carbon intensity that reflects the efforts made by SFDR funds (especially Article 9) to keep their promises of meeting decarbonisation targets based on their investment objectives rather than ESG ratings. In addition, this chapter aims to conduct a quasi-natural experiment research design based on the SFDR by measuring the impact on the greenwashing index before and after introducing the regulation.

Furthermore, Chapter 4 analyses a large dataset of EU mutual fund holdings to examine the impact of the SFDR on herding behaviour within the EU financial market. It explores whether the SFDR regulation curbs irrational collective behaviour by promoting informed, independent investment decisions or, conversely, reinforces herd-like tendencies due to conformity pressures. Through a detailed empirical analysis, this chapter aims to shed light on the extent to which the SFDR mitigates or exacerbates herding among investors, providing deeper insights into the regulatory mechanisms shaping investor behaviour and market dynamics in sustainable finance. It also investigates the role of information asymmetry in sustainable investing and its effect on herding, market efficiency, and sustainability goals.

1.4 Thesis Contribution

This thesis is structured along three papers debating key issues in sustainable finance. The thesis investigates greenwashing and herding behaviour among investment funds and the subsequent implications for regulation to prevent such practices. The connecting theme of these chapters is their ultimate focus on sustainable investing and investment funds behaviour. A brief summary of the contributions of each chapter is provided below.

1.4.1 Contribution of Chapter 2

Chapter 2 entitled “Spotting Portfolio Greenwashing in Environmental Funds"[1] examines whether environmental funds engage in unethical behaviour by providing misleading signals to attract investor funds or genuinely make efforts to align their portfolios with sustainability objectives by reducing their carbon footprint. This study aims to detect

[1]This chapter has been published as: Abouarab, R., Mishra, T. and Wolfe, S., 2024. Spotting Portfolio Greenwashing in Environmental Funds. *Journal of Business Ethics*, pp.1-29. https://doi.org/10.1007/s10551-024-05783-z

greenwashing practices in the sustainable investing theme by a class of investment funds that designate themselves as environmental funds.

This chapter contributes to the emerging literature on greenwashing practice. Although the research in the area of sustainable finance is growing, there is still a scarcity of research focusing on greenwashing in the investment funds industry. Some recent studies have focused on sustainability or ESG rating to examine greenwashing which suffers from several shortcomings (e.g., Kaustia and Yu, 2021; Kim and Yoon, 2023). In contrast, this study focuses on real fund outcomes by utilising the carbon emissions data of fund holdings to construct a measure of the fund's carbon footprint to provide robust evidence on greenwashing practices. In addition, utilising textual analysis techniques to examine the investment prospectuses of mutual funds to identify environmental funds and establish their commitments to sustainability as part of their fiduciary responsibilities.

This chapter also contributes to the literature by providing a direct approach combining insights from the research line focusing on fund flows and decarbonisation to examine greenwashing practice in environmental funds. Our research design enables us to link greenwashing to the fund's fiduciary duty, as we focus on environmental funds that integrate environmental sustainability as an investment objective within their prospectuses, making it imperative for them to strive to meet these objectives in the interest of their investors.

Empirically, the findings of Chapter 2 fill an important research gap in the existing literature focusing on greenwashing and sustainable investing. We focus on the real effect that follows from environmental fund pledges. The empirical evidence of this work confirms that, on average, an environmental fund portfolio's footprint increases relative to a conventional fund portfolio's footprint after the announcement date. Interestingly, the result shows significantly positive cumulative abnormal flows in the event window, while there are significant and negative incremental abnormal flows before and after the event window. In this sense, our findings provide evidence of greenwashing as environmental

funds use misleading signals to attract more flows and influence investors' behaviour by claiming that they align their portfolios with decarbonisation objectives.

1.4.2 Contribution of Chapter 3

Chapter 3 entitled "Does the EU Sustainable Finance Disclosure Regulation (SFDR) Mitigate Greenwashing Practice?"[2] The primary aim of the second study is to investigate the effectiveness of the new SFDR regulation in mitigating greenwashing practices among EU sustainable funds.

This chapter contributes to the existing academic literature on sustainable finance by constructing a new measure that captures greenwashing in sustainable funds by examining the sensitivity of the fund's net decarbonisation to its quarterly flows. Most importantly, this paper is the first to examine the impact of enacting the SFDR on the EU sustainable funds behaviour. We add to this critical debate on the decarbonisation of funds portfolios by taking advantage of a unique natural experiment based on the SFDR regulation to examine the pure effect of the regulation on greenwashing. We directly compare the greenwashing index before and after the introduction of the SFDR regulation.

Empirically, the results provide strong evidence on the effectiveness of SFDR regulation in mitigating greenwashing. First, the results confirm that Article 9 funds experience a decline in the greenwashing index relative to a control group of Article 6 & unclassified funds that are not subject to the regulation. The decrease in the greenwashing index following the introduction of SFDR regulation is also economically significant. However, for Article 8 funds we do not observe any significant reduction in the level of their greenwashing index relative to the same control group. These results indicate that Article 9

[2]This chapter has been published as: Abouarab, R., Mishra, T. and Wolfe, S., 2025. Does the EU Sustainable Finance Disclosure Regulation (SFDR) Mitigate Greenwashing Practice? *European Journal of Finance*, https://doi.org/10.1080/1351847X.2025.2457944

funds made efforts to decarbonise their portfolios compared to Article 6 & unclassified funds following the introduction of SFDR regulation.[3]

In addition, we use a different approach to examine the effectiveness of the regulation using a regression discontinuity design to compare the different classes of funds under the SFDR to check the robustness of our main results. The results of this exercise strongly suggest that the discontinuity in the greenwashing index is more concentrated in Article 9 funds than in Article 8, indicating a difference in greenwashing behaviour between funds above and below the carbon intensity threshold. Finally, given the above contribution, the paper addresses that rebalancing portfolio weights is crucial for SFDR funds to decarbonise their portfolios. Furthermore, the results confirm that portfolio tilting is most noticeable in Article 9 & 8 funds relative to Article 6 and unclassified funds according to the SFDR regulation.

1.4.3 Contribution of Chapter 4

The title of Chapter 4 is “Herding in Sustainable Investing: The Role of Regulations" This study examines the impact of the EU’s sustainable finance disclosure regulation on investor behaviour, focusing on how the regulation’s emphasis on sustainability disclosures influences market dynamics. Herding behaviour occurs when investors mimic others’ investment decisions rather than rely on their analysis. In the context of sustainable investing, emotional biases tied to herding can affect decisions regarding asset allocation, as well as buying and selling stocks. Understanding herding behaviour is crucial for shaping portfolio strategies for investors and fund managers.

[3]The SFDR categorises funds into Article 9, Article 8, or Article 6, each reflecting a different level of sustainability commitments. Article 9 funds are referred to as "dark green" and must demonstrate a clear and measurable sustainability objective, such as significantly lowering the carbon footprint of a fund. Article 8 funds are referred to as "light green" and are expected to promote environmental or social characteristics, though sustainability is not necessarily their core objective. In contrast, Article 6 funds are not explicitly focused on ESG aspects and only face minimal sustainability disclosure obligations.

This Chapter contributes to the academic debate on sustainable investing by examining herding behaviour specifically within the European domain, a key arena for sustainability efforts. To the best of the author's knowledge, the intersection of herding behaviour and sustainable investing has not been extensively explored in existing research. Using a comprehensive dataset on the holdings of EU equity funds, this study develops herding measures and conducts analyses for three different types of SFDR funds Articles 9, 8, and 6. The study provides insights into how differing regulatory constraints shape investor actions by comparing the trading behaviour and prevalence of herding across these funds.

In addition, Chapter 4 contributes to the literature that examines the trading behaviour of fund portfolios. We find evidence that Article 9 funds respond more positively to the SFDR than the controlled group (unclassified funds), indicating a reduction in their level of herding post the introduction of the SFDR. Moreover, the findings indicate that the SFDR has significantly influenced the trading behaviour of asset managers, particularly those prioritising ESG criteria. Therefore, the SFDR has significantly aligned investment strategies with sustainability objectives, leading to a noticeably lower level of herding behaviour among ESG-focused funds. This regulation has prompted institutional investors to move towards sustainable assets, driven by regulatory requirements and the increasing demand for responsible investment choices.

The findings of Chapter 4 has significant implications indicating that the SFDR compels investment funds to provide detailed information on how they integrate ESG factors into their investment decisions. This increased transparency reduces the information asymmetry that often leads to herding behaviour, as investors no longer need to follow the actions of others blindly. By offering more comprehensive information, the regulation empowers investors to make more informed and rational decisions based on a clearer understanding of a fund's strategy and the sustainability of its investments. This shift encourages more independent decision-making processes, reducing the tendency for investors to follow the crowd without grasping the underlying reasons. Taken together, these regional perspectives underscore how policy-driven frameworks in the EU, exemplified by the SFDR, may

shape fund behaviour differently than the more market-driven ESG environment in the US. This comparison highlights how regulatory and market differences can affect the credibility of sustainability claims, investor protection, and the overall effectiveness of sustainable investing strategies.

1.5 Thesis Structure

This PhD thesis is structured to provide a thorough investigation of greenwashing practice and herding behaviour in sustainable finance as follows:

- Chapter 2 investigates greenwashing practice in environmental funds portfolios. This chapter builds a theoretical framework based on agency theory and fiduciary duty and develops a robust econometric framework to identify whether environmental funds are involved in greenwashing.
- Chapter 3 examines the impact of the Sustainable Finance Disclosure Regulation (SFDR) on greenwashing by equity mutual funds in the EU. This chapter introduces a novel measure called the Greenwashing Index, based on a fund's decarbonisation effort relative to its flows, to examine the dynamics of greenwashing in response to the SFDR.
- Chapter 4 evaluates the impact of sustainability regulations on herding behaviour, focusing on how asset managers' trading behaviour changes following the introduction of SFDR in the EU financial markets and its impact on information asymmetry.
- Chapter 5 summarises the thesis's key contributions and outlines the most significant policy implications derived from the findings. It also discusses the research's limitations and identifies areas for future research.

Chapter 2

Spotting Portfolio Greenwashing in Environmental Funds

Chapter 2: Spotting Portfolio Greenwashing in Environmental Funds[4]

Abstract

This paper examines greenwashing practices in environmental funds. We utilize a unique data set of US equity mutual fund holdings between 2012 and 2021 to calculate the funds' carbon footprints. Using a difference-in-differences analysis, we find that, following their commitments to sustainability, environmental funds fail to reduce their carbon footprints relative to a matched group of conventional funds. We also find, using an event study, a significant increase in the flows of environmental funds in response to these sustainability commitments. The combination of the failure to reduce carbon footprints and the surge in inflows provides evidence of greenwashing by environmental funds, raising concerns about their fiduciary duty. Our findings also show that greenwashers tend to initially have low flows and high portfolio carbon emissions suggesting that they announce their commitments to sustainability just to attract investors.

Keywords: Greenwashing; Environmental funds; Fund prospectus; Carbon footprint; Decarbonization; Fiduciary duty.

JEL Classification: G10; G11; G14; Q54

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2.1 Introduction

In the evolving landscape of sustainable investing, a salient concern that emerges is the potential for misleading practices by mutual funds.[5] The lack of standardized definitions and regulations in sustainable investing creates an environment in which funds can exploit ambiguities by potentially making exaggerated or misleading claims about the sustainability of their investment strategies without facing substantial repercussions (Christensen et al., 2022). This ambiguity is exacerbated by the significant discrepancies observed in the environmental, social, and governance (ESG) scores provided by different rating agencies that cast doubt on the reliability of those scores as accurate reflections of firms' genuine ESG performance for the purpose of constructing sustainable investment strategies (Berg et al., 2022; Gibson Brandon et al., 2021; OECD, 2020; Avramov et al., 2022). Overall, this raises critical questions about the extent to which the commitments to sustainability made by some mutual funds are genuine. In this context, there is a need for empirical investigation to examine whether these commitments are part of a calculated strategy to attract inflows from investors under the guise of sustainability.

This practice of misleadingly overstating or misrepresenting the sustainability merits of investments to appeal to the rising awareness of sustainability among investors has become known as greenwashing (Lyon and Maxwell, 2011; Lyon and Montgomery, 2015; Marquis et al., 2016). This phenomenon has recently attracted the attention of the academic research (e.g., Berrone et al., 2017; Chen and Chang, 2013; Gibson Brandon et al., 2022; Liang et al., 2023). In particular, greenwashing by mutual funds can be defined as the practice of making misleading claims about integrating environmental criteria in a fund's investment strategy and decisions, which raises concerns about its commitment to sustainable investing (Marquis et al., 2016; Berrone et al., 2017).

[5]The increased interest in combating climate change, particularly following the 2015 Paris Agreement, has spurred the growth of sustainable investment strategies. As a result, the assets of global sustainable funds have surged, reaching nearly USD 2.74 trillion by the end of 2021, according to Morningstar (Morningstar Research, 2021).

In this paper, we examine greenwashing by environmentally-themed mutual funds, henceforth referred to as environmental funds. Mutual funds that base their investment decisions on ESG factors are commonly termed as ESG or sustainable funds. However, the literature lacks a consensus on their precise definition and identification (e.g., Nofsinger and Varma, 2023; Dumitrescu et al., 2022). For the purpose of this study, we limit our focus to environmental funds; a class of ESG funds that primarily integrate environmental factors in their investment strategies and decisions. This focus aligns with the overarching aim of reducing carbon emissions per the requirements of the Paris Agreement and the European Union Emission Trading Scheme (EU ETS), which created a target of net zero emissions by 2050. Despite their assertions of environmental responsibility, there is the potential for environmental funds to fall short in delivering on those promises to investors.

Our objective is to test whether environmental funds engage in misleading behavior to attract investors or genuinely make efforts to align their portfolios with environmental sustainability objectives (henceforth, sustainability objectives).[6] Specifically, we investigate whether environmental funds genuinely reduce their carbon footprints after announcing their commitment to sustainable investing; and whether the announcements made by these funds result in abnormal inflows from investors. If the evidence supports a lack of efforts despite significant inflows, it means that such funds engage in greenwashing with the aim of drawing in funds from investors but without channeling these funds to low-carbon firms, thus not showing any real impact on reducing carbon emissions.

We start our empirical analysis by examining whether environmental funds make efforts to align their portfolios with their commitments to sustainable investing. This examination allows us to improve on the usual but less effective way of examining greenwashing by

[6]Distinguishing between intentional greenwashing and managerial incompetence requires assessing whether discrepancies between sustainability claims and actual portfolio holdings are persistent and strategically timed. If environmental funds fail to reduce their carbon footprint despite significant inflows and repeated commitments to sustainability, it would suggest misleading behavior rather than mere inefficiency or poor execution of investment strategies.

looking only at inflows. Instead, we focus on the real effect that follows from environmental fund pledges. To this end, we use a difference-in-differences *(DID)* analysis to measure how much the carbon footprints of these funds change following the announcement dates. The results confirm that environmental funds' carbon footprints increase relative to those of a control group of conventional funds. Our findings indicate that environmental funds fail to keep their promises embedded in the prospectus and fail to achieve any actual carbon footprint reduction.

We further explore the differences in decarbonization efforts among environmental funds across various carbon footprint quantiles. Interestingly, the results show that the behavior of environmental funds in lower and higher quantiles differs remarkably from that of the average fund. Funds with lower carbon footprints exert less effort to decarbonize compared to their counterparts with higher carbon footprints. Nevertheless, the coefficient for the DID interaction variable is positive across all quantiles reported. This result confirms that, in general, those environmental funds fail to make a sufficient effort to decarbonize their portfolios irrespective of their initial level of carbon footprint.

Next, we examine how fund flows respond to announcements by environmental funds about committing to sustainability. To this end, we use an event study to examine fund flows around the announcement dates. We find that flows respond positively to the announcements by funds. Interestingly, the results show significantly positive abnormal flows in the event window, while there are significantly negative abnormal flows before and after the event window. Further, the increase in abnormal flows is mainly concentrated in the periods following the announcement date, confirming that the abnormal flows come as a result of the announcement. Overall, the results indicate that environmental funds benefit from announcing their commitment to sustainability in terms of increased inflows despite the lack of efforts to decarbonize their portfolios, consistent with greenwashing practices.

We further ask the question: What are the characteristics of greenwashing funds? To

answer this question, we use a panel probit regression to identify the characteristics of funds that make claims about integrating environmental factors into their investment decisions. The results show a significant relationship between fund flows and the likelihood of switching from being conventional to environmental. Particularly, funds with lower fund flows have a higher probability of switching, which confirms our main results.

We conduct a series of robustness tests. First, we compare the carbon footprints of environmental funds to those of a propensity-score-matched group of conventional funds, to dismiss the possibility that environmental funds may already be superior performers on carbon emissions, carbon footprint or flows. Second, we test whether the lack of immediate progress in carbon footprints is the result of funds taking some time to modify their portfolios, not misleading intentions. Third, we test whether the abnormal flows we report come as a response to changes in the fund's performance or other explanatory variables that could affect the fund flows. Fourth, to ensure that our findings are not endogenously driven by fund characteristics or any hot trend following the announcement date, we verify that these characteristics do not change around the event window. The results of these tests confirm our findings on greenwashing by environmental funds.

Our research contributes to the literature examining greenwashing in the broader mutual funds universe. Prior studies (e.g., Kim and Yoon, 2023; Liang et al., 2023; Gibson Brandon et al., 2022) find that funds from asset managers who are signatories to the Principles for Responsible Investment (PRI) do not show notable improvement in ESG performance after signing the PRI.[7] These asset funds seemingly employ PRI to bolster their image and attract more inflows. It is worth noting that while asset managers may be signatories to the PRI, not all their funds necessarily purport to be sustainable. This implies that using the link between signing the PRI and failing to improve ESG performance as evidence of greenwashing is not conclusive. By focusing on funds that explicitly declare the incorporation of environmental factors into their investment strategies and decisions, as indicated

[7] Further information on the Principles for Responsible Investment (PRI) can be found here: https://www.unpri.org/about-us/about-the-pri

in the fund prospectus, our research provides compelling evidence on greenwashing.

Another contribution of our work is examining greenwashing based on real fund outcomes, whereas the existing literature largely focuses on sustainability or ESG ratings (e.g., Kaustia and Yu, 2021; Kim and Yoon, 2023). Measuring impact based on ESG ratings suffers from several shortcomings. First, several studies document divergence in ESG ratings and lack of transparency on the methodologies employed by rating providers (e.g., Chatterji et al., 2016; Dimson et al., 2020; Christensen et al., 2022; Gangi et al., 2022; Semenova and Hassel, 2015; Gibson Brandon et al., 2021; Berg et al., 2022). Second, Morningstar sustainability ratings capture broader ESG risks not only environmental risks, thereby offering a skewed representation of the fund's environmental efforts. Finally, it is important to note that Morningstar globes, used for instance by Kaustia and Yu (2021) are affected by the number of funds in each Morningstar Global Category, so a fund could have similar ESG risk to another fund yet still receive a different rating if those funds are in different global categories.[8] So, the relevance of these ratings in assessing the genuine efforts made by funds to fulfil their environmental sustainability commitments is questioned. We avoid this issue by focusing on the real outcomes that reflect the efforts made by environmental funds to keep their promises of integrating sustainability into their investment decisions. Specifically, we utilize the carbon emissions data of fund holdings to construct a measure of the fund's carbon footprint. We then examine the dynamics of this carbon footprint measure to provide robust evidence on greenwashing practices. Our approach is in line with recent studies that focus on real outcomes rather than ESG ratings only. For instance, Dumitrescu et al. (2022) examine voting behavior of self-labeled ESG funds using their voting records on ESG-related proposals to assess their genuine commitment to integrating ESG in investment decisions. Also, Heath et al. (2023) examine the impact of socially responsible investment (SRI) funds on firm environmental behavior using detailed data on environmental and social dimensions from the

[8] Further information on the Morningstar sustainability rating methodology can be found here: https://www.morningstar.co.uk/uk/news/148119/the-morningstar-sustainability-rating.aspx

Environmental Protection Agency (EPA).

This paper further contributes to the literature by utilizing textual analysis techniques to examine the investment prospectuses of mutual funds for the purpose of identifying environmental funds and establishing their commitments to sustainability as part of their fiduciary responsibilities. Our methodology relies on searching the fund prospectus for specific keywords that funds include in their investment strategies to convey to investors their alignment with environmental sustainability. Prior research highlights the significance of the investment prospectus in shaping investor expectations. For example, Andrikogiannopoulou et al. (2022) examine prospectuses of ESG funds and show that investors respond strongly to text-based ESG measures such as including specific sustainability-related words in the prospectus than fundamentals-based measures such as ESG scores. Similarly, Kostovetsky and Warner (2020) find that investors respond more strongly to text-based signals than other measures like fund holdings or returns, while Abis and Lines (2022) find that funds tend to adjust their prospectuses to align closely with the average portfolio in their peer group to avoid market penalties for significant deviations. Consistent with these results, we find that the environmental funds in our sample enjoy relatively higher cash inflows compared to other funds that do not make claims about sustainability.

This paper contributes to the literature that examines the degree to which fund managers' behavior aligns with their fiduciary duties. Prior research approaches this topic in varied contexts. For instance, Heath et al. (2023) reveal that SRI funds often fall short in fulfilling their fiduciary obligations, engaging in impact-washing. While SRI funds claim to influence the environmental and societal practices of portfolio entities, evidence suggests a lack of effort to shape corporate actions via shareholder proposals. Hirst (2017) provides evidence that investment managers frequently deviate from their individual investors' sustainability preferences, raising concerns about breaches of their fiduciary duties. It is also important to acknowledge the inherent tension between meeting the return/risk objectives of the investors and pursuing genuinely sustainable investments. For example,

Schanzenbach and Sitkoff (2020) show that pension fund trustees routinely invoke fiduciary duty as a rationale to resist ESG investments, underscoring their prioritization of distinct financial objectives. To ensure we provide compelling evidence, we focus on environmental funds that integrate environmental sustainability as an investment objective within their prospectuses, rendering it imperative for them to endeavor to meet these objectives in the interest of their investors. Our findings reveal that environmental funds engage in greenwashing, thereby breaching their fiduciary duties.

This paper is organized as follows: In Section 2.2, we review the literature on greenwashing in sustainable investment. In Section 2.3, we describe the dataset and variables. In Section 2.4, we examine the change in the carbon footprints of environmental funds after committing to sustainability. In Section 2.5, we examine the reaction of fund flows after committing to sustainability. Section 2.6 presents the characteristics of greenwashing funds. Section 2.7 concludes the paper.

2.2 Greenwashing in Sustainable Investment

Agency theory can offer some insights into opportunistic behavior in investment management. Jensen and Meckling (1976) define an agency relationship as "a contract under which one or more persons (the principal(s)) engage another person (the agent) to perform some service on their behalf which involves delegating some decision-making authority to the agent" (p.308). An important assumption of the agency theory is that individuals are self-interested utility maximizers. It then follows that if both the principal and agent are utility maximizers there is good reason to believe that the agent may not always act in the best interests of the principal. This is known as the principal-agent problem. This problem is exacerbated by information asymmetry and could lead to opportunistic behavior (Eisenhardt, 1989).

In the context of investment management, investors (the principals) delegate the responsibility of allocating capital and managing assets to professional investment managers (the agents) with the anticipation of achieving specific objectives. Information asymmetry exists in this agency relationship, à la Akerlof (1970), since investment managers know more about the characteristics of the investment products. Investors, on the other hand, experience difficulty and incur costs in monitoring managers and evaluating the merits and outcomes of investment strategies. This imbalance can lead to opportunistic behaviors, as investment managers may exploit informational advantages to pursue personal gains or deviate from investors' objectives.

An example of opportunistic behavior in the investment management agency relationship is providing misleading or unsubstantiated information to investors. Numerous studies indicate that investment managers often use manipulative marketing strategies to attract investment flows, regardless of whether their actual practices or performance align with investors' objectives. For example, Cooper et al. (2005) shows that mutual funds change their names as a marketing strategy to match hot market trends leading to a significant increase in fund flows. These positive abnormal inflows do not seem to be driven by any actual change in the fund's portfolio holdings or investment strategy. Similar manipulative behavior is documented by Chen et al. (2021) who show that almost a third of their sample of bond funds misclassified holdings in their portfolios to attract a more favorable Morningstar rating and inflows from investors. Opportunistic behavior due to information asymmetry also exists in the context of sustainable investing where investment managers possess more knowledge about the true sustainability implications of the investments than the investors. For example, some mutual funds have recently sought to demonstrate a shift towards sustainability by adapting their names to reflect a greater focus on sustainability issues. This practice seems to pay off in the year following the name change in terms of increased inflows and portfolio turnover (El Ghoul and Karoui, 2021). Nevertheless, Cochardt et al. (2023) show that mutual funds change their names to appear environmentally friendly without actually affecting firms' green practices. While

these funds seem to enhance their sustainability ratings by excluding firms with poor sustainability performance from their portfolios, there is no evidence that they actively engage (e.g., through shareholder voting) in advancing the sustainability performance of their holdings.

This practice of misleadingly overstating or misrepresenting the sustainability merits of the investments to appeal to the rising awareness of sustainability among investors has become known as greenwashing (Lyon and Maxwell, 2011; Lyon and Montgomery, 2015; Marquis et al., 2016). Greenwashing is not only ethically questionable but also poses substantial risks to investors, particularly when the proclaimed sustainable investments underperform due to a lack of genuine commitment to ESG standards (Friede et al., 2015). Consequently, greenwashing emerges as an opportunistic behavior where investment managers prioritize their self-interests, such as attracting capital or charging premium fees, over the genuine sustainability concerns of their investors, leading to adverse consequences such as increased costs and inefficiencies (Seele and Schultz, 2022; Bosse and Phillips, 2016).

Much greenwashing in sustainable investing manifests as unsubstantiated claims.[9] Some funds signal their commitment to sustainability through self-designation as ESG funds. While Dumitrescu et al. (2022) show that at least one out of every four self-designated ESG funds fail to keep their pledge to investors, Kaustia and Yu (2021) show that those funds obtain more inflows than their conventional peers even though they are equivalent in terms of the Morningstar sustainability rating. Another way for funds to signal their commitment to sustainability is by endorsing recognised initiatives such as the PRI. Liang et al. (2023) show that hedge funds that sign PRI attract significantly larger inflows compared to other non-signatory funds. Those hedge funds with low ESG scores also attract relatively high inflows by marketing their funds aggressively to unsophisticated

[9]In the US, actions such as misstatements, omissions, failures in policies and procedures, or misleading existing or prospective clients regarding the ESG investment process are considered fraudulent, deceptive, or manipulative behavior. These actions are punishable under the Investment Advisers Act of 1940 and the Investment Company Act of 1940. For further details, please refer to the litigation releases of the US Securities and Exchange Commission (SEC): https://www.sec.gov/litigation/litreleases

investors. Evidence also shows that mutual funds from asset managers who are PRI-signatories either do not show notable improvement in ESG performance after signing the PRI (Kim and Yoon, 2023) or fail to uphold their responsible investment pledges to enhance the ESG performance of the firms they invest in (Gibson Brandon et al., 2022).

Sustainability ratings have emerged as a mechanism to mitigate asymmetric information and opportunistic practices, like greenwashing, in sustainable investing. These ratings aim to reduce asymmetric information by offering investors a simplified and accessible metric of an investment product's sustainable performance, thereby reducing search costs (Ben-David et al., 2022; Brito-Ramos et al., 2024). However, their relevance in assessing the genuine efforts made by funds to fulfil their sustainability commitments has recently been questioned. In fact, several studies document divergence in ESG ratings and lack of transparency on the methodologies employed by rating providers (e.g., Chatterji et al., 2016; Dimson et al., 2020; Christensen et al., 2022; Gangi et al., 2022; Semenova and Hassel, 2015; Gibson Brandon et al., 2021; Berg et al., 2022). An important consequence of this divergence is that, particularly in light of the increasing importance of ESG factors, there are concerns that a growing number of investment managers may emphasize ratings that favourably portray them without genuinely mirroring their sustainability performance.

An important implication of greenwashing as an opportunistic behavior is whether it represents a breach of the investment manager's fiduciary duty. Fiduciary duty refers to the legal obligation that investment managers, trustees, or other financial professionals have to act in the best interests of their investors or beneficiaries in accordance with the investment objectives outlined in the investment prospectus (Richardson, 2009).[10] The

[10]In the US, fiduciary duty is prescribed in different Acts including the 1974 Employment Retirement and Income Security Act (ERISA) which outlines the general responsibilities of pension fund trustees, and the 1994 Uniform Prudent Investor Act (UPIA) which applies to any fiduciary investing assets on behalf of others. Other notable federal legislation, including the 1940 Investment Advisors Act, and the 1940 Investment Company Act also add layers of duties specifically directed to fund managers and investment advisers. In addition to the legal obligation of the fiduciary duty, most financial professional bodies require their members to comply with codes of ethics that encompass the fiduciary duty towards clients. For example, in the US, the Chartered Financial Analyst (CFA) Institute mandates that finance professionals adhere to the Code of Ethics and Standards of Professional Conduct. This code includes

law tends to impose a fiduciary obligation on the agent in circumstances that present a principal-agent problem (Easterbrook and Fischel, 1993; Cooter and Freedman, 1991). Greenwashing is a manifestation of this principal-agent problem whereby investment managers misrepresent the true nature of the investments leading investors to believe they are contributing to environmental preservation when they are not (e.g., Delmas and Burbano, 2011; Torelli et al., 2020; Nyilasy et al., 2014). Nevertheless, in considering this question of whether greenwashing is a breach of the fiduciary duty, one should distinguish between two important cases: fiduciary duty in relation to integrating ESG risks into investment decisions, and fiduciary duty in relation to greenwashing.

There has been a lengthy debate on whether integrating ESG risks into the investment decision-making process is part of the investment manager's fiduciary duty. The core fiduciary duties of investment managers are loyalty (investing in the best interest of their beneficiaries) and exercising due care (applying the prudent investor rule in investing) (Sandberg, 2011; Langbein and Posner, 1980). Traditionally, this fiduciary duty has been interpreted as requiring managers to act prudently in the financial interests of their beneficiaries. Due to a lack of evidence on the financial materiality of ESG factors, many asset managers cited their fiduciary duty as a reason preventing them from actively integrating ESG in their investing strategies (Lewis and Juravle, 2010). An important counterargument to this view was provided in the Freshfields report[11] (Freshfields Bruckhaus Deringer, 2005) which concluded that: (1) integrating ESG considerations into an investment analysis so as to more reliably predict financial performance is clearly permissible and is arguably required in all jurisdictions; and (2) ESG considerations must be

Standard III(A) Loyalty, Prudence, and Care, which articulates the expected fiduciary duties of loyalty, care, and prudence with which the CFA members are required to comply.

[11]The Asset Management Working Group of the United Nations Environment Program Finance Initiative (UNEP FI) commissioned Freshfields Bruckhaus Deringer, a leading law firm based in London, to investigate whether the integration of ESG issues into investment policy (including asset allocation, portfolio construction and stock-picking or bond-picking) voluntarily permitted, legally required or hampered by law and regulation. The results of the investigation were published in 2005 and became widely referred to as the "Freshfields report". The UNEP FI has also issued a follow-up report in 2009 termed "Fiduciary II" to provide a legal roadmap for fiduciaries looking for concrete steps to operationalise their commitment to responsible investment (see United Nations Environment Programme Finance Initiative (UNEP FI), 2009).

integrated into an investment decision where a consensus (express or in certain circumstances implied) amongst the beneficiaries mandates a particular investment strategy. The report also argues that while seeking profitability for beneficiaries is part of the fiduciary duties, profit-maximisation is not (Freshfields Bruckhaus Deringer, 2005, pp. 6-13). The report contends that profit-maximization has never been a part of the fiduciary duties of asset managers in any country, hence, there are no legal restrictions that prevent managers from considering the interests of beneficiaries beyond financial return in arriving at investment decisions. These results have been widely supported by the literature on sustainable investing (e.g., Sethi, 2005; Sandberg, 2011; Gary, 2019; Kiernan, 2008), particularly in light of the growing evidence on the positive link between ESG factors and financial performance (Friede et al., 2015).

Fiduciary duty in relation to greenwashing is less contentious. As indicated by the Securities and Exchange Commission (SEC) in its recent interpretation of the standard of conduct for investment advisers under the Investment Advisers Act of 1940, "the duty of care requires an investment adviser to provide investment advice in the best interest of its client, based on the client's objectives" (SEC, 2019).[12] This fiduciary duty of care extends beyond the mere consideration of financial returns; it also entails incorporating sustainability factors into investment processes, decisions, and risk assessments when they form part of the investment objectives (PRI, 2019). Managers that market investment products as sustainable must ensure that their investment strategies align with the investors' financial goals while also accounting for their impacts on society and the environment. Fund managers that engage in greenwashing do not meet the sustainability commitments detailed in their prospectuses. Consequently, they fail to uphold their fiduciary duty of care (Martin, 2009; Woods and Urwin, 2010; Curtis et al., 2021;

[12]For a detailed discussion on the fiduciary duty in the mutual fund industry see Laby (2018) and Jackson (2021). While fiduciary duty requires investment advisers to act in their clients' best interest, investor objectives can vary. Some may prioritize genuine sustainability impact, while others may focus solely on financial returns, even if achieved through greenwashing. However, our analysis focuses on whether environmental funds genuinely align with their own sustainability commitments rather than whether investors willingly accept greenwashing for financial gain.

Sandberg, 2011). Additionally, when fund managers try to only appear sustainable without taking genuine actions to integrate sustainability into their investment process, they may overlook certain financial risks associated with green investments (Amel-Zadeh and Serafeim, 2018). Failing to properly account for or communicate these risks to investors could lead to financial losses, which directly contradicts the fiduciary duty to protect the financial interests of clients. Therefore, investment managers involved in greenwashing can inadvertently breach their fiduciary duties.

2.3 Data and Variables

In this paper, we use three levels of data: fund-level data, portfolio-level data, and fund prospectus. In this section, we explain the details of the sample and variables used in the analysis.

2.3.1 Mutual Fund Data

We use the Refinitiv database to obtain a dataset of US equity mutual funds and their holdings. We obtain data for both active and inactive funds. We include actively-managed open-end equity mutual funds, therefore excluding ETFs and passive mutual funds. Other types of funds, such as bond, money market, hedge, and pension funds are not examined. Based on these criteria, our sample consists of a total of 6,720 funds and spans from 2012-Q1 to 2021-Q4. We extract the following quarterly variables for individual share classes of each fund: net asset value (NAV), total net assets (TNA), total return, expense ratio, dividend payments, and capital gain payments. We then aggregate these share-class variables at the fund level. In addition, we also collect data on the characteristics

of each fund such as the Lipper RIC, inception date, ISIN code, domicile, asset status, asset type, and the investment style.[13]

2.3.2 Mutual Fund Holdings

Each mutual fund represents a portfolio composed of several stocks in which the fund has invested. We obtain the quarterly holdings data for all funds in our sample throughout the sample period from the Refinitiv database. Overall, the total number of holdings in the dataset is 800,875. We use the holdings data to calculate several fund-level variables needed for our subsequent analysis. These variables include the turnover ratio, price-to-book, number of holdings, and market cap. The turnover ratio refers to the minimum of total stock sales or total stock purchases in a given quarter as a percentage of the fund's total net assets in the previous quarter. The price-to-book is calculated as the holdings-value-weighted average price-to-book ratio of stocks in the fund's portfolio. The number of holdings refers to the total count of individual stocks or assets held in the fund's portfolio. The market cap refers to the holdings-value-weighted average market cap of firms in the fund's portfolio. Table 2.1 presents a detailed definition of all the variables used in the analysis.

[13]The investment style is reported based on Refinitiv Lipper's Holdings-Based Fund Classifications (HBC). Table A.2 in the Appendix provides a distribution of the investment styles of the funds included in our sample. For further information, please refer to https://lipperalpha.refinitiv.com/wp-content/uploads/2016/01/GlobalHBCMethodology.pdf

Table 2.1: Variable Definitions.

Variable	Definitions
Carbon emissions variables	
Carbon Emission (Scope 1)	Scope 1 refers to direct carbon emissions that originate from the firm's main sources, such as emissions from vehicles and chemical production.
Carbon Emission (Scope 2)	Scope 2 refers to the indirect amount of supplied electricity that the firm uses.
Carbon Emission (Scope 3)	Scope 3 refers to indirect emissions that are a consequence of the firm's activities but occur from sources not owned or controlled by the firm.
Emissions Score	The fund's emissions score is estimated as the weighted average of the emissions scores of its holdings and measures a holding's commitment and effectiveness towards reducing environmental emissions in the production and operational processes. It equals between 0 and 100.
Firm Carbon Footprint	Carbon footprint of a firm is calculated by scaling the firm's scope 1, 2, and 3 carbon emissions by its total revenues. It is expressed as tons of CO2 emissions per $1 million of revenues.
Fund Carbon Footprint	The fund's carbon footprint is calculated as the weighted average of the carbon footprints of its individual holdings, where the weight is determined by the proportion of each holding's market value relative to the total market value of the fund's portfolio.
Fund variables	
Total Net Assets (TNA)	The total net assets of a fund refer to the total market value of all the securities held by the fund, minus any liabilities measured in millions of dollars.
Net Asset Value (NAV)	The fund's net asset value is the market value of one share of the fund. It is calculated by dividing the total net assets of the fund by the number of shares outstanding.
Total Return	The return on investment of a specific fund which is measured monthly as the percentage change in the fund's net asset value (NAV).
Fund Flow	The change in total net assets of a fund over a month, adjusted by the fund's return for that month. It is calculated by dividing the net change in assets by the fund's net assets at the beginning of the month.
Jensen's Alpha	Alpha is the risk-adjusted performance of a given portfolio of assets relative to the expected market return as calculated using the Capital Asset Pricing Model (CAPM).
Fund Age	The fund age since its inception date measured in quarters.
Fund Size	The accumulative total net assets of the fund's portfolio measured in millions of dollars.
Expense Ratio	The expense ratio is expressed as a percentage of the fund's average assets under management (AUM). It represents what a mutual fund charges to cover expenses, including management fees, administrative fees, operating costs, and all other asset-based costs.
Total Load Fees	The sum of the front, deferred, and rear-end charges as a percentage of new assets. (Hong and Kostovetsky, 2012)

Continued on next page

Table 2.1 – continued from previous page

Variable	Definitions
Investment Style	The investment style of mutual funds refers to the specific approach or strategy that the fund manager uses when selecting investments for the fund's portfolio. Refinitiv Lipper's Holdings-Based Classification (HBC) which classifies investment styles into Large Cap Value, Large Cap Core, Large Cap Growth, Multi-Cap Value, Multi-Cap Core, Multi Cap Growth, Mid Cap Value, Mid Cap Core, Mid Cap Growth, Small Cap Value, Small Cap Core, and Small Cap Growth.
Portfolio Turnover	Portfolio turnover is calculated by taking the minimum of the aggregated sales and aggregated purchases of securities during a specific quarter and dividing it by the total value of the portfolio's holdings from the previous quarter.
Number of Holdings	The number of firms in which the fund invests.
Portfolio variables	
Price-to-Book Ratio	Refers to the weighted average price-to-book ratio of stocks in the fund's portfolio.
Revenues	The weighted average of the total revenues of firms in the fund's portfolio in millions of dollars.
Market Cap	The weighted average market capitalization of portfolio firms measured in millions of dollars.
Total Assets	The weighted average total assets of portfolio firms measured in millions of dollars.
Environmental fund identification	
Announcement Date	The announcement date refers to the date at which the fund designates itself as environmental, as reported in its prospectus. The fund prospectus is a legal document containing the fund's objectives, strategy, investment principles, risks, historical performance, and other information.
Difference-in-Differences variables	
Env	A dummy variable that equals one if the fund is integrating environmental criteria into its investment objectives and zero otherwise.
Post	A dummy variable that equals one after the fund announces that it is integrating environmental criteria into its investment objectives and zero otherwise.
Env*Post	An interaction variable that comprises two underlying dummy variables: *Env* and *Post*.
Event study variables	
Event Date	The event date refers to month 0 or the starting point in time when a fund is identified for the first time as being environmental. It is based on the announcement date.

Continued on next page

Table 2.1 – continued from previous page

Variable	Definitions
Event Window	The event window refers to the period of time around the announcement date that is chosen for analysis. The event window typically consists of a pre-event period, the event date itself (announcement date), and a post-event period. The event window is [-3, 3], i.e. three months before the event date, event date (t=0), and three months post the event date.
Estimation Window	The estimation window refers to the period of time used to estimate the normal or expected fund flow behavior for a environmental fund. We use 24 months of data as an estimation window.

2.3.3 Identifying Environmental Funds

According to Morningstar, "the global sustainable fund universe encompasses open-end funds and exchange-traded funds globally that, by prospectus, factsheet, or other available resources, claim to have a sustainability objective and/or use binding ESG criteria for their investment selection" (Morningstar Research, 2021). Mutual funds aligning with these criteria are commonly referred to as ESG funds or sustainable funds. Morningstar compiles a list of these sustainable funds by searching mutual fund prospectuses or other regulatory filings for keywords related to sustainability; impact; or environmental, social, and governance (ESG) factors. Our methodology mirrors Morningstar's in identifying a sample of environmental funds for our analysis. However, given our paper's objective of examining greenwashing by environmental funds, we narrow our keyword search in fund prospectuses and regulatory filings specifically to environmental themes. A significant advantage of this method is to ensure that our sample selection aligns with our greenwashing definition, wherein environmental funds claim to be environmentally responsible or focused on decarbonization targets but fail to deliver on those promises to investors.

We outline the process of identifying the sample of environmental funds in Table 2.2. First, to ensure high data quality in each quarter, we exclude any fund that does not have sufficient holdings with accessible reported data on carbon emissions.[14] In particular, we

[14]Not all firms consistently report their carbon emissions. In fact, it is only since 2009 that the US has required facilities emitting at least 25,000 metric tons or more of carbon dioxide to report their greenhouse gas emissions to the Environmental Protection Agency (EPA) every year. Together those facilities account for about 3 billion metric tons of CO2, which is about half of total US emissions. Many

require that these holdings with accessible data on carbon emissions represent at least 60% of the fund's total net assets (TNA). We implement this criterion to ensure we possess enough data to precisely compute the carbon footprint of our sample of funds, which is the primary variable used in our subsequent analysis. Applying this criterion results in a refined sample of 1,588 funds with sufficient data on carbon emissions.[15]

Subsequently, we obtain the most recent statement of investment objectives of this updated list of funds from Refinitiv. These investment objectives are typically extracted from the fund's prospectus and regulatory filings. Then, we screen each fund's objectives for keywords such as *sustainable, sustainability, climate, climate change, emissions, carbon emissions, environment, and environmental* to identify the initial sample of environmental funds. If a fund's objectives incorporate any of these keywords, we initially classify it as an environmental fund. To ensure that our sample only includes environmental funds, we exclude any funds that mention 'sustainable' or 'sustainability' terms in their investment objectives but primarily focus on social or governance, rather than environmental aspects. Out of the 1,588 mutual funds, 242 are identified as the initial sample of environmental funds. To validate our selection process, this sample is then compared with the list of US sustainable funds provided by Morningstar and the list of sustainable equity mutual funds provided by the US Sustainable Investment Forum (SIF).[16] This comparison shows that all the funds identified as environmental in our sample appear in either one or both lists.

Next, we need to identify the quarter in which the fund designates itself as an environmental fund for the first time by finding any of the search keywords mentioned above in its prospectus. We call this the *announcement date*. Identifying this announcement date is

small businesses are not required to report their emissions to the EPA. For more information, please refer to the US Greenhouse Gas Reporting Program (GHGRP) here: https://www.epa.gov/ghgreporting/learn-about-greenhouse-gas-reporting-program-ghgrp

[15]We also experiment with lower thresholds such as 50% and 40%. We find that the sample size increases but without any noticeable changes in the main results.

[16]For further details on the list of environmental funds provided by Morningstar please see https://www.morningstar.co.uk/uk/funds/esg.aspx?Page=6. For further details on the list of environmental funds provided by SIF please see https://charts.ussif.org/mfpc/

Table 2.2: Identifying Environmental Funds.
This table presents the criteria and steps followed to identify the sample of environmental funds. The Refinitiv database is used to obtain data on US equity mutual funds and their portfolio holdings with sufficient data on carbon emissions from 2012 to 2021 to identify a sample of environmental and conventional funds. From the subset of funds with sufficient data on carbon emissions, we form two subsamples of conventional and environmental funds. We identify 242 funds as the initial sample of environmental funds. Next, the EDGAR database is used to screen the prospectus of each potential environmental fund in the sample over the 10-year period to identify the announcement date. Finally, funds for which an announcement date could not be identified and those funds that were launched as environmental from the inception date during our sample period are dropped to reach the final sample of environmental funds.

Criteria	Number
Initial number of US equity mutual funds	6,720
(-) Number of funds without sufficient carbon emissions data	5,132
= Number of funds with sufficient carbon emissions data	1,588
(-) Initial sample of conventional funds	1,346
= Initial sample of environmental funds	242
(-) Number of environmental funds without identifiable announcement date	42
(-) Number of funds that were launched as environmental funds	67
= Final sample of environmental funds	133

pivotal for our subsequent analysis to examine the behavior of environmental funds. Following previous studies (e.g., Nofsinger and Varma, 2023; Sensoy, 2009; DeHaan et al., 2021), we use the Securities and Exchange Commission's EDGAR database to collect quarterly prospectuses reported on the "497K" and "485" forms for the 242 environmental funds, for the period from 2012 to 2021.[17] We then identify the announcement date of each environmental fund by searching for the first time the fund incorporates any of the keywords in its prospectus. As shown in Table 2.2, we were not able to identify the announcement date of 42 environmental funds. This inability might be due to the fact that those funds started integrating sustainability into their investment decisions before the start point of our sample period in 2012-Q1. Similarly, a further 67 environmental

[17]The 497K and 485 forms are filed with the US Securities and Exchange Commission (SEC) by investment funds. They encompass the prospectus which is a document that contains the fund's objectives, strategy, investment principles, risks, historical performance, and other information. The intent is to provide investors with key information in a more readable and accessible format. We focus on the investment strategy section in the prospectus which includes key important details about the investment product, such as its objectives, costs, risks, and performance. For further information, please refer to https://www.sec.gov/dera/data/mutual-fund-prospectus-risk-return-summary-data-sets

funds were launched during the sample period as environmental funds. The announcement date for those funds was the same as the launch date. Hence, we exclude those 67 funds because they do not have sufficient data before the announcement date to enable us to examine the change in their carbon footprint around the announcement date. Thus, we retain 133 US environmental funds with sufficient data pre and post-announcement quarters, as presented in Table 2.2. Furthermore, Figure A.1 in the Appendix illustrates the distribution of the announcement dates of environmental funds over time.

2.3.4 Fund Flows

Several studies (e.g., Hartzmark and Sussman, 2019; Ceccarelli et al., 2024) indicate that sustainability criteria can influence investors' preferences. We investigate the potential for environmental funds to mislead investors by proclaiming a commitment to these criteria, aiming to boost fund inflows. Therefore, a key metric in our analysis is fund flows. Consistent with existing literature (e.g., Benson and Humphrey, 2008; Cooper et al., 2005), fund flows are measured based on the change in their total net assets. Specifically, we calculate mutual fund flows by dividing each fund's monthly cash inflow from investors by its total net assets from the prior month. This inflow is the difference between the current month's total net assets and the sum of the prior month's total net assets and any returns accrued on those assets. Formally,

$$FundFlow_{i,t} = \frac{[TNA_{i,t} - (1 + r_{i,t})TNA_{i,t-1}]}{TNA_{i,t-1}} \tag{2.1}$$

where $TNA_{i,t}$ is the total net assets for fund i in month t, and $r_{i,t}$ is the return on fund i in month t.

2.3.5 Fund Performance

As shown by Smith (1978), investors' decision to invest in a given fund is affected by its past performance. We use Jensen's alpha as a measure of the risk-adjusted performance of funds in our sample. Alpha represents the excess return on a portfolio over its expected return as calculated by using the Capital Asset Pricing Model (CAPM) (Jensen, 1968). Following previous studies (e.g., Sheng et al., 2022; Abis and Lines, 2022; Dumitrescu et al., 2022), we estimate the alpha on a monthly basis using rolling regressions with an estimation window of 24 months based on the CAPM model shown in the following formula.

$$R_{i,t} - R_f = \alpha_i + \beta_i[R_{i,B,t} - R_f] + \varepsilon_{i,t} \tag{2.2}$$

where $R_{i,t}$ is the return on fund i in month t, R_f is the risk-free rate (3-months US treasury yield), $R_{i,B,t}$ is the return on the benchmark index (CRSP US Total Market Index) in month t, β_i is a measure of fund i's systematic risk relative to its benchmark, and α_i represents the alpha of fund i. We obtain monthly data on the return on funds and the benchmark, as well as the risk-free rate from the Refinitiv database.

2.3.6 Carbon Footprint

Carbon emissions data can be classified into two primary categories: historical data that encompasses both reported and estimated greenhouse gas (GHG) emissions, and carbon scores and ratings supplied by various data providers. An important contribution of our work is examining greenwashing based on real fund outcomes such as carbon footprint, whereas the existing literature largely focuses on ESG ratings. To this end, our carbon footprint measure is based on reported carbon emissions data. We collect data on carbon emissions of funds' holdings from 2012 to 2021 from the Refinitiv database which offers the most comprehensive dataset. The emissions data are classified per the Greenhouse Gas

Protocol (2015) into scope 1, 2, and 3 emissions.[18] Scope 1 emissions encompass direct carbon emissions emanating from primary company sources like vehicles and chemical production of firms, scope 2 pertains to the indirect carbon emissions resulting from the consumed electricity of firms, and scope 3 captures emissions indirectly stemming from other firm operations. The carbon emissions data extracted from Refinitiv comprise total $CO2$ equivalent emissions, scope 1 direct $CO2$ equivalent emissions, scope 2 indirect $CO2$ equivalent emissions, scope 3 indirect $CO2$ equivalent emissions, and the ratio of total $CO2$ equivalent emissions to revenues. To enhance the data integrity, we exclude firms that lack carbon emissions data from the analysis.

In order to calculate the funds' carbon footprints, we use the carbon emissions data, especially the reported emissions given that such data are not likely to be affected by the rating methodologies used by the data providers (Gibson Brandon et al., 2021; Liang and Renneboog, 2020). We start with calculating the carbon footprints of individual firms that funds hold in their portfolios.[19] Similar to Andersson et al. (2016), we estimate the carbon footprints for holdings by scaling the firm's scope 1, 2, and 3 carbon emissions by its total revenues each year, as shown by the following formula:

$$CFP_{j,t} = \frac{Scope_{1,2,3}CE_{j,t}}{REV_{j,t}} \tag{2.3}$$

where $CFP_{j,t}$ is the firm's carbon footprint, $Scope_{1,2,3}CE_{j,t}$ is the firm's total $CO2$ equivalent carbon emissions, and $REV_{j,t}$ is the firm's total revenues; j and t refer to firm and time, respectively.

[18]The Greenhouse Gas Protocol provides comprehensive global standards to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions. It was created as an initiative based on a partnership between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). It has issued several standards including the Corporate Accounting and Reporting Standard which is considered the world's most widely used greenhouse gas accounting standard. For further details, refer to https://ghgprotocol.org/standards

[19]Carbon footprint encompasses all greenhouse gas emissions associated with a firm's activities and can be expressed in various ways such as total emissions which refer to the total amount of carbon dioxide equivalent emissions released into the atmosphere by a firm's activities. In this paper, we measure carbon footprint as the ratio of total carbon emissions to a measure of the firm's size (e.g., sales or output). This measure, according to Aswani et al. (2024, p. 81), provides an appropriate way to measure a firm's carbon footprint.

Next, we derive each fund's carbon footprint (CFP) from its individual holdings. This method, as endorsed in the literature (e.g., Humphrey and Li, 2021; Rohleder et al., 2022), offers multiple advantages. Notably, the efforts of firms to reduce carbon emissions are better measured by their carbon footprints which show the effectiveness of converting carbon emissions into revenues. At the fund level, divestment policies predominantly focus on carbon footprints rather than mere carbon emissions (Bolton and Kacperczyk, 2021a), as the former provides a clear and quantifiable measure of a fund's environmental impact. This measure also enables comparability across funds due to the diverse sectors and industries in which these funds invest. Therefore, using this metric enables us to obtain a consistent and comparable measure of the decarbonization efforts across funds. This is essential for examining potential greenwashing in environmental funds due to the diverse investment styles and strategies implemented by the investment funds in our sample. Formally, we calculate the quarterly carbon footprint for fund i as the weighted average of the carbon footprints of its individual holdings using the following formula:

$$CFP_{i,t} = \sum_{j=1}^{N} W_{i,j,t} \times CFP_{j,t} \tag{2.4}$$

where $CFP_{i,t}$ is the carbon footprint of fund i in quarter t, $W_{i,j,t}$ refers to the weight of holding j in fund i's portfolio in quarter t, and $CFP_{j,t}$ is the carbon footprint of holding j in quarter t as calculated by Eq. 2.3. It should be noted that $W_{i,j,t}$ is calculated as the ratio of the market value of the shares of firm j held by fund i in quarter t to the total market value of fund i's portfolio in quarter t.

2.3.7 Descriptive Statistics

Table 2.3 presents the summary statistics for the entire sample alongside separate summary statistics for the subsamples of environmental and conventional funds. The summary statistics cover both the fund variables such as total net assets (TNA), total return, total expense ratio, total load fees, alpha, age, and fund flows; as well as holdings-based

variables such as revenues, total assets, market cap, price-to-book ratio, carbon footprint, and emissions score. Table A.1 presents the correlation matrix for the main variables. Both the associated significance levels and the test for the variance inflation factor (VIF) confirm the absence of multicollinearity. Notably, the summary statistics show that the average fund flows for environmental funds (5.02%) surpass those of conventional funds (4.27%). Moreover, the average carbon footprint for environmental funds stands at 251.49, while for conventional funds it is 174.60. These preliminary observations from the dataset hint at potential inconsistencies in environmental funds' decarbonization claims.

Figure 2.1 presents the quarterly fund flows of conventional and environmental funds from 2012 to 2021. Throughout this period, environmental funds predominantly register inflows, while conventional funds generally have outflows. Notably, there is a significant surge in inflows to environmental funds from 2020-Q2 to 2021-Q3, coinciding with significant outflows from conventional funds. These patterns indicate that environmental funds may have become more attractive to investors. However, this trend alone does not mean that environmental funds are engaging in greenwashing.

Moreover, Figure 2.2 illustrates the quarterly weighted average carbon footprints of both conventional and environmental funds. Initially, there is a modest decline in carbon footprints which then stabilizes until the end of 2016. However, the figure shows a noticeable increase in the carbon footprints of all funds after 2017. Notably, this increase is more pronounced in the case of environmental funds than for conventional ones, particularly from the first quarter of 2020 onward. These trends indicate that environmental funds may not be actively pursuing portfolio decarbonization. They also align with concerns that asset managers might be making unsubstantiated decarbonization claims, that potentially indicate that they are greenwashing.

Table 2.3: Descriptive Statistics.
This table provides the summary statistics for the whole sample of funds used in the analysis as well as the two samples of environmental and conventional funds separately. The samples include data for the period from 2012 to 2021. Detailed definitions of the variables are provided in Table 2.1.

Variables	Observations	Mean	Std.Dev.	Min	Max
Panel A : All Funds					
Total Net Assets ($ mil)	260097	198.01	1157.78	5.05	10903.25
Net Asset Value ($)	260097	650	1700	0.05	9620
Total Return (%)	260097	0.31	4.77	-51.19	22.42
Fund Flows ($ mil)	260097	-6.7	89.7	-535	411
Fund Flows (%)	260097	4.76	44.58	-52.37	103.76
Jensen's Alpha (%)	52839	-0.03	1.23	-87.63	0.51
Fund Age	260097	16.81	10.17	0.07	97.46
Total Expense Ratio (%)	260097	0.28	0.57	-0.18	9.19
Total Load Fees (%)	260097	2.54	1.23	0	4
Dividend Payments (%)	260097	0.06	0.19	0	1.45
Capital Gains Payments (%)	260097	0.33	0.99	0	6.02
Turnover	52839	0.0315	0.0488	0	4.835
Number of Holdings	52839	52.39	3.86	34	66
Carbon Footprint (Scope 1,2&3)	52839	179.32	204.65	0.13	725.29
Price-to-Book Ratio	52839	5	2.13	0.97	7.47
Revenues ($ mil)	52839	5960	4210	187	10200
Market Cap ($mil)	52839	13100	7190	0	18300
Total Assets ($ mil)	52839	7090	1680	1220	7820
Emissions Score	52839	41.46	23.63	2.22	75.33
Panel B : Environmental Funds					
Total Net Assets ($ mil)	14588	231	572	136.26	3100
Net Asset Value ($)	14588	32.33	147.44	0.07	837.04
Total Return (%)	14588	0.23	4.43	-37.55	14.17
Fund Flows ($ mil)	14588	1.37	30.90	-143	132
Fund Flows (%)	14588	5.02	24.57	-54.79	103.76
Jensen's Alpha (%)	3239	-0.04	1.47	-87.63	0.33
Fund Age	14588	13.41	9.92	0.17	97.46
Total Expense Ratio (%)	14588	0.27	0.57	0	5.02
Total Load Fees (%)	14588	2.54	1.19	0	4
Dividend Payments (%)	14588	0.14	0.67	0	5.16
Capital Gains Payments (%)	14588	0.14	0.58	0	3.94
Turnover	3239	0.0361	0.1316	0	4.835
Number of Holdings	3239	55.15	4.72	34	65
Carbon Footprint (Scope 1,2&3)	3239	251.49	212.30	0.51	728.99
Price-to-Book Ratio	3239	3.47	1.84	0.39	5.78
Revenues ($ mil)	3239	7420	3680	172	10500
Market Cap ($mil)	3239	58700	23800	2520	73600
Total Assets ($ mil)	3239	19500	5650	1670	22000
Emissions Score	3239	58.82	26.16	3.93	85.8
Panel C : Conventional Funds					
Total Net Assets ($ mil)	245509	100.24	399.44	4.94	3407.11
Net Asset Value ($)	245509	680	1780	0.06	10100
Total Return (%)	245509	0.31	4.78	-51.19	22.42
Fund Flows ($ mil)	245509	-7.42	93.00	-560	420
Fund Flows (%)	245509	4.27	42.81	-52.37	87.2
Jensen's Alpha (%)	49600	-0.03	1.14	-56.63	0.51
Fund Age	245509	17.01	10.15	0.07	93.88
Total Expense Ratio (%)	245509	0.28	0.57	-0.18	9.19
Total Load Fees (%)	245509	2.54	1.19	0	4
Dividend Payments (%)	245509	0.06	0.18	0	1.30
Capital Gains Payments (%)	245509	0.34	1.01	0	6.11
Turnover	49600	0.0312	0.0381	0	0.8544
Number of Holdings	49600	56.47	3.795	34	66
Carbon Footprint (Scope 1,2&3)	49600	174.60	203.23	0.12	724.91
Price-to-Book Ratio	49600	5.09	2.11	1.16	7.54
Revenues ($ mil)	49600	5860	4220	188	10100
Market Cap ($mil)	49600	11700	6450	0	16400
Total Assets ($ mil)	49600	6790	1580	1200	7460
Emissions Score	49600	40.38	23.12	2.16	73.46

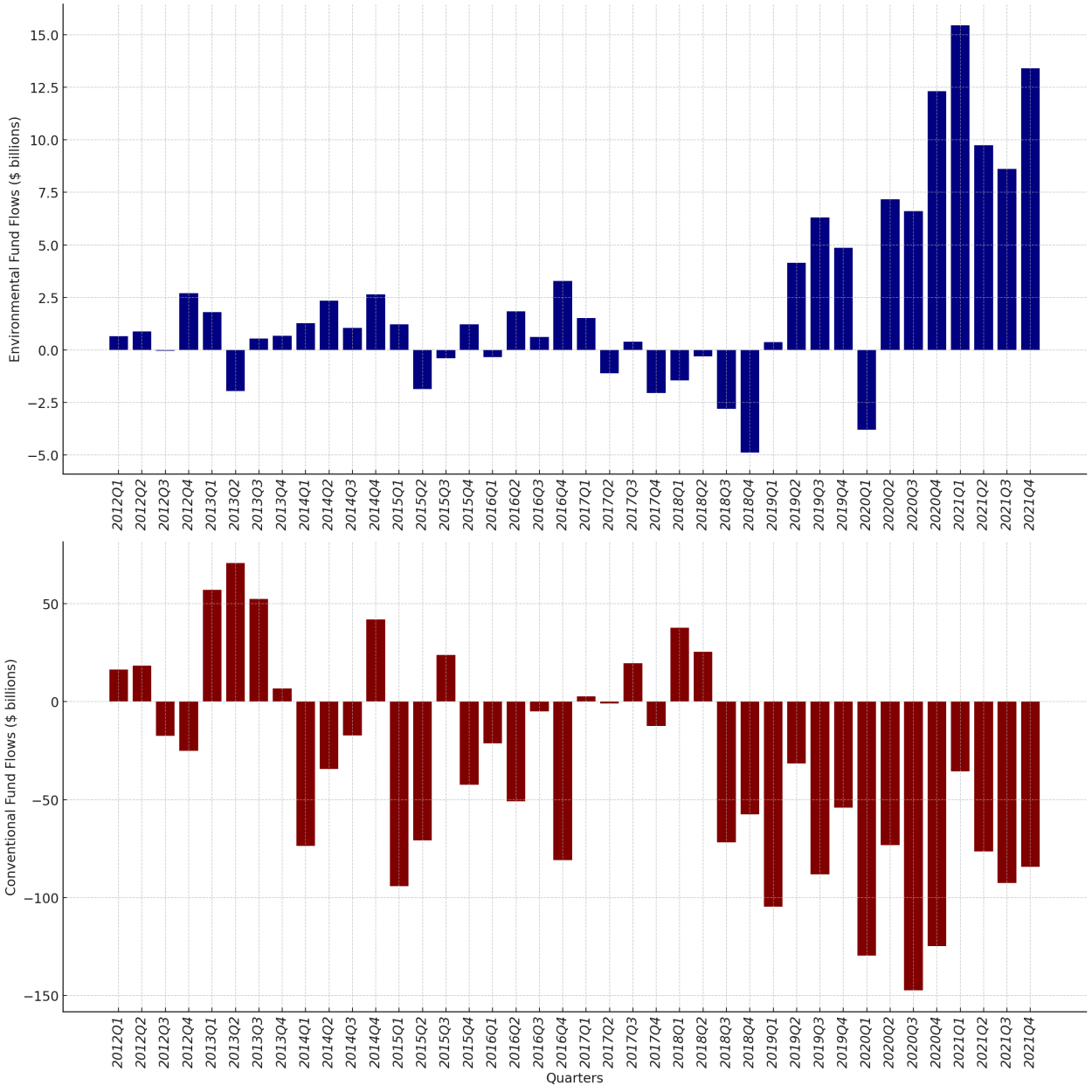

Figure 2.1: The Quarterly Flows of Environmental and Conventional Funds.
This figure shows the plots of the quarterly values of fund flows for both environmental(upper panel) and conventional (lower panel) funds in billions of USD over the sample period from 2012 to 2021.

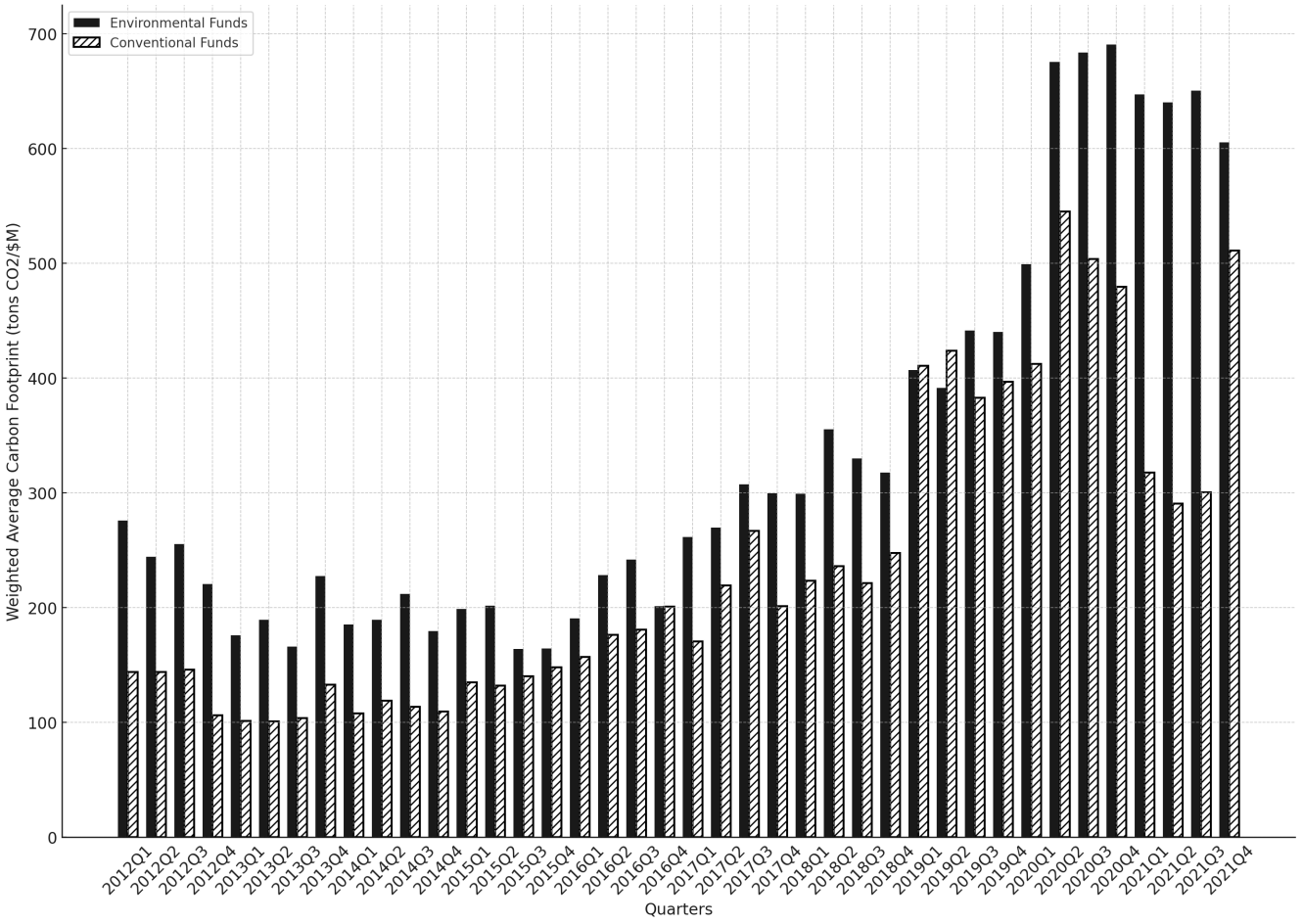

Figure 2.2: The Quarterly Weighted Average Carbon Footprint.
This figure shows the quarterly means of the weighted average carbon footprint of both environmental (solid bars) and conventional (dashed bars) funds over the sample period from 2012 to 2021. The fund's carbon footprint is calculated using Eq.2.4 as the weighted average of the carbon footprints of its individual holdings, where the weight is determined by the proportion of each holding's market value relative to the total market value of the fund's portfolio.

2.4 Do Environmental Funds Reduce their Carbon Footprints Following the Announcement Date?

In this section, we evaluate the extent to which environmental funds reduce their carbon footprints subsequent to announcing their commitment to sustainability. Should environmental funds fail to significantly reduce their carbon footprints post-announcement, such outcomes would indicate potential greenwashing. To assess this conjecture, we initially use Propensity Score Matching (PSM) to match the group of environmental funds with

a suitable control group of funds that do not make sustainability claims. Subsequently, we use a DID analysis to examine the changes in the carbon footprints of environmental funds.

2.4.1 Propensity Score Matching

We use the PSM to mitigate the sample selection bias prior to conducting the DID analysis. PSM is a technique to minimize sample selection bias by matching treatment groups and control groups with the same characteristics (Qi et al., 2020). We apply the PSM as in Kostovetsky (2016) to build a control group by matching each environmental fund with at least one conventional fund with the same characteristics. We define environmental funds as those that incorporate explicit environmental criteria as indicated in their prospectus, as a main element in their investment strategies, while conventional funds do not integrate such criteria into their portfolios. In this context, environmental funds represent the “treated" group, and conventional funds serve as the “control" group. To identify the matched control group, we use the “nearest neighbor" matching criterion. In line with Frésard and Valta (2016), the nearest neighbor is the conventional fund with the shortest distance to an environmental fund where the distance is calculated based on the matching characteristics. For the purpose of our subsequent DID analysis, we need to ensure that conventional funds have portfolios with similar characteristics to those of environmental funds. Therefore, we use matching characteristics based on various fund variables such as fund size, fund age, total load fees, expense ratio, total return, and fund flows, as well as various portfolio characteristics such as turnover ratio, weighted-average price-to-book ratio, number of holdings, weighted-average market cap, emissions score, carbon footprint, weighted-average total revenues, and the weighted-average total assets. These variables are estimated based on quarterly data.

Table 2.4 shows the descriptive statistics of the matching variables for both the treated and control groups. The results show that the environmental and matched conventional

Table 2.4: Propensity Score Matching
This table presents the descriptive statistics for the variables used to match environmental funds with conventional funds prior to the announcement dates. The columns labelled *Environmental Funds* and *Conventional Funds* display the mean value of each variable. The $Difference$ column indicates the percentage difference between the environmental and conventional funds for each variable. The $t-stat$ and $p-value$ columns provide the results from the t-test assessing the difference between the two means. Detailed definitions of the variables are provided in Table 2.1. The sample period is from 2012 to 2021. Estimations are based on data of one year pre-announcement dates.

Variables	Environmental Funds	Conventional Funds	Difference	t-stat	p-value
ln_Fund_Size	17.79	18.09	0.01	1.39	0.16
ln_Age	12.40	12.08	-0.02	-0.61	0.54
Total_Load_Fees	2.68	2.73	0.02	0.89	0.37
Expense_Ratio	0.25	0.24	-0.01	-0.11	0.91
Total_Return	2.75	3.93	0.40	1.63	0.10
Fund_Flows	18.20	18.36	0.00	0.01	0.99
Turnover	0.05	0.03	-0.20	-0.73	0.46
Price_to_Book	7.68	8.10	0.05	0.41	0.68
ln_Num_of_Holdings	55.55	55.98	0.00	1.59	0.11
ln_Market_Cap	1.20	1.20	0.00	0.12	0.90
ln_Revenues	1.30	1.10	-0.10	-1.14	0.25
ln_Total_Assets	1.50	1.40	-0.06	-0.38	0.70
Emissions_Score	51.44	50.66	-0.01	-0.40	0.69
Carbon Footprint	126.96	116.31	-0.08	-0.42	0.67

funds are not significantly different based on the matching variables (t-statistics on tests of differences between means are insignificant). This similarity is important to ensure that the control group is appropriate and can serve as the counterfactual against which we can compare environmental funds' carbon footprints before and after the announcement dates.[20]

2.4.2 Difference-in-Differences Analysis

We use a difference-in-differences (DID) analysis to identify whether environmental funds engage in greenwashing or genuinely make efforts to reduce their carbon footprints. In particular, we follow the literature (e.g., Alok et al., 2020; Kostovetsky, 2016; Humphrey

[20]We evaluate the effectiveness of our PSM method by employing a receiver operating characteristic curve (ROC) to check whether the area under the curve is greater than 0.5. This exercise shows that the value of the area under the curve is 0.685 which indicates that our model provides reasonably accurate predictions, supporting the results of PSM analysis and demonstrating good matching quality. The ROC curve figure A.2 is available in the Appendix.

and Li, 2021) and use a time series DID to measure the change in environmental funds' carbon footprints before and after the announcement date as follows:

$$CFP_{i,t} = \alpha_0 + \beta_1 Env_{i,t} + \beta_2 Post_{i,t} + \beta_3 Env * Post_{i,t} + \beta_4 Controls_{i,t-1} + \gamma_q + \delta_s + \varepsilon_{i,t} \quad (2.5)$$

where $CFP_{i,t}$ represents fund i's carbon footprint in quarter t measured as the weighted average of the carbon footprints of the fund's holdings. We define two dummy variables: Env which equals 1 if the fund integrates environmental criteria into its investment objectives and zero otherwise, and $Post$ which equals 1 after the fund announces that it is integrating environmental criteria into its investment objectives and zero otherwise. The coefficient for $Post$ represents the variation in the carbon footprints of environmental funds between the pre-and post-announcement periods. The interaction term $Env * Post$ serves as the key variable in this analysis. The coefficient for $Env * Post$ indicates whether there is a substantial difference in the carbon footprints of environmental and conventional funds' portfolios after the announcement dates. A significantly negative coefficient for this variable would enable us to reject the null hypothesis of "no difference in carbon footprint post-announcement" and conclude that environmental fund portfolios' footprint significantly falls after the announcement date compared to conventional fund portfolios' footprint indicating no evidence of greenwashing. Conversely, a non-significant (significantly positive) coefficient indicates that environmental funds fail to achieve a noticeable reduction (experience an increase) in their carbon footprints after the announcement dates compared to conventional funds indicating evidence of greenwashing.

Our regression controls for both fund characteristics and those of their underlying holdings. The control variables are *the fund size, age, total load fees, expense ratio, total return, fund flows, turnover, price-to-book ratio, number of holdings, market cap, revenues, and total assets.* All these variables are lagged to mitigate potential endogeneity. The estimation window is one year before and after the announcement dates. Further, we use a fixed-effect regression model that allows us to control for time variations across funds as well as unobserved macroeconomic conditions (Hartzmark and Sussman, 2019).

To ensure a robust estimation, we also incorporate quarter fixed effects denoted as γ_q and investment style fixed effects denoted as δ_s. We validate the parallel trends assumption and use the PSM to minimize the differences in observable fund characteristics between the treatment and control groups (Hainmueller, 2012).[21]

Table 2.5 displays the results of the difference-in-differences analysis without the control variables in Column 1 and after adding the control variables in Column 2. The variable of interest is $Env * Post$. Notably, the coefficient for this variable is positive, albeit statistically insignificant, in both specifications. These results indicate that relative to conventional funds, environmental funds fail to significantly reduce the carbon footprints of their portfolios after self-designating as environmental funds. Such results could be surprising given that environmental funds claim to be focused on environmental issues, yet, they do not outperform conventional funds in reducing their carbon footprints. This mismatch between claim and outcome aligns directly with the essence of greenwashing which entails a misrepresentation where funds claim to act in an environmentally responsible manner but fail to fulfill those promises. This finding provides substantial support for the idea that these funds may be engaging in deceptive practices that violate their fiduciary duty to clients. This fiduciary duty requires that fund managers act in the best interests of their investors in accordance with the investment objectives outlined in the investment prospectus including sustainability objectives (Richardson, 2009). If the primary selling point of environmental funds is their potential to reduce carbon footprints and they do not achieve this compared to conventional funds, then a significant issue arises. This inefficacy challenges their fiduciary duty and the premiums they might charge based on their sustainability claims. The fact that they do not demonstrate measurable benefits

[21] When the treatment effect occurs in stages, estimates from staggered DID regressions via OLS may be biased due to varying treatment timings and diverse effects. To address this concern, we adopt the methodology suggested by Baker et al. (2022) by conducting a robustness test based on the Callaway and Sant'Anna estimator (Callaway and Sant'Anna, 2021). Additionally, as another robustness test, we perform stacked DID regression following recent literature (e.g., Goodman-Bacon, 2021; Krueger et al., 2024; Kim et al., 2022). These methods enable us to calculate the static average treatment effect on the treated (ATT), considering both scenarios with and without control variables. Based on these robustness tests, we confirm that our results are robust when estimating stacked DID regression and the Callaway and Sant'Anna estimator. We report these results in Table A.3 in the Appendix.

Table 2.5: Results of the Difference-in-Differences Analysis
This table shows the results from the difference-in-differences (DID) regression on the carbon footprint of environmental funds before and after the announcement date. The fund's *Carbon Footprint* is calculated using Eq. 2.4 as the weighted average of the carbon footprints of its individual holdings, where the weight is determined by the proportion of each holding's market value relative to the total market value of the fund's portfolio. This regression uses the natural logarithm of *Carbon Footprint*. *Env* is a dummy variable that equals one if the fund integrates environmental criteria in its prospectus and zero otherwise. *Post* is a dummy variable that equals one after the fund announces that it is integrating environmental criteria into its prospectus and zero otherwise. *Env* ∗ *Post* is the DID interaction variable. Detailed definitions of the variables are provided in Table 2.1. The sample period is from 2012 to 2021. Estimations are based on data of one year pre and post-announcement dates. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)
Variables	Carbon Footprint	Carbon Footprint
Env*Post	0.08	0.07
	(0.63)	(0.41)
Env	-0.04	-0.04
	(-1.18)	(-1.49)
Post	-0.02 ***	-0.02 ***
	(-3.10)	(-2.35)
ln_Fund_Size		-0.02
		(-0.44)
ln_Age		0.63**
		(1.97)
Total_Load_Fees		0.08
		(0.85)
Expense_Ratio		0.07
		(0.95)
Total_Return		0.01***
		(3.83)
Fund_Flows		0.00**
		(1.97)
Turnover		-0.63***
		(-3.82)
Price_to_Book		0.00
		(0.32)
ln_Num_of_Holdings		1.33
		(1.26)
ln_Market_Cap		-0.48***
		(-2.88)
ln_Revenues		0.61***
		(2.87)
ln_Total_Assets		-0.05***
		(-2.83)
Constant	0.43***	0.08*
	(2.50)	(1.78)
Observations	7419	7234
R^2	0.15	0.35
Quarter FE	Yes	Yes
Investment Style FE	Yes	Yes

in the area they emphasize most strongly suggests a misalignment that is consistent with greenwashing behaviors. Our results provide evidence of greenwashing by environmental funds that extend the evidence in previous studies which examine this phenomenon in other contexts including PRI-signatories asset managers (Kim and Yoon, 2023), funds with broad ESG focus (Dumitrescu et al., 2022), and hedge funds (Liang et al., 2023).

2.4.3 Parallel Trends Assumption

To ensure the robustness of the results obtained from the DID analysis, it is crucial to validate the parallel trends assumption. This assumption requires that the expected evolution of the carbon footprints for both environmental and conventional funds be the same before the announcement dates. To ascertain the validity of this assumption within the context of our DID analysis, we follow the literature (e.g., De Chaisemartin and d'Haultfoeuille, 2023; Heath et al., 2023) and use an extended version of Eq. 2.5 to which we add an interaction variable between the time dummy variable of the year before the announcement date (Pre) and the treatment variable (Env). The parallel trends assumption is deemed satisfied if the coefficient for this interaction variable is statistically insignificant.

The results of our estimation are provided in Table 2.6. It shows that the coefficients for the interaction dummy $Env * Pre$ are negative yet statistically insignificant indicating that the trends in carbon footprints for both environmental and conventional funds are parallel before the announcement dates. To further confirm the results from the analysis, we graphically depict the time trends for both fund categories across four quarters before and after the announcement dates in Figure 2.3. The figure shows that the average carbon footprints of environmental and conventional funds have parallel trends before the announcement dates. Overall, the negligible difference in carbon footprints shown in Table 2.6 coupled with the stable trend illustrated in Figure 2.3 validate the assumption of parallel trends in our DID analysis. Consequently, we conclude that any

difference in the average carbon footprint of environmental funds around the announcement dates is attributable to the announcements of integrating environmental criteria into their prospectuses.

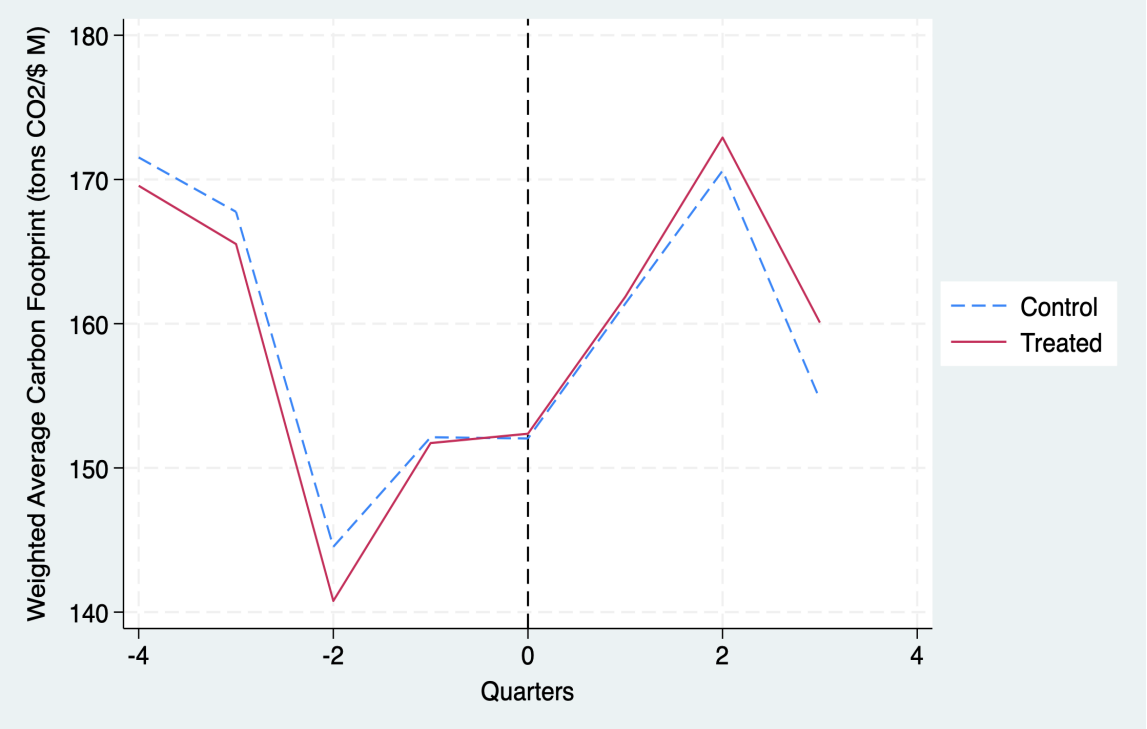

Figure 2.3: The Trends of Carbon Footprint.
This figure shows the means of the weighted average carbon footprint of environmental funds (Treated) and a matched group of conventional funds (Control) before and after the announcement date (t=0). The pre-quarters refer to the four quarters before the announcement date. The post-quarters encompass the announcement date and the subsequent three quarters.

2.4.4 Does it Take Funds Some Time to Reduce their Carbon Footprint?

Our findings so far show that environmental funds engage in greenwashing as evidenced by their failure to meaningfully reduce their carbon footprints. Nonetheless, a possible justification of these results is the potential time lag required for these funds to divest their holdings of carbon-intensive firms. Consequently, the perceived lack of immediate progress might not accurately reflect the misleading intentions of environmental funds but might indicate that while environmental funds are committed to reducing their carbon

Table 2.6: Results of Testing the Parallel Trends Assumption
This table shows the results from regressions examining the parallel trends assumption of the carbon footprint of environmental and conventional funds pre-announcement date. The fund's *Carbon Footprint* is calculated using Eq. 2.4 as the weighted average of the carbon footprints of its individual holdings, where the weight is determined by the proportion of each holding's market value relative to the total market value of the fund's portfolio. The regressions use the natural logarithm of *Carbon Footprint*. *Env* is a dummy variable that equals one if the fund is integrating environmental criteria into its prospectus and zero otherwise. *Pre* is a dummy variable that equals one in the four quarters before the fund announces that it is integrating environmental criteria into its prospectus and zero otherwise. *Post* is a dummy variable that equals one in the four quarters after the fund announces that it is integrating environmental criteria into its prospectus and zero otherwise. $Env * Pre$ is an interaction variable. Detailed definitions of the variables are provided in Table 2.1. The sample period is from 2012 to 2021. Estimations are based on data of one year pre and post-announcement dates. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)
Variables	Carbon Footprint	Carbon Footprint
Env*Pre	-0.11	-0.09
	(-0.65)	(-0.54)
Env	0.07	0.00
	(0.23)	(0.02)
Pre	0.30***	0.13
	(3.40)	(1.26)
ln_Fund_Size		-0.04
		(-0.80)
ln_Age		1.26***
		(4.77)
Total_Load_Fees		0.11
		(1.42)
Expense_Ratio		0.08
		(1.00)
Total_Return		0.01***
		(3.60)
Fund_Flows		0.00
		(1.31)
Turnover		-0.63***
		(-3.70)
Price_to_Book		-0.00
		(-0.38)
ln_Num_of_Holdings		1.48*
		(1.66)
ln_Market_Cap		-0.58***
		(-4.47)
ln_Revenues		0.49***
		(2.35)
ln_Total_Assets		0.34**
		(2.06)
Constant	4.03***	-8.64*
	(5.19)	(-1.90)
Observations	7419	7234
R^2	0.35	0.62
Controls	No	Yes
Quarter FE	Yes	Yes
Investment Style FE	Yes	Yes

footprints, portfolio modifications take time. To examine this possibility, we repeat our baseline DID analysis using extended estimation windows of two and four years before and after the announcement date. If funds effectively reduce their carbon footprints in two or four years, we should see the DID coefficient turning negative in the specifications with the extended windows compared to the baseline analysis. Therefore, these extensions help us investigate whether funds take some time after turning environmental and eventually keep their promises to divest away from carbon-intensive holdings to reduce their carbon footprints.

The results of these extensions are presented in Table 2.7. Column 1 shows the results of estimating the DID regression using a 2-year estimation window. The column shows that the coefficient for the interaction variable $Env * Post$ is still positive but not significant, echoing the baseline results based on a 1-year estimation window. The results of the 4-year window estimation are more pronounced. Column 2 shows that the coefficient for $Env * Post$ is significantly positive at 3.47% which indicates that the carbon footprints of environmental funds are significantly higher than those of conventional funds in the 4-year window that follows the fund announcements. This is most likely due to the failure of environmental funds to reduce their exposure to holdings with higher carbon emissions. Overall, the results indicate that environmental funds do not meet their commitments to decarbonization by reducing the carbon footprints of their portfolios, even after using extended estimation windows to allow for the potential lag that funds might need to make significant changes in their investment strategies.

2.4.5 Do Funds Vary in their Efforts to Reduce Carbon Footprints?

It is plausible that not all environmental funds engage in greenwashing to the same extent. Heterogeneity among these funds could significantly influence their commitment to sustainability claims. For instance, environmental funds do not have identical ex-ante

Table 2.7: Environmental Funds Carbon Footprint: Extending the Estimation Window This table shows the results from the robustness tests on our initial findings. The fund's *Carbon Footprint* is calculated using Eq. 2.4 as the weighted average of the carbon footprints of its individual holdings, where the weight is determined by the proportion of each holding's market value relative to the total market value of the fund's portfolio. The regressions use the natural logarithm of *Carbon Footprint*. *Env* is a dummy variable that equals one if the fund integrates environmental criteria into its prospectus and zero otherwise. *Post* is a dummy variable that equals one after the fund announces that it is integrating environmental criteria into its prospectus and zero otherwise. $Env * Post$ is the DID interaction variable. Detailed definitions of the variables are provided in Table 2.1. The sample period is from 2012 to 2021. Estimations are based on data of 2 years and 4 years pre and post-announcement dates as presented in Columns 1 and 2, respectively. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)
	2 Years	4 Years
Variables	Carbon Footprint	Carbon Footprint
Env*Post	0.09	0.03**
	(1.55)	(2.03)
Env	-0.10	-0.06***
	(-0.45)	(-3.14)
Post	-0.03***	-0.05***
	(-2.32)	(-4.40)
ln_Fund_Size	-0.06	-0.07*
	(-1.38)	(-1.91)
ln_Age	1.62***	0.88***
	(6.06)	(3.13)
Total_Load_Fees	0.13*	0.15***
	(1.68)	(2.24)
Expense_Ratio	0.15	0.09
	(1.62)	(1.23)
Total_Return	0.01***	0.01***
	(3.80)	(3.99)
Fund_Flows	0.00	0.00
	(1.52)	(1.63)
Turnover	-0.66***	-0.67***
	(-2.68)	(-2.73)
Price_to_Book	0.00	0.00
	(0.37)	(0.46)
ln_Num_of_Holdings	1.14	1.31
	(0.98)	(1.41)
ln_Market_Cap	-0.96***	-0.61***
	(-6.39)	(-5.62)
ln_Revenues	0.48***	0.38***
	(2.38)	(2.55)
ln_Total_Assets	0.40***	0.36***
	(2.46)	(3.09)
Constant	0.99	-2.32
	(0.19)	(0.55)
Observations	14,456	11,237
R^2	0.39	0.66
Quarter FE	Yes	Yes
Investment Style FE	Yes	Yes

carbon footprints. Funds with lower carbon footprints might find it more straightforward to proclaim sustainability, thereby attracting more investors, based on the presumption that less effort will be required to reduce the carbon footprint of their portfolios. Consequently, we expand our baseline findings to investigate if the efforts exerted by funds to reduce their carbon footprints post-announcement vary according to the initial level of those carbon footprints. To this end, we use a quantile regression model built on our baseline DID regression that is akin to the approach used by Reboredo and Otero (2021). We conduct this quantile regression analysis at six levels that enable us to examine the efforts undertaken to mitigate the carbon footprints of funds in the low (quantiles 5^{th}, 15^{th}, and 25^{th}), medium (quantile 50^{th}), and high (quantiles 75^{th} and 95^{th}) quantiles. This extension enriches the results obtained from the DID analysis.

The results, detailed in Table 2.8, demonstrate that the interaction variable $Env * Post$ has a positive coefficient across all reported quantiles. Additional variations in coefficient estimates for other variables apart from $Env * Post$ are summarized in Figure 2.4. The results show that environmental funds, on the whole, do not sufficiently reduce their carbon footprint post-announcement. Moreover, a notable decrease in the estimated coefficients is observed as we move from low-quantile to high-quantile funds in the right tail of the distribution of carbon footprints. For instance, the $Env * Post$ coefficient for the lowest quantile (5^{th}) is 9.79%, that is in contrast to 1.74% for the highest quantile (95^{th}), that indicates a variation in decarbonization efforts across different quantiles. This analysis shows that the behavior of environmental funds in lower and higher quantiles differs remarkably from that of the average fund. In particular, funds with low carbon footprints exert less effort to decarbonize compared to their counterparts with higher carbon footprints. One way to interpret these results is that funds with a lower carbon footprint perceive their position as sufficiently aligned with the criteria delineated in their prospectuses that they do not need to make additional decarbonization efforts. Conversely, funds with a more substantial carbon footprint undertake measures to reduce their emissions to align more closely with the stipulated criteria. However, even these

Table 2.8: Environmental Funds Carbon Footprint: Quantile Regression
This table presents the results of quantile regressions for the matched sample of environmental funds by different quantiles of carbon footprints. The fund's *Carbon Footprint* is calculated using Eq. 2.4 as the weighted average of the carbon footprints of its individual holdings, where the weight is determined by the proportion of each holding's market value relative to the total market value of the fund's portfolio. The regressions use the natural logarithm of *Carbon Footprint*. *Env* is a dummy variable that equals one if the fund integrates environmental criteria into its prospectus and zero otherwise. *Post* is a dummy variable that equals one after the fund announces that it is integrating environmental criteria into its prospectus and zero otherwise. $Env * Post$ is the DID interaction variable. Detailed definitions of the variables are provided in Table 2.1. The sample period is from 2012 to 2021. Estimations are based on data of one year pre and post-announcement dates. The results for the 5^{th}, 15^{th}, 25^{th}, 50^{th}, 75^{th}, and 95^{th} quantile regressions are presented in Columns 1, 2, 3, 4, 5, and 6, respectively. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	Carbon Footprint					
	Q5	Q15	Q25	Q50	Q75	Q95
Env*Post	0.09*	0.07**	0.06**	0.01	0.02	0.01
	(1.77)	(1.98)	(2.11)	(0.77)	(1.51)	(1.03)
Env	-0.02	-0.02	-0.02	-0.03*	-0.03***	-0.02*
	(-0.72)	(-0.93)	(-0.89)	(-1.88)	(-2.35)	(-1.89)
Post	-0.09***	-0.08***	-0.06***	-0.02*	-0.04***	-0.03***
	(-2.99)	(-3.87)	(-3.25)	(-1.89)	(-3.53)	(-3.35)
ln_Fund_Size	-0.16*	-0.20***	-0.16***	-0.01	0.04	0.04
	(-1.87)	(-3.38)	(-3.19)	(-0.44)	(1.31)	(1.48)
ln_Age	2.06***	1.58***	1.27***	0.62***	0.03	-0.11
	(5.33)	(5.85)	(5.56)	(3.89)	(0.25)	(-0.96)
Total_Load_Fees	0.21**	0.13*	0.09	0.14***	0.05	0.07**
	(2.06)	(1.83)	(1.55)	(3.38)	(1.44)	(2.22)
Expense_Ratio	0.02	-0.00	-0.06	0.08	0.02	-0.08
	(0.09)	(-0.05)	(-0.39)	(0.75)	(0.21)	(-0.95)
Total_Return	0.01	0.00	0.01**	0.00**	0.00*	0.00
	(0.92)	(1.11)	(2.06)	(2.12)	(1.85)	(0.76)
Fund_Flows	0.00	0.00	0.00	0.00	0.00*	0.00
	(1.18)	(1.52)	(1.37)	(1.14)	(1.74)	(0.38)
Turnover	-0.40	-0.51	-0.51	-0.54**	-0.59***	-0.67***
	(-0.60)	(-1.10)	(-1.31)	(-1.97)	(-2.46)	(-3.13)
Price_to_Book	0.01	0.00	0.00	0.00	0.00	-0.00
	(0.78)	(0.72)	(0.43)	(0.75)	(0.37)	(-0.43)
ln_Num_of_Holdings	1.29	1.34	1.48	0.21	-0.40	-0.00
	(0.40)	(0.59)	(0.78)	(0.16)	(-0.35)	(-0.01)
ln_Market_Cap	-0.86***	-0.79***	-0.80***	-0.92***	-0.81***	-0.42***
	(-2.65)	(-3.49)	(-4.19)	(-6.90)	(-6.92)	(-4.09)
ln_Revenues	0.64	0.14	0.20	0.52***	0.22	-0.15
	(1.58)	(0.49)	(0.84)	(3.08)	(1.55)	(-1.20)
ln_Total_Assets	0.04	0.66***	0.78***	0.46***	0.59***	0.57***
	(0.15)	(3.07)	(4.26)	(3.62)	(5.35)	(5.72)
Observations	774	774	774	774	774	774
R^2	0.50	0.47	0.39	0.31	0.29	0.30

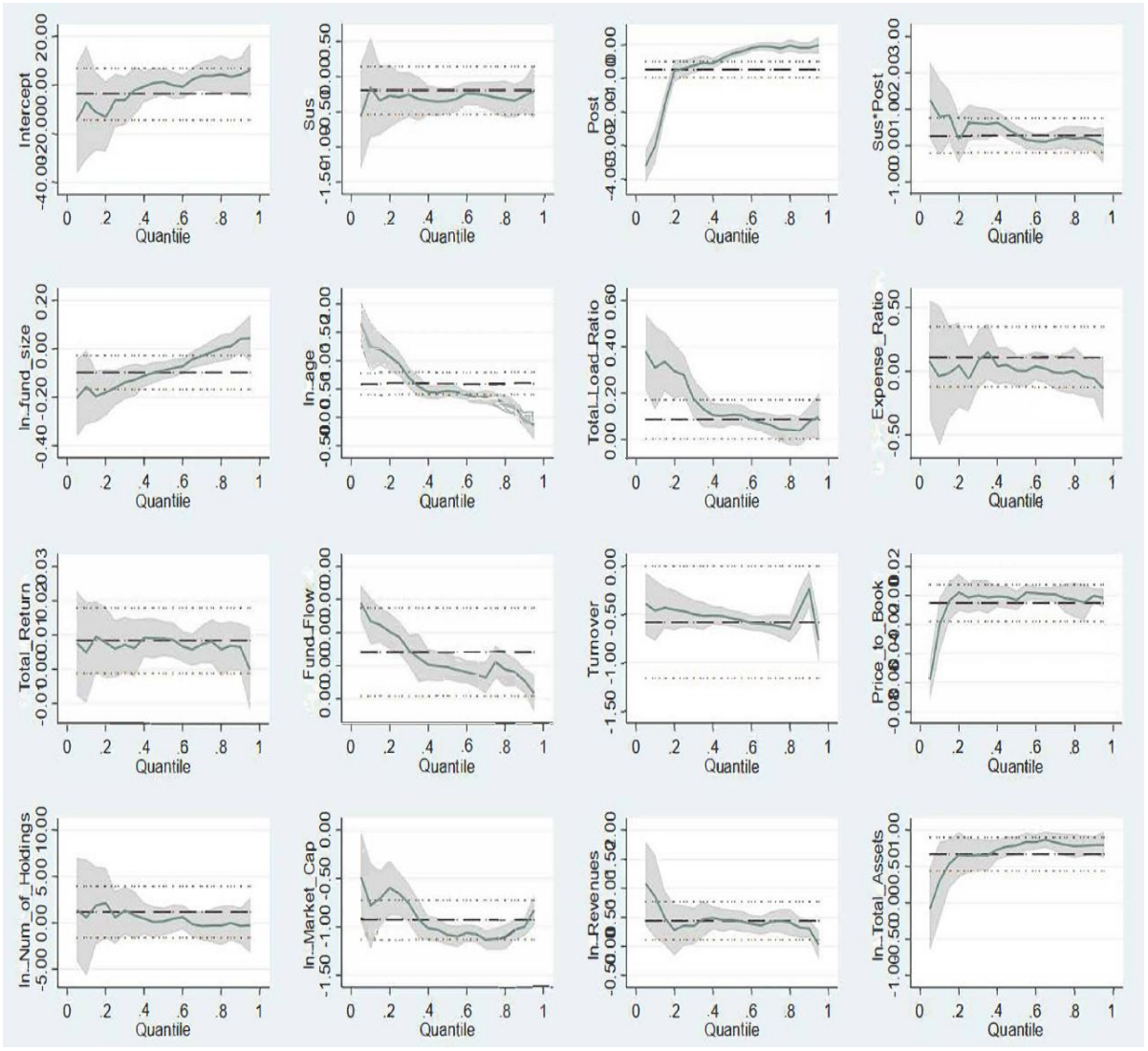

Figure 2.4: Quantile Regression Coefficient Estimates for the Carbon Footprints of Environmental Funds.
This figure shows the quantile distribution of different independent variables on environmental funds' carbon footprints. The solid line represents a 95% confidence level for the quantile regression estimates. The grey area around the solid line denotes the confidence interval for quantile estimates.

efforts remain inadequate when compared to conventional funds, reflecting a general failure among environmental funds to fulfil their sustainability commitments. Overall, this evidence is consistent with our baseline results that environmental funds mislead their investors about decarbonization which indicates that environmental funds are involved in greenwashing.

2.5 The Reaction of Flows to Environmental Funds' Announcements

In the previous section, we provide initial evidence of greenwashing practices by environmental funds by showing that environmental funds fail to reduce their carbon footprints relative to conventional funds. To confirm those results, we use an event study to examine how environmental fund flows respond following the announcement date. This analysis enables us to test whether the funds benefit from claiming to be environmental without necessarily making sufficient effort to reduce their carbon footprint, which would confirm our initial evidence of greenwashing.

2.5.1 Event Study

The event study methodology investigates how the stock market reacts when an event takes place (MacKinlay, 1997). Analogous to a standard event study examining stock returns, we use this approach to study the reaction of environmental fund flows following a fund's announcement of its commitment to sustainability criteria as outlined in its prospectus. In particular, we use an event study methodology to isolate the incremental flow following the fund's announcement date. We specify our model in keeping with Del Guercio and Tkac (2008) and estimate a time-series baseline regression for each specific fund i to compute its monthly normal flow. We incorporate certain variables known to exert a significant influence on fund flows as control variables in our regression. Specifically, these are previous fund flows, aggregate flows categorized by investment style, estimated Jensen's alpha, and the fund's historical returns. Formally,

$$F_{i,t} = \gamma_i + \beta_1 SF_{i,t} + \beta_2 RET_{i,t-1} + \beta_3 \Delta\alpha_{i,t-1} + \beta_4 (\Delta\alpha_{i,t-1})^2 + \beta_5 F_{i,t-1} + \varepsilon_{i,t} \tag{2.6}$$

where $F_{i,t}$ is the monthly flow value to fund i, $SF_{i,t}$ represents the aggregate flow to all funds in the same investment style classification of fund i in month t, $RET_{i,t-1}$ is the monthly return on fund i at $t-1$, $\Delta\alpha_{i,t-1}$ represents the change in fund i's Jensen's alpha from $t-2$ to $t-1$, and $F_{i,t-1}$ is the value of the flow to fund i in month $t-1$. To consider any potential convexities between flow and current performance, we add a squared term on the change in Jensen's alpha as in Del Guercio and Tkac (2008).

The event date of a given environmental fund, denoted as time 0, corresponds to its announcement date, that is the point in time at which a fund first identifies as being an environmental one. We use monthly data to conduct our event study analysis. Specifically, we use 24 months of data as an estimation window that terminates three months prior to time 0. Thus, the estimation window used to predict the coefficients for the baseline flow regressions encompasses a period from month $t-27$ to month $t-4$. Moreover, we use a baseline event window spanning 7 months, from month $t-3$ to month $t+3$. This timeframe is suitable to address potential delayed responses by adding the three months that follow the announcement date to the event window and to facilitate comparability by including the three months preceding the announcement date. Figure 2.5 represents our window for the event study.

The final step in our event study is calculating the abnormal fund flows over the event window. Abnormal flows refer to the difference between a fund's actual flow and the projected flow that would have occurred had the fund not incorporated sustainability criteria in its prospectus. As in Del Guercio and Tkac (2008), we calculate the abnormal flow to fund i in month t, denoted as $AF_{i,t}$, as the difference between the actual flow and the predicted flow. Formally,

$$AF_{i,t} = F_{i,t} - \hat{\gamma}_i - \hat{\beta}_1 SF_{i,t} - \hat{\beta}_2 RET_{i,t-1} - \hat{\beta}_3 \Delta\alpha_{i,t-1} - \hat{\beta}_4 (\Delta\alpha_{i,t-1})^2 - \hat{\beta}_5 F_{i,t-1} \tag{2.7}$$

where the predicted flows are estimated as a function of the average abnormal flow to fund i (γ_i), the aggregate investment style flow, the lagged return, the lagged change in

alpha, the square of the lagged change in alpha, and the lagged fund flows.

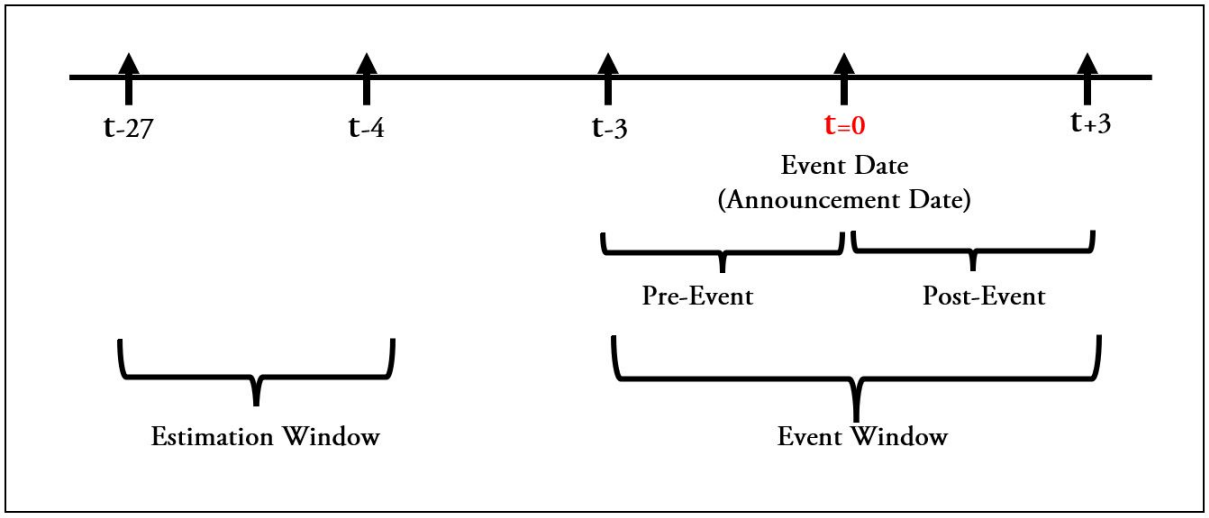

Figure 2.5: The Event Study Timeline
This figure illustrates the timeline of the event study. The event date refers to month 0 or the time when a fund is identified for the first time as being environmental, which we refer to as the announcement date. The event window refers to the period of time around the announcement date that is chosen for analysis. The event window typically consists of a pre-event period, the event time itself (announcement date), and a post-event period. Our event window is [t-3, t+3], i.e. three months before the event date, event date, and three months post the event date. The estimation window refers to the period of time used to estimate the expected fund flows of an environmental fund. Our estimation window is [t-27, t-4] since we use 24 months of data as an estimation window.

2.5.2 Results of Event Study

Table 2.9 presents the results of the event study. The analysis is based on 104 announcements from 2012 to 2021.[22] We compute the average abnormal flows (AAFs) and cumulative abnormal flows (CAFs) for each point in the event window by aggregating the abnormal flows of individual funds. Both AAFs and CAFs are reported as percentages for all points in the event window [t-3, t-2, t-1, t=0, t+1, t+2, t+3]. Notably, the results show that the increment in the CAFs is concentrated in the event date point (t=0) that

[22]The reduced number of funds included in the event study compared to the DID analysis is attributable to the prerequisites of the event study, which necessitates both an event window and an estimation window to determine abnormal fund flows. Specifically, for a fund to qualify for the event study, it must have a minimum of 27 months of data preceding the announcement date, which is much longer than the 12 months required for the baseline DID analysis. Funds lacking this duration of data are automatically excluded by the Stata software during the analysis, resulting in a decrease from 133 to 104 funds.

marks the point at which a fund self-designates as environmental for the first time. As shown in Table 2.9, these funds have significantly positive AAFs and CAFs of 71.60% and 69.67%, respectively, on the event date. All other AAFs before and after the event date are either negative or insignificant, affirming that the findings are not influenced by hot trends occurring around the event date. Positive CAFs indicate that the fund flows react positively following the announcements of sustainability by funds. Our results are consistent with previous studies that have shown that fund flows react positively to favorable changes in investment strategies and the main characteristics of the fund, such as the fund name (Cooper et al., 2005). In our context, when funds announce to investors their commitment to sustainability as shown in their prospectuses, their fund flows immediately and significantly increase.

The issue of whether the observed surge in fund flows signifies that environmental funds are engaging in greenwashing warrants further scrutiny. Our analysis considers the variables that seem to significantly affect fund flows as shown by the event study in Eq. 2.6. Among these variables, the historical performance of the fund emerges as the pivotal factor directing investors' capital allocations, as substantiated by other studies (e.g., Sirri and Tufano, 1998; Lynch and Musto, 2003). Our results indicate that notwithstanding the consideration of the explanatory variables influencing fund flows, environmental funds' abnormal flows increase significantly after the announcement date. This increase means that the abnormal flows are not tied to the actual performance of environmental funds. Rather, they can be attributed to the funds' announcements regarding the incorporation of sustainability in their investment decisions. These announcements make the funds more appealing to investors, especially those interested in sustainability objectives, that lead to increased fund inflows as shown by the results from the event study.

Drawing on our earlier DID analysis that showed the failure of environmental funds to sufficiently decarbonize their portfolios, it becomes clear that those environmental funds primarily aim to boost their fund flows without making sufficient efforts to meet their sustainability objectives. This lack of effort indicates misleading behavior by those funds

Table 2.9: Baseline Results of the Event Study
This table presents the average abnormal flows (AAFs) and the cumulative abnormal flows (CAFs) of environmental funds for different points of the event window around the announcement date. The sample consists of N= 104 announcement dates over the period from 2012 to 2021. The AAFs are estimated based on the model specified in Eq. 2.6. $t-stat$ is the t-statistic of the t-test used to assess the significance of the AAFs and CAFs. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Event Study				
Event Window	**Average Abnormal Flow**	**t-stat**	**Cumulative Abnormal Flow**	**t-stat**
t-3	-0.98	-0.13	-0.98	-0.07
t-2	-0.62	-0.08	-1.61	-0.12
t-1	-0.31	-0.04	-1.92	-0.14
t=0	71.60***	9.76	69.67***	5.22
t+1	-7.14	-0.97	62.53***	4.69
t+2	-10.7	-1.46	51.82***	3.88
t+3	5.37	0.73	57.20***	4.29

to maximize their benefits in terms of investment management fees and expenses which are directly correlated with fund flows. The evidence strongly indicates that these funds are potentially breaching their fiduciary duty to their clients. As per their investment prospectus, fund managers should prioritize investors' interests. However, if environmental funds market themselves as environmentally oriented but fail to deliver compared to other funds, it raises serious concerns. This ineffectiveness not only questions their commitment to their fiduciary responsibility but also the additional costs they might levy based on their sustainability promises. Their focus on obtaining fund flows from investors without showing tangible improvements in their environmental performance strongly supports the evidence provided by our earlier DID analysis on greenwashing practices in environmental funds. Overall, our findings extend the evidence provided in previous research that explores such practices among PRI-signatories asset managers (Kim and Yoon, 2023), funds with broad ESG focus (Andrikogiannopoulou et al., 2022; Dumitrescu et al., 2022), and hedge funds (Liang et al., 2023).

2.5.3 Are Abnormal Flows Driven by Fund Performance?

The interpretation of the announcement date effect in our event study hinges on the confidence in appropriately isolating the response of the fund flows to the announcement. This subsection provides a robustness test to address this concern. In particular, we test whether the AAFs and CAFs we report come as a response to changes in the fund performance or other explanatory variables that could affect the fund flows.

Thus, we rerun the event study by using different time windows before and after the initial event window. If the abnormal flows are driven by the fund performance or other factors, we should expect to see positive AAFs and CAFs in non-event windows before and after the announcement date window. As shown in Table 2.10, we report the AAFs and CAFs before, during, and after the baseline event window. There is a significant and positive increase in the AAFs and CAFs during the event window [t-3, t+3] of 71.60% and 69.67%, respectively. While there are negative AAFs and CAFs in the preceding window [t-10, t-4] and the subsequent window [t+4, t+10]. Consistent with the main estimation of abnormal flows shown in Table 2.9, this additional test shows that the announcement date effect generates abnormal flows in the event window but not before or after it. This result provides evidence that the abnormal flows to environmental funds are driven by the fund announcement, not the fund performance or other factors. Our result is consistent with a large body of literature that studies abnormal fund flows by using event studies to show that the abnormal fund flows respond to specific event dates like changing the fund name (e.g., Cooper et al., 2005) or the Morningstar star rating (e.g., Del Guercio and Tkac, 2008). Overall, this result raises confidence in the findings of our event study and the evidence it provides on greenwashing by environmental funds.

Table 2.10: Additional Results of the Event Study Analysis
This table presents the average abnormal flows (AAFs) and cumulative abnormal flows (CAFs) of environmental funds for different event windows around the announcement date. The sample consists of N= 104 environmental dates over the period from 2012 to 2021. The AAFs are estimated based on the model specified in Eq. 2.6. $t-stat$ reports the t-statistic of the t-test used to assess the significance of the AAFs and CAFs. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Event Window	Average Abnormal Flow	t-stat	Cumulative Abnormal Flow	t-stat
[t-10, t-4]	-0.17	-0.04	-4.64	-0.50
[t-3, t+3]	71.60***	9.76	69.67***	5.22
[t+4, t+10]	-5.52	-1.33	-23.83**	-2.32

2.5.4 Are Abnormal Flows Driven by Fund Characteristics?

Another potential issue pertaining to our event study results is the question of whether the observed abnormal fund flows are instigated by the announcements themselves or by a rational change in one or more of the fund characteristics. If the fund characteristics change around the event date in a way that could explain the abnormal fund flows, then those flows subsequent to the announcement date could be entirely attributed to changes in those characteristics.

Consequently, to validate the robustness of our results for the baseline event study results, we examine the change in the main characteristics around the event window. As shown in Table 2.11, we present the monthly average change in the characteristics of environmental funds pre and post-announcement date. The results show a significant increase in the monthly flows of environmental funds from 0.008% to 23.92%. This increase predominantly occurs in the window after the announcement date. Other variables remain steady around the event window. The average Jensen's alpha remains relatively unchanged with values of 0.042% and -0.053% in the pre-and post-event windows, respectively, that show no significant variations. Similarly, the monthly returns of environmental funds do not show considerable shifts following the announcement dates. Although there is a decrease in the average monthly return from 0.8% to -1.7% post-announcement, this change is statistically negligible. Also, there is an increase in TNA on average from $532 million to $539 million after the event window, but the difference is still statistically insignificant.

Table 2.11: The Average Change in Fund Characteristics Following the Announcement Date
This table presents the average monthly change in the fund characteristics in the year before and the year after the announcement date. *Abnormal Flows* is the difference between the actual flow and the predicted flow. *Fund Flows* represents the fund's total cash flow scaled by its total net assets in the previous period. *Total Return* measures the fund's historical performance over a given period. *Jensen's alpha* represents the excess return on the fund over its benchmark. *Total Net Assets* represents the market value of the fund's portfolio in millions of USD. *Investment Style Flows* is the aggregated fund flow at the investment style level. *Turnover* is determined as the minimum of either the fund's aggregated sales or purchases of stocks during a given period scaled by the value of the fund's portfolio in the previous period. Detailed definitions of the variables are provided in Table 2.1. *Pre* and *Post* refer to the average monthly change in fund characteristics before and after the announcement date, respectively. $t-stat$ reports is the t-statistic of the t-test used to assess the difference in mean values between the pre and post-announcement periods. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Fund Characteristics	Pre	Post	t-stat
Fund Flows (%)	0.00	23.92***	3.68
Total Return (%)	0.80	-1.70	-1.03
Jensen's alpha (%)	0.04	-0.05	-0.63
Total Net Assets ($ mil)	532.00	539.00	1.53
Investment Style Flows (%)	2.94	-0.26	-0.03
Turnover	0.04	0.03	1.09

Similar results are noted regarding investment styles, flows, and turnovers. Overall, this robustness test confirms our baseline results that the announcement date effect generates the abnormal flows as seen in the main result in Table 2.9. Had the abnormal flows been a consequence of shifts in fund characteristics, a positive and significant change in certain characteristics post-announcement would have been observed. However, we clearly find that the fund characteristics maintain a steady state around the event window. This state supports the reliability of the conclusions drawn from our event study by underscoring the evidence it offers concerning greenwashing by environmental funds.

2.6 Spotting Greenwashers

Our baseline and additional analyses show that environmental funds are involved in greenwashing. In this section, we explore the characteristics of greenwashing funds in more

detail. This extension of our main analysis is important to identify the characteristics of funds in our sample that decide to incorporate environmental sustainability objectives in their prospectuses. To this end, we use a panel probit regression in which the dependent variable is a dummy that equals one if the fund switched to be environmental and zero otherwise. In this regression, we control for portfolio and fund characteristics by including the following variables: the fund's size, age, total load fees, expense ratio, total return, carbon emissions, fund flow, turnover, price-to-book ratio, number of holdings, and market cap.

In Table 2.12, we display the results of the probit analysis relating fund characteristics to the likelihood of switching from conventional to environmental. Consistent with previous studies (e.g., Ferris and Yan, 2007; Chen et al., 2012), we also add the odds ratio for each explanatory variable alongside the estimated coefficient which provides a valuable tool to evaluate the economic significance of the dummy variables. As illustrated in Table 2.12, there is a significant relationship between fund flows and the probability of switching from conventional to environmental funds. The results show that a one-percentage-point increase in the fund flows significantly discourages switching, with the chance of switching only 0.90 times the chance of not switching. This means that funds with lower fund flows have a higher probability of switching to be environmental, as implied by the negative coefficient of the fund flows. In the same vein, an argument exists that funds charging low fees are more attractive to investors and, consequently, are more inclined to transition in order to attract bigger investments, thereby increasing their proceeds from management fees and expenses. This argument is substantiated by our results showing that a decrease in the total load fees makes these funds more likely to switch. These findings further corroborate the results of our event study indicating that environmental funds are primarily incorporating sustainability criteria in their prospectus to attract more investments with the aim of financial gains.

Furthermore, the results displayed in Table 2.12 show that funds with higher carbon emissions are more likely to transition from conventional to environmental, as indicated

by the positive coefficient for carbon emissions. Based on the odds ratio reported, given one additional percentage point increase in carbon emissions, the chance of switching from conventional to environmental is 1.51 times the chance of not switching. In terms of why such funds would switch from conventional to environmental, it might be because they want to adjust their portfolios to a low carbon economy by reducing their carbon risk exposure (Ceccarelli et al., 2024) or to merely follow the trend due to their inadequate performance in attracting flows (Cooper et al., 2005). Nevertheless, as we empirically show with the DID analysis, the carbon footprints of environmental funds do not improve relative to other conventional funds, indicating that they are most likely following the trend without reducing their carbon footprints to the anticipated levels. It is also worth noting that some other explanatory variables including fund size, age, market cap, and total assets (turnover) negatively (positively) affect the probability of switching.

Overall, the results of the probit regression show that funds experiencing low fund flows, low fees, and higher carbon emissions are more likely to make claims about sustainability. In their quest to secure investments to enhance their financial benefits, funds might resort to exaggerating their environmental credentials or sustainability efforts, even if their actual practices and investments do not align with these claims. This desperation can lead to greenwashing as a short-term strategy to attract investments. Our earlier results from the event study discussed in section 2.5.2 support this view by showing that environmental funds attract significant fund flows that can not be justified by their historical performance or investment style. In addition, funds that have a significant carbon footprint may feel pressured to mitigate this image by greenwashing. They may overemphasize their efforts to reduce emissions, while still holding or investing in carbon-intensive firms. Our earlier results from the difference-in-differences analysis in section 2.4.2 confirm that environmental funds fail to reduce their carbon footprint relative to conventional funds in the period that follows announcing their commitment to sustainability. This misalignment between their portfolio carbon emissions and their sustainability claims can be a clear indicator of greenwashing.

Table 2.12: A Panel Probit Regression of the Characteristics of Environmental Funds This table shows the results of a panel probit regression with a dummy variable *Env* equals one if the fund switched to be environmental and zero otherwise. The sample period is from 2012Q1 to 2021Q4. *ln_Carbon_Emission* represents the natural logarithm of the portfolio carbon emissions (scope 1&2). *ln_Fund_Size* is the natural logarithm of the fund's total net assets in millions of dollars. *ln_Age* is the natural logarithm of the fund's age since inception that is measured in quarters. *Expense_Ratio* is the fund's total expense ratio as a percentage of AUM. *Total_Return* measures the fund's historical performance over a given period. *Fund_Flows* represents the fund's total cash flow scaled by its total net assets in the previous period. *Turnover* is determined as the minimum of either the fund's aggregated sales or purchases of stocks during a given period scaled by the value of the fund's portfolio in the previous period. *Price_to_Book* is the fund's weighted average price-to-book ratio. *ln_Num_of_Holdings* is the natural logarithm of the number of holdings in the fund's portfolio. *ln_Market_Cap*, *ln_Revenues*, and *ln_Total_Assets* represent the natural logarithms of the fund's weighted average market cap, revenues, and total assets, respectively. Detailed definitions of the variables are provided in Table 2.1. We present the probit panel regression estimates, t-statistics, and odds ratio of the coefficient estimates. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Standard errors are clustered at the fund level.

	Coefficient	t-stat	Odds Ratio
ln_Carbon_Emission	0.193	4.55***	1.51
ln_Fund_Size	-0.152	-3.13***	0.73
ln_Age	-0.9108	-22.13***	0.15
Total_Load_Fees	-0.0333	-1.96**	0.93
Expense_Ratio	-0.0064	-0.18	0.97
Total_Return	-0.0039	-1.66	0.95
Fund_Flows	-0.047	-2.04**	0.90
Turnover	8.725	14.1***	1.03
Price_to_Book	0.0042	1.54	1
ln_Num_of_Holdings	0.952	1.59	4.3
ln_Market_Cap	0.316	10.42***	1.8
ln_Revenues	-0.051	-1.06	0.89
ln_Total_Assets	-0.168	-3.43***	0.73
Constant	-5.204	-2.31**	
Observations			16,875
R^2			0.2417

2.7 Conclusion

This paper provides evidence on greenwashing by environmental funds. Our findings confirm that the carbon footprints of environmental funds do not improve after announcing the integration of sustainability into their investment decisions as outlined in their prospectuses. We also find that environmental fund flows react positively resulting in significant abnormal flows after these announcements.[23] We subsequently identify the characteristics of those funds that proclaim a commitment to sustainability. We find that funds experiencing low fund flows, low fees, and higher portfolio carbon emissions are more likely to make claims about sustainability. The focus of environmental funds on obtaining flows from investors without showing tangible improvements in their environmental performance provides evidence of greenwashing practices by these funds. Overall, our findings extend the evidence provided in previous research that explores such practices among PRI-signatories asset managers (Kim and Yoon, 2023), funds with broad ESG focus (Andrikogiannopoulou et al., 2022; Dumitrescu et al., 2022), and hedge funds Liang et al. (2023).

Our paper makes several contributions to the emerging literature on greenwashing. First, to ensure compelling evidence on greenwashing, we uniquely focus on a sample of environmental funds that primarily address environmental issues, as opposed to the broader ESG or responsible factors. Second, we avoid issues related to ESG rating divergence by concentrating on the funds' carbon footprint, estimated based on their holdings' reported carbon emissions, as a more robust measure of the efforts made by environmental funds to fulfill their promises of integrating sustainability into their investment decisions. Third, we utilize textual analysis techniques to identify environmental funds and establish their

[23] It is worth noting that given the evolving political landscape surrounding sustainable investing, particularly in regions where sustainability initiatives face increased scrutiny, commitments to sustainable investing may, in some cases, lead to outflows rather than inflows. However, in our case, the results indicate that environmental funds continue to attract abnormal inflows following sustainability announcements, suggesting that investors still respond positively to these commitments.

commitments to sustainability as part of their fiduciary responsibilities. Fourth, our research design enables us to link greenwashing to the fund's fiduciary duty, as we focus on environmental funds that integrate environmental sustainability as an investment objective within their prospectuses, making it imperative for them to strive to meet these objectives in the interest of their investors.

Our findings provide regulators, supervisors, and investors with critical insights to navigate these practices more effectively. For regulators, our results reveal that the existing regulation framework needs more stringent and specific standards on what qualifies as green or sustainable so that funds cannot easily make vague or misleading claims inconsistent with their prospectuses. For supervisors, our findings suggest the need for a thorough and careful examination of the portfolio holdings of environmental funds. If a fund has disclosed its sustainability but holds significant investments in firms with high exposure to carbon emissions, it should be a red flag that raises concerns about its fiduciary duty and whether the fund truly decarbonizes its portfolio as claimed. Supervisors should strengthen oversight mechanisms and increase penalties for non-compliant funds. For investors, our results suggest that widespread greenwashing indicates a need for enhanced protection regulations for investors, such as measures that help them obtain accurate information to make informed decisions and to understand and compare funds' environmental claims. In addition, supervisors and investors can directly engage with fund managers to discuss their decarbonization strategies and ask questions. This engagement can help indicate whether a fund's sustainable investing is substantive and thoughtfully implemented, or just greenwashing.

Greenwashing by environmental funds poses various ethical implications. Most importantly, it violates the fiduciary duty of those funds to act in the best interests of their clients. When environmental funds purport to be environmentally committed and align their strategies with sustainability objectives, yet fail to genuinely integrate them into their practices, they potentially mislead investors who prioritize environmental aspects in their investment objectives. Such misleading actions can be interpreted as a violation of

fiduciary duty. In a fiduciary capacity, environmental funds are obligated to act in the best interests of their clients, but by presenting a facade of environmental commitment, they compromise the integrity of investment decisions and undermine the foundational trust placed in them by their clients. Another important ethical implication of greenwashing is the potential erosion of trust in the financial markets. If investors are unable to distinguish between genuinely environmental funds and those engaging in deceptive practices, confidence in the entire sustainable investment ecosystem may wane. As a consequence, the potential for environmental investments to drive positive societal change could be compromised. Investors interested in sustainability rely on the integrity of information to make informed decisions. When this trust is betrayed, it could lead to disengagement from sustainable investing altogether.

Chapter 3

Does the EU Sustainable Finance Disclosure Regulation Mitigate Greenwashing?

Chapter 3: Does the EU Sustainable Finance Disclosure Regulation Mitigate Greenwashing?[24]

Abstract

This paper examines the impact of the Sustainable Finance Disclosure Regulation (SFDR) on greenwashing by equity mutual funds in the EU. We propose a unique measure called *the Greenwashing Index*, based on a fund's decarbonisation effort relative to its flows, to quantify the level of greenwashing. Using a difference-in-differences analysis, we find that following the enactment of the SFDR, Article 9 funds experience a lower level in their greenwashing index relative to a control group of funds. However, for Article 8 funds, we do not observe any significant reduction in the level of greenwashing index relative to the same control group. We also use a regression discontinuity design (RDD) and find that the decline in the greenwashing index is more concentrated in Article 9 than in Article 8 funds, indicating a different effect of the SFDR on greenwashing behaviour between those funds. Our findings also show that Article 9 funds decarbonise their portfolios by primarily following a portfolio tilting strategy to overweight low carbon-intensive holdings following the introduction of the SFDR.

Keywords: SFDR regulation, Greenwashing Index, decarbonisation, Carbon intensity, Tilting strategy, Divestment.

JEL Classification: G10,G11,G14

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3.1 Introduction

Sustainable investing has quickly begun to dominate the financial sector by addressing global challenges such as climate change and decarbonisation pledges. However, the competing definitions of sustainable investing, the lack of transparency, and unreliable measures of environmental performance have combined to create mixed signals about which investment funds align their portfolios with sustainability objectives. This lack of transparency can lead to greenwashing behaviour, where asset managers exaggerate or falsely claim to integrate environmentally responsible practices into their fund's investment strategies. This practice can raise ethical concerns about their commitments to sustainable investing (Marquis et al., 2016; Berrone et al., 2017). The absence of mandatory disclosure can fuel greenwashing, which can distort the real impact of investing. This distortion can reduce the possibility of achieving decarbonisation pledges and can emphasise the need for regulatory frameworks that ensure transparency. As a result of these concerns, the European Union (EU) introduced the Sustainable Finance Disclosure Regulation (SFDR) that mandates clear and accurate disclosure requirements to prevent misleading signals from investment funds.[25]

The SFDR aims to promote sustainable investment by enhancing transparency in the financial market and combating greenwashing practices in the EU financial industry (EIOPA, 2023).[26] The SFDR mandates that market participants and financial advisers must disclose specific information regarding their consideration of sustainability in their investment decisions. By doing so, the SFDR seeks to ensure investors have access to consistent and comparable sustainability-related information to reduce information asymmetries. Furthermore, the SFDR has categories for investment products that are based on their sustainability objectives and risks that are intended to help investors make

[25]For further details, please see "Regulation (EU) 2019/2088 of the European Parliament and of the Council of 27 November 2019 on sustainability-related disclosures in the financial services sector https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32019R2088

[26]For further details about the definition of sustainable investment under the SFDR classification, please see https://eur-lex.europa.eu/eli/reg/2019/2088/oj

more informed decisions aligned with their sustainability goals. Before the SFDR, the disclosure standards for sustainable investment varied significantly across the EU, making it difficult for investors to compare financial products and for financial market participants to identify the information to disclose.

In this paper, we examine how the mandatory SFDR disclosure requirements affect greenwashing practices.[27] We use the introduction of the SFDR regulation as a quasi-natural experiment to test whether the introduction of SFDR can effectively mitigate greenwashing practices. The SFDR identifies three main classifications of funds.[28] We test whether Article 9 funds change their investment behaviour post the introduction of the SFDR relative to Article 8 funds. However, the SFDR may affect several dimensions of the sustainability performance of asset managers' portfolios. For the purpose of this study, we focus on carbon intensity that is directly aligned with the overarching aim of reducing carbon emissions per the requirements of the Paris Agreement.[29]

We start our empirical analysis by using a difference-in-differences *(DID)* design to measure the change in the greenwashing practices by Article 9 and 8 funds before and after implementing the SFDR. Our analysis utilises the SFDR as a quasi-exogenous shock. The results confirm that Article 9 funds experience a decline in greenwashing relative to a control group of Article 6 and unclassified funds that are not subject to the regulation. Further, the Article 8 funds experience an insignificant decline in their level of greenwashing relative to the same control group. Our findings indicate that Article 9 funds respond more positively to the mandatory SFDR by reducing greenwashing in their portfolios

[27] In the context of our study we define greenwashing as the practice of making misleading claims about integrating sustainability criteria in a fund's investment strategy and decisions that raise concerns about its commitment to sustainable investing.

[28] The SFDR classifies financial products into three main categories based on their sustainability characteristics and objectives. Article 9 funds are referred to as "dark green" funds they aim to achieve a positive social or environmental impact alongside financial returns. Article 8 funds are known as "light green" funds, these products must integrate ESG factors into their investment decisions and consider the sustainability impact of their investments. Article 6 funds which focus on financial products and do not integrate any sustainability considerations into their investment decisions.

[29] For further details please see Article 9(3) SFDR https://www.esma.europa.eu/sites/default/files/2023-05/JC_2023_18_-_Consolidated_JC_SFDR_QAs.pdf

than Article 8 funds. This suggests that the SFDR has a positive impact on mitigating greenwashing, particularly for Article 9 funds.

We further explore the causal effect of being classified as Article 9 vs Article 8 funds on greenwashing. To this end, we conduct a regression discontinuity design *(RDD)* for two treated groups of Article 9 and 8 funds against the same control group of Article 6 and unclassified funds. In particular, we investigate whether funds classified as Article 9 and with a carbon intensity below a specific threshold are less engaged in greenwashing than the second treated group of Article 8 funds with a carbon intensity below the threshold. Interestingly, the results strongly show that the decline in the greenwashing index is more concentrated in Article 9 than in Article 8, indicating a difference in greenwashing behaviour between funds above and below the carbon intensity threshold. This difference may be attributed to the higher transparency imposed on Article 9 funds that necessitates a more genuine decarbonisation effort as disclosed in their investment processes. These results provide further evidence of the effectiveness of the SFDR.

Next, we examine the different strategies that asset managers can adopt for portfolio decarbonisation. First, we ask the question: How do SFDR funds decarbonise their portfolios? To answer this question, first, we examine the portfolio tilting strategy. Portfolio tilting is a strategy that asset managers can use to reduce or adjust the carbon emissions of their portfolios by increasing (decreasing) their exposure to firms with lower (higher) carbon emissions. The results show that the strategy of tilting portfolio weights is an effective method for SFDR funds to decarbonise their portfolios. The results also confirm that portfolio tilting is most noticeable among Article 9 funds relative to Article 8 funds that show no significant shift toward firms with low carbon emissions. Second, we examine whether Articles 9 and 8 funds respond differently in terms of changing their portfolio holdings post the introduction of the SFDR. Our results show that Article 9 funds have strong incentives to change their portfolio holdings to divest away from high carbon-intensive firms compared to Article 8 funds.

We conduct a series of robustness tests. First, we investigate potential heterogeneity in the treatment effect. We use a Propensity Score Matching-Difference-in-Differences (PSM-DID) approach. The results confirm that Article 9 funds are uncorrelated with potential differences in the control group (Article 6 and unclassified funds) that is consistent with our DID results indicating that Article 9 funds see a significant decline in their level of greenwashing relative to Article 8 and other SFDR funds. Second, we validate the parallel trends assumption of our DID model. The result verifies that the greenwashing index of Articles 9 and 8 funds exhibits parallel trends before the introduction of the SFDR. In addition, we conduct a placebo test using the years before the introduction of the SFDR as a pre-regulation period. The result shows that there is no evidence that Article 9 funds decarbonise their portfolios or avoid engaging in greenwashing practices before the introduction of the regulation. Third, we examine the long-term impact of being classified as Article 9 funds on greenwashing using data observed two and three years post the introduction of the SFDR. To account for this possibility, we further explore the dynamic effects of the SFDR on greenwashing. The results show that in both the short and long-term, there is no evidence that Article 9 funds engage in greenwashing practices following the introduction of the SFDR.

Our paper contributes to the recent literature that examines the real impact of mandatory disclosure regulations for sustainability (e.g., Dai et al., 2023; Becker et al., 2022; Rannou et al., 2022; Lambillon and Chesney, 2023; Cremasco and Boni, 2022; Scheitza and Busch, 2023; Bengo et al., 2022). For example, Bengo et al. (2022) discuss how the SFDR relates to measuring the social impact by offering a framework that connects the SFDR disclosures with ESG and impact investing. Ferrarini and Siri (2023) explore how the SFDR motivates institutional investors to incorporate ESG considerations into their investment decisions and how asset managers select and categorize investments based on sustainability criteria. Becker et al. (2022) find that the SFDR has led to mutual funds in the EU increasing their ESG efforts and sustainability scores, and attracting

more sustainable investment. Scheitza and Busch (2023) provide evidence that only one-third of the impact funds meet real investment criteria, with private equity and debt funds more likely to qualify than public equity. Building on these insights, our research strengthens this link by providing compelling evidence on the SFDR efficacy in reducing the greenwashing practices of investment funds. We uniquely focus on Article 9 funds that explicitly claim a real impact on sustainable investing, especially decarbonisation. This paper is one of the first studies to exploit a quasi-exogenous shock to examine the impact of the SFDR on greenwashing by measuring the change in a greenwashing index before and after implementing the new regulation. Specifically, we investigate whether Article 9 funds have altered their investment behaviours post-SFDR relative to Article 8 funds by providing compelling evidence of the regulation's impact.

An important contribution of our work is constructing a novel measure that captures greenwashing in SFDR funds. Our approach relies on the definition of greenwashing that occurs when a fund makes promises to commit to sustainable investing criteria and receives flows from investors on the back of these promises without making sufficient effort to generate real impact by decreasing the carbon intensity of its investment portfolio. We call this measure the *Greenwashing Index*. We start by quantifying the effort made by a fund to decarbonise its portfolio. To this end, we estimate the net decarbonisation for each fund as the trades that reduce its carbon intensity adjusted by the trades that add to its carbon intensity during a given quarter. Then, we calculate the unjustified fund flows as the portion of the fund flows that are not met by decarbonisation in its portfolio. Finally, we calculate our greenwashing index by transforming the values of the unjustified fund flows into an index with values ranging from 0 to 100. Our greenwashing index represents a unique measure of the real outcomes using carbon intensity that reflects the efforts made by SFDR funds (especially Article 9) to keep their promises of meeting decarbonisation targets based on their investment objectives rather than ESG ratings.

This paper contributes to the literature that examines asset managers' behaviour about decarbonisation strategies. Prior research approaches this topic in varied contexts. For

example, Atta-Darkua et al. (2023) find that the investors who are signatories to the Carbon Disclosure Project(CDP) decarbonise their portfolios by investing their funds in low carbon emission stakes instead of using portfolio engagement with firms to lower their carbon emissions. Rohleder et al. (2022) provide evidence that funds that divest their holdings in firms with high carbon intensity for those with low carbon intensity experience a notable decline in their stock prices. Cheema-Fox et al. (2021) analyze different matrices of decarbonisation factors and find a significant effect on reducing exposure to low carbon emissions. In contrast, the “Big Three" asset managers have targeted their engagement strategy on firms with high emissions, and this engagement strategy effectively influences carbon emissions (Azar et al., 2021). Moreover, Bolton and Kacperczyk (2021c) use the CDP and the science-based target initiative to examine firm commitments toward reducing carbon emissions, which indicates these movements' impact is predominantly seen in firms that already have low carbon emissions. Boermans and Galema (2019) provide evidence that pension funds make a significant effort to decarbonise their portfolios and reduce their carbon footprint. While, Benz et al. (2020) find indications of decarbonisation herding among mutual and hedge funds, driven by reputation concerns. We add to this important debate on decarbonisation by examining how Article 9 funds actively change their portfolio holdings following the SFDR. Further, the responses to the quasi-natural experiment that we analyze highlight that both tilting and divestment strategies are the main mechanisms that shape Article 9 responses to reducing greenwashing in their portfolios. Furthermore, we develop an identified novel research design using discontinuities in carbon intensity. This design allows us to go a step further than other studies to examine the causal effect of being classified as an impact fund under the SFDR on greenwashing.

The remainder of this paper is organized as follows: Section 4.2 presents the institutional background of the SFDR. In Section 4.3 we describe the data set and variables. we examine the impact of SFDR on greenwashing In Section 4.4 and analyze how SFDR funds decarbonise their portfolios In Section 3.5. Section 4.6 provides the conclusion.

3.2 Institutional Background

Information asymmetry appears in the context of sustainable investing when investment managers possess more knowledge about the true sustainability implications of their investments than investors. In this context, private sustainability ratings have emerged as a potential tool to mitigate asymmetric information by offering investors a simplified and accessible metric of an investment product's sustainable performance, thereby reducing search costs for investors (Ben-David et al., 2022). However, there are serious concerns about the effectiveness of these ratings in curbing asymmetric information because of the absence of regulations to govern their preparation and provision, which can lead to divergence in ratings from different providers. In fact, several studies have underscored that this regulatory vacuum and the subsequent divergence in ratings not only mislead stakeholders but also undermine the efforts of genuinely sustainable investing (e.g., Chatterji et al., 2016; Dimson et al., 2020; Christensen et al., 2022; Gangi et al., 2022; Semenova and Hassel, 2015; Gibson Brandon et al., 2021; Berg et al., 2022). Such an environment of elevated asymmetric information and lack of regulations allows for opportunistic behaviour such as greenwashing to emerge and flourish.

Another mechanism, albeit indirect, to reduce asymmetric information in sustainable investing has been the introduction of regulatory requirements on sustainability disclosure by firms. These requirements have the potential to reduce asymmetric information by improving the quantity and quality of information available for investment managers to make more informed investment decisions. Nevertheless, early disclosure requirements were typically voluntary. An important consequence of such voluntary disclosure is greenwashing concerns given that firms might take advantage of unclear guidelines and adhere to the bare minimum disclosure standards without disclosing substantial information (Christensen et al., 2021; Xue, 2023; Balakrishnan et al., 2020). The empirical evidence supports this view. For example, Yu et al. (2020) find a considerable difference between the ESG disclosure and the actual ESG performance of large-cap firms indicating that

these firms are involved in greenwashing practices. Also, Kim and Lyon (2015) show that the profitability, unregulated environmental data, and misrepresented environmental performance drive the behaviour of the firms engaged in greenwashing.

Given the limitations of voluntary sustainability disclosure, regulations have recently shifted more toward imposing mandatory disclosure requirements on firms. This is expected to have a stronger effect on reducing asymmetric information than voluntary disclosure. The evidence shows that mandatory corporate social responsibility (CSR) and sustainability reporting for US firms have significant effects on firm behaviour, stakeholders, and capital markets (Christensen et al., 2021). Also, firms' plans for reducing emissions are significantly influenced by their beliefs about future climate policies (Ramadorai and Zeni, 2023). Several studies (e.g., Tomar, 2023; Bolton and Kacperczyk, 2021b; Grewal et al., 2022) document the positive effect of mandatory carbon disclosure by firms on their carbon emissions reduction. Similarly, Krueger et al. (2021) find that mandatory ESG disclosure improves the stock liquidity of a global sample of firms, especially when enforced by government institutions with strong enforcement mechanisms. Overall, the evidence shows that enforcement improves the effectiveness of sustainability regulations in influencing the firm's behaviour toward more genuine sustainability practices.

Despite the positive effects of sustainability regulations on reducing asymmetric information and subsequent greenwashing practices at the firm level, they do not necessarily affect the behaviour of investment managers. There is still a possibility for investment managers to misrepresent the integration of sustainability in their investment decisions and to withhold substantial information about the sustainability risks of their investments. Against this backdrop, on November 27, 2019, the European Parliament and the Council published the regulation (EU) 2019/2088 on sustainability-related disclosure in the financial services sector (SFDR), which came into effect on March 10, 2021. The primary purpose of the SFDR is to promote sustainable investing within the financial sector by elevating the disclosure requirements related to sustainable investing from a voluntary

disclosure to a mandatory obligation for market participants. In particular, the SFDR aims to reduce information asymmetries and to prevent greenwashing in sustainable investing by ensuring a systematic, transparent, and consistent approach to sustainability in financial markets.[30] According to the EU Taxonomy Regulation, "greenwashing refers to the practice of gaining an unfair competitive advantage by marketing a financial product as environmentally friendly, when in fact basic environmental standards have not been met" (Taxonomy Regulation, 2020).

The SFDR identifies a specific classification of funds to guide financial institutions in reporting about their sustainable investments. The main categories under this classification are known as Articles 9, 8, and 6 funds. Article 9 funds refer to impact-generating investments with a clear and measurable sustainable investment objective. These funds must disclose specific sustainability indicators used to measure their environmental performance such as their decarbonisation efforts (Busch et al., 2022).[31] Impact-aligned investments labeled as Article 8 funds must disclose how they integrate sustainability factors into their investment process even if they primarily focus on financial objectives. Exclusion-focused investments are known as Article 6 funds and are required to provide only minimal sustainability disclosures.

The SFDR applies to all participants in the European financial markets such as investment firms or credit institutions providing portfolio management, alternative investment

[30] According to the SFDR (2019), "the Regulation aims to reduce information asymmetries in principal-agent relationships about the integration of sustainability risks, the consideration of adverse sustainability impacts, the promotion of environmental or social characteristics, and sustainable investment, by requiring financial market participants and financial advisers to make pre-contractual and ongoing disclosures to end investors when they act as agents of those end investors (principals)." (OJ L 317, 9.12.2019, p. 3).

[31] Under the SFDR, the classification of funds into Article 9, 8, or 6 is determined through a self-assessment process by fund managers, based on the regulatory criteria outlined in the regulation framework. Fund managers decide whether their products qualify under these categories and must disclose relevant sustainability-related information accordingly. Article 9 funds must have a clear and measurable sustainable investment objective such as renewable energy projects (solar, wind, hydro, geothermal) that reduce carbon emissions and promote clean energy. They also include sustainable farming practices that enhance biodiversity, soil health, and reduce harmful chemicals, contributing to food security and environmental sustainability. Article 8 funds promote environmental or social characteristics without necessarily making sustainability their core focus. Article 6 funds, on the other hand, do not incorporate ESG considerations into their investment processes.

fund managers (AIFMs), undertakings for collective investment in transferable securities (UCITS), alternative investment funds (AIFs), and insurance-based investment products. Market participants are increasingly adopting ESG strategies like best-in-class or impact investing. Such approaches prioritize the allocation of capital to firms with positive environmental impact (Eurosif, 2022). Consequently, there has been a notable increase in the investment funds classified as either Article 9 or 8 funds post the implementation of the SFDR. At the end of September 2022, 33.6% of all funds were classified as Article 8, and 4.3% were classified as Article 9 (Morningstar Research, 2022a). The assets under management (AUM) of these funds surpassed 50% of the AUM of the EU investment funds.

Given the importance of the SFDR, some empirical research has emerged to study different aspects related to its effectiveness. Dai et al. (2023) find that EU funds have shifted their investment decisions to favour firms with low carbon emissions following the implementation of the SFDR. This shift aligns with Becker et al. (2022) whose findings show the SFDR's positive impact on the sustainability practices of EU mutual funds. However, Scheitza and Busch (2023) show that there are no notable variations between impact-focused funds like Article 9 funds and ESG-focused funds. In a similar vein, Cremasco and Boni (2022) examine the alignment of investment funds with the SFDR and find a 'category fuzziness' in distinguishing sustainability attributes among different SFDR fund categories. Nevertheless, there has been limited research that has explored the effects of SFDR on reducing greenwashing. We extend that research by examining the SFDR's impact on greenwashing practices. In particular, we study the differential response of different fund categories, particularly Article 9 and Article 8 funds, to the requirements of the SFDR in terms of their investment objectives.

3.3 Data and Variables

3.3.1 Data

3.3.1.1 Mutual Fund Data

We use the Refinitiv database to obtain a dataset of EU equity mutual funds and their holdings. We obtain data for both active and inactive funds. We include actively-managed open-end equity mutual funds, therefore we exclude ETFs and passive mutual funds. Other types of funds, such as bond, money market, hedge, and pension funds are not examined. The dataset spans from 2016-Q1 to 2022-Q4. Table 3.1, outlines the sample selection criteria. Our initial sample consists of a total of 8,725 EU equity mutual funds. We only keep funds for which carbon emissions data is available for holdings representing at least half of the fund's total net assets throughout the sample period. This reduces the sample size by 4,738 to 3,987 funds. The availability of carbon emissions data is crucial for accurately assessing the impact of the SFDR on funds behaviour and ensuring the robustness of our subsequent analysis. This restriction also aligns with the growing evidence in the literature using a similar approach to ensure the availability of carbon emissions data which might lead to reduced sample size. For example, (e.g., Aswani et al., 2024; Rohleder et al., 2022; Cohen et al., 2023) underscore the significance of comprehensive carbon emissions data in conducting accurate and reliable research on sustainable investing. We further exclude 1,546 funds lacking necessary data on control variables (e.g., financial performance), reducing the sample to 2,441 funds. Finally, another 1,196 funds are dropped since they were newly launched and did not have sufficient data before introducing the SFDR in 2019 Q4, resulting in a final sample size of 1,245 funds.

We extract the following quarterly mutual fund data: net asset value (NAV), total net assets (TNA), total return, expense ratio, dividend payments, and capital gain payments.

Table 3.1: Sample Selection
This table presents the criteria and steps followed to identify the sample of SFDR funds. The Refinitiv database is used to obtain data on EU equity mutual funds and their portfolio holdings with sufficient data on carbon emissions from 2016 to 2022 to identify a sample of SFDR funds.

Sample Criteria	Number of	Distinct Funds
Start: Initial sample of EU equity mutual funds		8,725
Less: Funds without available carbon emissions data for holdings	(4,738)	3,987
Less: Funds without available data on control variables	(1,546)	2,441
Less: Funds that are newly launched	(1,196)	1,245
Final sample		1,245

In addition, we also collect data on the characteristics of mutual funds, such as the Lipper RIC, inception date, ISIN code, domicile, asset status, asset type, and investment style.[32]

Each mutual fund represents a portfolio composed of several stock holdings in which the fund invests. We obtain the quarterly holdings data for all funds in our sample throughout the sample period from the Refinitiv database. Overall, the total number of holding-quarter observations in the dataset is 1,200,530. We use the holdings data to calculate several fund-level variables needed for our subsequent analysis, such as turnover ratio, price-to-book, and market cap. The turnover ratio refers to the minimum of total stock sales or total stock purchases in a given quarter as a percentage of the fund's TNA in the previous quarter. The price-to-book is calculated as the holdings-value-weighted average price-to-book ratio of stocks in the fund's portfolio. The market cap refers to the holdings-value-weighted average market cap of firms in the fund's portfolio. Table 3.2 presents definitions of all the variables used in the analysis.

[32]The investment style is reported based on Refinitiv Lipper's Holdings-Based Fund Classifications (HBC). For further information, please refer to https://lipperalpha.refinitiv.com/wp-content/uploads/2016/01/GlobalHBCMethodology.pdf

Table 3.2: Variable Definitions.

Variable	Definitions
Carbon emissions variables	
Carbon Emission (Scope 1)	Scope 1 refers to direct carbon emissions that originate from the firm's main sources, such as emissions from vehicles and chemical production.
Carbon Emission (Scope 2)	Scope 2 refers to the indirect amount of supplied electricity that the firm uses.
Carbon Emission (Scope 3)	Scope 3 refers to indirect emissions that are a consequence of the firm's activities but occur from sources not owned or controlled.
Company Carbon Intensity	Carbon intensity of a firm is calculated by scaling its scope 1, 2, and 3 carbon emissions by its total revenues. It is expressed as tons of CO2 emissions per $1 million of revenues.
Fund Carbon Intensity	The fund's carbon intensity is calculated as the weighted average of the carbon intensity of its individual holdings, where the weight is determined by the proportion of each holding's market value relative to the total market value of the fund's portfolio.
Fund-level variables	
Total Net Assets (TNA)	The total net assets of a fund refer to the total market value of all the securities held by the fund, minus any liabilities measured in millions of dollars.
Net Asset Value (NAV)	The fund's net asset value is the market value of one share of the fund. It is calculated by dividing the total net assets of the fund by the number of shares outstanding.
Fund Return	The return on investment of a specific fund that is measured as the percentage change in the fund's net asset value (NAV).
Fund Flow	The change in total net assets of a fund over a month, adjusted by the fund's return for that month. It is calculated by dividing the net change in assets by the fund's net assets at the beginning of the month.
Fund Age	The fund age since its inception date measured in quarters.
Fund Size	The natural logarithm of the accumulative total net assets of the fund's portfolio measured in millions of dollars.
Expense Ratio	The expense ratio is expressed as a percentage of the fund's average assets under management (AUM). It represents what a mutual fund charges to cover expenses, including management fees, administrative fees, operating costs, and all other asset-based costs incurred by the fund.
Greenwashing Index variables	
decarbonisation	Refers to the trades that reduce a fund's carbon intensity adjusted by the trades that add to its carbon intensity during a given quarter.
Greenwashing Index	Refers to a measurement used to evaluate and quantify the presence of greenwashing practices to examine to what extent SFDR funds are involved in providing misleading information about their sustainability performance.
Portfolio-based variables	

Continued on next page

Table 3.2 – continued from previous page

Variable	Definitions
Portfolio Tilting	Portfolio tilting is the strategy that asset managers use to reduce or adjust the carbon emissions of their portfolios or increase exposure to firms with lower carbon emissions. This can be done by over- or under-weighting specific stocks or adjusting the portfolio's holdings based on their carbon emissions. Following Atta-Darkua et al. (2023) we calculate our "portfolio re-weighting" measure as shown in subsection 3.3.2.4.
Position Change	Following (e.g., Gantchev et al., 2022; Ceccarelli et al., 2024), we calculate the change in the position of fund i in stock j in quarter$t$ as follows: $$Position\ Change_{i,j,t} = \frac{[NumberShares_{i,j,t} - NumberShares_{i,j,t-1}] * Price_{j,t-1}}{TNA_{i,t-1}} \quad (3.1)$$ We adjust the change in holdings of stock j by fund i in quarter t based on the fund's total net assets (TNA) from the previous quarter. Then, we calculate the value of the position using the stock's price at the end of that previous quarter.
Portfolio Turnover	Portfolio turnover is calculated by taking the minimum of the aggregated sales and aggregated purchases of securities during a specific quarter and dividing it by the total value of the portfolio's holdings from the previous quarter.
Price-to-Book Ratio	Refers to the weighted average price-to-book ratio of stocks in the fund's portfolio.
Revenues	The weighted average of the total revenues of firms in the fund's portfolio in millions of dollars.
Market Cap	The weighted average market capitalization of portfolio firms measured in millions of dollars.
Total Assets	The weighted average total assets of portfolio firms measured in millions of dollars.
Return on Equity	Refers to the weighted average return on equity ratio of stocks in the fund's portfolio.
SFDR Classification	
SFDR	The SFDR refers to the Sustainable Finance Disclosure Regulation that is a framework implemented by the European Union (EU) to promote sustainable finance and enhance transparency in the financial sector.
Article 9	Refers to funds that have generated a real impact on sustainable investing as their primary goal alongside a financial return. They must disclose the specific sustainability indicators used to measure their environmental or social impact and are labelled "Impact-generating investments."
Article 8	Refers to funds that include environmental, social, and governance (ESG) criteria in their investment strategy but are more interested in financial objectives and are labelled "Impact-aligned investments."
Article 6	These funds are not required to have any specific environmental or social objectives. However, they still need to provide disclosures on how they handle sustainability risks in their investment decisions.

3.3.1.2 SFDR Data

The SFDR introduces disclosure standards to the EU financial market. It imposes mandatory ESG disclosure obligations and requires asset managers to classify investment products based on sustainability criteria. According to the SFDR, asset managers are required to self-classify their investment products into three primary categories: Articles 6, 8, and 9 funds. We obtained the SFDR classification from the Refinitiv database on 28 January 2023. We use this classification throughout our subsequent analysis. This classification represents the data reported by funds as of 31 December 2022 which is the date on which the Regulatory Technical Standards (RTS) of the SFDR came into effect. Following these standards, it has become mandatory for EU funds to provide detailed sustainability-related disclosure including requiring sustainable investments with an environmental objective to disclose the extent to which they are aligned with the EU Taxonomy.[33] Therefore, the date of classification selected in our sample provides an optimal timing to examine the effect of the SFDR since it comes after most funds have settled on an appropriate classification given their investment objectives and in light of the newly implemented mandatory disclosure requirements.[34]

As illustrated in Figure 3.1, we provide a summary for our sample in terms of the percentage and the number of SFDR funds. Notably, funds classified as Article 8 account for 47% (585) of the funds since fund managers upgraded strategies and launched new products that meet the articles' requirements. About 15% (190) of our sample is classified as Article 9 funds that have a primary goal to generate a real impact on decarbonisation

[33]For further details on the RTS of the SFDR refer to the EU Commission Delegated Regulation (EU) 2022/1288 of 6 April 2022: https://eur-lex.europa.eu/eli/reg_del/2022/1288/oj

[34]According to reports published by Morningstar (Morningstar Research, 2022b, 2023b), in the second half of 2022, a significant number of funds were reclassified from Article 9 to Article 8 funds. At the same time, other funds were upgraded, with some moving from Article 8 to Article 9 and others from Article 6 to Article 8. This reclassification trend reflects the dynamic adjustments of asset managers to comply with evolving regulatory standards. Nevertheless, this reclassification movement has waned in the first half of 2023 resulting in most funds settling on appropriate classifications under the SFDR requirements. To ensure that the reclassification of SFDR funds does not influence our findings, we have obtained the classifications of the funds in our sample at the end of June 2023 and used them to rerun the main analysis. The results (untabulated) of this additional robustness check confirm our primary findings, demonstrating that our conclusion remains robust despite the classification changes.

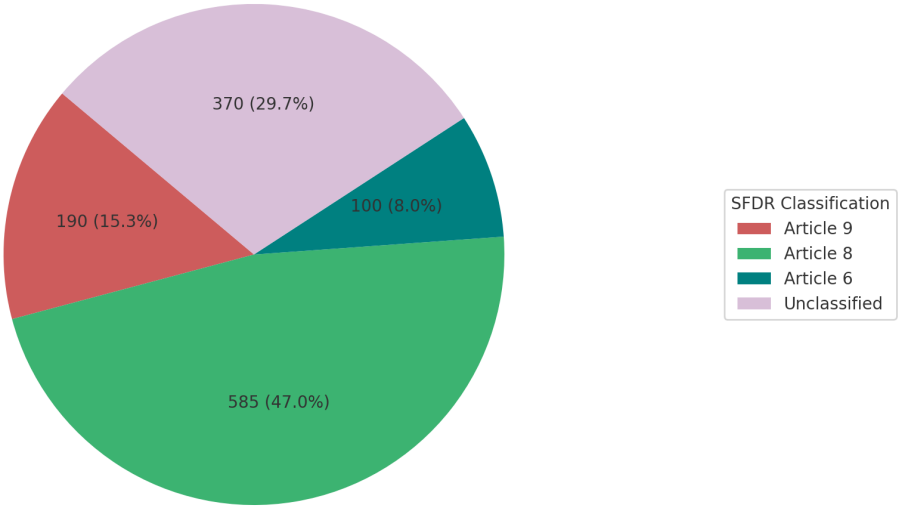

Figure 3.1: [SFDR Classification Based on the Number of Funds.
This figure presents the number and the proportion of funds in each one of the SFDR classifications.

alongside a financial return. In contrast, around 8% (100) of our sample falls under Article 6, that do not integrate any sustainability criteria into the investment objectives. Additionally, our data includes 29% (370) of the EU funds that opt out of marketing their financial products under the SFDR regulatory framework. These funds are not subjected to the regulatory mandates that govern disclosure and transparency requirements within the EU.[35] Furthermore, Table B.1 presents a summary of the distribution of the number of SFDR funds by domicile.

3.3.1.3 Carbon Emissions Data

The data on carbon emissions can be classified into two primary categories: historical data that encompasses both reported and estimated greenhouse gas (GHG) emissions, and carbon scores and ratings supplied by various data providers. We collect data between 2016 and 2022 at the holdings level from the Refinitiv database. The emissions data is

[35]To verify that non-reporting funds do not influence results under the SFDR, we have excluded these funds from the control groups and rerun the main analysis, the results have remained consistent with our initial results.

classified per the Greenhouse Gas Protocol (2015) as scope 1, 2, and 3 emissions.[36] Scope 1 encompasses direct carbon emissions emanating from primary firm sources like vehicles and chemical production, scope 2 pertains to the indirect carbon emissions resulting from consumed electricity, and scope 3 captures emissions indirectly stemming from other firm operations. The carbon emissions data are the total $CO2$ equivalent emissions, scope 1 direct $CO2$ equivalent emissions, scope 2 indirect $CO2$ equivalent emissions, and scope 3 indirect $CO2$ equivalent emissions.

3.3.2 Variables

3.3.2.1 Fund Flows

Increasing fund flows is an important motivation behind greenwashing. Several studies (e.g., Hartzmark and Sussman, 2019; Ceccarelli et al., 2024) indicate that implementing sustainability criteria can influence investors' preferences and in turn their investment choices. Given our paper's objective to examine the effect of the SFDR on greenwashing practices, it is important to quantify fund flows. Consistent with the literature (e.g., Benson and Humphrey, 2008; Cooper et al., 2005), we measure fund flows based on the change in a fund's TNA. Specifically, we calculate flows by dividing each fund's monthly cash inflow from investors by its TNA from the prior month. This inflow is the difference between the current month's TNA and the sum of the prior month's TNA and any returns accrued on those assets. Formally,

$$FundFlow_{i,t} = \frac{[TNA_{i,t} - (1 + r_{i,t})TNA_{i,t-1}]}{TNA_{i,t-1}} \tag{3.2}$$

[36]The Greenhouse Gas Protocol provides comprehensive global standards to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions. It was created as an initiative based on a partnership between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). It has issued several standards including the Corporate Accounting and Reporting Standard which is considered the world's most widely used greenhouse gas accounting standard. For further details, refer to https://ghgprotocol.org/standards

where $TNA_{i,t}$ is the total net assets for fund i in month t, and $r_{i,t}$ is the return on fund i in month t.

3.3.2.2 Measures of Carbon Intensity

Carbon intensity refers to the efficiency with which carbon emissions are converted into net sales. For a specific company, carbon intensity is measured as the amount of carbon emissions (scope 1 and scope 2) per $1 million of revenues during a given period (Jondeau et al., 2021; Rohleder et al., 2022). Formally,

$$CI_{j,t} = \frac{Scope_{1,2}CE_{j,t}}{REV_{j,t}} \tag{3.3}$$

where $CI_{j,t}$ is the carbon intensity of firm j at time t, $Scope_{1,2}CE_{j,t}$ is the firm's total $CO2$ equivalent carbon emissions, $REV_{j,t}$ is the firm's total revenues in millions of dollars, and j and t refer to the firm and time, respectively.

Consequently, a fund's carbon intensity can be estimated as the weighted average carbon intensity of its holdings. The Task Force on Climate-Related Financial Disclosures (TCFD) recommends that asset managers disclose the weighted average carbon intensity for each individual mutual fund as a measure of the fund's exposure to carbon-intensive firms (TCFD, 2022). Following Atta-Darkua et al. (2023) and Rohleder et al. (2022), we estimate the fund's carbon intensity as follows:

$$CI_{i,t} = \sum_{j=1}^{N} W_{j,i,t} \times CI_{j,t} \tag{3.4}$$

where $CI_{i,t}$ is fund i's carbon intensity, and $W_{j,i,t}$ refers to the weight of stock j in the portfolio of fund i in quarter t. It should be noted that $W_{i,j,t}$ is calculated as the ratio of the market value of the shares of firm j held by fund i in quarter t to the total market value of fund i's portfolio in quarter t. Thus, $CI_{i,t}$ represents the weighted average of the

carbon intensity of the fund's holdings measured in tons of $CO2$ emissions per $1 million of revenues. Using this metric, we obtain a compatible estimation of the carbon intensity for each fund based on its portfolio holdings.

Then, we estimate the contribution of a specific holding in the fund's carbon intensity in a given quarter as follows.

$$CI\_Cont_{j,i,t} = \frac{W_{j,i,t} \times CI_{j,t}}{CI_{i,t}} \tag{3.5}$$

where $CI\_Cont_{j,i,t}$ is the contribution of holding j to the carbon intensity of fund i in quarter t. This measure is useful for assessing the efforts made by the fund to decarbonise its portfolio.

3.3.2.3 Greenwashing Index

Measuring greenwashing in sustainable investing faces obstacles due to the difficulty of quantifying the discrepancy between stated intentions and actual investment behaviour (Christensen et al., 2022). A significant contributor to this issue is the absence of standardized definitions and regulations in sustainable investing, which creates an environment in which funds can exploit ambiguities by potentially making exaggerated or misleading claims about the sustainability of their investment strategies.

To examine the effect of the SFDR on greenwashing, we need a measure for greenwashing. Our approach relies on defining greenwashing as the practice that occurs when a fund makes promises to commit to sustainable investing criteria and receives flows from investors on the back of these promises without making sufficient effort to generate a real impact by decreasing the carbon intensity of its investment portfolio. Therefore, we start by quantifying the effort made by a fund to decarbonise its portfolio. To this end, we estimate the net decarbonisation for each fund as the trades that reduce its carbon intensity adjusted by the trades that add to its carbon intensity during a given quarter.

We build on a method widely used in the literature (e.g., Rohleder et al., 2022; Khan et al., 2012) to calculate net decarbonisation as follows.

$$DC_{i,t} = \sum_{j} (SharesSold_{j,i,t} \times CI\_Cont_{j,i,t-1}) - \sum_{j} (SharesBought_{j,i,t} \times CI\_Cont_{j,i,t-1}) \tag{3.6}$$

where $DC_{i,t}$ is the net decarbonisation of fund i in quarter t, and $SharesBought_{j,i,t}$ and $SharesSold_{j,i,t}$ represent the number of shares of a given stock j that fund i bought or sold in quarter t, respectively. As shown in the above equation, the greater the effort made by the fund to decarbonise its portfolio, the higher the $DC_{i,t}$.

Funds that announce their commitment to sustainability are expected to either have or move gradually toward a low-carbon intensity portfolio. Failing to do so while receiving fund flows from investors interested in sustainability is an indication of greenwashing. Therefore, we build on the literature (e.g., Zhang, 2022; Cao et al., 2023) to develop a measure of greenwashing by examining the sensitivity of the fund's net decarbonisation to its quarterly flows as follows.

$$Unjustified\_FundFlows_{i,t} = \left[\frac{\left(FundFlows_{i,t} - \overline{FundFlows_i}\right)}{\sigma_{FundFlows_i}}\right] - \left[\frac{(DC_{i,t} - \overline{DC_i})}{\sigma_{DC_i}}\right] \tag{3.7}$$

where $Unjustified\_FundFlows_{i,t}$ is the portion of the flows that are not met by decarbonisation in its portfolio. $\overline{DC_i}$ and σ_{DC_i} are the running mean and standard deviation of fund i's decarbonisation measure over the past four quarters. $\overline{FundFlows_i}$ and $\sigma_{FundFlows_i}$ are the running mean and standard deviation of fund i's flows over the past four quarters. The above equation shows that the more genuine the effort made by the fund to be truly sustainable relative to its flows received from investors, the lower its unjustified flows will be.

Finally, we calculate our new greenwashing index by transforming the values of the $Unjustified\_FundFlows_{i,t}$ into an index with values ranging from 0 to 100 as follows:

$$GW\_Index_{i,t} = 100 \times \frac{Unjustified\_FundFlows_{i,t} - min(Unjustified\_FundFlows_i)}{max(Unjustified\_FundFlows_i) - min(Unjustified\_FundFlows_i)} \tag{3.8}$$

where $GW\_Index_{i,t}$ is the greenwashing index of fund i in quarter t. Higher values of this index indicate higher greenwashing. This index shows that the less the effort made by a fund to decarbonise its portfolio as measured by $DC_{i,t}$, and consequently the higher the fund flows that are not justified by decarbonisation, the greater the level of greenwashing in this fund's investment portfolio.

3.3.2.4 Measures of Portfolio Tilting and Divestment

To examine the effect of the SFDR on greenwashing, we also need to examine whether and how funds tilt their portfolios following the introduction of the regulation. To calculate tilting, we emphasize absolute metrics for measuring greenhouse gas (GHG) emissions. This approach allows for a more accurate assessment of a fund's contribution to decarbonisation strategies (Bolton and Kacperczyk, 2021a). We estimate two measures of portfolio tilting. The first measure is based on total carbon emissions and is calculated by adjusting the "portfolio re-weighting" measure used in Atta-Darkua et al. (2023) to our context. Our approach is based on examining the reallocation of portfolio weights. In particular, to calculate the change in total carbon emissions of a fund portfolio, we adjust the portfolio weights from time t to time $t+1$ while keeping total carbon emissions the same as in time t. This calculation allows us to capture the degree to which asset managers redirect their equity portfolio allocation from high-emission stocks to stocks with lower emissions. Formally, we calculate the first portfolio tilting measure based on the change in a fund's total carbon emissions $\Delta \log(CO2)$ as follows:

$$\Delta \log(CO2)_{i,t} = \log\left[\sum_{j=1}^{N}\left(\frac{VH_{i,j,t+1}}{TVH_{i,t+1}}\right) \times (CO2)_{j,t}\right] - \log\left[\sum_{j=1}^{N}\left(\frac{VH_{i,j,t}}{TVH_{i,t}}\right) \times (CO2)_{j,t}\right] \quad (3.9)$$

where $\log(CO2)_{i,t}$ denotes the logarithm of the total $CO2$ equivalent carbon emissions of fund i in quarter t, N is the number of stocks in the fund's portfolio in quarter t, $VH_{i,j,t}$ represent the market value of stock j held by fund i in quarter t, $TVH_{i,t}$ denotes the aggregate market value of all the stocks held by fund i in quarter t that represents the funds' size, and $(CO2)_{j,t}$ is the total $CO2$ equivalent carbon emissions of firm j in quarter t.

The second measure of portfolio tilting is based on carbon intensity in which we scale the amount of carbon emissions by total revenues for each firm. This measure shows the efficiency of converting carbon emissions into net sales. We follow the same reasoning as with the measure above by adjusting portfolio weights from time t to time $t+1$ while keeping the carbon intensity variable the same as in time t as follows:

$$\Delta \log(CI)_{i,t} = \log\left[\sum_{j=1}^{N}\left(\frac{VH_{i,j,t+1}}{TVH_{i,t+1}}\right) \times CI_{j,t}\right] - \log\left[\sum_{j=1}^{N}\left(\frac{VH_{i,j,t}}{TVH_{i,t}}\right) \times CI_{j,t}\right] \quad (3.10)$$

where $\log(CI)_{i,t}$ denotes the logarithm of carbon intensity of fund i in quarter t, and $(CI)_{j,t}$ is the carbon intensity of firm j in quarter t.

Another way for funds to adhere to the SFDR requirements is to follow a divestment strategy. In the subsequent analysis, we examine whether Articles 9 and 8 funds respond differently in terms of divesting from carbon-intensive stocks post-SFDR. Following Gantchev et al. (2022) and Kim and Yoon (2023), we calculate the change in the position of fund i in stock j in quarter t as follows:

$$Position\ Change_{i,j,t} = \frac{[NumberShares_{i,j,t} - NumberShares_{i,j,t-1}] * Price_{j,t-1}}{TNA_{i,t-1}} \quad (3.11)$$

where the change in the position is calculated based on the change in the number of shares held by the fund and the stock price at the end of the previous quarter. We scale this absolute change by the fund's TNA from the previous quarter.

3.3.3 Descriptive Statistics

Table 3.3 presents the summary statistics for the entire sample, Article 9 funds, and Article 8 funds in Panels A, B, and C, respectively. We report the summary statistics for the fund-level variables such as TNA, greenwashing index, total return, total expense ratio, age, and fund flows; as well as the holdings-based variables such as revenues, total assets, market cap, price-to-book ratio, carbon intensity, and return on equity. Notably, the summary statistics show that the average fund flows for Article 9 funds (3.48%) surpasses that of Article 8 (1.01%). Moreover, the average carbon intensity of Article 9 funds stands at 305.72 compared to 488.87 for Article 8 funds. These preliminary observations from the dataset hint at potential inconsistencies in Article 8 funds' decarbonisation claims.

Figure 3.2 illustrates the evolution of the weighted average carbon intensity (Panel A), fund flows (Panel B), and the greenwashing index (Panel C) for Articles 9 and 8 funds from 2016 Q1 to 2022 Q4. Panel A shows an increase in the weighted average carbon intensity in the early stage of the sample period before the introduction of the SFDR for both Articles 9 and 8 funds. Article 9 funds exhibit notably high carbon intensity. This trend suggests that these funds may have been engaging in greenwashing, promoting themselves as environmentally friendly, without substantial evidence to support such claims. Before introducing the SFDR, the lack of standardised definitions and regulations in sustainable investing may have created an environment in which funds can exploit ambiguities by potentially making exaggerated or misleading claims about the sustainability of their investment strategies without facing substantial repercussions. Following the implementation of the SFDR from 2019 Q4 onward there is a noticeable decrease in the carbon intensity of Articles 9 and 8 funds. Notably, this decrease is more pronounced in

Table 3.3: Summary Statistics
This table provides the summary statistics for the entire sample used in the analysis (Panel A) from Q1 2016 to Q4 2022, alongside separate summary statistics for the subsamples of Articles 9 and 8 funds (Panels B and C). The variables included are for both at the fund and the portfolio levels. The definitions of the variables are provided in Table 3.2.

Variables	N	Mean	SD	Min	Max	p25	p50	p75
Panel A: All SFDR Funds								
Fund-Level Variables								
Total Net Asset($bil)	27,038	1.82	6.57	0.00	57.70	0.02	0.10	0.54
Net Asset Value($bil)	27,038	2.41	58.71	0.00	2.86	0.03	0.12	0.23
Total Return (%)	27,038	1.87	8.77	-94.16	41.40	-2.05	2.99	6.92
Fund Flow (%)	27,038	1.25	141.00	-19.73	15900.00	-2.15	0.33	3.15
Carbon Intensity	27,038	475.90	430.60	0.11	2940.59	161.73	404.32	658.12
Greenwashing Index	27,038	54.18	33.03	0.00	100.00	28.71	57.80	83.36
Total Expense Ratio (%)	27,038	1.48	0.71	0.01	4.83	1.00	1.50	1.89
Fund Age	27,039	50.76	44.47	1.00	338.00	15.00	44.00	74.00
Portfolio Characteristics								
Total Assets ($bil)	12,951	1060.00	2430.00	0.01	21900.00	67.00	206.00	812.00
Total Revenue ($bil)	12,964	74.50	162.00	0.01	1510.00	6.37	13.20	68.50
Market Cap ($bil)	13,327	461.00	812.00	0.30	4560.00	55.20	147.00	492.00
Return on Equity (%)	13,327	13.54	8.26	-9.71	51.22	7.42	12.09	18.51
Price to Book (%)	12,965	5.09	2.54	0.26	14.18	3.31	4.53	6.29
Turnover(%)	12,978	0.05	0.06	0.00	2.03	0.01	0.03	0.07
Panel B: Article 9 Funds								
Fund Level Variables								
Total Net Asset($bil)	3,660	2.93	9.81	0.00	57.70	0.04	0.16	0.69
Net Asset Value($bil)	3,660	2.41	58.71	0.00	2858.58	0.03	0.12	0.23
Total Return (%)	3,477	1.91	8.72	-30.20	41.40	-2.49	3.22	6.96
Fund Flow (%)	1,957	3.48	3.66	0.00	79.11	1.28	2.71	4.64
Carbon Intensity	1,957	305.72	245.32	1.40	1070.61	87.65	249.45	476.72
Greenwashing Index	2,144	44.27	32.06	0.00	100.00	20.43	29.84	75.82
Total Expense Ratio (%)	706	1.45	0.69	0.03	3.69	0.87	1.58	1.89
Fund Age	3,587	42.36	37.63	0.00	218.00	10.00	35.00	65.00
Portfolio Characteristics								
Total Assets ($bil)	1,912	764.00	1570.00	0.10	10000.00	81.90	213.00	878.00
Total Revenue ($bil)	1,912	56.50	106.00	0.03	636.00	7.78	14.00	63.30
Market Cap ($bil)	1,957	386.00	587.00	2.53	3720.00	74.30	174.00	452.00
Return on Equity (%)	1,957	13.50	7.91	-9.71	47.70	7.63	11.82	18.09
Price to Book (%)	1,912	5.42	2.52	0.91	14.18	3.73	4.75	6.65
Turnover(%)	1,913	0.05	0.06	0.00	0.65	0.02	0.04	0.07
Panel C: Article 8 Funds								
Fund Level Variables								
Total Net Asset($bil)	13,298	1.34	4.60	0.00	57.70	0.03	0.12	0.55
Net Asset Value($bil)	13,298	3.33	80.80	0.00	2858.58	0.05	0.12	0.22
Total Return (%)	13,298	1.91	8.98	-94.16	38.10	-2.04	3.05	7.14
Fund Flow (%)	13,298	1.01	48.17	-13.46	4,21	-2.59	-0.23	2.60
Carbon Intensity	13,298	488.87	408.96	0.17	2940.59	187.58	428.45	687.97
Greenwashing Index	13,298	68.12	28.88	0.00	100.00	53.18	76.75	90.93
Total Expense Ratio (%)	13,298	1.52	0.72	0.01	4.34	0.97	1.60	1.99
Fund Age	13,298	57.61	49.94	1.00	338.00	17.00	52.00	83.00
Portfolio Characteristics								
Total Assets ($bil)	7,517	1090.00	2560.00	0.01	19000.00	69.30	208.00	631.00
Total Revenue ($bil)	7,517	74.20	170.00	0.03	1270.00	6.32	12.70	55.80
Market Cap ($bil)	7,517	456.00	845.00	0.30	4560.00	51.00	134.00	448.00
Return on Equity (%)	7,517	13.90	8.20	-3.64	51.22	7.77	12.42	18.85
Price to Book (%)	7,517	4.86	2.50	0.26	14.18	3.12	4.27	6.08
Turnover(%)	7,517	0.05	0.06	0.00	1.08	0.02	0.04	0.07

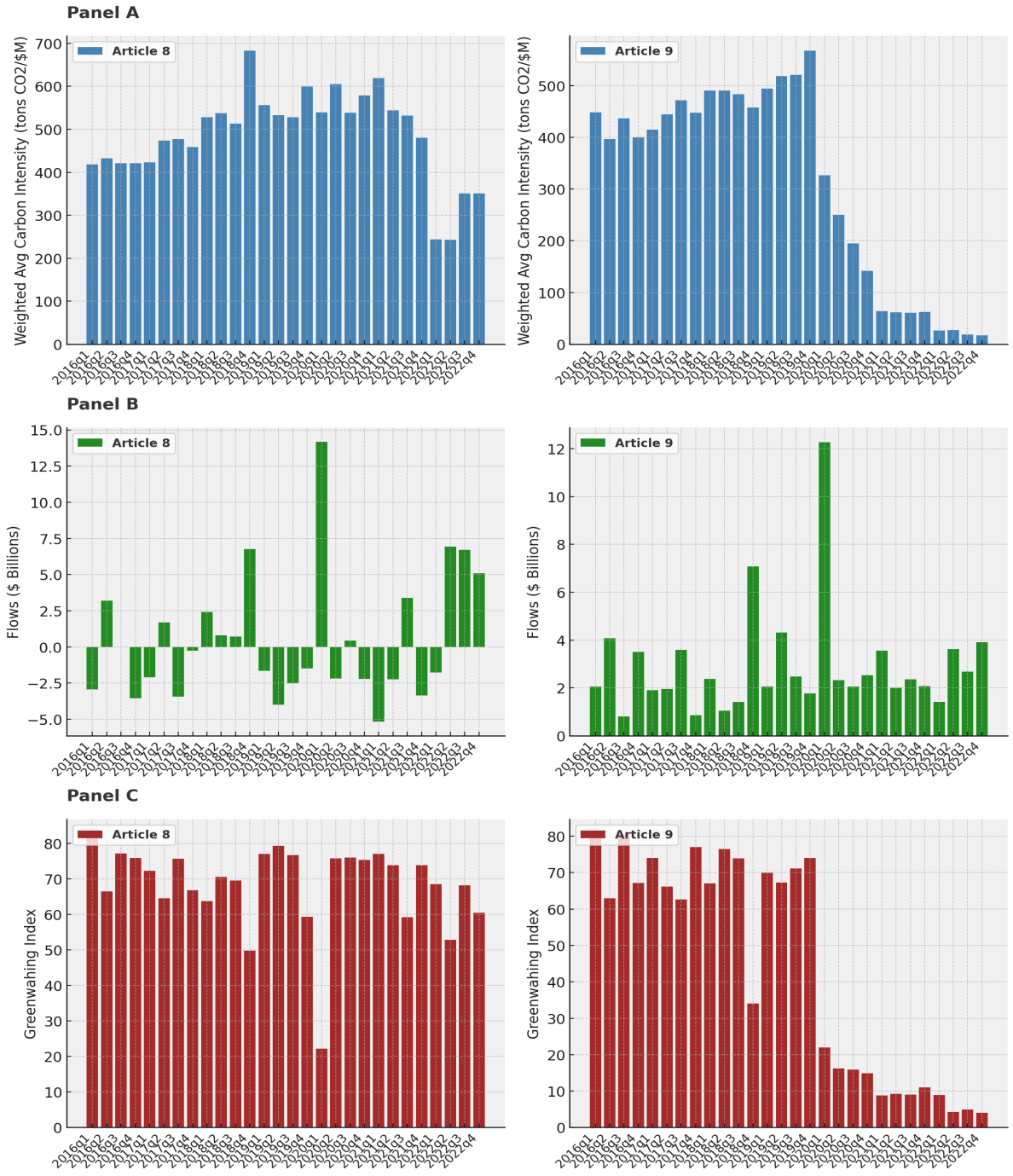

Figure 3.2: The Evolution of Carbon Intensity, Fund Flows, and Greenwashing Index for Article 9 and 8 Funds Over Time.
This figure shows the evolution of the weighted average carbon intensity, fund flows, and greenwashing index for Articles 9 and 8 funds from 2016 Q1 to 2022 Q4. Panel A illustrates the weighted average carbon intensity. Panel B displays the fund flows. Panel C presents the greenwashing index, which provides insights about the SFDR fund's decarbonisation efforts relative to fund flows.

the case of Article 9 funds compared to Article 8. This evolution indicates that there is a substantial difference between the reduction level of carbon intensity for Article 9 funds and that of Article 8 funds. This difference means that funds classified under Article 9 have generated a real impact on decarbonisation compared to Article 8 funds. Moreover, Panel B presents quarterly fund flows of Article 9 and 8 funds. Before the publication of the SFDR, Article 9 funds predominantly registered inflows, while Article 8 funds generally had outflows. Following the introduction of the SFDR, Article 9 funds still received similar levels of inflows.

In contrast, Article 8 funds experienced outflows after the introduction of the SFDR. This pattern indicates that Article 9 funds may have become more attractive to investors following the introduction of the SFDR given their positive response to the regulation and the actions taken to decarbonise their portfolios. Next, in Panel C, we look more closely at the time series of the greenwashing index for both Articles 8 and 9 funds. After the introduction of the SFDR, Article 9 funds experienced lower levels in the greenwashing index, while Article 8 funds show almost the same levels as before the regulation. These levels show that Article 9 funds made efforts to achieve the decarbonisation targets for their portfolios that were in line with the SFDR requirements. This is an important indicator that the SFDR has an impact on reducing the risk of greenwashing, especially in Article 9 funds. This indicator also aligns with our approach to calculating the greenwashing index based on the assertion that the higher the effort made by a fund to decarbonise its portfolio relative to its fund flows, the lower the fund level in the greenwashing index.

3.4 Greenwashing Reaction to the SFDR Regulation

We begin our analysis by using a DID setting to examine whether the SFDR mitigates greenwashing practices. We use the introduction of the SFDR as a quasi-natural experiment to measure the change in greenwashing practices by impact funds (Article 9) and aligned funds (Article 8) after enacting the regulation. The SFDR represents an external

change, that is not influenced by the funds' internal decisions. This exogeneity is crucial in a DID framework, as it means that the intervention is not correlated with unobservable factors that could otherwise bias the results. By concentrating on the incremental effect of the regulation, especially among funds already engaged in sustainability reporting (Article 9), our analysis targets the direct impact of the regulation. This focus helps isolate the effect of SFDR from other concurrent environmental or sustainability trends.

In our DID analysis, we use two separate treated groups. The first is Article 9 funds distinguished by their explicit commitment to positive sustainability impact. The control group comprises Article 6 and unclassified funds that do not fall under any of the three main categories and do not have specific sustainability requirements. The second comprises Article 8 funds which, unlike Article 9 funds, integrate environmental or social characteristics into their investment process without adhering to a stringent sustainability commitment. The control group is the same as for the Article 9 funds. The core of our analysis hinges on the difference in investment focuses and objectives between these treated groups as well as different responsible investment approaches applied by asset managers. This distinction is crucial to examining how the implementation of the SFDR might differently affect the greenwashing practices of Articles 9 and Article 8 funds.

Following the recent literature (e.g., Hu et al., 2019; Gropp et al., 2014), we use a time series DID model specification to measure the changes in the greenwashing index before and after the introduction date of SFDR as follows:

$$GW\ Index_{i,t} = \alpha_0 + \beta_1 Post_{i,t} + \beta_2 SFDR_{i,t} + \beta_3 SFDR{*}Post_{i,t} + \beta_4 controls_{i,t-1} + \gamma_q + \delta_c + \varepsilon_{i,t} \quad (3.12)$$

where the $GW\ Index_{i,t}$ denotes the greenwashing index of fund i in quarter t. The $SFDR * Post$ is the interaction of two underlying dummy variables: $SFDR$ that equals one if the fund belongs to a treated group (Article 9 or Article 8) funds and zero otherwise, and $Post$ that equals one following the introduction date of the SFDR in 2019 Q4 and

zero otherwise.[37] (e.g., Lambillon and Chesney, 2023; Dai et al., 2023; Becker et al., 2022). In addition, to ensure the robustness of our findings, we examine the dynamic effects of the SFDR regulation as reported in Table 3.7 using two extended estimation windows of 2 and 3 years. This adjustment allows us to scrutinize the sustained effects of the SFDR on greenwashing for up to three years after introducing the regulation in 2019 Q4, particularly focusing on the behaviour related to Articles 9 and 8 funds. The coefficient for *Post* represents the variations in the levels of the greenwashing index for Articles 9 or 8 pre and post-SFDR date. Our main interest is the coefficient for $SFDR * Post$ that indicates whether there is a substantial difference in the levels of the greenwashing index between Articles 9 or 8 funds and the control group following the introduction of SFDR. A significantly negative coefficient for this variable confirms an improvement in the level of the greenwashing index post the introduction of the SFDR and signifies the efforts made by funds to decarbonise their portfolios.

Our regression controls for the characteristics of both the fund and its portfolio. The control variables are portfolio size, turnover, price-to-book, market cap, float, volume, and return on equity. All these variables are lagged to reduce any endogeneity issues. The estimation window is one year before and after the introduction of the SFDR. In addition, we use quarter fixed effects denoted as γ_q and country-of-domicile fixed effects denoted as δ_c that allow us to control for any time variation across funds and unmeasured macroeconomic conditions (Hartzmark and Sussman, 2019). We verify the parallel

[37] The SFDR regulation was introduced on November 27, 2019, which creates a unique natural experiment to measure the change in greenwashing practices after introducing the regulation. To this end, we follow a difference-in-differences analysis using one year before and one year after the quarter in which the SFDR was introduced. Using 2019 Q4 as the cutoff point in our analysis is justified for a number of reasons. First, it marks a significant milestone in the EU regulatory landscape, thus providing insights into the immediate market response and investment decisions. These insights help with understanding the regulation's effectiveness in shifting the behaviour of fund managers and investors toward sustainability. Second, the period immediately following the regulation's introduction is crucial for understanding the preliminary adjustments made by the fund managers to classify their funds and adapt their strategies in response to the new requirements. By late 2019, financial market participants had received sufficient notice and guidance on the impending regulatory changes, allowing them to prepare and align their disclosure practices accordingly. Finally, several academic studies have used 2019 Q4 as a reference point for analysing the impact of SFDR, thus supporting our choice

trends assumption and use randomness to decrease the differences in the noticeable fund characteristics between the treated and control groups (Hainmueller, 2012).

Table 3.4 shows the results of the DID analysis. In columns (1) and (2), the coefficients for $SFDR*Post$ are significantly negative for various specifications, indicating that compared with the control group, Article 9 funds experience a lower level in the greenwashing index. The decrease in the greenwashing index following the introduction of SFDR is also economically significant. As column (1) shows, without including control variables, Article 9 funds experience a decline of 25.62% in their greenwashing index relative to Article 6 and unclassified funds. After adding control variables as shown in column (2), the coefficient for $SFDR*Post$ is still significantly negative, indicating that the level of the greenwashing index of Article 9 funds declines on average more than that of Article 6 and unclassified funds following the enactment of the SFDR. This finding suggests a notable influence of the SFDR on curbing greenwashing practices, as evidenced by the reduced levels of Article 9 funds in the greenwashing index.

Next, in columns (3) and (4) we use Article 8 funds as the treated group to examine the change in their greenwashing behaviour post-SFDR. The results show that Article 8 funds experience an insignificant decline of 1.57% in their greenwashing index compared to Article 6 and unclassified funds. This decline, though statistically insignificant, suggests a slight response to the SFDR by Article 8 funds. Under the SFDR, Article 8 funds encompass financial products that promote environmental or social characteristics but do not have sustainable investment as their core objective. Therefore, these funds must disclose how their environmental or social characteristics are met, increasing transparency and potentially influencing their operational practices. The slight decline in the greenwashing index could be interpreted as an initial effort by Article 8 funds to more closely align with the regulatory requirements, thereby enhancing their credibility with investors. These results indicate that Article 9 funds have made more effort to decarbonise their portfolios compared to Article 8 and other funds following the introduction of the SFDR. This effort means that the SFDR has a significant impact on reducing the greenwashing

Table 3.4: Results of the Difference-in-Differences Analysis
This table presents the estimated effects of the SFDR on the greenwashing index. The greenwashing index represents a standardization of the measure of unjustified fund flows as shown in Eq.3.8. In columns (1) and (2) ((3) and (4)) the $SFDR$ equals one for Article 9 (8) funds and zero for Article 6 and unclassified funds. *Post* has the same definition in all specifications and takes a value of 1 in the quarters following the introduction of SFDR and 0 otherwise. $SFDR * Post$ is an interaction variable. The odd columns represent the regression without control variables, while those in the even columns include control variables. Detailed definitions of the variables are provided in Table 3.2. All explanatory variables are lagged. The sample period is 2016 to 2022. t-statistics are reported in parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Greenwashing Index				
	Article 9		Article 8	
Variables	(1)	(2)	(3)	(4)
SFDR*Post	-25.62***	-25.73***	-1.57	-1.66
	(-3.23)	(-2.74)	(-0.50)	(-0.41)
SFDR	-16.20***	-15.48***	-3.00	-1.62
	(-8.71)	(-4.53)	(-1.00)	(-0.33)
Post	-11.14**	-6.88**	-11.50**	-6.54**
	(-2.19)	(-2.10)	(-2.12)	(-2.52)
Fund Size		-0.92		-0.62
		(-1.10)		(-1.10)
Fund Age		1.73**		-0.56
		(2.09)		(-0.80)
Total Return		0.60**		1.21***
		(2.54)		(4.63)
Market Cap		3.62		1.50
		(1.32)		(0.63)
Book to Market Ratio		-1.78*		-1.10
		(-1.70)		(-1.62)
Turnover Ratio		-107.30***		-105.30***
		(-3.36)		(-5.79)
Fund Flows		-0.00***		-0.01***
		(-5.97)		(-9.55)
Revenues		-7.55		-2.01
		(-1.87)		(-0.81)
Return on Equity		4.81		1.25
		(1.74)		(0.86)
Constant	8.09***	8.22***	7.99***	7.67***
	(3.63)	(3.80)	(2.71)	(5.69)
Observations	1,185	1,148	2,612	2,565
R-squared	0.25	0.33	0.04	0.26
Controls	No	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes

practices of Article 9 funds, but less so in the case of Article 8 funds. Overall, this result supports our conjecture that Article 9 funds adhere to the SFDR by decarbonising their portfolios, which leads to better alignment with their fund flows and lower greenwashing.

3.4.1 Further Analysis and Robustness Tests

To corroborate our results on the impacts of Article 9 funds', we conduct additional tests. First, we investigate the potential heterogeneity in the treatment effect to ensure that the two treated groups (Article 9 funds and Article 8 funds) are uncorrelated with potential differences with the control group. Second, we validate the parallel trends assumption of our model. Third, we examine the long-term impacts of Articles 9 and 8 funds on the greenwashing index.

3.4.1.1 Endogeneity Concerns

As we compare the impact of the SFDR on the greenwashing index for all funds, we need to ensure that the treated groups, including Article 9 funds and Article 8 funds, are uncorrelated with potential differences with the control group comprising Article 6 and unaffected funds. To address these concerns, we employ a Propensity Score Matching (PSM) technique to conduct a 1-to-1 nearest-neighbour matching of each treated unit (Article 9 or 8 fund) with the closest control unit (Article 6 or Unclassified fund). Our propensity matching accounts for variables derived from both portfolio and fund-level characteristics including fund size, fund age, turnover ratio, revenues, book-to-market ratio, market cap, total return, return on equity, and fund flows. The propensity scores are estimated using a logistic regression. Table B.2 presents the descriptive statistics for the matched treatment and control groups, along with t-tests comparing the means of the matching variables. The results indicate that the treated and matched control funds are not significantly different based on the matching variables, as evidenced by the insignificant t-statistics for the tests of differences between means.

In addition, we conduct a Difference-in-Differences (PSM-DID) approach. This method helps eliminate the selection bias in observable characteristics across the treatment and control groups (Hu et al., 2019). We implement the DID regression model described in Eq.3.12 that has both time and country fixed effects.

Table 3.5 shows the results of the PSM-DID analysis. In column (1), the coefficient for $SFDR * Post$ is significantly negative indicating a lower level of Article 9 funds in the greenwashing index relative to the control group. In column (2), when we add the control variables, the coefficient for the interaction variable $SFDR * Post$ indicates a significant reduction in the level of the greenwashing index of 25.63% relative to the matched control group. The results related to Article 8 funds are also aligned with the results in the main analysis above. Overall, these results confirm our findings from the main DID analysis, which indicates that Article 9 funds have taken more steps toward decarbonising their portfolios and show a more sustainable impact than Article 8 funds as shown in columns (3) and (4).

3.4.1.2 Parallel Trends Assumption

To ensure the robustness of the results obtained from the DID regression, it is crucial to validate the parallel trends assumption. This assumption requires that the expected evolution of the greenwashing index for both the treated and control groups be the same before the introduction date of the SFDR. In other words, when the treated group is not subjected to interventions, the greenwashing index should show the same trend as the control group. We graphically depict the time trends for the treated and control groups across four quarters before and after the enactment of the SFDR in Figure 3.3. The figure verifies that the levels of the greenwashing index for Articles 9 and 8 funds have parallel trends before the introduction. Overall, the negligible difference in the levels of the greenwashing index shown in Table 3.4 coupled with the stable trend illustrated in Figure 3.3 validate the assumption of parallel trends in our DID approach. Consequently, we

Table 3.5: Results of the Difference-in-Differences Analysis based on Propensity Score Matching
This table represents the results of the PSM-DID analysis used to match Article 9 funds to a group of Article 6 and unclassified funds before the introduction of the SFDR. We use the DID estimator setting outlined in Eq.3.12 with both time and country-fixed effects. The greenwashing index represents a standardization measure of the unjustified fund flows as shown in Eq.3.8. In columns (1) and (2) ((3) and (4)), $SFDR$ equals one for Article 9 (8) funds and zero for Article 6 and unclassified funds. $Post$ has the same definition in all specifications and equals one in the quarters following the introduction of SFDR and zero otherwise. $SFDR * Post$ is an interaction variable. The odd column represents the regression without control variables, while the even column has control variables. Detailed definitions of the variables are provided in Table 3.2. All variables are lagged. The sample period is 2016 to 2022. t-statistics are reported in parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Greenwashing Index			
	Article 9		Article 8	
Variables	(1)	(2)	(3)	(4)
SFDR*Post	-25.50***	-25.40***	4.38	4.68
	(-3.24)	(-2.73)	(0.65)	(0.63)
SFDR	-15.97***	-15.52***	6.90**	7.54**
	(-7.61)	(-6.63)	(2.60)	(2.20)
Post	-11.22**	-6.99**	-20.45***	-14.22**
	(-2.27)	(-2.16)	(-3.14)	(-2.09)
Constant	8.07***	8.20***	7.27***	8.39***
	(3.46)	(4.67)	(3.08)	(4.84)
Observations	1,153	1,138	2,226	2,208
R-squared	0.25	0.32	0.09	0.26
Controls	No	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes

conclude that any difference in the levels of the greenwashing index post the introduction of the SFDR is attributable to its significant impact on eliminating greenwashing. The comparison between Article 9 and Article 8 funds reveals distinct approaches to sustainability where Article 9 funds generally exhibit a stronger commitment to reducing their greenwashing post-regulation, suggesting a more genuine and effective engagement with decarbonising their portfolio.

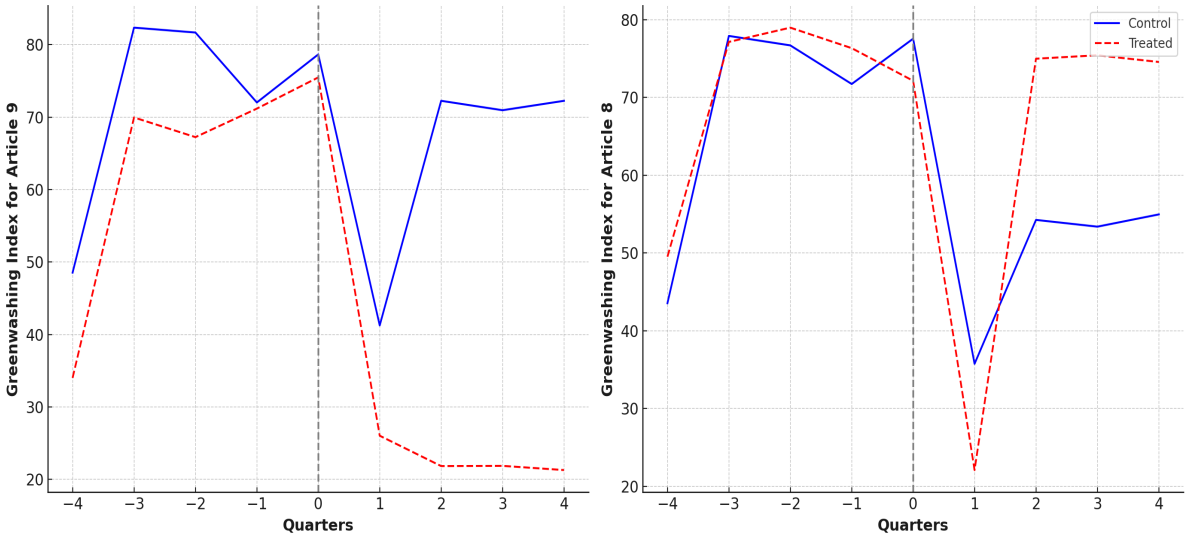

Figure 3.3: The Trends of the Greenwashing Index.
The left side of this figure displays the greenwashing index of Article 9 funds alongside a matched group of Article 6 and unclassified funds before and after the introduction date of the SFDR. The right side presents the greenwashing index of Article 8 funds and a matched group of Article 6 and unclassified funds. The pre-quarters refer to the four quarters before the introduction of the SFDR. The post-quarters include the introduction of the SFDR and the subsequent three quarters.

3.4.1.3 Placebo Test

In this analysis, to check the validity of our DID analysis we conduct falsification tests using the years before the introduction of the SFDR as a pre-regulation period to conduct a placebo test. This test aims to determine if there was a reduction in the levels of the greenwashing index before the introduction of the SFDR. We use an extended version of Eq. 3.12 whereby we introduce an interaction variable between the time dummy variable of the year before the adoption of SFDR (Pre) and the treatment variable (SFDR). In Table 3.6, the result of this exercise shows that there is no evidence that Articles 9 and 8 funds decarbonise their portfolios or avoid engaging in greenwashing practices during the period that precedes the regulation. This lack of significant activity during the pre-regulation period suggests that any changes in behaviour observed after the regulation's introduction are likely due to the regulation itself. The insignificance of this placebo test confirms that the SFDR has had a meaningful impact on reducing greenwashing

Table 3.6: Results of Placebo Test
This table shows the results of the placebo analysis for the greenwashing index for funds before the adoption of the SFDR. We use a DID estimator as in Eq.3.12 . The term $SFDR * pre$ is defined as an interaction variable consisting of two underlying dummy variables: SFDR equals one for Article 9 funds and zero otherwise. Pre equals one for the quarters before the adoption of the SFDR and zero otherwise. We use three placebo periods: Pre(2016), Pre(2017), and Pre(2018). The odd columns represent the regression without control variables, while the even columns have control variables. Detailed definitions of the variables are provided in Table 3.2, and all these variables are lagged. The sample period is 2016 to 2022. t-statistics are reported in parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Greenwashing Index			
	Article 9		Article 8	
Variables	(1)	(2)	(3)	(4)
SFDR*Pre	-0.64	1.20	0.37	0.44
	(-0.15)	(0.22)	(0.14)	(0.18)
Constant	5.97***	6.80***	6.80***	6.88***
	(2.69)	(6.54)	(12.39)	(5.37)
Observations	3,902	3,792	8,276	8,124
R-squared	0.17	0.21	0.15	0.18
Controls	No	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes

practices. This finding reinforces the conclusion that the SFDR effectively leads funds to adopt more genuine and transparent sustainability practices.

3.4.1.4 Dynamic Effects Analysis

One concern about our analysis of the impact of the SFDR on funds, especially Article 9 funds, is that we examine the change in the level of the greenwashing index for SFDR funds based on one year after the introduction of the regulation. Asset managers may require a longer time to adjust their portfolios toward decarbonisation targets, so one year might not provide sufficient time to observe a significant treatment effect. To account for this possibility, we further explore the dynamic effects of the SFDR on the greenwashing index. Therefore, we examine how the effectiveness of the regulation changes over two and three years. We verify this effectiveness by setting a series of dummy variables in the DID

regression in Eq.3.12 to trace the year-by-year effects of the SFDR on the greenwashing index. The regression controls for portfolio and fund-level characteristics. In addition, we use high-dimension quarter fixed effects and clustered standard errors at the geographical focus, domicile, and quarter date.

Table 3.7: Dynamic Effects Analysis
This table shows the results from regressions examining the greenwashing index of SFDR funds over 2-year and 3-year periods after introducing the regulation. The greenwashing index represents a standardization measure of the unjustified fund flows as shown in Eq.3.8. In columns (1) to (4) and ((5) to (8)), $SFDR$ equals one for Article 9 and 8 funds and zero for Article 6 and unclassified funds. $Post$ has the same definition in all specifications and equals one in the quarters following the introduction of the SFDR and zero otherwise. $SFDR * Post$ is an interaction variable. The odd columns represent the regressions without control variables, while even columns have control variables. Detailed definitions of the variables are provided in Table 3.2. The sample period is 2016 to 2022. t-statistics are reported in parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Greenwashing Index							
	Article 9				Article 8			
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SFDR*Post (2 years)	-34.28***	-35.23***			0.30	-0.36		
	(-5.26)	(-5.92)			(0.16)	(-0.15)		
SFDR*Post (3 years)			-43.54***	-43.35***			0.78	0.38
			(-9.14)	(-8.92)			(0.47)	(0.17)
Constant	7.03***	9.16***	7.17***	7.80***	6.97**	7.08***	7.11**	7.00***
	(2.83)	(4.56)	(2.85)	(4.33)	(2.31)	(4.71)	(2.28)	(4.76)
Observations	3,902	3,792	3,902	3,792	8,276	8,124	8,276	8,124
R-squared	0.23	0.32	0.32	0.38	0.01	0.13	0.01	0.13
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The results in Table 3.7 show that Article 9 funds are notably more active in decarbonising their portfolios when compared to Article 6 and other unclassified funds. This result is aligned with the outcomes from the main DID analysis in Table 3.4. Moreover, our analysis indicates that, over the long-term, Article 9 funds show lower greenwashing. This is evidenced by a negative and statistically significant effect on the level of the greenwashing index in both the 2-year (columns (1) and (2)) and 3-year (columns (3) and (4)) specifications. Conversely, Article 8 funds do not show a sustained effort toward decarbonising their portfolios over the long-term. Overall, these results highlight the

consistency in the short and long-term strategies between Article 9 and Article 8 funds, suggesting differing commitments to sustainability practices.

3.4.2 The Causal Effect of the SFDR on Articles 9 and 8 Funds

In this subsection, we extend our analysis by using the regression discontinuity design (RDD) to examine the causal effect of being classified as Article 9 or 8 funds under the SFDR on greenwashing practices. Our RDD tests the hypothesis that after implementing the SFDR, funds classified as Article 9 are expected to have a lower level in the greenwashing index than those classified as Article 8.

3.4.2.1 Specification of the Regression Discontinuity Design (RDD)

Following the literature (e.g., Cao et al., 2019; Reuter and Zitzewitz, 2021; Gigante and Manglaviti, 2022), we perform a sharp regression discontinuity (SRD) design to estimate the discontinuities in the reactions of the greenwashing index. The fundamental concept of the RDD is that the presence of any discontinuity in the conditional distribution of the outcome variable (Y) around a specific cutoff point (c) of a running variable (X) is considered evidence of a causal effect of the treatment. In other words, the treatment affects the outcome variable, and the discontinuity at the cutoff point indicates that the treatment effect is significant.

The EU Taxonomy Regulation establishes a framework for determining whether an economic activity is environmentally sustainable and sets out technical screening criteria for certain activities, including carbon intensity. Under the EU Taxonomy Regulation, investment funds classified under the SFDR must calculate the carbon intensity of their investments when reporting on their sustainability performance.[38] In our setting, we use

[38]Further information on the Taxonomy Regulation can be found here: https://ec.europa.eu/finance/docs/level-2-measures/taxonomy-regulation-delegated-act-2021-2800-annex-1_en.pdf

the carbon intensity as the running variable to determine whether an observation is above or below the threshold. The cutoff point c is set equal to the mean of the carbon intensity at t=0, which represents the date the SFDR was introduced in 2019-Q4. Following Reuter and Zitzewitz (2021), we estimate our regression as follows:

$$GW\_Index_{i,t} = \alpha + \beta_1\ CI_{i,t} + \beta_2\ SFDR_{i,t} + \beta_3\ controls_{i,t}\ +\ \varepsilon_{i,t} \tag{3.13}$$

where $GW\_Index_{i,t}$ denotes the greenwashing index of fund i in quarter t as the outcome variable. We use two versions of the $SFDR_{i,t}$. The first is a dummy variable that equals one if the fund is classified as Article 9 with carbon intensity below the cutoff point (treatment group) and that equals zero if the fund is classified as Article 6 with carbon intensity above the threshold (control group). The second is a dummy variable that equals one if the fund is classified as Article 8 with carbon intensity below the cutoff point (treatment group) and that equals zero if the fund is classified as Article 6 with carbon intensity above the threshold (control group). $CI_{i,t}$ is the carbon intensity of fund i in quarter t which is used as the running variable. We follow Calonico et al. (2014) to select the optimal bandwidths. Using this method allows us to examine the robustness of our findings by considering different bandwidth choices that vary in width compared to the optimal bandwidth. The coefficient estimate of β_2 captures the discontinuity difference in the outcome variable between the funds classified as Article 9 with a carbon intensity below the cutoff point and funds classified as Article 6 with a carbon intensity above the cutoff point. Therefore, if the coefficient for the treatment variable is statistically significant, there should be a difference in greenwashing between funds above and below the carbon intensity threshold. This difference indicates that the SFDR funds are complying with the regulation by reducing their carbon intensity in line with the classification requirements.

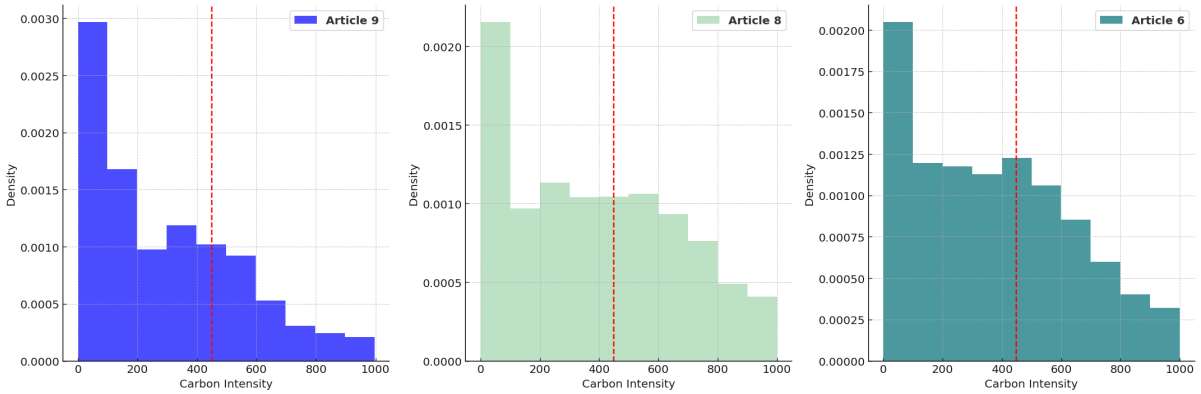

Figure 3.4: Histogram of the Distribution of Carbon Intensity.
This figure presents the distribution of the running variable, carbon intensity for Article 9, Article 8, and Article 6, through a histogram to assess its continuity around the cutoff point.

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3.4.2.2 Results of the Regression Discontinuity Design (RDD)

We start by examining the distribution of the running variable, carbon intensity for the treated groups (Article 9 & Article 8) and the control group (Article 6), through a histogram to assess its continuity around the cutoff point, as shown in Figure 3.4. The cutoff point is set equal to the mean of the carbon intensity in 2019 Q4, which is 448 tons $CO2$ emissions. This is important as any unexpected changes at the cutoff point may indicate potential manipulation of the variable. The plots show that the density distributions have a smooth continuity without any noticeable discontinuous jump around the threshold. Then, following McCrary (2008), we conduct a test of the discontinuity that examines the smoothness of the density around the cutoff point as shown in Figure 3.5. We use three different windows after the introduction of the SFDR for each sample of Article 9 and Article 8 funds. The plots show that while Article 9 funds with carbon intensity below the cutoff point have a negative change in the levels of their greenwashing index, Article 8 funds do not have similar changes since the levels of their greenwashing index are stagnant below the cutoff point.

Table 3.8 presents the results of the RDD. Following the method used by Calonico et al. (2014), we compare the results obtained from the conventional RD method with those

Table 3.8: Results of Regression Discontinuity Test
This table presents the regression discontinuity tests. The dependent variable is the greenwashing index for fund i in quarter t. The running variable is the carbon intensity with the mean value used as a cutoff point at t=0 representing the quarter in which the SFDR was introduced (2019-Q4). The treatment variable is a dummy that equals one if the fund is classified as Article 9 with carbon intensity below the cutoff point (treatment group) and that equals zero if the fund is classified as Article 6 with carbon intensity above the threshold (control group). The odd columns represent the local linear regression without adding control variables, while the even columns have the control variables. Our regression controls for the lagged fund characteristics (fund size, fund total return, fund flows, and expense ratio) and lagged portfolio characteristics (market cap, price to book, revenues, enterprise value, and turnover ratio). Detailed definitions of the variables are provided in Table 3.2. We follow the method used by Calonico et al. (2014) by comparing the results obtained from the conventional RD method with those obtained from the bias-corrected and robust methods. t-statistics are reported in parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: 1 Year Window				
Sample	Article 9		Article 8	
	(1)	(2)	(3)	(4)
Conventional	-28.61*	-34.6**	-5.74	-2.21
	(-1.91)	(-2.42)	(-0.54)	(-0.22)
Bias-corrected	-33.35**	-41.27***	-7.77	-3.71
	(-2.23)	(-2.89)	(-0.73)	(-0.38)
Robust	-33.35*	-41.27***	-7.77	-3.71
	(-1.86)	(-2.89)	(-0.61)	(-0.31)
Observations	327	319	821	799
Controls	No	Yes	No	Yes
Panel B: 2 Year Window				
Sample	Article 9		Article 8	
	(1)	(2)	(3)	(4)
Conventional	-30.96***	-33.16***	-3.52	-2.49
	(-2.66)	(-2.98)	(-0.50)	(-0.36)
Bias-corrected	-36.00***	-37.72***	-4.10	-2.89
	(-3.09)	(-3.39)	(-0.59)	(-0.41)
Robust	-36.00***	-37.72***	-4.10	-2.89
	(-2.64)	(-2.86)	(-0.48)	(-0.34)
Observations	745	725	1829	1789
Controls	No	Yes	No	Yes
Panel C: 3 Year Window				
Sample	Article 9		Article 8	
	(1)	(2)	(3)	(4)
Conventional	-20.09***	-17.97**	-1.78	-0.52
	(-2.68)	(-2.46)	(-0.50)	(-0.09)
Bias-corrected	-23.33***	-21.37***	-2.07	-0.78
	(-3.11)	(-2.93)	(-0.38)	(-0.14)
Robust	-23.33**	-21.37**	-2.07	-0.78
	(-2.63)	(-2.45)	(-0.31)	(-0.12)
Observations	983	954	2389	2333
Controls	No	Yes	No	Yes

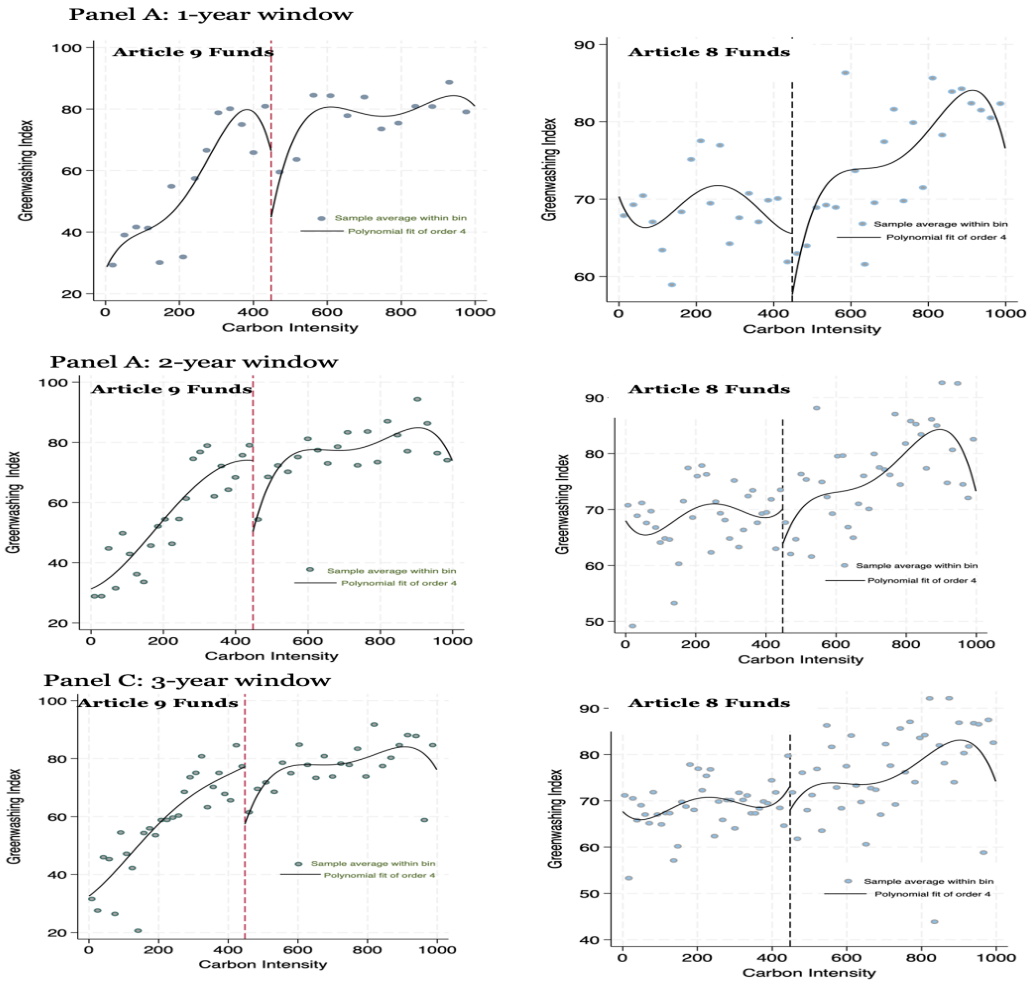


Figure 3.5: Articles 9 and 8 RD Plots.
This figure displays the plots of the density of the levels in the greenwashing index following the method in McCrary (2008). The x-axis is the distance (in carbon intensity) from the majority carbon intensity threshold. The solid line represents the fitted density function of the running variable. In Panel A we use 1-year window before and after introducing the SFDR. In Panel B we use a 2-year. In Panel C we use a 3 year. The left side represents Article 9 funds, and the right side represents Article 8 funds.

obtained from the bias-corrected and Robust methods. We run the analysis using 1-year, 2-year, and 3-year estimation windows post the introduction of the SFDR. For Article 9 funds, the estimated coefficient for the greenwashing index is negative and statistically significant. As reported in Panel A of Table 3.8, we estimate the regression using 1-year before and after the SFDR for Articles 9 and 8 funds. The odd columns (1)-(3) show the regression results without adding controls, while the even columns (2)-(4) show the results after adding them. The results show that there is a reduction in the level of the greenwashing index following the introduction of the SFDR. These findings indicate that

there are discontinuities surrounding the cutoff point between funds classified as Article 9 with carbon intensity below the cutoff point and funds classified as Article 6 with carbon intensity above the cutoff point. As shown in columns (1) and (2), the estimated coefficient is negative and significant under the conventional method. Furthermore, we estimate separate regressions on funds classified under Article 8. Columns (3) and (4) clearly show that the estimates are negative and statistically insignificant which indicates the Article 8 funds still engage in greenwashing practices. In other words, unlike Article 8 funds, Article 9 funds engage more in making a real impact on reducing carbon intensity in their portfolios and eliminating greenwashing practices by following SFDR guidelines. Similar conclusions are shown under the bias-corrected and robust methods. These results strongly indicate that the discontinuity in the greenwashing index is more concentrated in Article 9 than in Article 8 funds, indicating a difference in greenwashing between funds above and below the carbon intensity threshold.

In Panels B and C, we extend the estimated regression to measure the long-term impact on the greenwashing index. Importantly, we continue to find evidence of more discontinuity in the greenwashing index for Article 9 than for Article 8 funds. As shown in Panel B using a 2-year window and Panel C using a 3-year window, the estimated coefficients are still negative and significant for Article 9 funds. These coefficients confirm that funds classified as Article 9 decarbonise their portfolios more than funds classified as Article 8. The results show that the causal effects we have documented for Article 9 funds are robust. These results also confirm our findings from the DID analysis in Table 3.4, which indicates the SFDR indeed has a significant effect on the greenwashing index.

3.5 How do SFDR Funds Decarbonise their Portfolios?

In the previous section, we provide evidence that the SFDR has a significant impact on eliminating greenwashing practices as shown by the reduction in the levels of the greenwashing index especially among Article 9 funds compared to Article 8 funds. It is

crucial to understand better the mechanisms through which Article 9 funds adjust their portfolios to achieve the decarbonisation goals to adhere to the SFDR requirements. Based on the literature (e.g., Azar et al., 2021; Atta-Darkua et al., 2023; Jouvenot and Krueger, 2019), there are three main channels through which asset managers can influence the behaviour of a firm: Divestment of holdings, execution of voting rights, and active engagement with management. So, in this section, we examine the different channels that SFDR funds use to achieve portfolio decarbonisation.

3.5.1 Portfolio Tilting: Do SFDR Funds Decarbonise their Portfolio via Tilting?

Portfolio tilting is a strategy that asset managers can use to increase their portfolio's exposure to firms with lower carbon emissions. This exposure can be done by over- or under-weighting specific stocks or adjusting the portfolio's holdings based on their carbon emissions. However, it does not necessarily translate into making significant efforts to achieve carbon emission reduction. Instead, it is a way for investors to align their financial goals with their environmental values while potentially mitigating the risks associated with high carbon emissions. Atta-Darkua et al. (2023) document that investors who are signatories of the CDP and operate in a country that has an emissions scheme tend to reduce the carbon exposure of their portfolios primarily by adjusting the weights of their investments to favour firms with lower emissions, rather than through direct corporate engagement. So, in this section, to gauge how SFDR funds, especially Article 9 funds increase their exposure to low-emitting firms by using a portfolio tilting strategy, we adjust the "portfolio re-weighting" measure used in Atta-Darkua et al. (2023) to our context as shown in Eqs. 3.9 and 3.10.

Therefore, we conduct a regression analysis to examine whether portfolio tilting is affected by the SFDR. We first decompose our SFDR funds into two groups: the first group includes Article 9 funds as the treated group and funds classified as Article 6 and

Table 3.9: Results of Article 9 Funds Portfolio Tilting Analysis
This table presents the regression analyses of quarterly changes in the portfolio tilting strategy. The main independent variable of interest is SFDR that equals one for funds classified as Article 9 and equals zero for Article 6 and unclassified funds. Our regression controls for fund characteristics (fund size, fund total return, fund flows, and expense ratio) and portfolio characteristics (market cap, price-to-book, revenues, enterprise value, and turnover ratio). All the definitions of variables are provided in Table 3.2. Panel A (B) shows the result of portfolio tilting based on the measure of carbon emission (carbon intensity). The odds columns (1)-(9) represent the results without control variables, while the even columns (2)-(10) show those with control variables. Our regression analysis includes high-dimension quarter fixed effects, and standard errors are clustered at the geographical focus and quarter date. t-statistics are reported in parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Portfolio Tilting (carbon emission)										
	CO2 Scope1		CO2 Scope2		CO2 Scope3		CO2 Scope1,2		CO2 Scope1,2,3	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SFDR	-0.10***	-0.09**	-0.09***	-0.08***	-0.09***	-0.10***	-0.10***	-0.09**	-0.13***	-0.12***
	(-2.93)	(-2.56)	(-2.68)	(-2.71)	(-3.84)	(-3.59)	(-2.95)	(-2.84)	(-5.28)	(-5.03)
Fund characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Portfolio characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,271	7,769	10,074	9,491	9,238	8,694	9,067	8,531	9,320	8,773
R-squared	0.06	0.07	0.09	0.10	0.07	0.08	0.06	0.07	0.07	0.09
Panel B: Portfolio Tilting (carbon intensity)										
	CO2 Scope1		CO2 Scope2		CO2 Scope3		CO2 Scope1,2		CO2 Scope1,2,3	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SFDR	-0.14***	-0.12***	-0.17***	-0.14***	-0.10*	-0.09*	-0.14***	-0.11***	-0.23***	-0.22***
	(-3.98)	(-3.36)	(-4.45)	(-3.82)	(-1.94)	(-1.74)	(-3.47)	(-3.19)	(-4.27)	(-3.97)
Fund characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Portfolio characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,407	6,020	7,286	6,841	7,610	7,148	6,579	6,169	6,467	6,080
R-squared	0.04	0.05	0.06	0.07	0.05	0.06	0.04	0.05	0.21	0.23

unclassified funds as the control group. The second group includes Article 8 funds as the treated group and Article 6 and unclassified funds as the control group. We then create a dummy variable (SFDR) that equals one if the fund belongs to the treated group and zero if it belongs to the control group. In our regression analysis, we include high-dimension time fixed effects and controls for portfolio and fund-level characteristics that are potentially related to portfolio tilting. Also, we use double clustering to estimate standard errors considering geographical focus and quarter dates. This clustering allows us to consider the potential heterogeneity and clustering of data within both a geographical focus and specific periods.

Table 3.9 shows how SFDR funds tilt their portfolios by adjusting the weights of their holdings while the carbon emission metrics are kept at the same levels without changing.

We calculate the portfolio tilting measures based on five carbon emission metrics: CO2 Scope 1, CO2 Scope 2, CO2 Scope 3, CO2 Scope 1-2, and CO2 Scope 1-3. The odd columns (1)-(9) show the regression results without controls, while the even columns (2)-(10) show the results with controls. Panel A shows that the strategy of rebalancing portfolio weights is a key method for Article 9 funds to decarbonise their portfolios. This is shown by the negative and significant coefficient for the dummy variable SFDR across all specifications and carbon emissions measures relative to Article 6 and unclassified funds. This result confirms that portfolio tilting is most noticeable among Article 9 funds. This result confirms that SFDR funds comply with the requirements of the SFDR mostly by tilting their portfolios away from stocks with high carbon emissions. In Panel B, we estimate the portfolio tilting based on carbon intensity metrics. The results indicate that Article 9 funds decarbonise 14.7% to 22.3% more than Article 6 and unclassified funds by adjusting portfolio weights to decrease their exposure to high carbon-emitting firms.

The results in Table 3.9 confirm that Article 9 funds effectively decarbonise their portfolios by reallocating their portfolio weights toward low-emission stocks; a strategy not observed in Article 8 funds, as detailed in Table 3.10. Article 8 funds show no significant shift toward firms with low carbon emissions as highlighted by the consistently positive coefficient for the dummy variable SFDR across all specifications and measures of carbon emissions (Panel A) and carbon intensity (Panel B). There are different considerations in interpreting why Article 9 funds decarbonise their portfolios via a tilting approach. First, Article 9 funds may need to reallocate their portfolios to accurately reflect and report their carbon exposure and emissions to ensure adherence to the SFDR requirements. Second, aiming to enhance sustainability performance may motivate adjusting emission weights in portfolios. Funds can improve their environmental credentials and appeal to investors seeking more sustainable investment options by reallocating to firms or sectors with lower carbon emissions or those actively working on carbon reduction initiatives rather than pushing firms to improve emissions. Furthermore, SFDR funds may reallocate their portfolios to mitigate climate-related risks and preserve long-term

Table 3.10: Results of Article 8 funds Portfolio Tilting Analysis
This table presents the regression analyses of quarterly changes in the portfolio tilting strategy. The main independent variable of interest is SFDR that equals one for funds classified as Article 8 and equals zero for Article 6 and unclassified funds. Our regression controls for fund characteristics (fund size, fund total return, fund flows, and expense ratio) and portfolio characteristics (market cap, price-to-book, revenues, enterprise value, and turnover ratio). All the definitions of variables are provided in Table 3.2. Panel A (B) shows the result of portfolio tilting based on the measure of carbon emission (carbon intensity). The odds columns (1)-(9) represent the results without control variables, while the even columns (2)-(10) show those with control variables. Our regression analysis includes high-dimension quarter fixed effects, and standard errors are clustered at the geographical focus and quarter date. t-statistics are reported in parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Portfolio Tilting (carbon emissions)										
	CO2 Scope1		CO2 Scope2		CO2 Scope3		CO2 Scope1,2		CO2 Scope1,2,3	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SFDR	0.09**	0.05	0.01	-0.00	0.04	-0.00	0.06	0.02	0.08**	0.03
	(2.10)	(1.08)	(0.44)	(-0.02)	(1.33)	(-0.06)	(1.27)	(0.54)	(2.13)	(1.01)
Fund characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Portfolio characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,012	6,573	8,564	8,045	7,831	7,351	7,678	7,208	7,885	7,404
R-squared	0.06	0.07	0.08	0.10	0.06	0.08	0.06	0.07	0.07	0.08
Panel B: Portfolio Tilting (carbon intensity)										
	CO2 scope1		CO2 scope2		CO2 Scope3		CO2 Scope1,2		CO2 Scope1,2,3	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SFDR	0.12**	0.09*	0.05	0.03	0.00	-0.03	0.10**	0.08*	0.03	0.01
	(2.41)	(1.85)	(1.06)	(0.76)	(0.03)	(-0.79)	(2.16)	(1.85)	(0.58)	(0.24)
Fund characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Portfolio characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,491	5,151	6,209	5,817	6,458	6,055	5,616	5,254	5,486	5,150
R-squared	0.04	0.06	0.06	0.07	0.05	0.07	0.05	0.06	0.21	0.23

value. Firms with high carbon exposure could face regulatory, reputation, and financial risks, as the planet moves to a low-carbon economy. Consistent with this, Becht et al. (2023) find that divestment effectively impacts changes toward net-zero and encourages asset managers to decarbonise their portfolios to promote change in social preferences. Considering these arguments, it can be suggested that portfolio tilting is expected to dominate the decarbonisation efforts of Article 9 funds.

3.5.2 Divestment: Do SFDR Funds Divest from Carbon-Intensive Stocks?

An alternative mechanism for SFDR funds to decarbonise their portfolios is through a divestment strategy. Divestment strategies can influence firms' behaviour by increasing the cost of capital for firms that are not making sufficient progress on reducing their carbon emissions, thereby incentivising them to adopt more sustainable operating models. Article 9 funds are expected to achieve a tangible impact leading them to have incentives to improve their holdings to be more sustainable compared to Article 8 funds. Consequently, we expect that Article 9 funds will change their portfolios more significantly by shifting their investments toward stocks with lower carbon intensity relative to other types of SFDR funds.

To formally test how Article 9 funds change their trading decisions toward decarbonisation, we run the following DID regression analysis of the position change of stock j by fund i in quarter t.

$$Position\ Change_{i,j,t} = \alpha_0 + \beta_1 CI\_Indicator_j + \beta_2 CI\_Indicator_j * Post_t + \beta_3 controls_{i,t-1} + \varepsilon_{j,i,t} \tag{3.14}$$

where $Position\ Change_{i,j,t}$ denotes the dependent variable measured as the change in the position of stock j held by fund i in quarter t. We use two versions of the $CI\_Indicator_j$. The first is $High\ CI_j$ that is defined as a dummy variable that equals one for stocks with a carbon intensity $\geq 75^{th}$ percentile in the entire universe of stocks with available carbon intensity data during the specific quarter and zero otherwise. The second is $Low\ CI_j$ defined as a dummy variable that equals ones for stocks with a carbon intensity $< 25^{th}$ percentile in the entire universe of stocks with available carbon intensity data during the specific quarter and zero otherwise. *Post* is a dummy variable that equals one for the eight quarters post the introduction of the SFDR and zero for the preceding eight quarters. Our regression controls for portfolio and fund-level characteristics that are

potentially related to a stock's carbon intensity. We include fund size, age, expense ratio, fund flows, portfolio size, turnover ratio, price to market, market cap, revenues, and total return. All these variables are lagged to reduce endogeneity issues. In addition, we use high-dimension quarter fixed effects, and standard errors are clustered at the geographical focus, domicile, and quarter date.

The results in Table 3.11 show that the coefficient for the variable of interest $HighCI * Post$ is significantly negative for Article 9 funds. This indicates that post the introduction of the SFDR, Article 9 funds reduced their exposure to carbon-intensive firms in their portfolios. As seen in columns (3) and (4), Article 9 funds sell relatively more stocks with high carbon intensity post the introduction of the SFDR. While in columns (5) and (6) we do not observe any significant change in position for Article 8 fund portfolios that indicates these funds continue to hold higher carbon intensity stocks even after the SFDR came into effect. Overall, the results provide strong evidence that Article 9 funds have strong incentives to decarbonise their portfolios by divesting away from carbon-intensive firms after being classified as impact funds. In contrast, Article 8 funds do not show any significant change in carbon intensity among firms in their portfolios.

In Panel B, we adjust our approach by using $Low\ CI_j$ as the carbon intensity indicator. The results show that Article 9 funds not only divest from stocks with high carbon intensity but also invest in stocks with low-carbon intensity post-SFDR. This position change is marked by a significantly positive coefficient for the interaction term for Article 9 funds, as shown in columns 3 and 4 which signifies an increased allocation to lower carbon intensity firms. In contrast, when we examine the investment behaviours of Article 8 funds, the results confirm that these funds do not follow the same strategy, unlike Article 9 funds. Article 8 funds are divesting from low carbon intensity stocks, opting not to reposition their portfolios toward more environmentally sustainable investments (see columns 5 and 6 in Panel B). These results underscore the distinct investment responses of Articles 9 and 8 funds to the SFDR. While Article 9 funds embrace a low-carbon

Table 3.11: SFDR Funds Divestment from Carbon-Intensive Stocks
This table presents the DID regression analyses of quarterly position change in the carbon intensity of holdings. In Panel A, we define an indicator $High\ CI_j$ as a dummy variable that equals one for stocks with a carbon intensity $\geq 75^{th}$ percentile of the universe of stocks with available carbon intensity data during the specific quarter and zero otherwise. In Panel B, we define an indicator $Low\ CI_j$ as a dummy variable that equals one for stocks with a carbon intensity $< 25^{th}$ percentile of the universe of stocks with available carbon intensity data during the specific quarter and zero otherwise. *Post* is a dummy variable that equals one for the eight quarters post the introduction of SFDR and zero for the preceding eight quarters. The sample includes all SFDR funds in columns (1) and (2), Article 9 funds are in columns (3) and (4), and Article 8 funds are in columns (5) and (6). The odd columns (1)-(5) represent the results without control variables, while the even columns (2)-(6) show those with control variables. Our regression controls for lagged fund characteristics (fund size, fund total return, fund flows, and expense ratio) and lagged portfolio characteristics (market cap, price-to-book, revenues, enterprise value, and turnover ratio). All the definitions of the variables are provided in Table 3.2. Our regression analysis includes high-dimension quarter and country fixed effects, and standard errors are clustered at the geographical focus, domicile, and quarter date. t-statistics are reported in parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Panel A: Indicators for high carbon-intensive stocks						
Position Change						
	All Funds		Article 9		Article 8	
	(1)	(2)	(3)	(4)	(5)	(6)
High CI	2.20*	2.53*	-0.02**	0.03	-0.04	-0.01
	(1.97)	(1.88)	(-2.36)	(0.15)	(-0.68)	(-0.18)
High CI*Post	2.51*	2.76	-3.21***	-3.23***	0.09	0.03
	(1.96)	(0.99)	(-5.57)	(-3.68)	(1.28)	(0.3)
Observations	395,383	393,264	80,376	80,302	218,859	218,466
R-squared	0.37	0.44	0.01	0.01	0.08	0.08
Controls	No	Yes	No	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: Indicators for low carbon-intensive stocks						
Position Change						
	All Funds		Article 9		Article 8	
	(1)	(2)	(3)	(4)	(5)	(6)
Low CI	-1.67	-1.90	0.092*	0.16*	-0.16	-0.19
	(-1.35)	(-1.17)	(1.88)	(1.81)	(-1.35)	(-0.78)
Low CI*Post	-1.83	-1.35	0.73**	0.62*	-0.11*	-0.054
	(-1.37)	(-0.82)	(2.02)	(1.73)	(-1.67)	(-1.29)
Observations	395,383	393,264	80,376	80,302	218,859	218,466
R-squared	0.37	0.44	0.01	0.02	0.08	0.09
Controls	No	Yes	No	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes

investment strategy, Article 8 funds do not demonstrate the same commitment to lowering carbon intensity in their portfolios.

Overall, Table 3.11 shows that following the introduction of the SFDR, Article 9 funds changed their investment strategies toward low carbon-intensive firms. This decarbonisation is achieved by the acquisition of shares in firms with low carbon intensity and the divestment from those with high carbon intensity. Such changes in investment behaviour strongly support our conjecture that Article 9 funds actively contribute to impactful investing. This behaviour not only aligns with investors' expectations, who increasingly seek investments that reflect their ethical concerns on environmental issues, but also moves capital toward more sustainable firms. Our findings are consistent with the recent literature (e.g., Ceccarelli et al., 2024; Gantchev et al., 2022; Rohleder et al., 2022) that document that institutional investors divest their portfolios of firms with high carbon emissions. Importantly, our results further solidify the argument that the more effort the fund makes to decarbonise its portfolio, the less likely it is to engage in greenwashing practices. This result validates our findings in Table 3.4 that Article 9 funds significantly reduce greenwashing practices in their portfolios to adhere to the requirements of the SFDR.

3.6 Conclusion

In this paper, we propose a novel measure to capture greenwashing by SFDR funds that we call the greenwashing index. We uniquely use a DID with a quasi-natural experiment to examine its effect on greenwashing. Our findings confirm a significant effect of the SFDR on greenwashing, particularly for Article 9 funds. We find evidence that Article 9 funds respond more positively to the SFDR than Article 8 funds indicating a reduction in their level of greenwashing index post the introduction of the SFDR. In addition, the results support the conjecture that the higher the effort made by the fund to decarbonise its portfolio, the lower its level of the greenwashing index. Moreover, the results give a strong indication that the discontinuity in the greenwashing index is more concentrated in Article 9 than in Article 8 funds, which indicates a difference in greenwashing behaviour between the different categories of SFDR funds. We also find that tilting and changing position strategies are key methods for Article 9 funds to decarbonise their portfolios.

Our paper significantly enriches the evolving field of literature on mandatory disclosure regulations with several key contributions. First, we offer compelling evidence based on actual outcomes by uniquely examining a sample of SFDR funds that prioritise environmental issues. We achieve this evidence by focusing on a fund's carbon intensity that is based on its holdings' reported carbon emissions. This approach provides a robust measure of the genuine efforts by SFDR funds, particularly those classified under Article 9, to fulfil their commitments to generating a tangible impact. Second, our findings support the idea that funds focused on impact (Article 9) demonstrate lower levels of greenwashing in their portfolios. This insight underscores the effectiveness of the SFDR criteria in distinguishing between various financial products that comply with disclosure requirements. It highlights how these criteria distinguish between funds that are truly aligned with decarbonisation and investor preferences for impact generation (Article 9) and those that merely integrate environmental or social criteria (Article 8). Third, our research design allows us to explore the behavioural differences between SFDR funds.

We observe that post-SFDR, Article 9 funds have shown a positive response by actively maintaining portfolios with lower carbon intensity and shifting their investments toward firms with lower carbon footprints as compared to Article 8 funds. This behaviour indicates a proactive adaptation to the regulation, reinforcing the role of Article 9 funds in leading decarbonisation efforts within the financial sector.

The findings of our study carry significant implications for supervisors, policymakers, and investors. For supervisors, the regulation introduces a new frontier of oversight in which they ensure that financial entities not only comply with disclosure requirements but also accurately reflect the sustainability risks and impacts in their investment decisions. This new frontier underscores the critical role of supervisors in enhancing transparency and integrity within the financial sector, thereby facilitating a more informed and responsible approach to sustainable investment. For investors, our results demonstrate that Article 9 funds react positively to the regulation and, therefore, lower greenwashing in their portfolios. This regulation empowers investors by producing better information that enables them to discern between truly sustainable investments and those that are merely marketed as such, that is, subject to greenwashing. As investors deepen their sophistication regarding sustainability issues, their preferences are becoming more nuanced, prioritizing financial returns and positive sustainable impact. This shift could lead to a reallocation of capital toward more sustainable investing, potentially influencing firms' behaviour toward greater sustainability. For policymakers, the SFDR represents a critical tool in the broader strategy to channel capital flows toward sustainable economic activities, supporting the transition to a low-carbon, more sustainable economy. It offers a concrete step toward the ultimate goal of the European Green Deal and the achievement of the Sustainable Development Goals (SDGs). Our findings shed light on the effectiveness of the SFDR and its implications for achieving net-zero carbon emissions, improving market efficiency, reducing information asymmetry, and fostering investors' confidence in sustainable investing.

Chapter 4

Herding in Sustainable Investing: The Role of Regulations

Chapter 4: Herding in Sustainable Investing: The Role of Regulations

Abstract

This paper examines the impact of sustainability-related regulations on herding behaviour by equity mutual funds. We use a difference-in-differences setting to examine the change in herding behaviour following the enactment of the Sustainable Finance Disclosure Regulation (SFDR) in the EU. The results confirm that herding among SFDR funds is substantially lower post the regulation. Notably, Article 9 funds experience a decline in the herding level relative to a control group of unclassified funds. Further, Article 8 and 6 funds experience an insignificant decline in their level of herding relative to the same control group. Our findings indicate the effectiveness of the regulation on reducing asymmetric information as shown by the positive response of Article 9 funds to the mandatory SFDR requirements by reducing their herding relative to Article 8 & 6 funds which are subject to less stringent requirements.

Keywords: SFDR regulation, Herding measure, Trading behaviour, Information asymmetry

JEL Classification: G10,G11,G14

4.1 Introduction

Sustainable investing has gained substantial traction over recent years, driven by increased transparency about asset managers' portfolios. However, although transparency is often advocated as a means to influence capital allocation towards sustainable investments, it is worth noting that the incentives of investors interested in sustainable investments are not solely determined by transparency. These incentives are shaped by how investors balance sustainability and performance, which is influenced by their preferences and attentiveness to these objectives (Gantchev et al., 2024). In addition, the growing investor interest in environmental, social, and governance (ESG) issues has been hampered by emerging complexities in distinguishing genuinely sustainable investments from those that superficially claim sustainability impact (Kim and Yoon, 2023; Curtis et al., 2021; Starks, 2023). As a result, this dynamic can lead to *herding* behaviour when certain sustainability trends gain popularity resulting in a risk that both investors and asset managers follow these trends without thoroughly assessing their long-term sustainability impact.

Herding occurs when institutional investors mimic the actions of others and move in and out of the same securities at the same time rather than relying on independent analysis, which leads to market distortions (e.g., Choi and Sias, 2009; Sias, 2004). In the context of sustainable finance, numerous funds seem to have simultaneously adjusted their portfolios to align with sustainability criteria (e.g., Kim and Yoon, 2023; Lowry et al., 2023; Berg et al., 2022). Herding can result in collective movements towards certain "green" stocks or sectors perceived as sustainable, regardless of their fundamental value. Such behaviour can inflate valuations and create bubbles, undermining both the efficient allocation of capital and sustainability goals.

This paper examines the impact of mandatory disclosure requirements on herding behaviour among investment funds. By using the introduction of the Sustainable Finance

Disclosure Regulation (SFDR) in the European Union (EU) financial markets as a quasi-natural experiment, we assess whether the implementation of the SFDR effectively mitigates the tendency of investment funds to engage in herding behaviour.[39] In particular, we test whether Articles 9, 8, and 6 funds change their trading behaviour post the introduction of the SFDR relative to unclassified funds.[40]

Using a comprehensive dataset on the SFDR funds' holdings, we thoroughly analyse the herding behaviour of SFDR funds in EU stocks. First, we estimate the magnitude of SFDR herding based on the widely used measure "LSV" introduced by Lakonishok et al. (1992). Importantly, we conduct our analyses separately for three different SFDR fund types including Articles 9, 8, and 6. This helps us better understand the implications of herding because SFDR funds' behaviours may differ due to being subject to different regulation constraints. As such, we compare the trading behaviours and prevalence of herding across these funds.

We start our empirical analysis by exploring how the EU regulation affects SFDR funds' herding behaviour. In a difference-in-differences *(DID)* design we measure the change in the herding level by Article 9, 8, and 6 funds before and after implementing the SFDR. The results confirm that SFDR funds herding is substantially lower post the regulation. Notably, Article 9 funds experience a decline in the herding level relative to a control group of unclassified funds that are not subject to the regulation. Further, Articles 8, and 6 funds experience an insignificant increase in herding levels compared to the same control group. Our findings indicate that Article 9 funds respond more positively to the mandatory SFDR with a lower tendency to herd than Article 8 and 6 funds. This reduction means a more disciplined approach to investing, consistent with the stringent sustainability objectives these funds are required to meet. While herding among Article

[39]For further details on the SFDR please see https://eur-lex.europa.eu/eli/reg/2019/2088/oj

[40]The SFDR classifies financial products into three main categories based on their sustainability characteristics and objectives. Article 9 funds are referred to as " dark green" funds, and they aim to achieve a positive social or environmental impact alongside financial returns. Article 8 funds are known as "light green" funds; these products must integrate ESG factors into their investment decisions and consider the sustainability impact of their investments. Article 6 funds which focus on financial products and do not integrate any sustainability considerations into their investment decisions.

8 and 6 funds is notably more. These findings suggest that the impact of SFDR varies across different fund types, reflecting the differential trading behaviour in light of the sustainability commitments required by each fund group.

We conduct several additional tests to help draw inferences from the changes in herding behaviour of SFDR funds. First, to validate our empirical findings, we examine the parallel trends in herding measures between the treated and control groups. The results verify that prior to the regulation, the herding measure for Articles 9, 8, and 6 have parallel trends. Second, we employ a Propensity Score Matching Difference-in-Differences (PSM-DID) approach to address any concerns regarding heterogeneity in the treatment effect. Additionally, we conduct a placebo test where the pre-period is set to three years before the regulation. We find that the observed changes in herding measure can be attributed to the regulation rather than pre-existing trends. Third, we examine the long-term impact by extending the post-regulation window to 3 and 5-year rather than one year, as some funds may take longer time to adjust their strategies in response to new regulations. The results show that in both the short and long term, there is no evidence that Article 9 funds exhibit herding behaviour following the introduction of the SFDR regulation.

In addition, we examine how stock characteristics influence the herding behaviour of SFDR funds, focusing on subgroups of stocks based on size and ESG score. First, our findings reveal that herding levels vary significantly based on the stock size. Notably, we observe a more pronounced reduction in herding among small-cap stocks, particularly on the sell side, for Article 9 funds compared to Article 8 and 6 funds. Second, we examine how funds reallocate their portfolios in response to ESG considerations. We find that Article 9 funds reduce their herding in both purchases and sales of stocks with high ESG scores relative to unclassified funds. Also, Article 9 funds reduce herding in selling brown stocks with low ESG scores, possibly to avoid reputational risks and to comply with the stricter sustainability standards introduced by the SFDR. The results of Article 8 display that sell herding decreases slightly for stocks with low ESG scores, while buy herding significantly increases for those with mid and high ESG scores. This indicates more varied

herding in Article 8 funds than in Article 9 funds. In addition, Article 6 funds show mixed herding patterns, with an insignificant reduction in sell herding for stocks in the low ESG quantiles and no clear trend across other quantiles. Overall, the evidence shows that the herding behaviour of funds is strongly influenced by the SFDR classification and the ESG characteristics of their portfolios, highlighting the role of regulatory stringency in shaping investor behaviour.

This paper contributes to the literature on asset managers' herding behaviour. Prior research approaches this topic in varied contexts. For example, Lakonishok et al. (1992) and Wermers (1999) find no herding in average stocks but significantly higher levels in small stocks. Choi and Skiba (2015) provide evidence that institutional investors herd more in highly transparent markets due to correlated signals from fundamental information, resulting in faster price adjustments. Brown et al. (2014) show that career-concerned managers are more likely to herd on negative stocks due to the higher reputations and litigation risks associated with holding underperforming stocks. Cui et al. (2019) indicate that closed-end fund investors exhibit significant herding, primarily driven by non-fundamental factors and that this herding increases during economic and market uncertainty, especially after 2007. While Jiang and Verardo (2018) propose a dynamic measure of fund-level herding, revealing a negative relationship between herding behaviour and skill in the mutual fund industry. Our study engages with this important debate by examining how the SFDR regulation influences herding behaviour, specifically in the context of sustainable investing. This focus shifts the analysis from traditional stock price-based measurements to exploring how herding manifests in sustainability-focused investments. Previous research has predominantly centered on understanding herding dynamics through the lens of stock price movements, leaving a significant gap in the exploration of herding in ESG-oriented investments. By analysing herding behaviour among investors who prioritize environmental, social, and governance criteria, our study broadens the scope of herding behaviour analysis. It provides valuable insights into the decision-making processes of investors interested in sustainability. This novel approach

enriches the existing body of knowledge and offers a more comprehensive understanding of herding behaviour in the realm of sustainable investing.

Our paper also contributes to the recent literature that examines the real impact of mandatory disclosure regulations for sustainability (e.g., Dai et al., 2023; Becker et al., 2022; Rannou et al., 2022; Lambillon and Chesney, 2023; Cremasco and Boni, 2022; Scheitza and Busch, 2023; Bengo et al., 2022). Ferrarini and Siri (2023) investigate how the SFDR encourages institutional investors to integrate ESG factors into their investment strategies and how asset managers choose and classify investments according to sustainability standards. Becker et al. (2022) find that the SFDR has driven mutual funds in the EU increasing their ESG initiatives and sustainability ratings and resulting in a higher influx of sustainable investments. Scheitza and Busch (2023) demonstrate that only one-third of impact funds adhere to genuine investment criteria, with private equity and debt funds being more likely to meet these standards than public equity funds. Gavrilakis and Floros (2023) find evidence that ESG funds exhibited herding behaviour in the EU market during the COVID-19 pandemic. Building on these insights, our research strengthens this link by providing compelling evidence on the SFDR efficacy in reducing herding behaviour. This paper is one of the first studies to exploit a quasi-exogenous shock to examine the impact of the SFDR on herding behaviour by measuring the change in a herding measure before and after implementing the new regulation. Specifically, we investigate whether Articles 9, 8, and 6 funds have altered their trading behaviour post-SFDR relative to other funds, hence providing compelling evidence of the regulation's impact.

The remainder of this paper is organized as follows: Section 4.2 presents the literature review. In Section 4.3, we describe the data set and variables. We examine the impact of SFDR on herding behaviour and provide the results of robustness tests in Section 4.4. In Section 4.5 we investigate how stock characteristics influence the herding behaviour of SFDR funds. Section 4.6 provides the conclusion.

4.2 Literature Review

Information asymmetry is a critical concept in financial markets, where one party holds more or better information than others, leading to imbalances in decision-making. In the context of sustainable investing, information asymmetry is particularly pronounced due to the lack of standardised ESG data and inconsistent sustainability reporting. Investors often struggle to assess the true environmental, social, and governance (ESG) performance of companies because disclosures can be selective or incomplete, contributing to the risk of greenwashing (e.g., Chatterji et al., 2016; Dimson et al., 2020; Christensen et al., 2022; Gangi et al., 2022; Semenova and Hassel, 2015; Gibson Brandon et al., 2021; Berg et al., 2022). This uncertainty can lead to inefficiencies in capital allocation, as investors may misinterpret the sustainability credentials of financial products. Such an environment where information asymmetry prevails and a lack of mandatory regulations allows for institutional investors to engage in herding behaviour, and asset managers just follow the trend and misrepresent their commitment to sustainable investing.

From a theoretical perspective, herding is identified as a phenomenon where investors neglect their unique signals or fundamental information and instead choose to mimic their peers' trading patterns (Hirshleifer and Hong Teoh, 2003). Herding behaviour can be intentional or unintentional. Information cascades play a pivotal role in driving herding behaviour in financial markets; this occurs when investors, in the absence of strong personal convictions or information, follow the actions of previous investors (Bikhchandani et al., 1992; Banerjee, 1992). Asset managers and investors might herd to protect their reputation. By following the crowd, they ensure that if an investment performs poorly, they won't be singled out because their peers made the same decision. Scharfstein and Stein (1990) document that asset managers could be involved in herding behaviour due to reputation concerns. In addition, when the goals of investors (principals) and fund managers (agents) are not aligned, managers might engage in herding to minimise their risk, aligning their actions with the majority to avoid underperformance. Similarly, Sias

(2004) finds that US institutions exhibit greater herding behaviour in small securities and concludes that informational cascades provide the best explanation for institutional herding.

Fund managers frequently experience pressure to align their investment strategies with the perceived preferences of their principals. This pressure can lead to herding behaviour, where managers replicate each other's sustainable investment approaches to conform with sustainability trends and reassure their investors. Recent studies indicate that the growing availability of sustainability ratings around sustainable investing also decreases companies' incentives to enhance their ESG performance (e.g., Berg et al., 2022; Gibson Brandon et al., 2021). Such herding behaviour may lead asset managers to unintentionally show overinvestment in sustainability criteria to attract flow from investors. Li and Wang (2022) find that firms mimic the behaviour of their peers, driven primarily by incentives to secure financing, suggesting that they replicate unethical practices to enhance their CSR performance. Similarly, Borghesi et al. (2014) argues that shareholders engage in CSR activities just for personal benefits rather than act in the principal's best interests.

The practice of herding emerges as a critical phenomenon that significantly shapes the trading behaviour of institutional investors. Choe et al. (1999) find evidence that foreign investors exhibited strong positive feedback trading and herding behaviour before Korea's economic crisis. Hudson et al. (2020) show that fund managers exhibit herding behaviour around the market portfolio, which is influenced by investor sentiment. Also, Koch (2017) find that leader funds consistently lead the mutual fund industry's trades, showing informed trading and outperforming, while managers who trade together don't perform better, suggesting that leader fund managers receive early private signals. This behaviour can lead to correlated trading, increased market volatility, and asset price distortions. Cai et al. (2019) show that sell herding is stronger and more persistent than buy herding, causing temporary but significant price distortions, especially for small and illiquid bonds during financial crises. Additionally, Nofsinger and Sias (1999) document

a robust positive correlation between changes in herding behaviour and stock return momentum.

In the context of sustainable investing, fund herding is driven by the inherent challenges of evaluating sustainability criteria. Investors often face informational asymmetry and limited data when assessing firms' sustainability practices, leading them to adjust their investment choices according to peers' strategies. This herding behaviour relies on informational cascades, which prompt fund managers to emulate these trends to protect their reputations and meet increasing client expectations for responsible investing. However, this collective approach risks overvaluing certain sectors while neglecting others with strong but less visible sustainability credentials. Therefore, while herding can steer capital toward positive environmental and social impacts, investors must complement these signals with thorough analysis, ensuring that ESG compliance also aligns with sound financial performance. The empirical evidence supports this view. For example, Przychodzen et al. (2016) find that mutual funds integrate ESG considerations to mitigate reputation risk, a behaviour influenced by herding rather than creating sustainability impact. Deng et al. (2018) show that mutual fund herding is linked to an inadequate information environment and poor disclosure quality. Also, Saeed et al. (2024) find that firms commonly adopt mimicking behaviour to enhance market reputation and improve their sustainability performance.

Recently, sustainability regulations shifted toward imposing mandatory disclosure requirements on institutional markets. This is expected to have a more substantial effect on reducing asymmetric information. However, asset managers still misrepresent the integration of sustainability in their investment objectives and herd toward ESG investing to remain compliant with sustainability trends and attract capital. Benz et al. (2020) find indications of decarbonisation herding among mutual and hedge funds. Wang (2023) provides evidence of a divergence in ESG performance among EU banks, driven by herding behaviour among banks with lower ROE and leverage towards improving sustainability criteria in their prospectus. Similarly, herding towards carbon neutrality is noticeable in

the Chinese stock market, particularly during periods of market stress (Shi et al., 2024). Additionally, European ESG leaders' portfolios, biased towards stocks with strong profitability, generated significant negative alphas and exhibited tilts towards volatility and herding bias (Gavrilakis and Floros, 2024). Consequently, while sustainability disclosures aim to enhance transparency and accountability, the presence of herding behaviour can undermine their effectiveness and obscure the actual sustainability performance.

As a result of the limitation of existing sustainability regulations, on November 27, 2019, the European Parliament and the Council introduced the EU 2019/2088 Sustainable Finance Disclosure Regulation (SFDR) to regulate sustainability-related disclosures in the financial services sector, which came into effect on March 10, 2021. The SFDR's main objective is to foster sustainable investing in the financial sector by elevating disclosure requirements from voluntary to mandatory for market participants. The regulation aims to reduce information asymmetries and combat greenwashing in sustainable investing by ensuring a systematic, transparent, and consistent approach to sustainability in financial markets, thereby facilitating informed investment decisions that align with environmental, social, and governance (ESG) criteria. This regulation is instrumental in driving the shift towards more sustainable financial practices by ensuring that investors have access to consistent and reliable information.[41] The SFDR identifies a specific classification of funds to guide financial institutions in reporting about their sustainable investments. The main categories under this classification are known as Articles 9, 8, and 6 funds. Article 9 funds refer to impact-generating investments with a clear and measurable sustainable investment objective. These funds must disclose specific sustainability indicators used to measure their environmental performance, such as their decarbonisation efforts (Busch et al., 2022). Impact-aligned investments labelled as Article 8 funds must disclose how they integrate sustainability factors into their investment process, even if they primarily

[41] According to the SFDR (2019), "the Regulation aims to reduce information asymmetries in principal-agent relationships about the integration of sustainability risks, the consideration of adverse sustainability impacts, the promotion of environmental or social characteristics, and sustainable investment, by requiring financial market participants and financial advisers to make pre-contractual and ongoing disclosures to end investors when they act as agents of those end investors (principals)." (OJ L 317, 9.12.2019, p. 3).

focus on financial objectives. Exclusion-focused investments are known as Article 6 funds and are required to provide only minimal sustainability disclosures.

Despite the SFDR's significance, only a limited number of empirical studies have focused on its implications and effectiveness. Becker et al. (2022) find that the SFDR has a positive impact on the sustainability practices of EU mutual funds. Cremasco and Boni (2022) investigate the alignment of investment funds with the SFDR and uncover a 'category fuzziness' in distinguishing sustainability attributes among different SFDR fund categories. However, Scheitza and Busch (2023) show no significant differences between impact-focused funds like Article 9 and ESG-focused funds. Nevertheless, there is limited research on the SFDR's effectiveness in mitigating herding behaviour within financial markets. Understanding whether SFDR's disclosure requirements reduce such behaviour is crucial. Empirical studies are needed to assess if increased transparency and accountability lead to more diversified investment decisions, thereby stabilizing markets and promoting genuine sustainability or exhibiting herding behaviour. We extend that research by examining the SFDR's impact on fund herding. Specifically, we examine how various fund categories, such as Article 9, 8, and 6 funds, react differently to the SFDR's criteria in terms of their investment objectives and trading behaviour.

4.3 Data

This section provides details on the data sample, the variable, and summary statistics.

4.3.1 Mutual Fund Data

We obtain monthly data on both active and inactive EU equity mutual funds from the Refinitiv database. We include actively-managed open-end equity mutual funds; therefore, we exclude ETFs and passive mutual funds. Other types of funds, such as bond, money market, hedge, and pension funds are not examined. Based on these criteria, our

sample consists of a total of 4,800 EU equity mutual funds. The data sample spans from 2016-Q1 to 2024-Q1. We extract the following monthly data: Net asset value (NAV), total net assets (TNA), expense ratio, and turnover, along with fund characteristics data such as Lipper RIC, inception date, ISIN code, domicile, asset status, asset type, investment style, and investment objectives.

SFDR classification: we collect the SFDR classification from the Refinitiv database on 25 April 2024. Refinitiv offers comprehensive coverage of SFDR-related metrics including the SFDR classification for each EU mutual fund. The SFDR introduces disclosure standards for the financial market. It imposes mandatory ESG disclosure obligations and requires asset managers to classify investment products based on sustainability criteria. According to the SFDR regulations, there are three primary types of funds: Articles 6, 8, and 9. In line with this classification, asset managers are obligated to self-classify investment products based on sustainability criteria.

4.3.2 Fund Holdings Data

Each mutual fund represents a portfolio composed of several stock holdings in which the fund invests. We obtain the quarterly holdings data for all funds in our sample throughout the sample period from the Refinitiv database, which provides detailed information such as the number of shares in the fund's portfolio, and holding value. The number of holdings refers to the total count of individual securities or assets held in a fund's portfolio. We require funds to have at least 10 stock holdings in a given quarter to be considered for our analysis. This means that at least 10 funds are actively buying or selling a specific stock during a given quarter. As Wermers (1999) argues, it would not be economically reasonable to classify it as herding if there is very little trading activity involved. Applying these criteria leaves us with 615824 stock-quarter observations. In addition, we collect portfolio-level data such as price-to-book (the holdings-value-weighted average price-to-book ratio of stocks in the fund's portfolio), market cap (the holdings-value-weighted

average market cap of firms in the fund's portfolio), stock volume (the total trading volume of publicly traded securities, adjusted according to the market capitalization), and float (refers to the total number of a firm's shares that are available for public trading on the market). Table 4.1 presents definitions of all the variables used in the analysis.

In addition, we collect data on holdings' carbon emissions between 2016 and 2024. The emissions data is classified per the Greenhouse Gas Protocol (2015) as scope 1, 2, and 3 emissions.[42] Scope 1 encompasses direct carbon emissions emanating from primary firm sources like vehicles and chemical production, scope 2 pertains to the indirect carbon emissions resulting from consumed electricity, and scope 3 captures emissions indirectly stemming from other firm operations. The carbon emissions data are the total $CO2$ equivalent emissions, scope 1 direct $CO2$ equivalent emissions, scope 2 indirect $CO2$ equivalent emissions, and scope 3 indirect $CO2$ equivalent emissions.

4.3.3 Fund Herding Measure

Following the existing literature (see Sias, 2004), we employ the herding measure proposed by Lakonishok et al. (1992), LSV henceforth, to estimate the extent of herding by SFDR funds in trading stocks. The LSV measure is specifically designed to determine whether an excessive number of institutions are buying or selling a particular stock relative to the overall market buying or selling intensity within a given period. We calculate the herding measure for each stock on a quarterly basis.

Formally, we estimate our measure of herding by SFDR funds into (or out of) stock i in quarter t as follows.

$$HM_{i,t} = |P_{i,t} - E[P_{i,t}]| - E\,|P_{i,t} - E[P_{i,t}]| \tag{4.1}$$

[42]The Greenhouse Gas Protocol provides comprehensive global standards to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions. It was created as an initiative based on a partnership between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). It has issued several standards, including the Corporate Accounting and Reporting Standard, which is considered the world's most widely used greenhouse gas accounting standard. For further details, refer to https://ghgprotocol.org/standards

where $HM_{i,t}$ is the measure of herding by SFDR funds into (or out of) stock i in quarter t. $P_{i,t}$ is the proportion of SFDR funds buyers relative to the total number of SFDR funds trading stock i in quarter t which is estimated as follows.

$$P_{i,t} = \frac{\#\text{of Buy}_{i,t}}{\#\text{ of Buy}_{i,t} + \#\text{ of Sell}_{i,t}} \tag{4.2}$$

The term $E[P_{i,t}]$ is the expected level of buy intensity. In line with previous studies, we estimate $E[P_{i,t}]$ with the market-wide intensity of buying, denoted as $\overline{p_t}$ as follows,

$$\overline{p}_t = \frac{\sum_i \#\text{ of Buy}_{i,t}}{\sum_i \#\text{ of Buy}_{i,t} + \sum_i \#\text{ of Sell}_{i,t}} \tag{4.3}$$

Consequently, the first term in Eq.4.1 measures the extent to which the trading pattern of stock i deviates from the overall trading pattern of all stocks in quarter t, which is driven by disproportionate funds buying or selling. It is important to note that $\overline{p}_t$ varies only over time. To address the fact that the absolute value of $|P_{i,t} - E[P_{i,t}]|$ is always zero or positive, we use the second term in Eq.4.1 as an adjustment factor to ensure that the expected value of the herding measure under the null hypothesis is zero.[43]

Herding is measured as the tendency of funds to trade a specific stock simultaneously and in the same direction (either buying or selling) more frequently than would be expected if they were trading independently. To distinguish between buy-herding and sell-herding, we follow Wermers (1999) and Brown et al. (2014) by defining a buy-herding measure (BHM), and a sell-herding measure (SHM) as follows.

$$\text{BHM}_{i,t} = \text{HM}_{i,t} \mid p_{i,t} > E[p_{i,t}] \tag{4.4}$$

[43]Following Lakonishok et al. (1992), under the null hypothesis of no herding, all SFDR funds make independent trading decisions, and all stocks should have the same probability of being bought or sold in a given quarter. Thus, a positive and significant herding measure will indicate evidence of institutional herding in the stock. Additionally, since herding measures are defined to account for the overall trading pattern within a given quarter, they are comparable across different periods.

$$\mathrm{SHM}_{i,t} = \mathrm{HM}_{i,t} \mid p_{i,t} < E[p_{i,t}] \tag{4.5}$$

A given stock has either a BHM or an SHM (but not both) in a given quarter, depending on its buying intensity relative to the market-wide buying intensity in that quarter. In the absence of buy (sell) herding, the BHM (SHM) for a particular stock in a given quarter is expected to be zero. If funds are more prone to herd selling than herd buying, the average SHM will be noticeably higher than the average BHM.

Table 4.1: Variable Definitions.

Variable	Definitions
Fund Herding	
Herding Measure	Following Lakonishok et al. (1992) and Sias (2004), we estimate a measure of herding by SFDR funds into (or out of) stock i in quarter t as follows. $$HM_{i,t} = \lvert P_{i,t} - E[P_{i,t}]\rvert - E\lvert P_{i,t} - E[P_{i,t}]\rvert$$ where $HM_{i,t}$ is the measure of herding, and $P_{i,t}$ is the proportion of SFDR funds buyers relative to the total number of SFDR funds trading stocks i in quarter t.
Fund Characteristics	
Total Net Assets (TNA)	The total net assets of a fund refer to the total market value of all the securities held by the fund, minus any liabilities measured in millions of dollars.
Net Asset Value (NAV)	The fund's net asset value is the market value of one share of the fund. It is calculated by dividing the total net assets of the fund by the number of shares outstanding.
Fund Return	The return on investment of a specific fund that is measured as the percentage change in the fund's net asset value (NAV).
Fund Age	The fund age since its inception date measured in quarters.
Expense Ratio	The expense ratio is expressed as a percentage of the fund's average assets under management (AUM). It represents what a mutual fund charges to cover expenses, including management fees, administrative fees, operating costs, and all other asset-based costs incurred by the fund.
Turnover	Portfolio turnover is calculated by taking the minimum of the aggregated sales and aggregated purchases of securities during a specific quarter and dividing it by the total value of the portfolio's holdings from the previous quarter.
Stock Characteristics	
Price-to-Book Ratio	Refers to the weighted average price-to-book ratio of stocks in the fund's portfolio.
Number of Holding	The natural logarithm of the number of stocks in which the fund invests.
Market Cap	The weighted average market capitalization of portfolio firms measured in millions of dollars.
Total Assets	The weighted average total assets of portfolio firms measured in millions of dollars.
Return on Equity	Refers to the weighted average return on equity ratio of stocks in the fund's portfolio.
Volatility	Refers to how much and how quickly the price of a financial asset changes over time as measured by the standard deviation of the asset price.
SFDR Classification	
SFDR	The SFDR refers to the Sustainable Finance Disclosure Regulation which is a framework implemented by the European Union (EU) to promote sustainable finance and enhance transparency in the financial sector.

Continued on next page

Table 4.1 – continued from previous page

Variable	Definitions
Article 9	Refers to funds that set generating a real impact on sustainable investing as their primary goal alongside a financial return. They must disclose the specific sustainability indicators used to measure their environmental or social impact and are labelled "impact-generating investments."
Article 8	Refers to funds that include environmental, social, and governance (ESG) criteria in their investment strategy but are more interested in financial objectives and are labelled "impact-aligned investments."
Article 6	These funds are not required to have any specific environmental or social objectives. However, they still need to provide disclosures on how they handle sustainability risks in their investment decisions.

4.3.4 Summary Statistics

We start by examining the evolution of the number of stocks, the average value held, and the average herding measure for Articles 9, 8, and 6 funds over time using the full sample. Panel A in Figure 4.1 shows that Article 8 funds consistently held the highest number of stocks, with noticeable fluctuations, while Article 9 funds showed a steady increase, and Article 6 maintained a relatively stable but lower number of stocks. Panel B highlights the average value of stocks held per fund, with Article 8 again leading to reach about $2.43 million in 2024Q1, displaying substantial growth post-2019. Article 9 funds also demonstrated significant growth of about $1.27 million per fund on average between 2019Q4 and 2024Q1, whereas Article 6 exhibited more variability reaching the lowest average value per fund of $1.11 million in 2024Q1. Panel C presents the average herding measure, indicating that Articles 8 and 6 fund groups experienced similar trends with moderate fluctuations. In contrast, Article 9 generally maintained a lower herding tendency than Articles 8 and 6 after 2019, suggesting the average tendency to follow the crowd decreases over time for this group of funds. These observations indicate substantial differences in trading behaviour among SFDR funds which warrant further investigation.

Table 4.2 presents the summary statistics for fund holdings and trading behaviour, categorised by SFDR fund groups. Notably, the data reveal that an average Article 9 fund holds 180 stocks worth $172 million. On average, an Article 9 fund actively buys 67

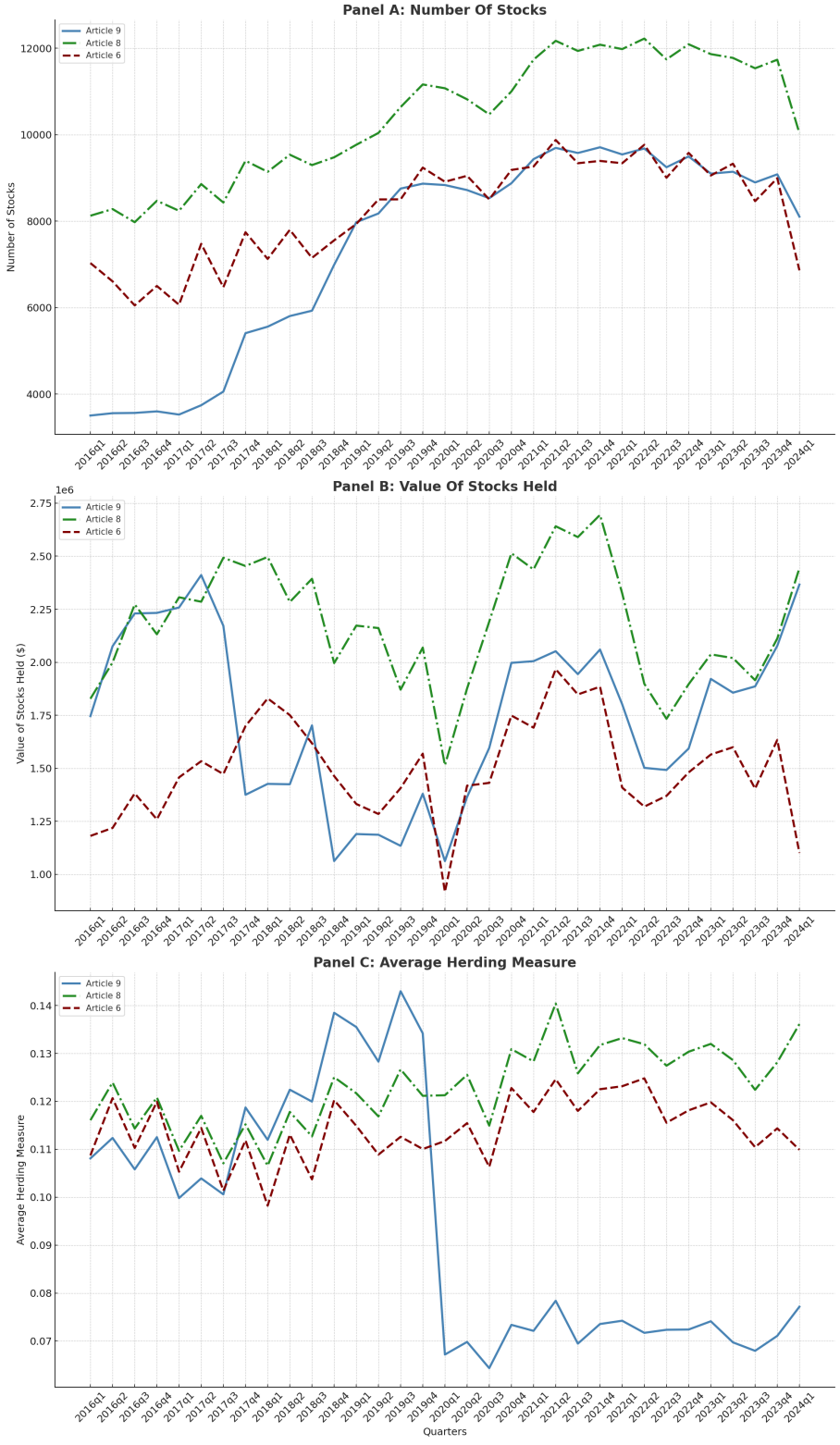


Figure 4.1: The Evolution of the Number of Stocks, the Value of Stocks Held, and the Average Herding Measure for Articles 9, 8, and 6 funds Over Time.

This figure displays the time series of data coverage on holdings of SFDR funds and stocks from 2016-Q1 to 2024-Q1, categorised into three SFDR fund types: Article 9, Article 8, and Article 6. Other unclassified SFDR funds, which are unaffected by the regulation, are excluded. Panel A illustrates the time series of the number of stocks held by SFDR fund type. Panel B displays the time series of the dollar value of stocks held by SFDR funds (in dollars). Panel C presents the average herding measure over time.

Table 4.2: Summary Statistics.
This table provides summary statistics for stock holdings of average SFDR funds, broken down into Article 9, 8 and 6 funds. In the "Holdings" columns, the average total dollar values and numbers of stocks are calculated across all funds and all quarters. In the "Quarterly trades" columns, a fund is defined as a buyer (seller) of stock i in quarter t if its holdings of stocks i increase (decrease) from the end of quarter $t-1$ to the end of quarter t. The average number of trades is then calculated across all funds and all quarters. In the "Percentage of portfolio traded" columns, sales and purchases are defined as follows: $\text{Sales}_{i,t} = \left(\sum_j \text{Amount Sold}_{i,j,t} / \sum_j \text{Amount Held}_{i,j,t-1}\right) \times 100$ and $\text{Purchases}_{i,t} = \left(\sum_j \text{Amount Bought}_{i,j,t} / \sum_j \text{Amount Held}_{i,j,t-1}\right) \times 100$, where $\text{Amount Sold (Bought)}_{i,j,t}$ is the net par amount of stock j sold (bought) by fund i in quarter t, and $\text{Amount Held}_{i,j,t-1}$ is the par amount of stock j held by fund i at the end of quarter $t-1$. The average percentage of traded portfolios is then calculated across all funds and all quarters.

Type of investors	Holdings		Quarterly trades		Percentage of portfolio traded	
	Holdings (millions $)	Number of holdings	Number of sales	Number of purchases	Sales (%)	Purchases (%)
Article 9 funds	172	180	29	67	14	27
Article 8 funds	218	125	27	57	11	23
Article 6 funds	149	91	24	42	11	15
Unclassified funds	117	130	29	61	13	18

stocks and sells 29 stocks in a given quarter. These active purchases account for 27% of the fund's portfolio value, while active sales make up 14%. When comparing by SFDR fund type, Article 9 and Article 8 funds demonstrate significantly higher trading activity than Article 6 funds, both in the number of trades and the proportion of their portfolios involved. As shown in the table, on average, Article 9 funds exhibit the highest trading activity among the three categories which again points to the need for further investigation.

In Table 4.3, we summarise the herding measures of SFDR funds across various thresholds of active trades for Article 9, 8, and 6 funds. Following Lakonishok et al. (1992), we require that stocks are traded by at least five different SFDR funds in a given quarter.[44] The herding measure (HM) generally decreases as the number of active stock trades increases across all SFDR fund types. For trades involving five or more active traders (≥ 5), the HM

[44]Building on Wermers (1999), we exclude newly launched stocks during their first year to concentrate on active trading decisions rather than initial allocations. Moreover, we require a stock to be traded by at least five funds within a given quarter to ensure robust institutional trading data for the herding analysis.

Table 4.3: Herding Measures (in percent) of Stocks by SFDR Funds Classification. This table displays the average herding measures of SFDR funds over the period from 2016-Q1 to 2024-Q1, excluding stocks launched within a year. The herding measure $HM_{i,t}$ for a specific stock-quarter is defined as $HM_{i,t} = |p_{i,t} - E[p_{i,t}]| - E[|p_{i,t} - E[p_{i,t}]|$, where $p_{i,t}$ represents the proportion of SFDR funds trading stock i during quarter t that are buyers. The expected value $E[p_{i,t}]$ is estimated as the proportion of all stock trades by SFDR funds during quarter t that are buying. $E[|p_{i,t} - E[p_{i,t}]|]$ is calculated assuming funds trade stocks independently and randomly. The buy herding measure $BHM_{i,t}$ is computed for stocks with a higher proportion of buyers than average and is defined as $BHM_{i,t} = HM_{i,t} \mid p_{i,t} > E[p_{i,t}]$. Likewise, the sell herding measure $SHM_{i,t}$ is calculated for stocks with a higher proportion of sellers than average and is defined as $SHM_{i,t} = HM_{i,t} \mid p_{i,t} < E[p_{i,t}]$. Columns 1, 3, and 5 show the average of herding measures $HM_{i,t}$, $BHM_{i,t}$, and $SHM_{i,t}$ for Articles 9, 8, and 6, respectively, Additionally, we compute the difference between the mean of $BHM_{i,t}$ and $SHM_{i,t}$ for each group of the number of active trades. Columns 2, 4, and 6 provide the number of stock-quarters observations included in these calculations.

Number of active trades	Herding Measures	Article 9 Funds		Article 8 Funds		Article 6 Funds	
		(1)	(2)	(3)	(4)	(5)	(6)
≥ 5	HM	0.093	(129,230)	0.123	(183,614)	0.114	(156,169)
	BHM	0.092	(74,287)	0.122	(105,651)	0.111	(86,899)
	SHM	0.089	(52,943)	0.125	(77,963)	0.119	(69,270)
	BHM-SHM	0.003		-0.003		-0.008	
≥ 10	HM	0.076	(97,692)	0.097	(125,664)	0.095	(118,269)
	BHM	0.086	(55,560)	0.095	(71,110)	0.092	(65,832)
	SHM	0.077	(42,132)	0.099	(54,554)	0.098	(52,437)
	BHM-SHM	0.009		-0.004		-0.006	
≥ 20	HM	0.065	(70,191)	0.079	(81,945)	0.079	(81,271)
	BHM	0.064	(38,416)	0.077	(45,056)	0.077	(44,538)
	SHM	0.067	(31,775)	0.081	(36,889)	0.082	(36,733)
	BHM-SHM	-0.003		-0.004		-0.005	
≥ 30	HM	0.059	(54,545)	0.069	(60,057)	0.069	(59,996)
	BHM	0.056	(28,624)	0.067	(31,706)	0.067	(31,662)
	SHM	0.062	(25,921)	0.072	(28,351)	0.073	(28,334)
	BH-SHM	-0.006		-0.005		-0.005	
≥ 50	HM	0.050	(33,893)	0.059	(35,364)	0.060	(35,363)
	BHM	0.045	(15,957)	0.054	(16,751)	0.054	(16,751)
	SHM	0.055	(17,936)	0.062	(18,613)	0.063	(18,612)
	BHM-SHM	-0.010		-0.008		-0.009	
≥ 100	HM	0.043	(11,658)	0.052	(11,740)	0.053	(11,740)
	BHM	0.034	(3,927)	0.039	(3,963)	0.038	(3,963)
	SHM	0.048	(7,731)	0.058	(7,777)	0.058	(7,777)
	BHM-SHM	-0.014		-0.019		-0.020	

is highest (9.3% for Article 9 funds) and decreases to the lowest value for trades involving one hundred or more active traders (≥ 100) (4.3% for Article 9 funds). It is observed that stocks frequently traded by many funds are typically large-cap stocks, which tend to exhibit lower levels of herding. This shift in focus to more extensive stocks can obscure any rise in herding that might occur due to an increased number of funds trading these stocks. This finding is consistent with what is reported about herding in stocks. For instance, Wermers (1999) shows that the level of herding in stocks does not consistently

increase; it slightly decreases as more mutual funds trade the stock.

Article 9 funds that have generated a real impact on sustainable investing exhibit the highest herding measures across all thresholds compared to Article 8 and 6 funds. The decrease in herding measures with increasing trade activity suggests that larger groups of traders tend to trade more independently. Also, Article 8 funds follow a similar trend as Article 9 funds but with slightly lower herding measures, while Article 6 funds exhibit the lowest herding measures among the three groups.

We also find that herding behaviour is more concentrated in buy herding than sale herding. For example, the BHM shows a declining trend as active trades increase. The highest BHM is observed for trades with (≥ 5) active traders (9.2 for Article 9 funds), while the lowest BHM is found for trades with (≥ 100) active traders (3.4 for Article 9 funds). Interestingly, the difference between BHM and SHM is positive for lower thresholds indicating more buy herding than sell herding, while it is negative for higher thresholds indicating more sell herding than buy herding.

This suggests that higher trading activity correlates with more independent trading decisions. Article 8 funds display the highest levels of herding, while Article 9 funds show the lowest, highlighting differences in trading behaviour across different categories of SFDR funds. As active trades increase, the transition from a positive to a negative difference between BHM and SHM values reflects a shift from buy herding to sell herding.

4.4 The Reaction of Fund Herding to the SFDR

This section provides the results of the main analysis and robustness checks.

4.4.1 Main Results

We begin our analysis by using a difference-in-differences (DID) setting to examine whether the SFDR influences herding behaviour. We use the introduction of the SFDR as a quasi-natural experiment to examine the change in the fund herding behaviour by impact funds (Article 9) and aligned funds (Article 8) after enacting the regulation. The SFDR represents an external change that is not influenced by the funds' internal strategies. This exogeneity is vital in a DID framework, ensuring that the intervention is not correlated with unobservable factors that could otherwise bias the results. By concentrating on the incremental effect of the regulation, especially among funds already engaged in sustainability reporting (Article 9), our analysis targets the direct impact of the regulation. This focus helps isolate the effect of SFDR from other simultaneous environmental or sustainability trends.

In our DID analysis, we use three separate treated groups. The first is Article 9 funds, distinguished by their explicit commitment to positive sustainability impact. The second comprises Article 8 funds, which, unlike Article 9 funds, integrate environmental or social characteristics into their investment process without adhering to a stringent sustainability commitment. The third group is Article 6 funds that do not have a sustainability objective, and they are not required to consider sustainability risks in their investment processes. The control group is unclassified funds that are unaffected by the regulation. The core of our analysis hinges on the difference in investment objectives between these treated groups and different trading behaviours applied by asset managers. This distinction is crucial to examining how the implementation of the SFDR might differently affect the herding behaviour of Articles 9 and Article 8 funds.

Following the recent literature (e.g., Gropp et al., 2014; Hu et al., 2019), we use a time series DID model specification to measure the changes in the herding measure before and after the introduction date of SFDR as follows:

$$HM_{i,t} = \alpha_0 + \beta_1 Post_{i,t} + \beta_2 SFDR_{i,t} + \beta_3 SFDR * Post_{i,t} + \beta_4 controls_{i,t-1} + \gamma_q + \delta_c + \varepsilon_{i,t} \quad (4.6)$$

where the $HM_{i,t}$ denotes the measure of herding by SFDR funds into (or out of) stock i in quarter t. The $SFDR * Post$ is the interaction of two underlying dummy variables: $SFDR$ that equals one if the fund belongs to a treated group (Articles 9, 8, or 6 funds) and zero otherwise, and $Post$ that equals one for the quarters following the introduction date of the SFDR and zero otherwise. We consider 2019Q4 to be the quarter in which the SFDR was introduced.[45] The main analysis uses an estimation window of one year before and one year after introducing the SFDR. The coefficient for $Post$ represents the variations in the levels of the herding measure for Articles 9, 8, and 6 pre and post-SFDR date. Our main interest is the coefficient for $SFDR * Post$ that indicates whether there is a substantial difference in the levels of the herding measure between Articles 9, 8, and 6 funds and the control group following the introduction of SFDR. A significantly negative coefficient for this variable confirms a decrease in the level of herding measure post the introduction of the SFDR and signifies that SFDR funds don't follow the crowds.

Our regression controls for portfolio characteristics. Control variables are portfolio size, book-to-market ratio, market cap, return on assets, turnover ratio, carbon emission, and volatility. All these variables are lagged to reduce any endogeneity issues. The estimation window is one year before and after the introduction of the SFDR. In addition, we use quarter fixed effects denoted as γ_q and country fixed effects denoted as δ_c that allow us to control for any time variation across funds and unmeasured macroeconomic conditions (Hartzmark and Sussman, 2019).

Table 4.4 shows the results of the DID analysis. In columns (1) and (2), the coefficients for $SFDR * Post$ are significantly negative for various specifications, indicating that Article 9 funds exhibit a lower level of herding behaviour compared with the control group. The

[45]The SFDR regulation, introduced on November 27, 2019, created a unique natural experiment to assess changes in fund trading behaviour before and after the regulation. For this test, we employ a difference-in-differences analysis using one year prior to the introduction date (November 27, 2019) and one year after. This approach provides insights into the immediate impacts of the regulation on investment decisions, aiding in the understanding of its effectiveness in influencing market behaviour. We then replicate the analysis in Table 4.7, redefining the "post" period from 2020 to 2024. This adjustment allows us to evaluate the sustained effects of the SFDR on the herding measure, particularly focusing on the behaviour of funds under Articles 9, 8, and 6.

Table 4.4: Results of the Difference-in-Differences Analysis
This table presents the estimated effects of SFDR regulations on the herding measure. Herding measure is calculated as as $HM_{i,t} = |p_{i,t} - E[p_{i,t}]| - E[|p_{i,t} - E[p_{i,t}]|$, as shown in Eq.4.1. In columns 1 & 2, $SFDR * Post$ is defined as an interaction variable comprised of two underlying dummy variables where SFDR has a value of 1 for Article 9, 8, or 6 funds and 0 otherwise, excluding Article 8 & 6 funds from the sample. In Columns 3 & 4, $SFDR * Post$ is defined as an interaction variable comprised of two underlying dummy variables where SFDR has a value of 1 for Article 8 funds and 0 for unclassified funds, excluding Article 9 & 6 funds from the sample. In columns 5 & 6, $SFDR * Post$ is defined as an interaction variable comprised of two underlying dummy variables where SFDR has a value of 1 for Article 6 funds and 0 for unclassified funds, excluding Article 9 & 8 funds from the sample. *Post* takes a value of one for the four quarters following the introduction date of the SFDR (2019Q4) and zero otherwise. We consider 2019Q4 to be the quarter in which the SFDR was introduced. The main analysis uses an estimation window of one year before and one year after introducing the SFDR. The odd columns represent the regression without control variables, while those in the even columns include control variables. Detailed definitions of the variables are provided in Table 4.1. All explanatory variables are lagged. The sample period is 2016Q1 to 2024Q1. t-statistics are included in Parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Herding Measure					
Variables	Article 9		Article 8		Article 6	
	(1)	(2)	(3)	(4)	(5)	(6)
SFDR*Post	-0.058***	-0.059***	-0.0058	0.004	0.010*	0.001
	(-19.420)	(-8.835)	(-0.719)	(0.057)	(2.052)	(0.301)
SFDR	-0.045***	-0.018***	-0.005**	-0.007	-0.067***	-0.003
	(-4.481)	(-5.398)	(-2.438)	(-0.286)	(-8.564)	(-1.819)
Post	-0.011***	-0.007**	0.004	-0.007*	-0.011**	-0.006
	(-3.807)	(-2.297)	(0.718)	(-2.086)	(-3.004)	(-1.719)
Portfolio Size		-0.001		-0.003		-0.001
		(-1.509)		(-1.453)		(-1.766)
Market Cap		-0.011***		-0.014***		-0.011***
		(-3.943)		(-3.991)		(-4.473)
ROA		-0.007***		-0.007***		-0.006***
		(-5.619)		(-6.890)		(-6.147)
Turnover Ratio		0.029		0.079*		0.080*
		(1.608)		(1.997)		(2.175)
Carbon emission		-0.003***		-0.004***		-0.003***
		(-5.997)		(-5.792)		(-5.524)
Book to Market Ratio		4.590		4.080		4.005
		(1.451)		(1.149)		(1.116)
Volatility		0.020***		0.021***		0.018**
		(3.824)		(4.732)		(3.597)
Constant	0.180***	0.439***	0.140***	0.439***	0.179***	0.439***
	(30.59)	(8.174)	(74.64)	(8.890)	(35.79)	(10.39)
Observations	50,204	22,959	56,350	25,299	51,995	20,538
R-squared	0.097	0.203	0.583	0.153	0.059	0.135
Controls	No	Yes	No	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes

decrease in the herding measure following the introduction of SFDR is also economically significant. As column (1) shows, without including control variables, Article 9 funds show a lower level of herding than unclassified funds. When control variables are added, as shown in column (2), the coefficient for $SFDR * Post$ is still significantly negative, suggesting that Article 9 funds herd less after the regulation. This indicates that these funds are more independent in their investment decisions, possibly reflecting a more deliberate focus on sustainability rather than simply following market trends. In columns (3) and (4), we analyze the herding behaviour of Article 8 funds post-SFDR, using them as the treated group instead of Article 9 funds. The findings reveal that Article 8 funds experience an insignificant increase in herding levels compared to unclassified funds. This suggests that while Article 8 funds may promote ESG factors, their response to the SFDR in terms of changing their herding behaviour is not as pronounced as that of Article 9 funds.

The relationship between information asymmetry and herding behaviour plays a crucial role in shaping the behaviour of institutional investors, particularly within the framework of SFDR funds. Our findings indicate that Article 9 funds, which are deeply committed to sustainability, likely have better access to relevant information. This enables them to make informed decisions and reduce their reliance on herding. Consequently, these funds show a significant reduction in herding behaviour, aligning more closely with their sustainable investment objectives and SFDR guidelines. In contrast, Article 8 and Article 6 funds, which may experience greater information asymmetry, tend to exhibit an increase in herding behaviour. These funds might be more prone to using herding as a strategy due to their relatively limited access to sustainability information. Overall, our results underscore the significant influence of information-related factors on the herding behaviour of institutional investors. Article 9 funds, with their better access to and utilization of sustainability information, are better positioned to mitigate the effects of information asymmetry.

A potential concern with our difference-in-differences methodology is the possibility of

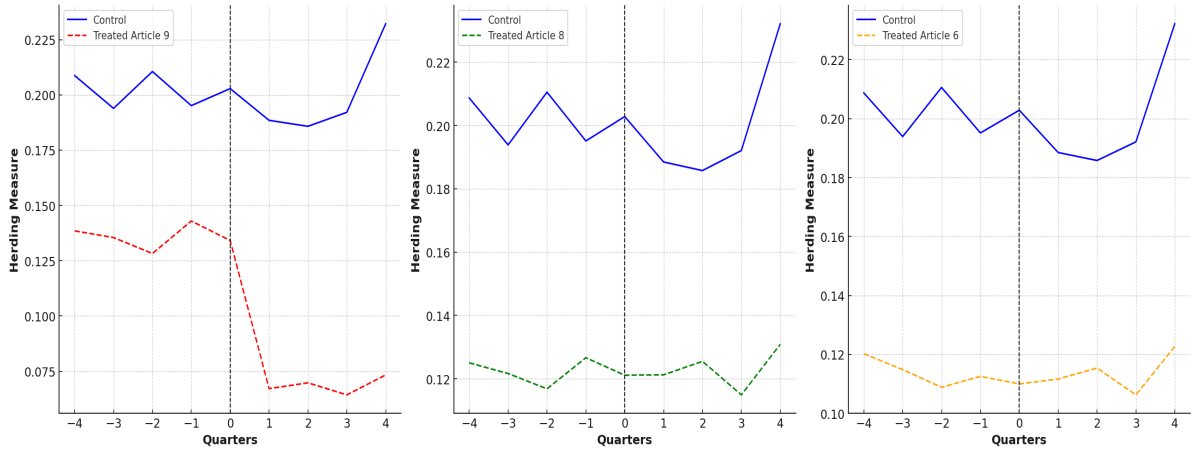


Figure 4.2: The Trends of Herding Measure.
This figure displays the herding measure of Articles 9, 8, and 6 funds alongside a matched group of unclassified funds before and after the introduction date of the SFDR. The pre-quarters refers to the four quarters before the introduction of the SFDR. The post-quarters include the quarter in which the SFDR was introduced and the subsequent three quarters.

confounding differences in herding behaviour trends between Article 9, 8, & 6 funds (treated group), and unclassified funds (control group). To address this concern, we validate our empirical analysis by examining the parallel trends in herding measures between the treated and control groups, as any significant differences would be most evident between these categories. Figure 4.2 shows that prior to the regulation the herding measure for Articles 9, 8, and 6 have parallel trends. Around the introduction date of SFDR regulation, we observe a clear divergence where Article 9 funds herding measure significantly drops relative to unclassified funds. The parallel pre-event trend mitigates concerns that confounding differences may be driving the large subsequent divergence in herding behaviour between Article 9, 8, and 6 funds (treated group), and unclassified funds (control group), validating the assumption of parallel trends in our DID approach. Therefore, we conclude that the observed differences in the herding measure post-SFDR implementation are attributable to its significant impact on changing asset managers' trading behaviour.

4.4.2 Corroborating Results

To further validate our findings on the impact of SFDR funds, particularly regarding herding behaviour, we conduct three additional sets of tests. First, we explore potential heterogeneity in the treatment effect by analysing how Articles 9, 8, and 6 funds align with their respective sustainability objectives. Second, we investigate the long-term impact of SFDR funds on the herding measure, particularly how these strategies may reduce information asymmetry and consequently mitigate herding tendencies. These tests aim to provide a comprehensive understanding of how SFDR regulations shape the behaviour of institutional investors. Third, we conduct falsification tests using the years before the introduction of the regulation as a pre-regulation period.

4.4.2.1 Heterogeneous Treatment Effects of SFDR Funds

To assess the heterogeneous treatment effects of SFDR funds on herding behaviour, we employ a Propensity Score Matching-Difference-in-Differences (PSM-DID) approach. This analysis allows us to control for selection bias and ensure a robust comparison between treated and control groups. Matching SFDR Articles 9, 8, and 6 with unclassified funds that have similar characteristics isolates the effect of the regulation itself. The results of this matching exercise indicate that the treated and matched control funds are not significantly different based on the matching variables.

Table 4.5 shows the results of the PSM-DID analysis. In column 1, the coefficient for $SFDR * Post$ is significantly negative indicating a lower level in herding measure for Article 9 funds relative to the control group. In column 2, when we add the control variables, the coefficient for the interaction variable $SFDR * Post$ indicates a significant reduction in the level of herding relative to the matched control group. The results related to Articles 8, and 6 funds are also aligned with the results in the main analysis as shown in Table 4.4 indicating no significant change in herding behaviour post-regulation for these funds compared to the unclassified funds.

Table 4.5: Heterogeneous Treatment Effects of SFDR Funds
This table presents the estimated effects of SFDR regulations on the herding measure. Herding measure is calculated as as $HM_{i,t} = |p_{i,t} - E[p_{i,t}]| - E[|p_{i,t} - E[p_{i,t}]|$, as shown in Eq.4.1. In columns 1 & 2, $SFDR * Post$ is defined as an interaction variable comprised of two underlying dummy variables where SFDR has a value of 1 for Article 9, 8, or 6 funds and 0 otherwise, excluding Article 8 & 6 funds from the sample. In Columns 3 & 4, $SFDR * Post$ is defined as an interaction variable comprised of two underlying dummy variables where SFDR has a value of 1 for Article 8 funds and 0 for unclassified funds, excluding Article 9 & 6 funds from the sample. In columns 5 & 6, $SFDR * Post$ is defined as an interaction variable comprised of two underlying dummy variables where SFDR has a value of 1 for Article 6 funds and 0 for unclassified funds, excluding Article 9 & 8 funds from the sample. *Post* takes a value of one for the four quarters following the introduction date of the SFDR (2019Q4) and zero otherwise. We consider 2019Q4 to be the quarter in which the SFDR was introduced. The main analysis uses an estimation window of one year before and one year after introducing the SFDR. The odd columns represent the regression without control variables, while those in the even columns include control variables. Detailed definitions of the variables are provided in Table 4.1. All explanatory variables are lagged. The sample period is 2016Q1 to 2024Q1. t-statistics are included in Parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Herding Measure					
Variables	Article 9		Article 8		Article 6	
	(1)	(2)	(3)	(4)	(5)	(6)
SFDR*Post	-0.045**	-0.043**	0.005	0.002	0.006	0.003
	(-3.521)	(-3.099)	(0.937)	(0.381)	(0.874)	(0.778)
SFDR	-0.045***	-0.017***	-0.060***	-0.002	-0.068***	-0.0048**
	(-4.258)	(-3.520)	(-6.216)	(-0.555)	(-7.667)	(-2.13)
Post	-0.008***	-0.007***	-0.008	-0.008**	-0.008	-0.007**
	(-3.510)	(-3.306)	(-1.384)	(-3.336)	(-1.254)	(-3.047)
Portfolio Size		-0.001		-0.001		-0.002
		(-1.316)		(-1.332)		(-1.693)
Market Cap		-0.010***		-0.011***		-0.011***
		(-3.864)		(-3.985)		(-4.492)
ROA		-0.007***		-0.007***		-0.007***
		(-5.020)		(-6.077)		(-6.022)
Turnover Ratio		0.032		0.077		0.079*
		(1.505)		(1.666)		(2.196)
Carbon emission		-0.000***		-0.000***		-0.000***
		(-6.209)		(-6.173)		(-5.592)
Book to Market Ratio		0.000		0.000		0.000
		(1.118)		(1.150)		(1.157)
volatility		0.020**		0.018**		0.019**
		(3.463)		(3.667)		(3.703)
Constant	0.180***	0.418***	0.180***	0.438***	0.178***	0.441***
	(27.060)	(8.167)	(26.622)	(8.972)	(29.079)	(10.459)
Observations	15,734	5,653	18,783	8,433	17,331	6,846
R-squared	0.083	0.172	0.049	0.157	0.061	0.135
Controls	No	Yes	No	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes

4.4.2.2 Falsification Test

To validate our main findings and determine whether the observed changes in herding behaviour can indeed be attributed to the SFDR, rather than to other unrelated factors, we apply a falsification test. This test is crucial in confirming that the reduction in herding measure observed among SFDR funds, particularly Article 9, is a result of introducing the regulatory framework. If the SFDR is truly the causal factor, the test should show no significant changes in herding behaviour for variables or outcomes that are theoretically unrelated to the regulation. The absence of significant effects in these unrelated factors would further support the argument that the SFDR's impact on herding behaviour is both real and accurately identified, thereby enhancing the robustness and credibility of our main results. We use an extended version of Eq.4.6 whereby we introduce an interaction variable between the time dummy variable of the year before the adoption of SFDR (Pre)[46] and the treatment variable SFDR.

The results in Table 4.6 confirm that the observed changes in herding measure can be attributed to the regulation rather than pre-existing trends. The significant positive coefficient for $SFDR * Pre$ indicates that Article 9 funds exhibited higher herding behaviour before the regulation. This increased herding can be attributed to greater information asymmetry since prior to implementing the SFDR, there was a lack of transparency in disclosure practices. Without clear and standardised disclosure requirements, these funds may have had less motivation to make fully independent investment decisions based on reliable information, making it difficult to assess the true sustainability of their investments. These funds might have found it less costly to rely to some extent on market trends and the actions of other funds rather than on informed independent decision-making. While the negative and significant coefficients for $SFDR * Pre$ suggest lower herding levels for Articles 8 and 6 funds pre-regulation. These findings reinforce the conclusion that the

[46]For the placebo test, Pre is equal to 1 for the four quarters before the placebo date (2018Q4) and 0 otherwise. The estimation window covers one year before and one year after the placebo date; we then replicate the analysis from Table 4.6, redefining the "Pre" period by using 2017 and 2016 as alternative starting points and re-run the analysis accordingly. The results of this additional robustness check are consistent with the findings reported in Table 4.6.

Table 4.6: Results of the Falsification Analysis
This table shows the results of the falsification analysis for the herding measure for SFDR funds before the adoption of the SFDR. Herding measure is calculated as $HM_{i,t} = |p_{i,t} - E[p_{i,t}]| - E[|p_{i,t} - E[p_{i,t}]|$, as shown in Eq.4.1. We use a DID estimator as in Eq. 4.6 . The term $SFDR * pre$ is defined as an interaction variable consisting of two underlying dummy variables where SFDR equals one for Articles 9, 8, & 6 funds and zero otherwise. For the placebo test, Pre is equal to 1 for the four quarters before the placebo date (2018Q4) and 0 otherwise. The estimation window covers one year before and one year after the placebo date. The odd columns represent the regression without control variables, while the even columns report the results of regressions with control variables. Detailed definitions of the variables are provided in Table 4.1. All explanatory variables are lagged. The sample period is 2016Q1 to 2024Q1. t-statistics are reported in parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Herding Measure					
Variables	Article 9		Article 8		Article 6	
	(1)	(2)	(3)	(4)	(5)	(6)
SFDR*Pre	0.023***	0.016***	-0.012***	-0.008***	-0.012***	-0.006***
	(5.430)	(4.869)	(-3.613)	(-3.834)	(-3.790)	(-3.756)
Portfolio Size		-0.002		0.004		0.006**
		(-0.603)		(0.860)		(2.043)
Market Cap		-0.008***		-0.015***		-0.013***
		(-3.514)		(-9.009)		(-6.558)
ROA		-0.003***		-0.004***		-0.003***
		(-3.063)		(-4.212)		(-3.309)
Turnover Ratio		0.026		0.027		0.022
		(1.475)		(1.155)		(1.145)
Carbon emission		-0.001***		-0.000		-0.000
		(-4.261)		(-1.015)		(-0.629)
Book to Market Ratio		0.000		0.000		0.000
		(1.114)		(1.093)		(1.116)
Volatility		-0.000		-0.011		-0.009
		(-0.001)		(-1.581)		(-1.190)
Constant	0.119***	0.382***	0.136***	0.393***	0.132***	0.276**
	(26.657)	(3.072)	(36.442)	(2.861)	(32.763)	(2.524)
Observations	247,137	80,450	309,638	97,710	280,669	88,677
R-squared	0.458	0.318	0.408	0.335	0.425	0.331
Controls	No	Yes	No	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes

reduction in herding behaviour, especially for Article 9 funds post-SFDR, is genuinely due to the regulation's effectiveness, thereby validating the robustness of our main results.

4.4.2.3 Long-Run Impact of SFDR Regulation on Herding

One concern with our analysis of the SFDR regulation's impact on herding behaviour is the potential for using a short window to capture the regulation's effects. However, changes in investor behaviour, particularly those influenced by new regulatory frameworks like SFDR, may take longer to materialize as asset managers may need long time to adjust their strategies in response to new regulations. To address this concern, we further explore the dynamic effects of the SFDR on the herding measure by extending our analysis to longer time horizons examining changes in herding behaviour over 3 and 5-year periods. This extended timeline is necessary to accurately assess whether SFDR influences the tendency of investors to herd, potentially reducing or exacerbating this behaviour over time. We verify this effectiveness by setting a series of dummy variables in the DID regression in Eq.4.6 to trace the year-by-year effects of the SFDR on the herding measure.

The results, presented in Table 4.7, reveal that Article 9 funds exhibit a lower tendency toward herding behaviour relative to unclassified funds. This result aligns with those from the main analysis, as shown in Table 4.4. Furthermore, over the long term, Article 9 funds demonstrate a significant reduction in herding measure, as evidenced by a negative and statistically significant effect in both the 3-year (columns 1 and 2) and 5-year (columns 3 and 4) analyses. This reduction implies that, over time, Article 9 funds may become more confident in their independent investment strategies, gradually moving away from the herd as they establish a clearer direction in their portfolio management. In contrast, Article 8 and 6 funds do not display a sustained change in herding behaviour over the long term, suggesting that they may continue to follow market trends rather than develop a distinct investment approach. This difference suggests that while Article 9 funds initially show some tendency toward herding before the regulation, they eventually adopt a more consistent and independent investment approach. On the other hand, Article 8 and 6 funds seem to be more influenced by the actions of their peers, reflecting varying levels of commitment to developing unique investment strategies and reducing herding.

Table 4.7: Evidence of Long-Term Effects

This table shows the results from regressions examining the herding behaviour of SFDR funds over 3-year and 5-year periods after introducing the regulation. Herding measure is calculated as as $HM_{i,t} = |p_{i,t} - E[p_{i,t}]| - E[|p_{i,t} - E[p_{i,t}]|$, as shown in Eq.4.1. In columns 1 to 4, 5 to 8, and 9 to 12, $SFDR$ equals one for Article 9, 8, and 6 funds, respectively, and zero for unclassified funds. We consider 2019Q4 to be the quarter in which the SFDR was introduced. We use two different estimation windows: three years and five years. In the three-year analysis, $Post(3\ years)$ is a dummy variable that takes a value of one in the 12 quarters before introducing the SFDR and 0 otherwise. In the five-year analysis, $Post(5\ years)$ is a dummy variable that takes a value of one in the 20 quarters before introducing the SFDR and 0 otherwise. $SFDR * Post$ is an interaction variable. The odd columns represent the regressions without control variables, while even columns have control variables. Detailed definitions of the variables are provided in Table 4.1. The sample period is 2016Q1 to 2024Q1. t-statistics are reported in parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Herding Measure											
Variables	Article 9				Article 8				Article 6			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	11	12
SFDR*Post (3 years)	-0.045***	-0.048***			0.021***	0.011**			0.018**	0.010**		
	(-6.270)	(-9.296)			(2.983)	(2.426)			(2.784)	(2.168)		
SFDR*Post (5 years)			-0.047***	-0.048***			0.017	0.013***			0.013	0.010**
			(-3.884)	(-7.615)			(1.593)	(2.807)			(1.287)	(2.299)
Portfolio Size		-0.001		-0.000		-0.000		-0.000		-0.000		-0.000
		(-0.672)		(-0.157)		(-0.441)		(-0.141)		(-0.421)		(-0.028)
Market Cap		-0.012***		-0.013***		-0.013***		-0.013***		-0.013***		-0.013***
		(-5.073)		(-4.571)		(-4.583)		(-4.190)		(-5.390)		(-4.753)
ROA		-0.005***		-0.005***		-0.005***		-0.006***		-0.005***		-0.005***
		(-4.654)		(-4.252)		(-5.187)		(-5.106)		(-4.974)		(-4.660)
Turnover Ratio		-0.001		0.027		0.002		0.046		0.003		0.038
		(-0.205)		(1.220)		(0.264)		(1.243)		(0.461)		(1.240)
Carbon emission		-0.000***		-0.000***		-0.000***		-0.000***		-0.000***		-0.000***
		(-5.876)		(-7.723)		(-6.811)		(-8.201)		(-6.091)		(-7.907)
Book to Market Ratio		0.000		0.000		0.000		0.000		0.000		0.000
		(1.065)		(0.515)		(0.526)		(0.108)		(0.877)		(0.397)
Volatility		0.022***		0.012		0.021**		0.011		0.020**		0.009
		(2.834)		(1.666)		(2.753)		(1.610)		(2.453)		(1.449)
Constant	0.179***	0.444***	0.164***	0.444***	0.179***	0.457***	0.164***	0.452***	0.178***	0.451***	0.163***	0.446***
	(30.162)	(8.984)	(12.263)	(7.711)	(28.611)	(8.508)	(12.219)	(7.360)	(32.361)	(9.522)	(12.417)	(8.035)
Observations	167,588	64,984	243,164	80,925	203,069	75,512	302,372	97,624	183,997	67,956	274,255	88,902
R-squared	0.107	0.169	0.090	0.150	0.045	0.139	0.038	0.130	0.059	0.124	0.049	0.117
Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

4.5 Do Stock Characteristics Affect Herding Behaviour of Funds?

Our overall herding results from the previous section 4.4 indicate that Article 9 funds exhibit a lower level of herding in the average stock quarter post-SFDR regulation than Articles 8 and 6 funds. To further investigate the reasons behind this finding, we analyse herding levels in subgroups of stocks with particular characteristics based on size and ESG score. We also assess whether herding is more common on the buy-side or sell-side of SFDR funds trading.

4.5.1 Herding in Small and Large Stocks

It is crucial to understand how mutual funds adjust their investment strategies and, in turn, their herding behaviour post-regulation. The literature on herding behaviour highlights various theories that explain herding among institutional investors, particularly in the presence of information asymmetry and market uncertainties (e.g., Lakonishok et al., 1992; Wermers, 1999; Sias, 2004). In the context of the SFDR, funds may exhibit different herding patterns depending on the characteristics of the stocks they invest in and the extent of information asymmetry they face. Funds that invest in smaller, less liquid stocks tend to face higher levels of information asymmetry because these stocks generally provide less transparent and reliable financial information. In such cases, fund managers may be more inclined to follow the market consensus, engaging in herding behaviour as a way to manage the uncertainty caused by limited or imprecise information.

Conversely, funds that invest in larger, more liquid stocks typically experience lower levels of information asymmetry, as these stocks are more transparent. As a result, herding behaviour may be less prevalent in these funds given that fund managers have motivation to obtain reliable information, allowing them to make more independent investment decisions. Therefore, the SFDR which imposes sustainability standards, may influence

herding patterns differently as fund managers navigate this new regulatory environment may react differently based on the characteristics of the stocks in their portfolios.

To explore these dynamics, we extend our DID analysis by examining herding behaviour across the size quantiles of the stocks in which funds are invested segregated by market capitalization. This allows us to observe how stock size influences herding patterns. By categorizing the stocks according to size, we can better assess whether the SFDR has affected herding behaviour differently, depending on the stock size within the SFDR fund portfolios.

In panel A of Table 4.8, we present herding measures in the quarters that follow introducing the SFDR, segregated by market capitalization. The results reveal a more pronounced reduction in herding among smaller stocks (S1) compared to larger stocks (S5) post-regulation. This suggests that Article 9 funds have increasingly focused on trading smaller stocks, aiming to minimise information asymmetry, which was more prevalent in smaller stocks prior to the regulation. On the buy-side, the coefficient of the buy herding measure (BHM) shows significantly lower herding in smaller stocks compared to larger ones. Fund managers are likely becoming more selective, moving away from following the herd in buying small stocks with high uncertainty around sustainability performance toward only those with potentially stronger sustainability credentials. This is likely driven by the SFDR's strict sustainability requirements, which compel Article 9 fund managers to make independent decisions based on stock-specific disclosures rather than market trends. In contrast, on the sell-side (SHM), Article 9 funds may be more inclined to avoid exiting their current investments in small stock quickly. They seem to be taking some time to reconsider these investments instead of rushing to divest from stocks with potentially weaker sustainability practices and high levels of information asymmetry. Overall, our findings show that the reduction in herding among Article 9 funds is concentrated in the trades of small stocks (S1) and is more on the sell side than on the buy side.

Table 4.8: Results of Evaluating Herding in Small and Large Stocks
This table shows the results from regressions examining the herding measures over stock quarters, segregated by market capitalization post-regulation. Herding measure is calculated as $HM_{i,t} = |p_{i,t} - E[p_{i,t}]| - E[|p_{i,t} - E[p_{i,t}]|$, as shown in Eq.4.1. The buy herding measure $BHM_{i,t}$ is computed for stocks with a higher proportion of buyers than average and is defined as $BHM_{i,t} = HM_{i,t} \mid p_{i,t} > E[p_{i,t}]$. Likewise, the sell herding measure $SHM_{i,t}$ is calculated for stocks with a higher proportion of sellers than average and is defined as $SHM_{i,t} = HM_{i,t} \mid p_{i,t} < E[p_{i,t}]$. The main independent variable of interest is $SFDR * Post$, defined as an interaction variable comprised of two underlying dummy variables where $SFDR$ has a value of 1 for Article 9, 8, or 6 funds and 0 for unclassified funds, and $Post$ takes a value of one for the four quarters following the introduction date of the SFDR (2019Q4) and zero otherwise. We consider 2019Q4 to be the quarter in which the SFDR was introduced. The main analysis uses an estimation window of one year before and one year after introducing the SFDR. Panel A, B, and C show the result of Articles 9, 8, and 6 herding measures, respectively, by size quantile based on the market capitalization of stocks in which funds are invested. We partition the SFDR fund's portfolios into five equal size quantiles including small stocks (S1), medium stocks (S2-S4), and large stocks (S5). The odd columns 1-9 represent the results with control variables, while the even columns 2-10 report the number of stock-quarter observations included in the calculation. Detailed definitions of the variables are provided in Table 4.1. The sample period is 2016Q1 to 2024Q1. t-statistics are reported in parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Article 9 Herding Measures By Size Quintile											
		S1		S2		S3		S4		S5	
		Small Stocks								Large Stocks	
Variables		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SFDR*Post	HM	-0.087***	9593	-0.085***	9606	-0.069	9908	-0.055***	10332	-0.051***	10398
		(-7.583)		(-10.127)		(-10.243)		(-6.255)		(-15.734)	
	SHM	-0.102***	5,455	-0.091***	5,229	-0.055***	5,571	-0.054***	5,391	-0.051	5,402
		(-10.394)		(-9.222)		(-12.432)		(-4.103)		(-9.015)	
	BHM	-0.060**	4,138	-0.072***	4,380	-0.061	4,337	-0.052***	4,941	-0.044***	4,996
		(-2.949)		(-8.397)		(-3.723)		(-5.051)		(-7.453)	
Controls		Yes		Yes		Yes		Yes		Yes	
Country FE		Yes		Yes		Yes		Yes		Yes	
Quarter FE		Yes		Yes		Yes		Yes		Yes	
Panel B : Article 8 Herding Measures By Size Quantile											
		S1		S2		S3		S4		S5	
		Small Stocks								Large Stocks	
Variables		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SFDR*Post	HM	0.011	10,260	-0.007	10,711	0.006	10,773	-0.000	11,096	0.010	13,852
		(1.092)		(-0.993)		(1.217)		(-0.017)		(1.830)	
	SHM	0.035*	4,426	0.004	4,903	0.015	4,732	-0.008	5,336	0.009	6,574
		(2.141)		(0.520)		(1.577)		(-0.839)		(1.318)	
	BHM	-0.004	5,834	-0.012	5,808	-0.001	6,041	0.009	5,760	0.011**	7,278
		(-0.566)		(-1.393)		(-0.268)		(0.940)		(2.458)	
Controls		Yes		Yes		Yes		Yes		Yes	
Country FE		Yes		Yes		Yes		Yes		Yes	
Quarter FE		Yes		Yes		Yes		Yes		Yes	
Panel C: Article 6 Herding Measure By Size Quantile											
		S1		S2		S3		S4		S5	
		Small Stocks								Large Stocks	
Variables		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SFDR*Post	HM	0.015	9,442	-0.002	9,153	0.006	10196	0.000	10332	0.010*	12462
		(1.470)		(-0.235)		(1.108)		(0.004)		(2.304)	
	SHM	0.036*	4,198	0.006	4,365	0.013	4,503	-0.008	5,087	0.007	6,239
		(2.137)		(0.725)		(1.549)		(-0.804)		(1.369)	
	BHM	0.001	5,244	-0.004	4,788	-0.001	5,693	0.008	5,245	0.012***	6,223
		(0.242)		(-0.437)		(-0.124)		(0.866)		(3.708)	
Controls		Yes		Yes		Yes		Yes		Yes	
Country FE		Yes		Yes		Yes		Yes		Yes	
Quarter FE		Yes		Yes		Yes		Yes		Yes	

In panel B, the herding behaviour of Article 8 funds shows mixed results post-SFDR, reflecting the funds' slightly less stringent sustainability requirements. In small stocks, sell-side herding (SHM) increases, likely because these stocks are more prone to higher information asymmetry. This asymmetry, particularly in smaller stocks, creates uncertainty in assessing their true values, which amplifies volatility and prompts investors to follow the actions of others, thereby contributing to herding behaviour when selling. On the buy-side, no significant changes in herding are observed for small stocks, suggesting that the SFDR regulation did not strongly impact buying behaviour for these funds. For larger stocks, the data shows an unexpected increase in both sell-side and buy-side herding. This suggests that investors may still engage in herding behaviour, potentially driven by broader market trends or the appeal of balancing sustainability goals with financial returns. Overall, Article 8 stocks exhibit greater variability in herding behaviour compared to Article 9 stocks, particularly with increased sell herding in small stocks and buy herding in large ones. This variability likely reflects the differing levels of information asymmetry between small and large stocks, as well as the less stringent regulatory framework for Article 8 funds, contributing to more herding behaviour in both buying and selling decisions.

In panel C, the results reveal that Article 6 funds tend to herd more when selling small stocks (S1), compared to larger stocks. The level of sell-side herding, approximately 3.6 percent, is significantly higher than that observed on the buy side. In contrast, for larger stocks (S5), buy herding in large stocks (S5) shows a significant rise, possibly driven by increased investor confidence in the sustainability credentials of these stocks. The finding of higher sell herding among Article 6 funds, especially in trades involving small stocks, is not surprising given the limited transparency and higher information asymmetry associated with these stocks. These findings suggest that fund investments in these stocks are less driven by sustainability considerations. Similarly, the higher buy herding among Article 6 funds trading large stocks indicates less independence in the investment decisions of these funds. This contributes to more pronounced herding in both buying and selling

decisions. The observed herding behaviour is consistent with the nature of Article 6 funds, which typically invest in stocks with weaker sustainability profiles and limited transparency, further amplifying information asymmetry and uncertainty.

4.5.2 ESG Trading and Herding Behaviour

Another way to understand how SFDR funds change their herding behaviour post-regulation is to partition stock quarters based on ESG scores. This approach allows for an examination of how funds reallocate their portfolios in response to ESG considerations. In ESG trading, herding behaviour can manifest in both the buying and selling of stocks, depending on market trends and external pressures. For example, funds may herd into buying stocks with high ESG score when there is strong market sentiment or regulatory pressure to prioritise sustainability in their portfolios, driven by a desire to improve their ESG ratings or meet investor demand for responsible investment.

On the other hand, herding can also occur in the selling of stocks with low ESG score, particularly when these stocks face negative ESG-related news or when regulatory standards, such as the SFDR, require stricter sustainability disclosures. Funds might sell these lower ESG-scoring stocks to minimise potential reputational risk or to align their portfolios with shifting regulatory and market expectations. These stocks often face higher information asymmetry due to less transparent ESG disclosures, increasing uncertainty and prompting fund managers to follow broader market trends in their decisions. As a result, fund managers may resort to herding, either following the broader market in divesting from stocks with low ESG score or acquiring stocks with high ESG score to align with perceived market consensus.

Funds that invest in stocks with high ESG score tend to encounter lower levels of information asymmetry due to more reliable and transparent ESG disclosures. This access to better information enables fund managers to make more independent and informed decisions, reducing the likelihood of herding. However, even in stocks with high ESG score,

herding can still occur as managers seek to capitalise on trends in sustainable investing or follow market leaders in acquiring these stocks.

Table 4.9 demonstrates how SFDR funds change their herding behaviour in response to regulation. In Panel A, we measure the change in herding behaviour for Article 9 funds using a quantile-based approach to our baseline DID model, where we examine different ESG score quantiles for the stocks in which these funds invest. Specifically, we divide the Article 9 fund portfolios into five ESG-based quantiles: low ESG score (S1), medium ESG score (S2-S4), and high ESG score (S5). In column 1, the dependent variable is the herding (HM), sell herding (SHM), and buy herding (BHM) measures. The negative and statistically significant coefficient on the interaction variable $SFDR * Post$ clearly shows that both sell herding (SHM) and buy herding (BHM) across various ESG score quantiles experience lower levels of herding for Article 9 funds relative to unclassified funds post-regulation. Notably, Article 9 funds reduce their herding in both purchases and sales of high ESG stocks (S5) relative to unclassified funds. This suggests that these funds are less likely to follow market trends when buying and selling green stocks, which can be attributed to the superior ESG disclosures associated with green stocks. Improved transparency allows fund managers to make more independent and informed decisions, thereby decreasing reliance on herding. Additionally, the negative SHM for brown stocks (S1) implies that Article 9 funds are also reducing herding in the selling of these stocks, possibly to avoid reputational risks and to comply with the stricter sustainability standards introduced by the SFDR. Overall, the reduction in herding behaviour reflects strategic portfolio adjustments to align with regulatory sustainability goals rather than being driven by poor performance. The shift towards more independent ESG-focused trades underscores the funds' adaptation to the regulatory environment.

In Panel B, the results of Article 8 funds present a more mixed picture. While there is some reduction in sell herding (SHM) for low ESG (brown) stocks (S1), this effect is not statistically significant, and no consistent pattern emerges across the other ESG quantiles. On the buy side (BHM), however, there are statistically significant increases in herding

behaviour, particularly for mid-ESG stocks (S3) and high ESG stocks (S5). These findings suggest that Article 8 funds, which operate under less stringent sustainability criteria compared to Article 9 funds, display more varied herding patterns. Notably, the increase in buy herding for higher ESG stocks (S3 and S5) post-regulation indicates that these funds are more influenced by market trends when acquiring ESG stocks. This selective increase in greener assets may reflect efforts to align with growing investor demand for sustainability despite the funds being less tightly bound by regulatory mandates.

Similarly, in Panel C, the results for Article 6 funds, which are subject to the least stringent sustainability requirements, also show mixed herding patterns. There is a slight reduction in sell herding (SHM) for low ESG (brown) stocks (S1), but these changes are not statistically significant, and no clear trend is observed across other ESG quantiles on the sell side. On the buy side (BHM), however, significant increases in herding behaviour are observed for mid-ESG stocks (S3) and high ESG stocks (S5), mirroring the pattern seen in Article 8 funds but with a more pronounced effect. These results suggest that the lower transparency and sustainability requirements in Article 6 funds contribute to higher buy herding, particularly for stocks with higher ESG scores. The pronounced increase in buy herding for high ESG stocks indicates that Article 6 funds are more prone to follow market trends when purchasing greener assets, potentially as a way to signal some level of sustainability focus despite their less rigorous regulatory obligations. This behaviour underscores the more pronounced influence of market movements on portfolio adjustments in response to the SFDR for Article 6 funds.

Overall, the evidence suggests that funds' herding behaviour is significantly influenced by their SFDR classification and the ESG characteristics of the stocks in their portfolios. The findings emphasise the importance of regulatory stringency in shaping investor behaviour, as SFDR requirements directly impact how funds approach ESG-related risks and opportunities. Stricter regulations, such as those under Article 9, promote more independent and informed decision-making, reducing herding by encouraging more disclosure of sustainability metrics. In contrast, funds classified under the less restrictive frameworks of

Table 4.9: Results of Evaluating Herding by ESG Score of Stocks
This table shows the results from regressions examining the herding measures over stock quarters, segregated by ESG score post-regulation. The buy herding measure $BHM_{i,t}$ computed for stocks with a higher proportion of buyers than average and is defined as $BHM_{i,t} = HM_{i,t} \mid p_{i,t} > E[p_{i,t}]$. Likewise, the sell herding measure $SHM_{i,t}$ is calculated for stocks with a higher proportion of sellers than average and is defined as $SHM_{i,t} = HM_{i,t} \mid p_{i,t} < E[p_{i,t}]$. The main independent variable of interest is $SFDR * Post$, defined as an interaction variable comprised of two underlying dummy variables where $SFDR$ takes a value of 1 for Article 9, 8, or 6 funds and 0 for unclassified funds, and $Post$ takes a value of one for the four quarters following the introduction date of the SFDR (2019Q4) and zero otherwise. We consider 2019Q4 to be the quarter in which the SFDR was introduced. The main analysis uses an estimation window of one year before and one year after introducing the SFDR. Panel A ,B, and C show the result of Articles 9, 8, and 6 herding measures, respectively, by quantile based on the ESG score of stocks in which funds are invested. We divide the SFDR fund's portfolios into five ESG-based quantiles: low ESG score (S1), medium ESG score (S2-S4), and high ESG score (S5). The odd columns 1-9 represent the results with control variables, while the even columns 2-10 report the number of stock-quarter observations that are included in the calculation. Detailed definitions of the variables are provided in Table 4.1. The sample period is 2016Q1 to 2024Q1. t-statistics are reported in parentheses. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Article 9 Herding Measures, By ESG Score											
		S1		S2		S3		S4		S5	
		Low ESG								High ESG	
Variables		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SFDR*Post	HM	-0.099***	7749	-0.082***	7820	-0.052***	8097	-0.048***	8575	-0.039***	9352
		(-8.108)		(-16.474)		(-11.589)		(-12.311)		(-11.345)	
	SHM	-0.105***	3,036	-0.080***	3,284	-0.056***	3,711	-0.051***	4,215	-0.042***	5,060
		(-5.401)		(-6.378)		(-5.782)		(-7.779)		(-17.029)	
	BHM	-0.092***	4,713	-0.079***	4,536	-0.052***	4,386	-0.049***	4,360	-0.037***	4,292
		(-8.830)		(-15.189)		(-9.776)		(-8.117)		(-5.530)	
Controls		Yes		Yes		Yes		Yes		Yes	
Country FE		Yes		Yes		Yes		Yes		Yes	
Quarter FE		Yes		Yes		Yes		Yes		Yes	
Panel B: Article 8 Herding Measures, By ESG Score											
		S1		S2		S3		S4		S5	
		Low ESG								High ESG	
Variables		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SFDR*Post	HM	-0.015	9122	-0.006	8974	0.013**	8989	0.010**	9335	0.008**	9899
		(-1.312)		(-1.256)		(2.710)		(3.597)		(3.379)	
	SHM	-0.031	3,636	-0.009	3,840	0.006	4,115	0.006	4,577	0.003	5,293
		(-1.826)		(-0.766)		(0.545)		(0.867)		(1.281)	
	BHM	-0.003	5,486	-0.004	5,134	0.016***	4,874	0.007	4,758	0.012*	4,606
		(-0.263)		(-0.821)		(4.830)		(1.685)		(2.059)	
Controls		Yes		Yes		Yes		Yes		Yes	
Country FE		Yes		Yes		Yes		Yes		Yes	
Quarter FE		Yes		Yes		Yes		Yes		Yes	
Panel C: Article 6 Herding Measure, By ESG Score											
		S1		S2		S3		S4		S5	
		Low ESG								High ESG	
Variables		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SFDR*Post	HM	-0.013	7578	-0.005	7770	0.012**	8338	0.008***	8936	0.010***	9636
		(-1.413)		(-0.803)		(2.941)		(4.246)		(4.191)	
	SHM	-0.026	3,142	-0.014	3,408	0.000	3,908	0.003	4,422	0.003	5,215
		(-1.630)		(-1.160)		(0.037)		(0.406)		(1.370)	
	BHM	-0.003	4,436	0.002	4,362	0.017***	4,430	0.006	4,514	0.015**	4,421
		(-0.377)		(0.319)		(6.363)		(1.307)		(2.507)	
Controls		Yes		Yes		Yes		Yes		Yes	
Country FE		Yes		Yes		Yes		Yes		Yes	
Quarter FE		Yes		Yes		Yes		Yes		Yes	

Articles 8 and 6 display greater herding, particularly when dealing with high-ESG stocks. In addition, the varying degrees of information asymmetry faced by these funds influence their trading strategies, often leading to increased investments in high-ESG stocks or divestment from low-ESG ones. This underscores how different regulatory classifications can lead to divergent trading behaviours across funds.

4.6 Conclusion

In this paper, we examine the impact of sustainability-related disclosure requirements on herding behaviour among mutual funds, using the introduction of the Sustainable Finance Disclosure Regulation (SFDR) as a quasi-natural experiment to assess changes in fund behaviour across mutual funds in the EU. Our findings reveal that not all SFDR funds exhibit the same level of herding post-regulation, indicating the incomplete effectiveness of regulatory requirements in reducing herding behaviour. Specifically, we find that Article 9 funds exhibit a significant decline in herding levels compared to unclassified funds, suggesting that funds with stricter sustainability mandates are more likely to make independent investment decisions post-regulation. This response highlights the role of SFDR in shaping fund managers' trading behaviour, encouraging them to move away from market-driven strategies and toward sustainability-focused decision-making.

Furthermore, the increased transparency introduced by Article 9 funds has played a pivotal role in reducing information asymmetry, offering investors greater clarity and confidence in distinguishing between genuinely sustainable funds and those engaging in misleading behaviour. By mandating enhanced disclosure requirements, the SFDR ensures that asset managers justify and substantiate their sustainability claims, strengthening the integrity of ESG classifications. Investments classified under Article 9 must genuinely adhere to environmental and social objectives, reducing ambiguity and skepticism surrounding sustainability commitments. This reduction in uncertainty discourages herding

behaviour, which is often fueled by insufficient data, investor doubts, or a lack of reliable ESG performance indicators. As a result, the SFDR has not only influenced fund managers' trading decisions but has also fostered a more transparent, data-driven, and independent investment landscape, ultimately enhancing market efficiency and reinforcing the credibility of sustainable finance initiatives.

In contrast, Article 8 and Article 6 funds exhibit an insignificant change in herding behaviour, implying that the SFDR's impact varies depending on the level of sustainability commitments. While Article 8 funds promote ESG factors, their response to SFDR in terms of herding behaviour is less pronounced than that of Article 9 funds. This suggests that Article 8 and 6 funds may not have undergone the same level of transformation in investment strategies, possibly because their ESG mandates are not as strictly defined or enforced.

Our results offer valuable insights for both investors and regulators regarding the broader impact of SFDR on investment behaviour. For investors, the increased transparency mandated by SFDR helps reduce information asymmetry, enabling them to make more informed and independent investment decisions rather than relying on market trends or engaging in herding behaviour. Article 9 funds, with their stronger alignment with sustainability commitments, provide a clearer path for investors seeking genuinely sustainable investments, fostering rational, long-term decision-making. Conversely, funds with less stringent ESG criteria, such as Article 8 and 6 funds, do not experience the same level of benefits, highlighting the need for enhanced regulatory scrutiny to ensure their ESG claims align with investment practices. For regulators, our findings suggest that SFDR plays a critical role in reducing information asymmetry, which in turn enhances market stability by curbing irrational herding behaviour, particularly among funds with higher ESG commitments. By promoting transparency and requiring funds to disclose standardised sustainability metrics, SFDR encourages more independent investment decisions, leading to improved market efficiency and lower volatility. The regulation ensures

that investment decisions are based on robust ESG disclosures rather than short-term market signals, fostering a more stable and predictable investment environment.

These findings underscore the importance of transparency and regulatory oversight in sustainable finance. While SFDR has made significant progress in enhancing market discipline and promoting responsible investing, our results indicate that there is still room for improvement, particularly for Article 8 and 6 funds. Future policy refinements could focus on strengthening the regulatory requirements for lower-tier ESG funds, ensuring that all sustainability-labeled investments align with meaningful and verifiable environmental or social objectives. Overall, our study demonstrates the effectiveness of regulatory frameworks in fostering a more stable, transparent, and efficient market for sustainable investing, reinforcing the critical role of SFDR in shaping the future of sustainable investing.

Chapter 5

Conclusion

5.1 Overview

This thesis has studied several key issues in sustainable finance. Section 5.2 provides a summary of the overall content and outlines the contributions of the three main chapters. Section 5.3 discusses the limitations of the methodologies employed. Section 5.4 highlights directions for future research. Finally, Section 5.5 offers concluding remarks.

5.2 Summary of Contributions and Policy Implications

This thesis has addressed key challenges in sustainable investing, focusing on greenwashing phenomena, decarbonisation, and herding behaviour in financial markets. It has analysed the complex issue of identifying and measuring greenwashing in mutual funds. Additionally, the thesis has examined how the EU Sustainable Finance Disclosure Regulation affects investment funds herding behaviour. In the author's view, this work provides valuable contributions to the field of sustainable finance, offering insights for mitigating greenwashing, achieving decarbonisation targets, and promoting more independent, responsible investment decisions. These findings have important implications for regulatory, investors, and policy-making in the context of sustainable investing and decarbonisation efforts.

Chapter 2 has examined greenwashing practices in environmental funds. It has contributed to the growing literature on greenwashing by focusing on funds that explicitly declare the incorporation of environmental factors into their investment strategies and decisions, as indicated in the fund prospectus and utilizing textual analysis techniques to examine the investment prospectuses of mutual funds to identify environmental funds and establish their commitments to sustainability as part of their fiduciary responsibilities. Results show that the carbon footprints of environmental funds do not improve after announcing the integration of sustainability into their prospectus. Results have also found that environmental fund flows react positively, resulting in significant abnormal

flows after these announcements. As a result, the combination of the failure to reduce carbon footprints and the surge in inflow provides evidence of greenwashing by environmental funds, raising concerns about their fiduciary duty. These findings carry important policy implications. Given the ongoing debates about sustainable investing, these findings are of great interest to regulators, supervisors, and investors. The current regulatory framework requires stricter and more specific standards to define what qualifies as green or sustainable, preventing funds from making vague or misleading claims. Supervisors should carefully scrutinise the portfolio holdings of environmental funds, particularly if they invest heavily in stocks with high carbon emissions, which would raise concerns about their fiduciary duty and true commitment to decarbonisation. Strengthening oversight and increasing penalties for non-compliance are necessary. For investors, the widespread occurrence of greenwashing underscores the need for stronger protections, including regulations that ensure access to accurate information, helping them make more informed decisions and compare funds' environmental claims effectively.

Chapter 3 has investigated the impact of SFDR regulation on greenwashing practice in the EU mutual funds industry by proposing the greenwashing index, a novel measure to capture greenwashing by SFDR funds. The results have confirmed the significant effect of the SFDR on greenwashing, particularly for Article 9 funds, which responded more positively to the SFDR than Article 8 funds indicating a reduction in their level of greenwashing index post the introduction of the SFDR. In addition, the results support the conjecture that the higher the effort made by the fund to decarbonise its portfolio, the lower its level of the greenwashing index. Results have also shown that tilting and changing position strategies are key methods for Article 9 funds to decarbonise their portfolios. These findings have important implications. The SFDR introduces a new level of regulatory oversight, ensuring that financial entities not only meet disclosure requirements but also accurately reflect sustainability risks and impacts in their investment strategies. It hints to regulators concrete steps toward the ultimate goal of the European Green Deal and the achievement of the Sustainable Development Goals (SDGs). This chapter sheds

light on the effectiveness of the SFDR and its implications for achieving net-zero carbon emissions, improving market efficiency, reducing information asymmetry, and fostering investors' confidence in sustainable investing.

Chapter 4 has explored an important sustainability disclosure shock imposed by the EU regulation to investigate the herding behaviour of SFDR funds. The results provided evidence that the SFDR has significantly influenced the trading behaviour of asset managers, particularly Article 9 funds, indicating a significant change in their herding behaviour post-regulation. In contrast, we find that Article 8 and 6 funds experience an insignificant increase in herding levels compared to unclassified funds. This suggests that while Article 8 funds may promote ESG factors, their response to the SFDR in terms of changing their herding behaviour is less pronounced than that of Article 9 funds. In addition, the findings have documented that not all SFDR funds exhibit the same level of herding post-regulation. Chapter 4 has presented valuable insights for policy making. First, by underscoring the effectiveness of mandating greater transparency and standardised disclosures regarding the sustainability characteristics of investment products. Second, the SFDR regulation helps to reduce information asymmetry. This, in turn, empowers investors to make more informed decisions based on reliable data rather than simply following market trends or the actions of their peers. In addition, SFDR encourages more independent investment strategies and reduces the tendency for investors to engage in herding behaviour, where they mimic others without fully understanding the underlying sustainability risks and opportunities. Finally, the regulation holds fund managers accountable for accurately representing their sustainability commitments, discouraging greenwashing practices and further fostering trust in individual decision-making.

5.3 Limitations

This thesis provides robust results and valuable implications for regulators, investors, and policymakers in the realm of sustainable finance. Nevertheless, a critical assessment and

limitations of the chosen methods should be acknowledged.

In Chapter 2, to provide more compelling evidence of greenwashing, we narrow our focus to a sample of environmental funds that explicitly prioritise environmental issues, rather than addressing the broader ESG or responsible investment factors. In addition, we avoid issues related to ESG rating divergence by concentrating on the funds' carbon footprint, estimated based on their holdings' reported carbon emissions, as a more robust measure of the efforts made by environmental funds to fulfil their promises of integrating sustainability into their investment decisions. Given that the focus of the analysis in Chapter 2 is examining greenwashing based on real fund outcomes such as carbon footprint, the data availability to conduct the empirical analysis has been limited by the number of holdings within each fund's portfolio that provide sufficient data on carbon emissions to calculate the funds' carbon footprints.

The greenwashing index measure presented in Chapter 3 is designed to assess the impact of the SFDR regulation on greenwashing practices among EU financial market participants. It applies only to EU financial market participants. However, many large firms operate globally, and funds may adhere to SFDR-compliant measures in the EU while continuing less transparent or greenwashing practices in other regions. This limitation complicates the assessment of SFDR's overall effectiveness in curbing global greenwashing. Consequently, the study's findings may not be generalizable to regions with different environmental regulations or where SFDR does not apply and does not provide insight into global market dynamics.

While the study presented in Chapter 4 provides valuable insights into the impact of SFDR on herding behaviour among equity mutual funds, it is subject to certain limitations. The study is limited to EU-based mutual funds, hence, the findings may not be directly applicable to markets with different regulatory frameworks or sustainability disclosure requirements. Another limitation of this study is the potential influence of market sentiment and external shocks on herding behaviour, independent of the SFDR

regulation. While the analysis attempts to isolate the impact of SFDR, global economic events, financial crises, or sudden shifts in ESG sentiment could also contribute to changes in fund trading patterns. For example, heightened climate risk awareness or political debates surrounding sustainable investing may have influenced fund managers' decisions, making it difficult to disentangle the effect of regulation from broader market dynamics. Additionally, the study does not account for differences in the enforcement and interpretation of SFDR across EU member states, which could lead to variations in compliance and reporting standards. These inconsistencies may affect the extent to which funds genuinely adjust their strategies in response to regulatory pressure. Finally, while the study focuses on fund managers' trading behaviour, it does not directly account for investor sentiment and demand-side dynamics, which could also play a role in shaping post-SFDR herding patterns. Addressing these limitations in future research could provide a more comprehensive understanding of the evolving role of sustainability-related regulations in shaping investment behaviour.

5.4 Further Research

While this research has provided significant insights, several areas are identified as promising avenues for future research.

In Chapter 2, the results have provided evidence of greenwashing by environmental funds. A more general line of research can be done to detect greenwashing by incorporating broader ESG metrics or alternative sustainability measures to offer a more comprehensive picture of sustainability impact. In addition, further research should be conducted to investigate whether the high carbon footprint is a result of portfolio companies' insufficient progress in achieving sustainability goals and to explore how funds can actively drive meaningful change within the companies they invest in. It is also necessary to conduct research focused on the impact of these findings on investor behaviour and decision-making.

Do investors continue to trust environmental funds, or do they shift their investments after recognising greenwashing patterns?

In Chapter 3, we propose a novel measure to capture greenwashing by EU SFDR funds that we call the greenwashing index. Therefore, there is a need to conduct research using different geographical samples, such as funds from the US instead of the EU to investigate whether sustainability expectations differ significantly between regions, which could influence the extent and nature of greenwashing practices. Research is also needed to understand how the greenwashing index compares with other existing measures of greenwashing or ESG performance. Future research could focus on applying the greenwashing index to funds using different sustainability regulations frameworks beyond the SFDR. Investigating how greenwashing manifests under varying regulatory environments would provide insights into whether these frameworks effectively curb misleading sustainability claims or allow greenwashing to persist in different ways.

In Chapter 4, we examine an important sustainability disclosure shock imposed by the EU regulation to investigate the herding behaviour of SFDR funds. Further research is needed to explore the impact of SFDR on market stability, by investigating whether herding behaviour driven by SFDR compliance impacts overall market stability. Excessive herding in sustainable assets could lead to asset bubbles or volatility, which might have broader implications for financial markets. An additional area for future research could focus on investor preferences and their role in driving herding behaviour under SFDR regulation by understanding how these preferences contribute to concentrated investment flows into certain asset classes or funds labelled as sustainable or green.

Finally, future research could examine how greenwashing or its absence affects fund performance, investor sentiment, and capital flows. Understanding whether genuinely sustainable funds outperform those employing misleading ESG claims would yield valuable insights into the financial materiality of greenwashing. Moreover, exploring how changes in regulatory priorities and enforcement of ESG disclosure requirements—especially in the

evolving political landscape of the United States—shape mutual fund behaviour could further illuminate the interplay between policy and sustainability. The divergence between U.S. and EU regulatory approaches also presents an opportunity to evaluate whether market-driven efforts in the U.S. can attain the same levels of transparency and accountability as regulation-driven frameworks in the EU. Such research would deepen our comprehension of how shifting regulatory and political environments ultimately influence the effectiveness of sustainability disclosures and impact investor decision-making on a global scale.

5.5 Concluding Remark

I am deeply grateful for the opportunity to have conducted my doctoral research on this topic. This thesis has significantly expanded my knowledge and understanding of sustainable finance, and I hope my contributions will help further the discourse in sustainable investing. The field remains abundant with opportunities, presenting numerous unresolved questions and promising benefits. As I conclude this research, I find myself equipped with more insightful and ambitious questions than when I began, and I am excited to continue exploring this dynamic and impactful area of study in the future.

Appendix A

Supplementary Analysis for Chapter 2

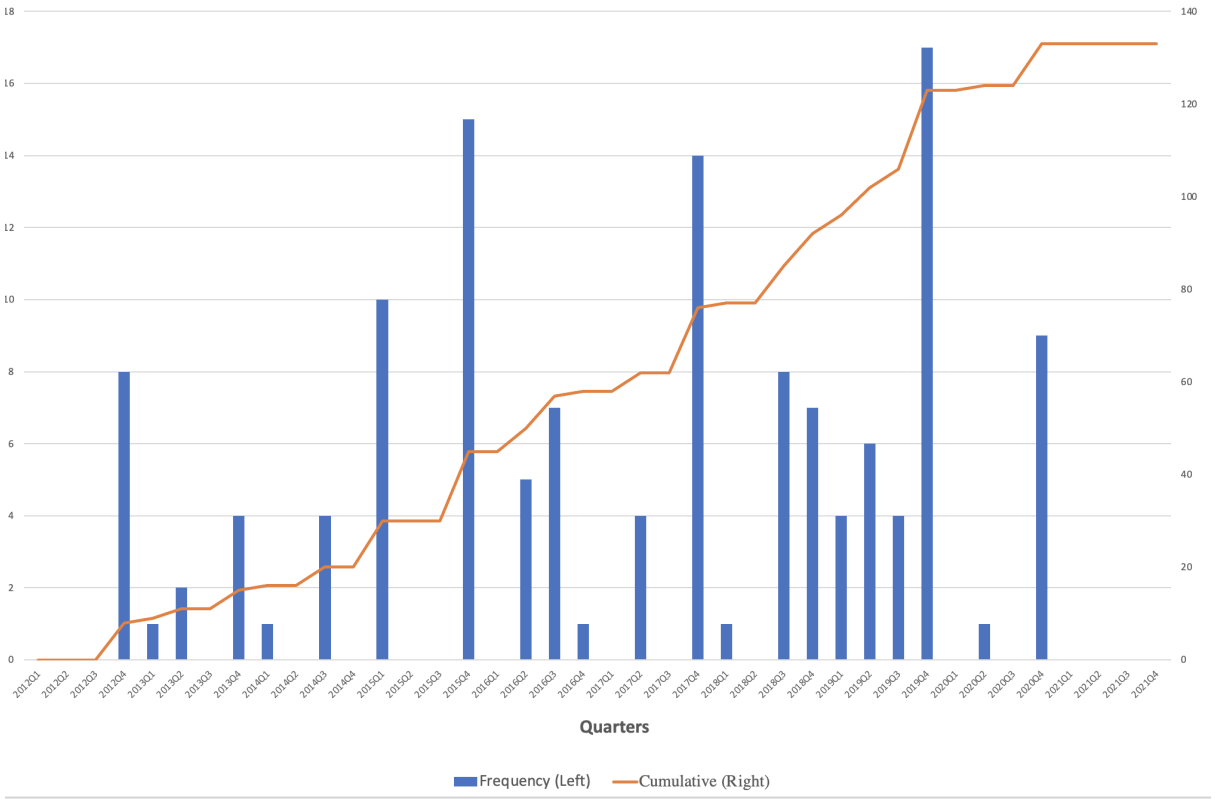


Figure A.1: The Distribution of Announcement Dates
This figure illustrates the distribution of the announcement dates quarterly from 2012Q1 to 2021Q4 of the environmental funds sample. The announcement date refers to the quarter in which the fund designates itself as an environmental fund, as reported in its prospectus. Each bar on the figure represents the number of announcement dates that fall in the respective quarter. The line on the figure represents the cumulative number of announcement dates over time.

Table A.1: Correlation Matrix

This table presents the correlation coefficients between the main variables. The sample includes quarterly data for the period from 2012Q1 to 2021Q4. The variables included are for both the fund level and the portfolio level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Variables	Fund Flow	TNA	NAV	Return	TER	Load Fees	Fund Age	Alpha	CFP	Revenues	Total Assets	Mkt Cap	P/B	Turnover	Holdings	Emission
Fund Flow	1															
Total Net Assets (TNA)	-0.122***	1														
Net Asset Value (NAV)	-0.009**	0.021***	1													
Total Return	-0.022***	0.013***	0.010**	1												
Total Expense Ratio (TER)	0.009**	-0.045***	0.020***	0	1											
Total Load Fees	0.033***	-0.097***	-0.164***	0.001	-0.006	1										
Fund Age	-0.078***	0.258***	0.025***	-0.002	0.002	-0.257***	1									
Alpha	0.043	0.085***	0.124***	0.193***	0.013	-0.048	0.043	1								
Carbon Footprint (CFP)	0.003	-0.013***	-0.019***	-0.025***	0.004	0.004	0.030***	-0.121***	1							
Revenues	-0.009**	0.037***	-0.001	0.006	-0.004	-0.040***	0.021***	0.005	-0.015***	1						
Total Assets	-0.008*	0.036***	-0.001	0.006	-0.005	-0.042***	0.025***	-0.012	-0.015***	0.977***	1					
Market Cap	-0.010**	0.040***	-0.003	0.016***	-0.005	-0.019***	-0.005	0.062**	-0.023***	0.756***	0.744***	1				
Price to Book (P/B)	0.001	0.002	-0.004	0.004	-0.003	0.008*	-0.006	0.008	0.029***	-0.002	-0.003	-0.001	1			
Turnover Ratio	-0.011***	0.009**	-0.002	-0.065***	0.008**	0	0.090***	0.019	0.021***	0.018***	0.020***	0.006	0.006	1		
Number of Holdings	0.037***	0.303***	0.004	0.008**	-0.043***	-0.081***	0.197***	0.126***	0.025***	0.028***	0.031***	0.025***	0.007*	0.078***	1	
Emission Score	-0.006	0.092***	0.015***	-0.013***	-0.001	-0.084***	0.128***	0.047*	0.182***	0.053***	0.075***	0.040***	0.004	0.036***	0.121***	1

Table A.2: The Distribution of Investment Styles
This table illustrates the distribution of the investment styles of the initial sample of US mutual fund sample. The investment style of mutual funds refers to the specific approach or strategy that the fund manager employs when selecting investments for the fund's portfolio. It is a characterization of the types of securities the fund primarily invests in. The investment style is reported based on Refinitiv Lipper's Holdings-Based Fund Classifications (HBC).

Investment Style	Number of Funds	Percent
Multi Cap Growth	656	9.76%
Multi Cap Core	745	11.09%
Multi Cap Value	763	11.35%
Large Cap Growth	727	10.82%
Large Cap Core	874	13.01%
Large Cap Value	384	5.71%
Mid Cap Growth	372	5.54%
Mid Cap Core	292	4.35%
Mid Cap Value	187	2.78%
Small Cap Growth	743	11.06%
Small Cap Core	777	11.56%
Small Cap Value	200	2.98%
Sum	6720	100.00

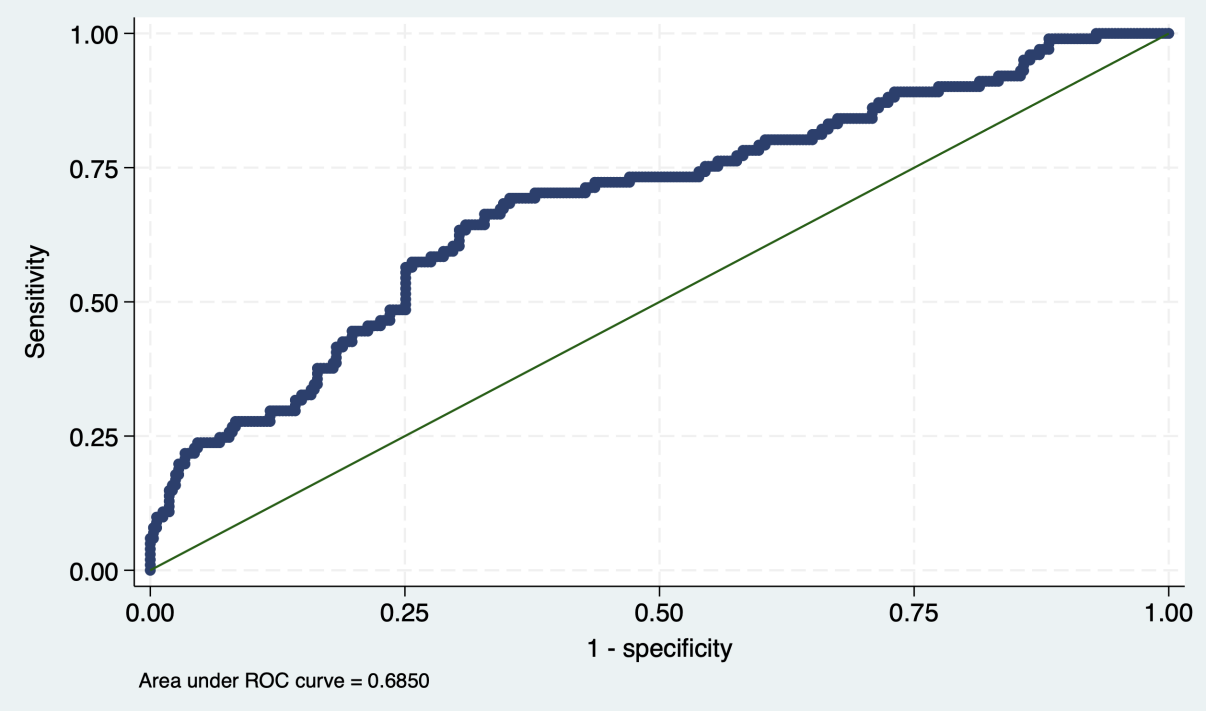
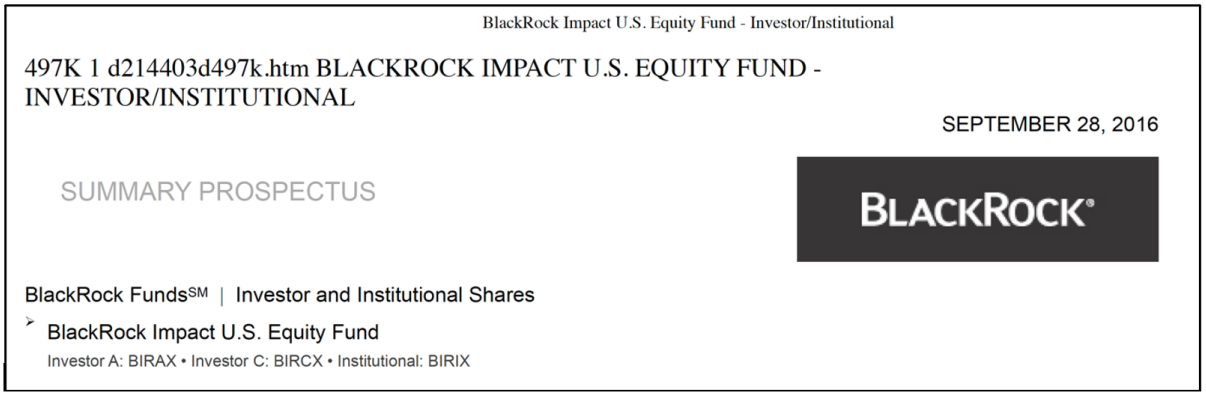


Figure A.2: The ROC Curve of the PSM
This ROC curve represents a plot of the sensitivity versus (1-specificity) for a binary classification system using a logistic regression model to distinguish between environmental and conventional funds.

Table A.3: Robustness Test: Alternative Measures
This table reports the results from difference-in-differences (DID) regression on the carbon footprint of environmental funds before and after the announcement date using different estimators. Based on the methodology of Baker et al. (2022), we use the Callaway and Sant'Anna (Callaway and Sant'Anna, 2021) estimator alongside a stacked DID regression. The fund's Carbon Footprint is calculated using Eq. 4 as the weighted average of the carbon footprints of its individual holdings, where the weight is determined by the proportion of each holding's market value relative to the total market value of the fund's portfolio. This regression uses the natural logarithm of Carbon Footprint. Env is a dummy variable that equals one if the fund integrates environmental criteria in its prospectus and zero otherwise. Post is a dummy variable that equals one after the fund announces that it is integrating environmental criteria into its prospectus and zero otherwise. Env*Post is the DID interaction variable. Detailed definitions of the variables are provided in Table A.1. The sample period is from 2012 to 2021. Estimations are based on data of one year pre and post-announcement dates. The ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Carbon Footprint				
	Callaway & Sant'Anna Estimator		Stacked DID regressions	
	(1)	(2)	(3)	(4)
Env*Post	0.020	0.038	0.012	0.084
	(0.08)	(0.34)	(0.53)	(0.48)
Controls	No	Yes	No	Yes
Quarter FE	Yes	Yes	No	No
Investment Style FE	Yes	Yes	No	No
Quarter x Stack FE	No	No	Yes	Yes
Investment x Style FE	No	No	Yes	Yes



BlackRock Impact U.S. Equity Fund - Investor/Institutional

497K 1 d214403d497k.htm BLACKROCK IMPACT U.S. EQUITY FUND - INVESTOR/INSTITUTIONAL

SEPTEMBER 28, 2016

SUMMARY PROSPECTUS

BLACKROCK®

BlackRock Funds℠ | Investor and Institutional Shares

BlackRock Impact U.S. Equity Fund

Investor A: BIRAX • Investor C: BIRCX • Institutional: BIRIX

Principal Investment Strategies of the Fund

The Fund will seek to provide total return by investing in a portfolio of equity securities of companies with positive aggregate societal impact outcomes, as determined by BlackRock using the BlackRock Scientific Active Equity ("SAE") Impact Methodology (as developed for the Fund and described further in the section "Details About the Fund — How the Fund Invests — Investment Process — BlackRock SAE Impact Methodology"), compared to the Russell 3000® Index (the "Benchmark"), and systematic, quantitative security selection models. The principal societal impact outcomes that are currently measured include green innovation, corporate citizenship, high impact disease research, ethics controversies and litigation, although these may change at any time and one or more societal impact outcomes may not be relevant to all companies that are eligible for investment. The Fund will screen out certain companies or industries, including companies that are classified in the tobacco and alcohol industry based on Global Industry Classification (GIC) codes and certain companies whose primary business is weapons, as determined by BlackRock. Securities will then be selected and weightings allocated based on the issuer's measurable societal impact outcomes, as determined by BlackRock, in conjunction with forecasts of return, risk and transaction costs.

Under normal circumstances, the Fund seeks to invest at least 80% of its net assets plus any borrowings for investment purposes in U.S. equity securities, which include common stock, preferred stock and convertible securities. Generally, the Fund will invest in equities or other financial instruments that are components of, or have market capitalizations similar to the securities included in, the Benchmark. The companies included in the Benchmark have market capitalizations that range from approximately $24 million to $580 million as of September 6, 2016. The Fund primarily seeks to buy common stock. From time to time the Fund may invest in shares of companies through "new issues" or initial public offerings ("IPOs").

To manage cash flows into or out of the Fund, the Fund may buy and sell financial futures contracts or options on such contracts.

Figure A.3: Sample 1 of Funds Prospectus
We provide below the "Investment Objectives" section of an example fund prospectus before the fund identifies itself as "environmental."

497 1 d783208d497.htm BLACKROCK FUNDS

Table of Contents

SEPTEMBER 27, 2019

PROSPECTUS

BLACKROCK®

BlackRock Funds℠ | Investor and Institutional Shares

- BlackRock Impact U.S. Equity Fund
  Investor A: BIRAX • Investor C: BIRCX • Institutional: BIRIX

How the Fund Invests

Investment Objective

The investment objective of the Fund is to seek to provide total return.

Should the Trust's Board of Trustees (the "Board") determine that the investment objective of the Fund should be changed, shareholders will be given at least 30 days' notice before any such change is made. However, such change can be effected without shareholder approval.

Investment Process

The Fund will seek to provide total return by investing in a portfolio of equity securities with positive aggregate societal impact outcomes, as determined by BlackRock Advisors, LLC ("BlackRock") using the BlackRock Systematic Active Equity ("SAE") Impact Methodology (as developed for the Fund and described below), compared to the Russell 3000® Index (the "Benchmark"), and systematic, quantitative security selection models. Securities in which the Fund invests will generally be instruments that are components of, or have market capitalizations similar to the securities included in, the Benchmark. The Fund will screen out certain companies or industries, including companies that are classified in the tobacco and alcohol industry based on Global Industry Classification (GIC) codes and certain companies whose primary business is weapons, as determined by BlackRock. Securities will then be selected and weightings allocated based on the issuer's measurable societal impact outcomes, as determined by BlackRock, in conjunction with forecasts of return, risk and transaction costs.

The Fund will seek to identify overvalued, undervalued or mispriced stocks through proprietary ranking techniques that analyze a broad universe of equity instruments. The investment process is fundamentally driven with systematic and quantitative implementation based on expected returns. The stock selection model, constructed by BlackRock's SAE Team, will direct the strategy using advanced techniques to identify misvaluation across stocks and markets.

BlackRock SAE Impact Methodology

The BlackRock SAE Impact Methodology seeks to measure select societal impact outcomes of companies. Where one or more measurable societal impact outcomes are identified in an eligible company, that information will be considered, together with forecasts of return, risk and transaction costs, as well as other information, in determining whether the weight of an investment in that company will be higher or lower than its Benchmark weight.

To evaluate a company using the BlackRock SAE Impact Methodology, BlackRock measures a series of societal impact outcomes. The societal impact outcomes utilized in the process may change over time and one or more outcomes may not be relevant to all companies that are eligible for investment. The BlackRock SAE Impact Methodology does not attempt to capture all positive or negative outcomes, rather those that, in BlackRock's opinion, can be measured and have an investment thesis associated with the outcome. BlackRock determines which outcomes to include in the model and what changes are made in the model over time.

The principal societal impact outcomes that are currently measured include the following, although they may change at any time:

- **Carbon Intensity** — Companies that represent a lower level of carbon emission from sources owned or controlled by the company, or from the generation of electricity, heat or steam purchased by the company.
- **Green Innovation** — Companies that demonstrate "green innovation" focus on environmentally sustainable technologies as described by the United Nations Framework Convention on Climate Change and the World Intellectual Property Organization.
- **Corporate Citizenship —** "Corporate citizenship" focuses on companies whose employees have a high level of satisfaction working for their employers.

Figure A.4: Sample 2 of Funds Prospectus

Then we provide the "Investment Objectives" section of the same fund prospectus the first time the fund identifies itself as "environmental."

Appendix B

Supplementary Analysis for Chapter 3

Table B.1: The Distribution of SFDR Funds by Domicile
This table illustrates the distribution of our sample of EU SFDR funds based on the fund domicile.

Domicile	Article 9	Article 8	Article 6	Unclassified
Australia	4	7	3	164
Austria	9	45	1	4
Belgium	7	15	3	15
Czech Republic	2	5	1	1
Denmark	13	37	2	21
Finland	4	28	2	54
France	63	141	20	80
Germany	8	95	21	26
Greece	3	5	4	20
Hungary	3	21	6	5
Iceland	1	4	3	1
Italy	3	15	7	2
Netherlands	26	52	3	6
Norway	11	9	3	8
Poland	3	3	1	3
Portugal	1	1	2	10
Slovenia	3	1	4	7
Spain	5	37	7	4
Sweden	23	58	7	2
Switzerland	2	13	3	101
Total	190	585	100	370

Table B.2: Descriptive Statistics of the Matched Treatment and Control Groups
This table presents the descriptive statistics for PSM analysis. Panel A & panel B describe the variables used to match Article 9 (8) funds with Article 6 and unclassified funds prior to the SFDR date. The columns labelled Article 9(8) and Article 6 and unclassified funds display the mean value of each variable. The difference column indicates the percentage difference between Article 9(8) and Article 6 and unclassified funds for each variable. The t-stat and p-value columns provide the results from the t-test assessing the difference between the two means. Detailed definitions of the variables are provided in Table 3.2. All variables are lagged. The sample period is 2016 to 2022.

Panel A: Article 9 funds					
Variable	Article 9	Article 6 and Unclassified Funds	Difference	t-stat	p-value
Fund Size	19.76	19.53	0.01	1.33	0.18
Fund Age	3.58	3.53	0.01	0.70	0.48
Total Return	0.92	0.89	0.03	1.22	0.22
Market Cap	25.86	25.68	0.00	1.69	0.09
Book to Market Ratio	5.05	4.88	0.03	1.10	0.27
Turnover Ratio	0.04	0.05	-0.20	-1.37	0.17
Fund Flows	5.13	6.83	-0.24	-0.36	0.71
Revenues	23.74	23.58	0.00	1.24	0.21
Return on Equity	2.43	2.41	0.00	0.30	0.76
Panel B: Article 8 funds					
Variable	Article 8	Article 6 and Unclassified Funds	Difference	t-stat	p-value
Fund Size	19.20	19.09	0.00	1.12	0.26
Fund Age	3.75	3.74	0.00	0.24	0.81
Total Return	0.79	0.83	-0.04	1.53	0.12
Market Cap	25.63	25.64	-0.00	1.69	0.09
Book to Market Ratio	4.87	4.81	0.01	0.84	0.40
Turnover Ratio	0.04	0.05	-0.20	-1.00	0.31
Fund Flows	3.64	5.55	-0.34	-0.75	0.45
Revenues	23.50	23.53	-0.00	-0.54	0.59
Return on Equity	2.40	2.37	0.01	0.96	0.33

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