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Does the EU sustainable finance disclosure regulation mitigate greenwashing?

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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 their 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 which indicates 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.

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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 (Amel-Zadeh and Serafeim 2018; Edmans 2023; Horn 2024). 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 (Dumitrescu, Gil-Bazo, and Zhou 2022; Raghunandan and Rajgopal 2022). This practice can raise ethical concerns about their commitments to sustainable investing (Berrone, Fosfuri, and Gelabert 2017; Marquis, Toffel, and Zhou 2016). 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.[1]

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).[2] 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

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to help investors make 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.[3] While greenwashing can take various forms, our study focuses on carbon intensity as a primary measure that is directly aligned with the overarching aim of reducing carbon emissions per the requirements of the Paris Agreement on Climate Change.[4] Using the introduction of SFDR as a quasi-natural experiment, we test whether this regulation effectively mitigates greenwashing practices.

The SFDR classifies financial products into three main categories based on their sustainability characteristics and objectives: Articles 6, 8, and 9 funds.[5] We test whether Article 9 funds change their investment behaviour post the introduction of the SFDR relative to Article 8 funds.

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 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.

In the next step of our analysis, we examine the different strategies that asset managers can use to decarbonise their portfolios. To this end, we first examine the portfolio tilting 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. Becker, Martin, and Walter 2022; Bengo, Boni, and Sancino 2022; Cremasco and Boni 2024; Dai et al. 2024; Lambillon and Chesney 2023; Scheitza and Busch 2024). For example, Bengo, Boni, and Sancino (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 categorise investments based on sustainability criteria. Becker, Martin, and Walter (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 (2024) 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, Wilkens, and Zink (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 (2023) 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 organised as follows: Section 2 presents the institutional background of the SFDR. In Section 3 we describe the data set and variables. we examine the impact of SFDR on greenwashing In Section 4 and analyze how SFDR funds decarbonise their portfolios In Section 5. Section 6 provides the conclusion.

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. Berg, Koelbel, and Rigobon 2022; Chatterji et al. 2016; D. M. Christensen, Serafeim, and Sikochi 2022; Dimson, Marsh, and Staunton 2020; Gangi et al. 2022; Gibson Brandon, Krueger, and Schmidt 2021; Semenova and Hassel 2015). 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 (Balakrishnan, Ertan, and Lee 2020; H. B. Christensen, Hail, and Leuz 2021; Xue 2023). The empirical evidence supports this view. For example, Yu, Van Luu, and Chen (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, E. H. 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 (H. B. Christensen, Hail, and Leuz 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. Bolton and Kacperczyk 2021b; Grewal, Richardson, and Wang 2022; Tomar 2023) document the positive effect of mandatory carbon disclosure by firms on their carbon emissions reduction. Similarly, Krueger et al. (2024) 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.[6] 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).[7] Impact-aligned investments labelled as Article 8 funds must disclose how they integrate sustainability factors into their investment process even if they primarily focus on financial objectives. Exclusion-focussed 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 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 prioritise 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. (2024) 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, Martin, and Walter (2022) whose findings show the SFDR's positive impact on the sustainability practices of EU mutual funds. However, Scheitza and Busch (2024) show that there are no notable variations between impact-focussed funds like Article 9 funds and ESG-focussed funds. In a similar vein, Cremasco and Boni (2024) 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. Data and variables

3.1. Data

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 1, outlines the sample selection criteria. Our initial sample consists of a total of 8725 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 4738 to 3987 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

Table 1. Sample selection.

Sample Criteria		Number of Distinct Funds
Start: Initial sample of EU equity mutual funds		8725
Less: Funds without available carbon emissions data for holdings	(4738)	3987
Less: Funds without available data on control variables	(1546)	2441
Less: Funds that are newly launched	(1196)	1245
Final sample		1245

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.

approach to ensure the availability of carbon emissions data which might lead to reduced sample size. For example, (e.g. Aswani, Raghunandan, and Rajgopal 2024; Cohen, Kadach, and Ormazabal 2023; Rohleder, Wilkens, and Zink 2022) underscore the significance of comprehensive carbon emissions data in conducting accurate and reliable research on sustainable investing. We further exclude 1546 funds lacking necessary data on control variables (e.g. financial performance), reducing the sample to 2441 funds. Finally, another 1196 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 1245 funds.

We extract the following quarterly mutual fund data: total net assets (TNA), total return, expense ratio, dividend payments, and capital gain payments. 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.[8]

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 A1 presents definitions of all the variables used in the analysis.

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.[9] 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.[10]

As illustrated in Figure 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 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

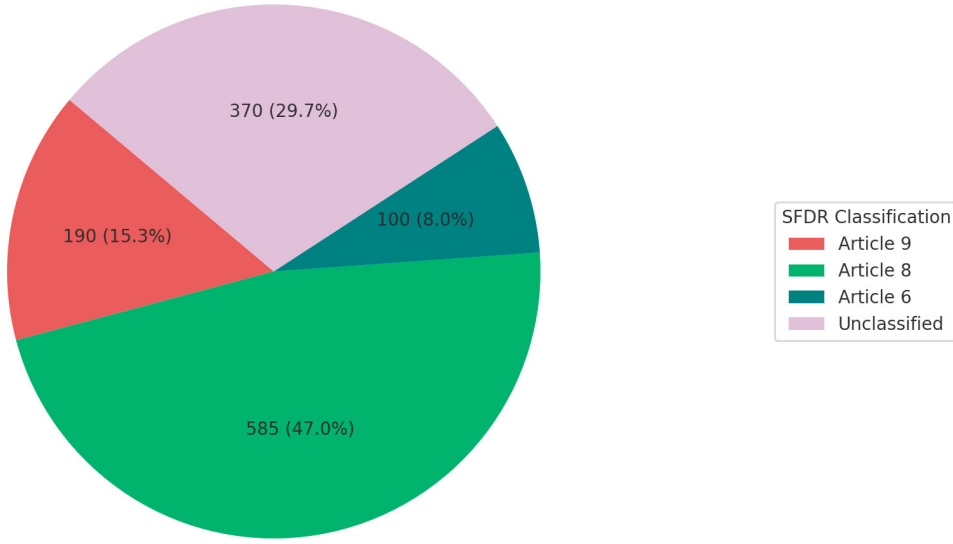

Figure 1. SFDR classification based on the number of funds.
This figure presents the number and the proportion of funds in each one of the SFDR classifications.

Table 2. The distribution of SFDR funds by Domicile.

Domicile	*Article9*	*Article8*	*Article6*	*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

This table illustrates the distribution of our sample of EU SFDR funds based on the fund domicile.

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.[11] Furthermore, Table 2 presents a summary of the distribution of the number of SFDR funds by domicile.

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 classified per the Greenhouse Gas Protocol (2015) as scope 1, 2, and 3 emissions.[12] 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.

3.2. Variables

3.2.1. Fund flows

Increasing fund flows is an important motivation behind greenwashing. Several studies (e.g. Ceccarelli, Ramelli, and Wagner 2024; Hartzmark and Sussman 2019) 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, Gulen, and Rau 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,

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

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.

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, Mojon, and Pereira da Silva 2021; Rohleder, Wilkens, and Zink 2022). Formally,

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

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, Wilkens, and Zink (2022), we estimate the fund's carbon intensity as follows:

$$CI_{i,t} = \sum_{j=1}^{N} W_{j,i,t} \times CI_{j,t} \tag{3}$$

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.

$$CI\_Cont_{j,i,t} = \frac{W_{j,i,t} \times CI_{j,t}}{CI_{i,t}} \tag{4}$$

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.

3.2.3. Greenwashing index

Measuring greenwashing in sustainable investing faces obstacles due to the difficulty of quantifying the discrepancy between stated intentions and actual investment behaviour (D. M. Christensen, Serafeim, and Sikochi 2022). A significant contributor to this issue is the absence of standardised 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. (Khan, Kogan, and Serafeim 2012; Rohleder, Wilkens, and Zink 2022)) to calculate net decarbonisation as follows.

$$DC_{i,t} = \sum_{j} \left(SharesSold_{j,i,t} \times CI\_Cont_{j,i,t-1}\right) - \sum_{j} \left(SharesBought_{j,i,t} \times CI\_Cont_{j,i,t-1}\right) \tag{5}$$

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. Cao et al. 2023; Zhang 2022) to develop a measure of greenwashing by examining the sensitivity of the fund's net decarbonisation to its quarterly flows as follows.

$$Unjustified\_FundFlows_{i,t} = \left[\frac{\left(FundFlows_{i,t} - \overline{FundFlows_i}\right)}{\sigma_{FundFlows_i}}\right] - \left[\frac{\left(DC_{i,t} - \overline{DC_i}\right)}{\sigma_{DC_i}}\right] \tag{6}$$

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:

$$GW\_Index_{i,t} = 100 \times \frac{Unjustified\_FundFlows_{i,t} - \min(Unjustified\_FundFlows_i)}{\max(Unjustified\_FundFlows_i) - \min(Unjustified\_FundFlows_i)} \tag{7}$$

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.

3.2.4. 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 emphasise 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 $\Delta \log(\mathrm{CO2})$ as follows:

$$\Delta \log(\mathrm{CO2})_{i,t} = \log\left[\sum_{j=1}^{N}\left(\frac{VH_{i,j,t+1}}{TVH_{i,t+1}}\right) \times (\mathrm{CO2})_{j,t}\right] - \log\left[\sum_{j=1}^{N}\left(\frac{VH_{i,j,t}}{TVH_{i,t}}\right) \times (\mathrm{CO2})_{j,t}\right] \tag{8}$$

where $\log(\mathrm{CO2})_{i,t}$ 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 $(\mathrm{CO2})_{j,t}$ 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:

$$\Delta \log(CI)_{i,t} = \log\left[\sum_{j=1}^{N}\left(\frac{VH_{i,j,t+1}}{TVH_{i,t+1}}\right) \times CI_{j,t}\right] - \log\left[\sum_{j=1}^{N}\left(\frac{VH_{i,j,t}}{TVH_{i,t}}\right) \times CI_{j,t}\right] \tag{9}$$

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, Giannetti, and Li (2024) and S. Kim and Yoon (2023), we calculate the change in the position of fund i in stock j in quarter t as follows:

$$Position\ Change_{i,j,t} = \frac{[NumberShares_{i,j,t} - NumberShares_{i,j,t-1}]^{*} Price_{j,t-1}}{TNA_{i,t-1}} \tag{10}$$

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. Descriptive statistics

Table 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, 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

Table 3. Summary statistics.

Variables	N	*Mean*	*SD*	*Min*	*Max*	*p25*	*p50*	*p75*
				Panel A: All SFDR Funds				
Fund-Level Variables								
Total Net Asset ($bil)	27,038	1.82	6.57	0.00	57.70	0.02	0.10	0.54
Total Return (%)	27,038	1.87	8.77	−94.16	41.40	−2.05	2.99	6.92
Fund Flow (%)	27,038	1.25	141.00	−19.73	15, 900.00	−2.15	0.33	3.15
Carbon Intensity	27,038	475.90	430.60	0.11	2940.59	161.73	404.32	658.12
Greenwashing Index	27,038	54.18	33.03	0.00	100.00	28.71	57.80	83.36
Total Expense Ratio (%)	27,038	1.48	0.71	0.01	4.83	1.00	1.50	1.89
Fund Age	27,039	50.76	44.47	1.00	338.00	15.00	44.00	74.00
Portfolio Characteristics								
Total Revenue ($mil)	12,964	74.50	162.00	0.01	1510.00	6.37	13.20	68.50
Market Cap ($mil)	13,327	461.00	812.00	0.30	4560.00	55.20	147.00	492.00
Return on Equity (%)	13,327	13.54	8.26	−9.71	51.22	7.42	12.09	18.51
Price to Book (%)	12,965	5.09	2.54	0.26	14.18	3.31	4.53	6.29
Turnover (%)	12,978	0.05	0.06	0.00	2.03	0.01	0.03	0.07
				Panel B: Article 9 Funds				
Fund Level Variables								
Total Net Asset ($bil)	3660	2.93	9.81	0.00	53.20	0.04	0.16	0.69
Total Return (%)	3477	1.91	8.72	−30.20	41.40	−2.49	3.22	6.96
Fund Flow (%)	1957	3.48	3.66	0.00	79.11	1.28	2.71	4.64
Carbon Intensity	1957	305.72	245.32	1.40	1070.61	87.65	249.45	476.72
Greenwashing Index	2144	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	3587	42.36	37.63	0.00	218.00	10.00	35.00	65.00
Portfolio Characteristics								
Total Revenue ($mil)	1912	56.50	106.00	0.03	636.00	7.78	14.00	63.30
Market Cap ($mil)	1957	386.00	587.00	2.53	3720.00	74.30	174.00	452.00
Return on Equity (%)	1957	13.50	7.91	−9.71	47.70	7.63	11.82	18.09
Price to Book (%)	1912	5.42	2.52	0.91	14.18	3.73	4.75	6.65
Turnover (%)	1913	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 ($bil)	13,298	1.34	4.60	0.00	50.30	0.03	0.12	0.55
Total Return (%)	13,298	1.91	8.98	−94.16	38.10	−2.04	3.05	7.14
Fund Flow (%)	13,298	1.01	48.17	−13.46	4, 21	−2.59	−0.23	2.60
Carbon Intensity	13,298	488.87	408.96	0.17	2940.59	187.58	428.45	687.97
Greenwashing Index	13,298	68.12	28.88	0.00	100.00	53.18	76.75	90.93
Total Expense Ratio (%)	13,298	1.52	0.72	0.01	4.34	0.97	1.60	1.99
Fund Age	13,298	57.61	49.94	1.00	338.00	17.00	52.00	83.00
Portfolio Characteristics								
Revenue ($mil)	7517	74.20	170.00	0.03	1270.00	6.32	12.70	55.80
Market Cap ($mil)	7517	456.00	845.00	0.30	4560.00	51.00	134.00	448.00
Return on Equity (%)	7517	13.90	8.20	−3.64	51.22	7.77	12.42	18.85
Price to Book (%)	7517	4.86	2.50	0.26	14.18	3.12	4.27	6.08
Turnover (%)	7517	0.05	0.06	0.00	1.08	0.02	0.04	0.07

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 A1.

preliminary observations from the dataset hint at potential inconsistencies in Article 8 funds' decarbonisation claims.

Figure 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

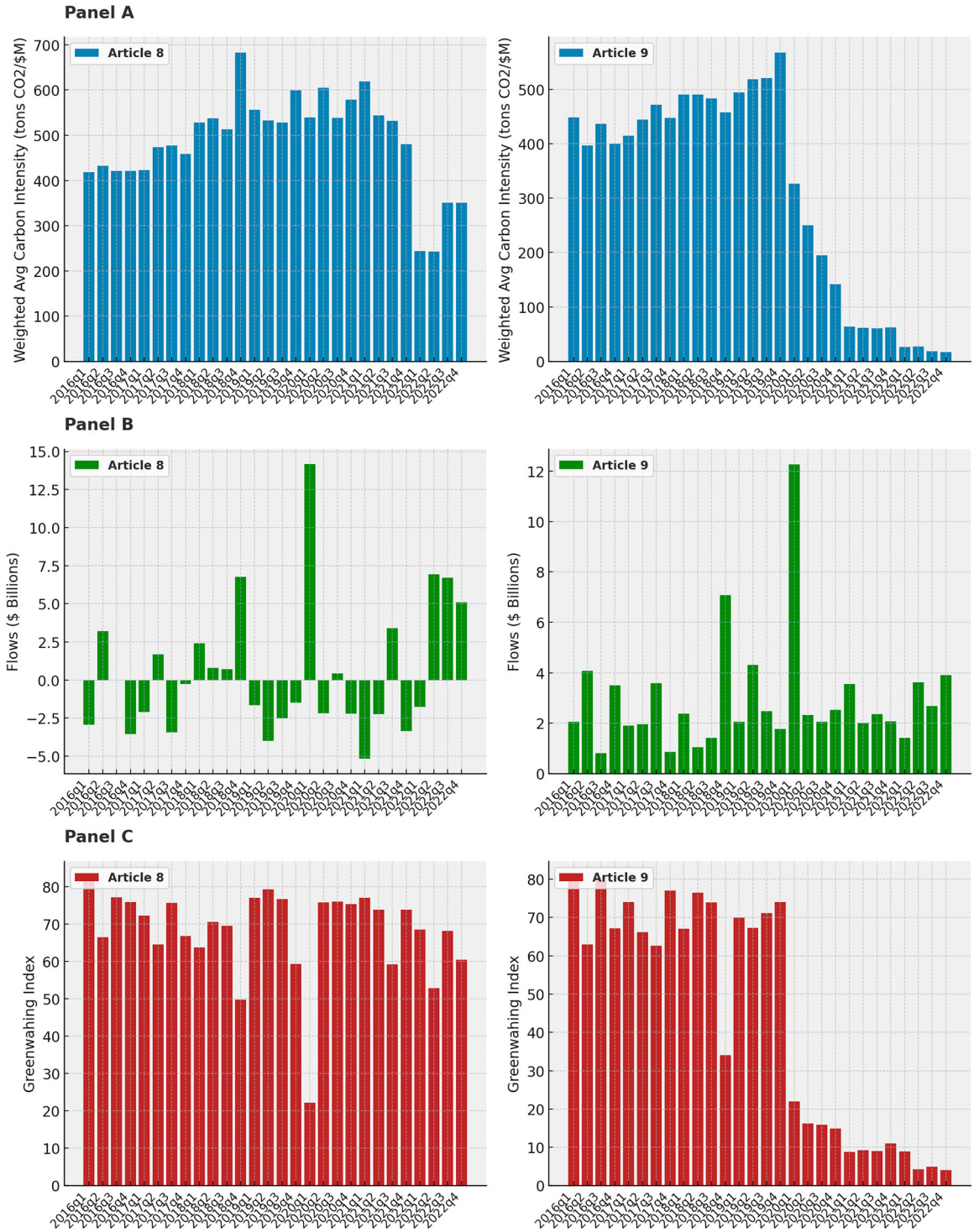

Figure 2. The evolution of carbon intensity, fund flows, and greenwashing index for Article 9 and 8 funds over time.

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.

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 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.

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. Gropp, Gruendl, and Guettler 2014; Hu et al. 2019), 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:

$$GW\ Index_{i,t} = \alpha_0 + \beta_1 Post_{i,t} + \beta_2 SFDR_{i,t} + \beta_3 SFDR^{*} Post_{i,t} + \beta_4 controls_{i,t-1} + \gamma_q + \delta_c + \varepsilon_{i,t} \quad (11)$$

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.[13] (e.g. Becker, Martin, and Walter 2022; Dai et al. 2024; Lambillon and Chesney 2023). In addition, to ensure the robustness of our findings, we examine the dynamic effects of the SFDR regulation as reported in Table 7 using two extended estimation windows of 2 and 3 years. This adjustment allows us to scrutinise the sustained effects of the SFDR on greenwashing for up to three years after introducing the regulation in 2019 Q4, particularly focussing 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 trends assumption and use randomness to decrease the differences in the noticeable fund characteristics between the treated and control groups (Hainmueller 2012).

Table 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 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.

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.

Table 4. Results of the difference-in-differences analysis.

	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	1185	1148	2612	2565
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

This table presents the estimated effects of the SFDR on the greenwashing index. The greenwashing index represents a standardisation of the measure of unjustified fund flows as shown in Equation (7). 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 A1. 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.

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 A2 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.

Table 5. Results of the difference-in-differences analysis based on propensity score matching.

	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	1153	1138	2226	2208
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

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 Equation (11) with both time and country-fixed effects. The greenwashing index represents a standardisation measure of the unjustified fund flows as shown in Equation (7). 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 A1. 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.

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 Equation (11) that has both time and country fixed effects.

Table 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).

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. 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 4 coupled with the stable trend illustrated in Figure 3 validate the assumption of parallel trends in our DID approach. Consequently, we conclude that any difference in the levels of the greenwashing index post the introduction of the SFDR is attributable to its significant impact

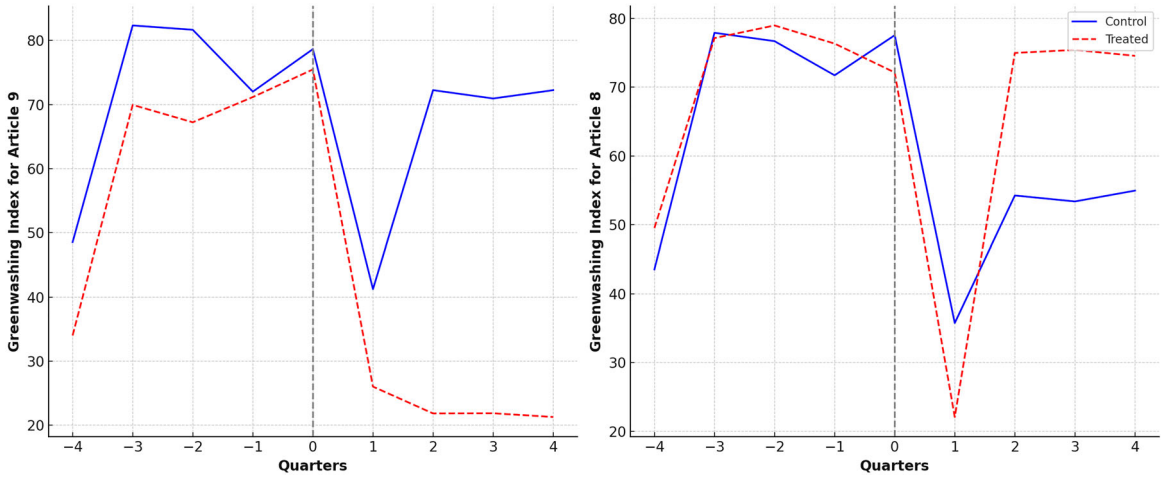

Figure 3. The trends of the greenwashing index.

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.

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.

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 Equation (11) 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 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 practices. This finding reinforces the conclusion that the SFDR effectively leads funds to adopt more genuine and transparent sustainability practices.

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 Equation (11) 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.

The results in Table 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

Table 6. Results of placebo test.

	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	3902	3792	8276	8124
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

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 Equation (11). 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 A1, 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.

Table 7. Dynamic effects analysis.

	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	3902	3792	3902	3792	8276	8124	8276	8124
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

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 standardisation measure of the unjustified fund flows as shown in Equation (7). 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 A1. 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.

DID analysis in Table 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.

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.

4.2.1. Specification of the regression discontinuity design (RDD)

Following the literature (e.g. Cao, Liang, and Zhan 2019; Gigante and Manglaviti 2022; Reuter and Zitzewitz 2021), 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.[14] In our setting, we use 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:

$$GW\_Index_{i,t} = \alpha + \beta_1\, CI_{i,t} + \beta_2\, SFDR_{i,t} + \beta_3\, controls_{i,t} + \varepsilon_{i,t} \tag{12}$$

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, Cattaneo, and Titiunik (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.

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 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 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.

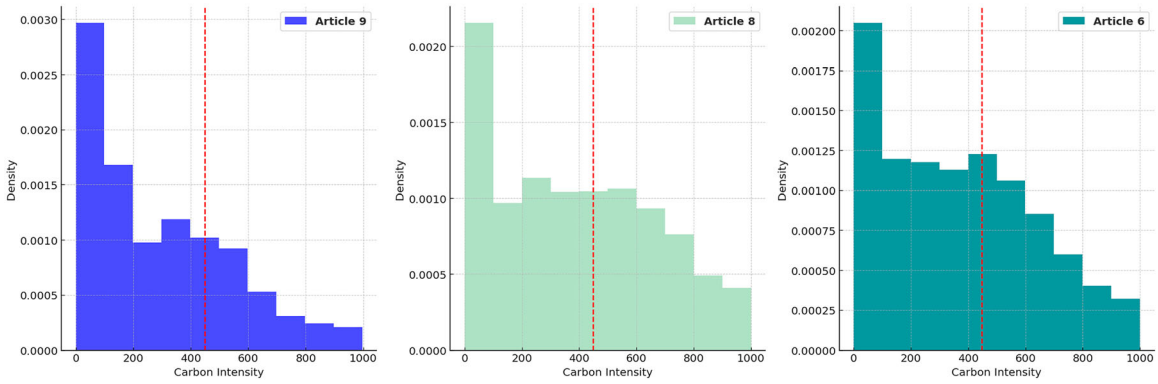

Figure 4. Histogram of the distribution of carbon intensity.

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.

Table 8 presents the results of the RDD. Following the method used by Calonico, Cattaneo, and Titiunik (2014), we compare the results obtained from the conventional RD method with those 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 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 4, which indicates the SFDR indeed has a significant effect on the greenwashing index.

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

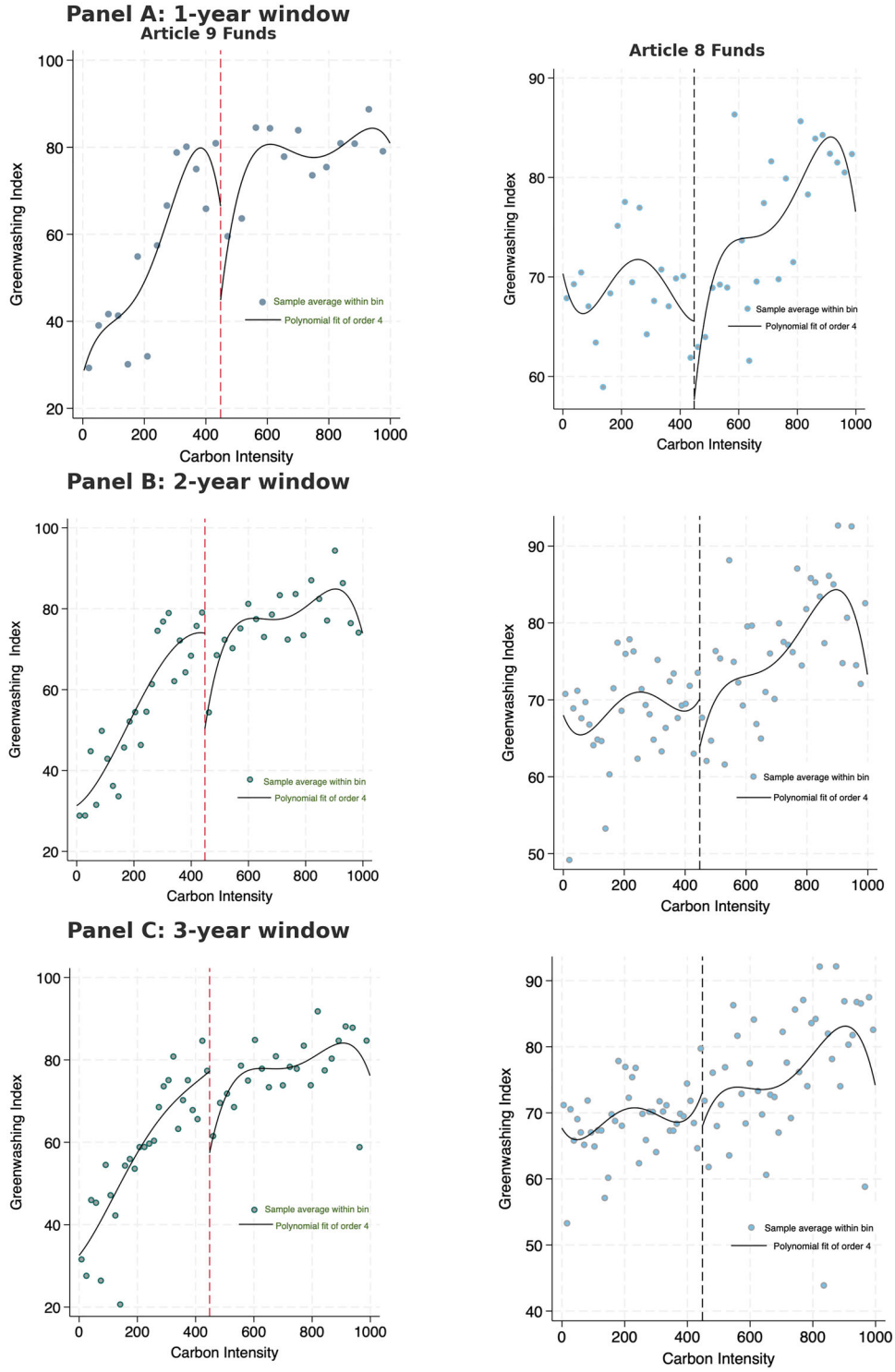

Figure 5. Articles 9 and 8 RD plots.

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.

Table 8. Results of regression discontinuity test.

	Article 9		Article 8	
Sample	(1)	(2)	(3)	(4)
Panel A: 1 Year Window				
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				
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				
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

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 A1. We follow the method used by Calonico, Cattaneo, and Titiunik (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.

literature (e.g. Atta-Darkua et al. 2023; Azar et al. 2021; 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.

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 Equations (8) and 9.

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 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 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

Table 9. Results of Article 9 funds portfolio tilting analysis.

	CO2 Scope1		CO2 Scope2		CO2 Scope3		CO2 Scope1,2		CO2 Scope1,2,3	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Portfolio Tilting (carbon emission)										
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	8271	7769	10,074	9491	9238	8694	9067	8531	9320	8773
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)										
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	6407	6020	7286	6841	7610	7148	6579	6169	6467	6080
R-squared	0.04	0.05	0.06	0.07	0.05	0.06	0.04	0.05	0.21	0.23

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 A1. 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.

Table 10. Results of Article 8 funds portfolio tilting analysis.

	CO2 Scope1		CO2 Scope2		CO2 Scope3		CO2 Scope1,2		CO2 Scope1,2,3	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Portfolio Tilting (carbon emissions)										
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	7012	6573	8564	8045	7831	7351	7678	7208	7885	7404
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)										
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	5491	5151	6209	5817	6458	6055	5616	5254	5486	5150
R-squared	0.04	0.06	0.06	0.07	0.05	0.07	0.05	0.06	0.21	0.23

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 A1. 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.

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 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 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 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, Pajuste, and Toniolo (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. However, it is important to recognise that a concentrated focus on low-carbon stocks could lead to less diversification. Concentrating investments in stocks with lower carbon intensity could increase exposure to systematic risks. As recent literature suggests, this reduced diversification could unintentionally heighten portfolio risk (e.g. Drempetic, Klein, and Zwergel 2020; Gougler and Utz 2020; Horn 2024). Specifically, Article 9 funds often favour low-carbon stocks, which tend to be large-cap firms with low book-to-market ratios and relatively low capital expenditures. Although these investments align with sustainability goals, they could expose Article 9 funds to unintended risks due to limited diversification within low-carbon stocks.

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*.

$$Position\ Change_{i,j,t} = \alpha_0 + \beta_1 CI\_Indicator_j + \beta_2 CI\_Indicator_j{}^{*} Post_t + \beta_3 controls_{i,t-1} + \varepsilon_{j,i,t} \quad (13)$$

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 11 show that the coefficient for the variable of interest *High CI* 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 investment strategy, Article 8 funds do not demonstrate the same commitment to lowering carbon intensity in their portfolios.

Overall, Table 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, Ramelli, and Wagner 2024; Gantchev, Giannetti,

Table 11. SFDR funds divestment from carbon-intensive stocks.

Position Change						
	All Funds		Article 9		Article 8	
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A: Indicators for high carbon-intensive stocks			
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			
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

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 A1. 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.

and Li 2024; Rohleder, Wilkens, and Zink 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 4 that Article 9 funds significantly reduce greenwashing practices in their portfolios to adhere to the requirements of the SFDR.

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 focussing 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 focussed 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, prioritising 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.

Notes

1. 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
2. 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
3. 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.
4. 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
5. 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.
6. 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).
7. Investments considered under Article 9 are those that have explicit sustainable investment objectives. For example, investments in firms or projects focussed on renewable energy sources such as solar, wind, hydroelectric, or geothermal power. These

investments contribute to reducing carbon emissions and promoting clean energy. Another example is investments in sustainable farming practices that promote biodiversity, soil health, and the reduced use of harmful chemicals that contribute to food security and environmental sustainability.

8. 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
9. 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
10. According to reports published by Morningstar (Morningstar Research 2022b, 2023), 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.
11. 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.
12. 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
13. 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.
14. 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

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No potential conflict of interest was reported by the author(s).

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Appendices

Appendix 1. Variable Definitions

Table A1. 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.

(*continued*)

Table A1. Continued

Variable	Definitions
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.
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	
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 3.2.4.
Position Change	Following (e.g. Ceccarelli, Ramelli, and Wagner 2024; Gantchev, Giannetti, and Li 2024), we calculate the change in the position of fund *i* in stock *j* in quarter*t* as follows: $$Position\ Change_{i,j,t} = \frac{[Number\ Shares_{i,j,t} - Number\ Shares_{i,j,t-1}]^{*} Price_{j,t-1}}{TNA_{i,t-1}} \quad (A1)$$ 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 capitalisation 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.

This table provides a summary of all the variables used in our empirical analyses.

Appendix 2. Propensity Score Matching

Table A2. Descriptive statistics of the matched treatment and control groups.

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

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 A1. All variables are lagged. The sample period is 2016 to 2022.