Navigating the Transition: The Impact of the SFDR on Sustainability Strategies of Brown Firms*

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Abstract

This paper investigates the effects of the European Union's Sustainable Finance Disclosure Regulation (SFDR) on institutional investor behavior and firm-level sustainability transitions. Using investor-level ownership data and firm-level sustainability outcomes for EU-listed firms from 2018 to 2023, we provide evidence on how regulation shapes both market dynamics and corporate responses. First, employing a difference-in-differences framework with US investors as a control group, we show that EU-based institutional investors significantly reduce their holdings of high-emission (brown) firms following the SFDR, while no comparable changes are observed among US investors. Second, at the firm level, we find that the SFDR itself triggers meaningful sustainability initiatives. Brown firms, initially the least aligned with environmental objectives, exhibit the largest post-regulation improvements in emissions management, green patent, and environmental innovation, while gray firms show more moderate gains. Finally, we examine how institutional investor exit interacts with this transition process. We find that reductions in institutional ownership dampen the sustainability improvements of brown firms, weakening their capacity to sustain innovation and emissions reductions. Together, these findings reveal a dual mechanism: regulation incentivizes high-emission firms to accelerate their transition, but sustained investor engagement is critical to maintaining these efforts. Our results contribute to ongoing debates on whether sustainable finance regulation should emphasize investor exit or engagement to achieve long-term environmental goals.

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I. Introduction

Sustainable investing has gained popularity over the past decades. In June 2023, 5,372 institutional investors worldwide representing over $120 trillion in assets under management had committed to incorporating environmental, social, and governance (ESG) information into their investment processes (PRI, 2023). In recent years, the European Commission (EC) introduced multiple initiatives focused on sustainable development, aiming to integrate ESG factors into the financial system. According to the EC, this approach is essential to address significant challenges such as climate change, social inequality, and biodiversity loss. For instance, implementing the Sustainable Finance Disclosures Regulation (SFDR) has mandated investors to prioritize sustainability considerations in their investment decisions, leading to a potential shift towards favoring green over brown firms.[1]

Prior studies examine institutional investors' role in shaping corporate governance policies and influencing firms' ESG (Dyck et al., 2019; Gillan and Starks, 2000; Gloßner, 2019; Kim et al., 2019). Drawing on Hirschman's (1970) framework, stakeholders' decisions can be framed as a choice between exit and voice. Cronqvist and Fahlenbrach (2008) argue that the effects of institutional investors on firm policies can be explained in two ways: Influence or selection. These mechanisms parallel the concepts of exit and voice described by Hirschman's (1970), Edmans (2014) and Broccardo et al. (2022). Under the influence mechanism (akin to "voice"), institutional investors actively engage with firms to drive ESG improvements, shaping policies through direct involvement (Dyck et al., 2019; Gloßner, 2019). Under the selection interpretation (resembling "exit"), institutional investors choose firms that match their preferred policies. In other words, institutional investors may either drive firms towards ESG practices in line with their preferences (Heath et al., 2023) or may select (exit) firms whose existing ESG profiles already (do not) match those preferences (Dimson et al., 2021).

EU regulations, such as the SFDR, can influence institutional investors' choice to either select firms with strong ESG profiles or to actively influence firms to improve their sustainability practices. Both mechanisms significantly affect the capital flows for green and brown firms. In the selection scenario, if regulations primarily motivate investors to allocate capital toward green firms and divest from brown firms as a penalty for poor sustainability practices, unintended consequences may arise. Recent empirical studies show that sustainable investors have increased the cost of capital for brown firms compared to green firms (Aladangady et al., 2023; Green and

[1] Green (brown) firms are firms that create economic value while minimizing (not minimizing) damages that contribute to climate change(Ardia et al., 2023).

Vallee, 2022; Van der Beck, 2021). This approach may inadvertently lead to brown firms facing challenges in accessing affordable capital, potentially limiting their ability to transition towards more sustainable practices.

In contrast, the influence channel offers a more promising path for systemic change. Broccardo et al. (2022) highlight that in competitive markets, influence is more effective than selection in encouraging firms to adopt socially responsible practices. By engaging with management and driving ESG reforms, institutional investors incentivize brown firms to transition toward greener operations, ultimately broadening the impact of sustainable finance initiatives. While the influence channel is often discussed as a path for long-term change, our analysis focuses on the selection mechanism, given that we do not observe direct engagement behavior.

The dynamics of selection and influence raise concerns about the overall effectiveness of EU sustainable finance regulations in promoting sustainability across a broader spectrum of firms. Hartzmark and Shue (2023) raise critical concerns that ESG-based capital reallocation may be counterproductive, suggesting that penalizing brown firms by restricting capital could impair their ability to decarbonize, inadvertently making them "browner". This perspective challenges the broader policy narrative that shifting capital away from high-emission firms encourages systemic environmental progress. Several studies have empirically examined the implementation and market effects of the SFDR (Becker et al., 2022; Bengo et al., 2022; Cremasco and Boni, 2024; Lambillon and Chesney, 2023). Therefore, a central question emerges: Does regulation that targets investor transparency and ESG information into investment decisions ultimately accelerate the transition of brown firms toward sustainability? Whether regulation triggers disengagement or transformation, remains an open question.

We address this issue in the context of the European Union's SFDR, introduced in 2021 as part of a broader effort to align capital markets with the EU Green Deal. The SFDR imposes mandatory ESG disclosure requirements on institutional investors, aiming to enhance transparency and redirect capital toward sustainable activities (European Commission, 2021). SFDR has been characterized as a policy shock that potentially reshapes both investor behavior and firm strategy (Berg et al., 2022; Zetzsche and Anker-Sørensen, 2022). Using ownership and financial data from LSEG (formerly Refinitiv) for 1,750 EU listed firms covering the period from 2018 to 2023, this study examines whether brown firms respond to the SFDR by improving their sustainability performance, and assesses whether institutional investor divestment constrains or supports these transition efforts. To classify firms, we divide the sample into terciles based on their environmental scores for each year, where the bottom tercile represents brown firms, the

top tercile represents green firms, and the middle tercile includes neutral firms. This approach allows us to capture relative ESG performance annually and ensuring comparability across years, even as absolute environmental scores evolve over time (Ardia et al., 2023; Pástor et al., 2022). A key component of our empirical strategy is the distinction between EU-based and US-based institutional investors, reflecting the fact that the SFDR regulation is binding only on financial market participants located within the EU, while investors based in the US are not subject to the SFDR disclosure requirements. This allows us to use a difference-in-difference design.

Using investor-level ownership data from LSEG, our findings show that the implementation of SFDR in 2021 changes the behavior of EU institutional investors, who reduce their exposure to brown firms following the regulation. In contrast, US investors, who are not subject to SFDR, do not exhibit similar changes, reinforcing the interpretation that the observed shift is driven by regulatory pressure rather than broader market trends.We find a significant decline in brown firm holdings, indicating that the SFDR prompts investors to shift capital away from firms with weak environmental performance. This shift in investment strategy is consistent with broader market trends reported by Gözlügöl (2022) and Steuer and Tröger (2022), who document widespread rebalancing of portfolios across Europe in favor of firms with stronger ESG credentials. Before the regulation, EU-based investors hold sizable positions in brown firms. After 2021, their exposure to these firms drops sharply.

Next, we find that the effect of the SFDR extends beyond investor portfolio allocation to firm-level sustainability outcomes. Using a comprehensive sample of EU-listed firms, we show that the regulation induces significant improvements in sustainability performance, particularly among firms with weaker environmental profiles. Brown firms demonstrate the strongest post-SFDR gains, including substantial improvements in emissions management, green patenting, and environmental innovation. Gray firms also exhibit moderate progress, especially in innovation-related areas, though their response is less pronounced than that of brown firms. This provides firm-level evidence that regulation, rather than investor preferences alone, directly incentivizes high-emission firms to enhance their transition efforts and align more closely with sustainability objectives.

Moreover, our results complement findings by Berg et al. (2022), who show that mandatory ESG disclosures improve market pricing of sustainability risks, by highlighting how regulation alters institutional investor behavior in ways that indirectly shape firm-level sustainability outcomes. Prior research establishes that institutional investor exit often translates into constrained financing and reduced strategic flexibility for affected firms (Dyck et al., 2019; Gloßner, 2019). Consistent with this view, we interpret institutional investor reduction as a

credible signal of capital withdrawal and heightened financing frictions. This mechanism aligns with evidence from Green and Vallee (2022) and Aladangady et al. (2023), who document that sustainability-driven divestment increases the cost of capital for high-emission firms and limits their access to resources for transition.

Building on this, we extend the literature by examining how the withdrawal of institutional ownership following the SFDR affects firms' ability to sustain their transition efforts. While the regulation itself strongly incentivizes brown firms to improve emissions performance, increase green patenting, and enhance environmental innovation, we find that these improvements are significantly decreased when institutional investors reduce their holdings. In particular, the three-way interaction between SFDR implementation, brown firm classification, and investor reduction shows that ownership exit weakens emissions improvements and reduces innovation activity. These findings resonate with Hartzmark and Shue (2022), who argue that divestment strategies may inadvertently limit the capacity of high-emission firms to transition, and reinforce the view that engagement, rather than exit, may be necessary to achieve deeper, long-term sustainability outcomes.

Taken together, our results reveal a nuanced regulatory mechanism. While the SFDR effectively pushes high-emission firms to adopt greener practices, its full potential depends on whether investors remain engaged to support costly transition efforts. As Zetzsche and Anker-Sørensen (2022) note, sustainable finance regulation serves not only as a disclosure standard but also as a market signal, reshaping incentives for both investors and firms. Our evidence shows that when regulatory pressure is accompanied by investor exit, it reduces the ability of high-emission firms to improve, thereby constraining the transition of those most in need of change.

Our findings contribute to several important debates in the literature on sustainable finance, institutional investor behavior, and firm-level environmental transition. First, we contribute to the literature on sustainable finance regulation and institutional investor behavior by showing how mandatory ESG disclosure requirements under the SFDR reshape portfolio allocation. Prior work has primarily focused on how ESG disclosure improves pricing of sustainability risks (Berg et al., 2022; Gibson et al., 2021) and shifts investor preferences toward green assets (Ilhan et al., 2021). Consistent with this stream, we find that EU-based institutional investors significantly reduce their holdings of brown firms after the SFDR, while US investors, who are not subject to the regulation, show no comparable change. By leveraging this EU–US distinction as a treatment-control setting, we move beyond preference-based explanations (e.g., (Barber et al., 2021; Pástor et al., 2022) and provide causal evidence that regulation itself drives

portfolio reallocation. This highlights the SFDR as a market-coordinating policy instrument that enforces selection mechanisms by institutional investors.

Second, we extend the literature on how regulation affects firm-level sustainability strategies by showing that the SFDR directly incentivizes firms to improve their transition efforts. Recent studies have debated whether divestment pressures can lead to real environmental performance improvements (Hartzmark & Shue, 2022; Kölbel et al., 2020), with some suggesting that disclosure rules mostly affect market signals rather than corporate strategy. In contrast, our results demonstrate that brown firms respond most strongly after SFDR implementation, with significant improvements in emissions performance, green patenting, and environmental innovation. This is in line with the "Porter Hypothesis" (Aghion et al., 2016; Porter and Linde, 1995), which argues that regulatory pressure can trigger innovation even in laggard firms. Importantly, our findings move beyond earlier studies focusing solely on capital market outcomes (Aladangady et al., 2023; Green and Vallee, 2022) by showing how a disclosure-based regulatory intervention can generate real effects on firm innovation pathways.

Third, we bridge the voice–exit debate in ESG investing by examining how investor exit shapes post-regulation firm responses. Much of the literature has treated investor exit as either an effective market discipline mechanism (Dimson et al., 2021; Edmans, 2014) or as a potentially counterproductive strategy that deprives high-emission firms of transition capital (Hartzmark and Shue, 2022). We nuance this debate by showing that institutional investor reduction after the SFDR weakens the sustainability improvements of brown firms, particularly in emissions management and innovation activity. This suggests that regulation alone can trigger sustainability transitions, but sustained investor engagement is necessary to maintain their momentum. Our results therefore complement the engagement literature (Dyck et al., 2019; Gloßner, 2019), highlighting that voice rather than exit may yield more durable outcomes in high-emission sectors.

In sum, our evidence adds a new layer to the discussion on sustainable finance: we show that ESG disclosure regulation like the SFDR can both trigger investor-led selection mechanisms and induce real behavioral change in firms, but the persistence of these improvements depends on whether investors remain engaged. By integrating insights from the sustainable finance, corporate innovation, and investor stewardship literatures, we provide a more complete view of how disclosure-based regulation interacts with market forces to shape firm-level transition dynamics.

II. Institutional Background

SFDR introduced by the European Union and effective from March 2021, establishes a mandatory ESG disclosure framework for financial market participants and advisers. Its primary aim is to enhance transparency, prevent greenwashing, and align private capital flows with the EU's broader sustainability objectives under the European Green Deal. A key component of the SFDR is the classification of financial products into three categories: Article 6 products, which do not integrate sustainability considerations; Article 8 products, which promote environmental or social characteristics; and Article 9 products, which have sustainable investment as their explicit objective. This classification system plays a significant role in structuring the ESG disclosure obligations for investment firms and, by extension, shapes how these firms assess and report the sustainability of underlying assets (European Commission, 2021).

In the literature on sustainable finance, SFDR has been adopted as a quasi-exogenous policy shock that creates a new regulatory environment for institutional investors. Scholars emphasize that the regulation alters the strategic behavior of asset managers by increasing the cost of maintaining exposure to high-emission firms, while simultaneously incentivizing transparency and sustainability-oriented capital reallocation (Boni and Scheitza, 2025; Spaans et al., 2024). Several studies have used this regulatory boundary to assess the effect of the SFDR on portfolio reallocation. For instance, Spaans et al. (2024) demonstrate that fund managers within the EU reallocate capital away from firms with high carbon emissions or poor ESG performance, a pattern not observed among non-EU investors. While their study highlights aggregate portfolio shifts, our analysis differs by using investor-firm level ownership data to quantify how regulatory exposure affects capital allocation across green and brown firms. Emiris et al. (2024) also find evidence that EU investors exhibit stronger responses to firm-level ESG information than their US counterparts, further supporting the interpretation of SFDR as a regulatory shock that changes the informational and compliance landscape for investment decisions.

Another aspect that enhances the SFDR's value as a regulatory shock in empirical settings is the heterogeneity of investor exposure across jurisdictions. While EU-based investors must comply with SFDR requirements, US-based investors are not subject to the regulation even when they invest in the same EU-listed companies. This jurisdictional divide creates a natural control group that can be used to isolate the regulatory effect from global ESG investment trends. Several studies adopt this contrast to implement difference-in-differences strategies, finding that EU investors change their investment behavior in ways that are not mirrored by their US counterparts (Boni and Scheitza, 2025; Spaans et al., 2024). This distinction is crucial for

confirming that observed effects are truly regulatory in nature, rather than reflective of general market sentiment toward ESG investing.

One of the most important implications of SFDR lies in how it shapes the classification of firms as green or brown in the investment ecosystem. The regulation indirectly requires asset managers to adopt consistent, transparent frameworks for evaluating the sustainability of portfolio companies. Firms with lower emissions, better environmental practices, and stronger sustainability disclosures are more likely to be included in Article 8 or Article 9 funds. In contrast, firms operating in carbon-intensive sectors or lacking robust ESG reporting are more likely to be excluded or divested. This classification has real consequences for firms' access to capital, influencing investor preferences and cost of financing. As noted by Bofinger et al. 2024, this regulatory shift has resulted in an implicit market division, where firms are increasingly categorized as either green or brown based on their environmental performance, accelerating capital flows toward sustainable assets and marginalizing high-emission companies. Spaans et al. (2024) argue that this reallocation is primarily driven by regulatory compliance incentives introduced by SFDR. This interpretation is consistent with findings that show significant reductions in brown firm exposure post-SFDR, especially among EU-based institutional investors.

At the same time, the SFDR provides a foundation for evaluating whether institutional investors may pursue influence-based strategies, wherein they retain stakes in brown firms but engage with them to drive ESG improvements. However, as several studies emphasize, evidence for this voice mechanism remains limited in the context of the SFDR. While EU investors reduce their exposure to brown firms, there is little indication that they increase engagement efforts to transition those firms toward sustainability goals.

III. Data and Summary Statistics

Our sample includes all publicly listed companies in the European Union from 2018 to 2023, enabling us to capture both pre- and post-regulation dynamics surrounding the introduction of the SFDR in 2021. We begin by using the environmental (E) score from LSEG ESG to assess firms' environmental performance over time. LSEG ESG provides firm-level data on environmental, social, and governance practices. The E score reflects a firm's performance in managing environmental risks and opportunities. It is based on multiple dimensions, including emissions, resource use, environmental innovation, and controversies. These indicators are collected from publicly available corporate disclosures such as annual reports, sustainability reports, company websites, and verified media sources. Each component is standardized and

aggregated using a rules-based methodology to generate a normalized E score ranging from 0 to 100. This score reflects a company's relative performance compared to sector and regional peers, enabling consistent classification across years. The use of LSEG ESG data is supported by a large body of literature that recognizes its methodological transparency and widespread adoption by asset managers and academic researchers. Prior studies such as Chatterji et al. (2016), Amel-Zadeh and Serafeim (2018), Gibson et al. (2021), and Berg et al. (2022) have shown that LSEG ESG scores are reliable indicators of corporate sustainability performance and are frequently used in research examining the relationship between ESG factors and capital allocation.

We restrict our analysis to firms that have complete data available for the E score, ensuring consistency in ESG classification over the sample period. We exclude firms in industries classified under financials based on the Fama-French 12 industry classification(Almeida et al., 2017; El Ghoul et al., 2023). We then match the resulting sample with financial data obtained from FactSet, using the International Securities Identification Number (ISIN).

Next, we link each firm to its institutional investors using LSEG's ownership data, which contains information on the holdings of institutional investors across EU-listed firms. For every investor and year, we then calculate how much of their overall EU portfolio is allocated to green, neutral, and brown firms. To do this, we first compute the total portion of their portfolio that is invested in each category by summing up their holdings in green, brown, and neutral firms separately. Then, to capture the relative portfolio composition, we divide each of these category-specific totals by the investor's total holdings in all EU firms for that year. This gives us the percentage of each investor's EU portfolio that is allocated to green, neutral, and brown firms annually. This approach allows us to track how institutional investors adjust their portfolio allocation toward firms with different environmental characteristics over time. More importantly, we examine how exposure to sustainability regulation affects portfolio decisions by comparing investors based in the EU (who are subject to the SFDR) with US-based investors. Table 1 reports the number of institutional investors in our sample, distinguishing between EU-based and US-based investors.

Table 2 reports descriptive statistics for the main variables used in the analyses.[2] Panel A presents statistics at the institutional investor level, while Panel B summarizes firm-level characteristics. In Panel A, the average *Brown portfolio* is 0.37, indicating that, on average, 37%

[2] All continuous variables are winsorized at the 1st and 99th percentiles to mitigate the influence of outliers.

of an institutional investor's EU equity holdings are allocated to brown firms. The *EU* variable shows that 29% of investors in the sample are based in the EU.

In Panel B, firm-level data reveal that average invested capital is approximately 542.69, though the high standard deviation and wide range (from 0.8 to over 8108.83) suggest significant variation in capital flows. Average *R&D* expenditure is 27.16, average firm size is 7.52, and *ROA* averages 2.94%. The dividend payout ratio has a mean of 45.70%. Detailed definitions for the variables are reported in Appendix 1.

IV. Results

3.1. Subsample Evidence: EU vs. US Investor Responses to SFDR

We begin our analysis by presenting table 4, which uses subsamples to highlight the differences in SFDR-related portfolio changes between EU and US investors. We observe a significant reduction in brown asset holdings among EU investors following the implementation of SFDR. The coefficient on the $Post$ is -0.034 and statistically significant at the 1% level, indicating that EU investors reduce their $BrownPortfolio$ by approximately 3.4 percentage points after the regulation. In contrast, US investors slightly increased their brown exposure by 1.3 percentage points, a small but significant change. This difference in behavior shows that *EU* investors adjust their portfolios in response to the SFDR, while US investors, who are not subject to the regulation, do not. The clear distinction between the regulatory environments of EU and US investors provides a credible setting to identify the impact of the SFDR. The results demonstrate that regulation can influence investor behavior by reducing exposure to firms with weaker environmental performance.

3.2. The impact of SFDR on the institutional investor portfolio

To examine the impact of SFDR implementation on institutional investors' allocation to brown firms, we estimate the following model, as presented in Equation (1):

$$BrownPortfolio_{it} = \beta_0 + \beta_1 EU_i + \beta_2 Post_t + \beta_3 (EU_i \times Post_t) + \beta_4 X_{it} + \varepsilon_{it} \qquad (1)$$

In this specification, the dependent variable $BrownPortfolio$ represents the share of investor i total EU holdings that is allocated to brown firms in year t. The variable EU is an indicator variable that equals one if the institutional investor is domiciled in the EU, and zero for US-based investors. The variable $Post_t$ is an indicator variable equal to one for years following the implementation of the SFDR (2021 onwards), and zero otherwise. The interaction term

$EU_i \times Post_t$ captures the differential change in brown portfolio holdings of EU investors after the SFDR took effect, relative to US investors who are not subject to the regulation. The coefficient β_3 thus provides the estimate of the regulation's impact on institutional investment behavior with respect to brown firms. The vector X_{it} includes control variable, $InvSize$ which is measured as the natural logarithm of total assets held by investor i in year t.

Table 5 presents the impact of the SFDR on the brown portfolio share of institutional investors. In Column 1, the coefficient on $Post$ is positive and statistically significant (0.015, $p < 0.05$), indicating a slight overall increase in brown asset allocations across all investors after the implementation of the SFDR. However, the coefficient on the EU dummy remains large and highly significant (0.188, $p < 0.01$), showing that, prior to the regulation, EU-based institutional investors held a substantially higher share of brown assets, about 18.8 percentage points relative to US-based institutional investors. Crucially, the interaction term $Post \times EU$ is negative and statistically significant (−0.052, $p < 0.01$), suggesting that, despite the overall marginal rise in brown allocations, EU investors reduced their exposure to brown assets by 5.2 percentage points more than US investors after the regulation took effect. This finding highlights a clear regulatory-induced portfolio adjustment among EU investors compared to their US counterparts.

In Column 2, we include year-specific interaction terms to capture the dynamic trajectory of this regulatory effect. The interaction terms for $EU \times Y2019$ and $EU \times Y2020$ are small and statistically insignificant, indicating no meaningful adjustment by EU investors relative to US investors in the years leading up to the regulation's formal implementation. In contrast, the interaction terms for $EU \times Y2021$, $EU \times Y2022$, and $EU \times Y2023$ are all negative and statistically significant at the 1% level, with coefficients of −0.052, −0.055, and −0.072, respectively. These results show a clear and persistent reduction in brown holdings by EU investors relative to US investors immediately after the policy's enactment, with the decline deepening through 2023. This dynamic evidence indicates that the SFDR triggered a sustained shift away from brown investments among EU institutional investors, aligning capital allocation more closely with the regulation's sustainability objectives.

3.3. The effect of SFDR on sustainability transition

To investigate how the SFDR affects firm-level sustainability transition, we estimate the regression model shown in Equation (2):

$$SustainabilityTransition_{jt} = \beta_0 + \beta_1 Gray_{jt} + \beta_2 Brown_{jt} + \beta_3 Post_t + \beta_4 (Gray_{jt} \times Post_t) + \beta_5 (Brown_{jt} \times Post_t) + \beta_6 X_{jt} + \alpha_j + \gamma_k + \varepsilon_{jt} \quad (2)$$

The dependent variable, $SustainabilityTransition$, consist of four outcome variables: $EmissionScore, R\&D, GreenPatent$ and $EnvInnovation$ in firm j in year t. $EmissionScore$ is measures how well a firm manages and discloses greenhouse gas emissions, $R\&D$ is natural logarithm of total research and development cost, $GreenPatent$ reflects number of environmentally related patents filed by a firm,[3] and $EnvInnovation$ indicates a firm's performance in developing environmentally sustainable innovations.

The two key independent variables are interaction terms: $Gray \times Post$ and $Brown \times Post$. $Gray$ is an indicator variable equal to one if firm j is classified as neutral, and $Brown$ is an indicator variable equal to one if firm j is classified as green. $Post$ is an indicator variable equal to one for the post-regulation period. These interaction terms allow us to capture differential responses to the regulation for $Gray$ and $Brown$ firms after the SFDR, relative to green firms. The vector X includes firm-level control variables, including dividend payout (Div) measured as dividends per share divided by earnings per share, multiplied by 100, leverage (Lev) is the debt to equity ratio, Book to market value (BTM), firm size ($Size$) measured as the natural logarithm of total assets firm size,and return on assets (ROA) as a proxy for profitability.

The results in table 6 show that $Gray$ firms, which underperform relative to $Green$ firms before the regulation, exhibit moderate improvements following the SFDR. The coefficient on $Gray \times Post$ for $EmissionScore$ is 2.436 and statistically significant at the 1% level, indicating that after the regulation, $Gray$ firms improved their emissions management by 2.4 points relative to $Green$ firms. For $R\&D$, the coefficient remains small and statistically insignificant, suggesting no clear additional innovation spending by $Gray$ firms compared to $Green$ firms post-SFDR. However, $Gray$ firms demonstrated innovation-related responses, with $GreenPatent$ increasing by 1.22 ($p < 0.05$) and $EnvInnovation$ improving by 7.188 points ($p < 0.01$).

The coefficient on $Brown \times Post$ for $EmissionScore$ is 6.411 ($p < 0.01$), indicating an effect in emissions reduction and disclosure relative to $Green$ firms. For $R\&D$, the coefficient is 0.097 ($p < 0.05$), suggesting a modest increase in innovation spending for $Brown$ firms compared to $Green$ firms after the regulation. Moreover, $Brown$ firms exhibit a substantial shift toward environmentally focused innovation, with $GreenPatent$ rising by 2.140 ($p < 0.01$) and $EnvInnovation$ improving by 15.303 points ($p < 0.01$).

[3] Green patents refer to environmentally related patents filed by firms, as classified under the Y02 and Y04S CPC codes in the European Patent Office (EPO) database. These codes cover technologies related to climate change mitigation, renewable energy, energy efficiency, and sustainable innovation. Data on green patents can be accessed via the EPO's Espacenet platform: https://www.epo.org/en/searching-for-patents/business/patstat

Taken together, these findings show that while brown firms start from the weakest position relative to green firms, they demonstrate the largest relative improvements after SFDR implementation, highlighting the regulation's effectiveness in incentivizing higher-risk firms to accelerate their sustainability transition.

Overall, these results confirm that the SFDR reshaped sustainability strategies within the EU by inducing stronger behavioral changes among firms with weaker environmental profiles.

3.4. Institutional investor reduction and sustainability transitions

To examine whether institutional investors reduction resulting from the SFDR influenced firms' innovation activity, we estimate the following model, as presented in Equation (3):

$$Transition_{jt} = \beta_0 + \beta_1 Gray_{jt} + \beta_2 Brown_{jt} + \beta_3 Post_t + \beta_4 IOReduction_{jt} + \beta_5(Gray_{jt} \times Post_t) + \beta_6(Brown_{jt} \times Post_t) + \beta_7(IOReduction_{jt} \times Post_t) + \beta_8(Gray_{jt} \times IOReduction_{jt}) + \beta_9(Brown_{jt} \times IOReduction_{jt}) + \beta_{10}(Gray_{jt} \times Post_t \times IOReduction_{jt}) + \beta_{11}(Brown_{jt} \times Post_t \times IOReduction_{jt}) + \beta_{12}X_{jt} + \alpha_j + \gamma_k + \varepsilon_{jt} \quad (3)$$

The dependent variable, $SustainabilityTransition$, consist of four outcome variables: $EmissionScore, R\&D, GreenPatent$ and $EnvInnovation$ in firm j in year t. $EmissionScore$ is measures how well a firm manages and discloses greenhouse gas emissions, $R\&D$ is natural logarithm of total research and development cost, $GreenPatent$ reflects number of environmentally related patents filed by a firm, and $EnvInnovation$ indicates a firm's performance in developing environmentally sustainable innovations. The key independent variables capture the interaction between $IOReduction \times Gray \times Post$ and $IOReduction \times Brown \times Post$ which representing the effect of reduction in institutional investors for gray and brown firms, respectively, after the implementation of the SFDR. These terms allow us to test whether reduction of institutional investors after the regulation led to different sustainability initiative responses for $Gray$ and $Brown$ firms.

In table 7, we regress four measures of firm sustainability performance on the triple interaction $IOReduction \times Gray \times Post$ and $IOReduction \times Brown \times Post$. We control for all direct effects and two-way interactions. The two-way interaction terms confirm that after the SFDR, $Brown$ firms improve significantly across all sustainability measures relative to $Green$ firms, with notable increases in $EmissionScore$ (6.76), $R\&D$ (0.227), $GreenPatent$ (2.22), and $EnvInnovation$ (15.3). $Gray$ firms also exhibit moderate improvements post-

regulation, particularly in $GreenPatent$ and $EnvInnovation$. These two-way effects demonstrate that SFDR alone strongly incentivizes weaker environmental performers to transition toward more sustainable practices.

The triple interaction terms reveal how institutional investor reduction modifies these regulatory effects. For $Brown$ firms, the coefficient on $IOReduction \times Brown \times Post$ is negative and statistically significant for $EmissionScore$ (−3.81, p<0.1) and $R\&D$ (−0.272, p<0.05), while also negative but insignificant for $GreenPatent$ and $EnvInnovation$. This indicates that $Brown$ firms experiencing investor exit respond less to SFDR, they reduce emissions and invest in innovation to a smaller extent than comparable $Brown$ firms that maintain investor support. In contrast, the corresponding three-way terms for $Gray$ firms are small and statistically insignificant, suggesting that investor reductions do not meaningfully alter the moderate improvements $Gray$ firms achieve post-SFDR.

These results highlight that institutional investor engagement plays an important role in sustaining the regulatory effect of SFDR. While the regulation itself pushes brown firms to improve emissions performance and green innovation, the withdrawal of institutional ownership appears to constrain their ability or willingness to undertake these costly transitions. This pattern suggests that divestment may unintentionally limit the regulation's effectiveness for the highest-risk firms, while continued investor presence may be necessary to fully realize SFDR's sustainability objectives.

3.5.Robustness check

3.5.1. Propensity Score Matching (PSM)

Table 8 reports the results for the matched sample obtained using propensity score matching to balance EU and US investors on key characteristics. After matching, the results remain consistent with those observed in the table 5. The coefficient on $Post \times EU$ is -0.097 and significant at the 1% level, indicating that even after balancing the investor sample, EU investors reduced their brown portfolio share by about 9.7 percentage points more than US investors following the implementation of the SFDR.

When examining the dynamic specification, the year-specific interaction terms confirm the same pattern. The coefficients for $EU \times Y2021$, $EU \times Y2022$, and $EU \times Y2023$ remain negative and significant, showing reductions of 8.9, 13.1, and 11.2 percentage points, respectively, relative to US investors. By contrast, the pre-regulation years, $EU \times Y2019$ and $EU \times Y2020$, remain statistically insignificant, supporting the parallel trends assumption. Taken together, these findings demonstrate that even after controlling for observable differences

between EU and US investors through PSM, the SFDR effect persists. This provides stronger evidence that the observed decline in brown holdings among EU investors is driven by regulatory pressure rather than sample composition or baseline differences between the two groups.

3.5.2. Robustness check

One potential concern in our analysis arises from the fact that the $Gray$ and $Brown$ classifications are assigned on a yearly basis, which allows for some firms to switch categories over time. This switching could confound our estimates. To address this issue and ensure the robustness of our findings, we conducted an additional analysis in which we excluded all firms that changed their classification during the sample period. Table 9, confirm that our primary conclusions hold even when excluding firms that switch classifications. The results of this robustness check are consistent with the main regression findings in table 6.

Specifically, the coefficient on $Brown \times Post$ is positive and statistically significant for $EmissionScore$ and $GreenPatent$, indicating that $Brown$ firms improve their emissions performance and increase green patenting after the SFDR. Conversely, for $R\&D$, the coefficient on $Brown \times Post$ is small and statistically insignificant. Finally, for $EnvInnovation$, the coefficient is positive (20.7) and significant at the 1% level, showing that $Brown$ firms enhance their broader environmental innovation efforts post-SFDR. Similarly, the coefficient on $Gray \times Post$ is positive across all outcomes, though weaker in magnitude and significance. $Gray$ firms improve $GreenPatent$ slightly (1.57, $p<0.1$) and show a moderate gain in $EnvInnovation$ (13.4, $p<0.01$), while the $EmissionScore$ and $R\&D$ remain statistically insignificant.

In table 10, the two-way interaction $Brown \times Post$ remains positive for several outcomes, showing that $Brown$ firms continue to improve their sustainability performance relative to $Green$ firms after the SFDR. Specifically, $Brown$ firms gain 6.4 points in $EmissionScore$ and increase $GreenPatent$ by 3.3, while also achieving a 19-point rise in $EnvInnovation$, all statistically significant at the 1% level. However, the effect on $R\&D$ remains insignificant. Similarly, $Gray$ firms improve modestly, with significant gains only in $EnvInnovation$ (14.8, $p<0.01$), while $EmissionScore, R\&D$,and $GreenPatent$ effects remain insignificant.

The triple interaction $IOReduction \times Brown \times Post$ is negative and statistically significant for $EmissionScore$ (-6.9, $p<0.05$), indicating that investor exit dampens the emission improvements post-SFDR. For other outcomes $EmissionScore, R\&D$,and

$EnvInnovation$, the triple interaction remains negative but statistically insignificant. For $Gray$ firms, the three-way terms are small and insignificant across all measures. Overall, these findings highlighting the importance of continued investor engagement to support the sustainability transition of the most high-emission firms.

III. Conclusion

We provide novel evidence on the multi-dimensional effects of sustainable finance regulation by using the EU's SFDR as an exogenous policy shock to examine how institutional investors and firms adapt their behavior. At the investor level, we show that EU-based institutional investors significantly reduce their exposure to brown firms following the introduction of the SFDR, with the largest reductions observed in the years immediately after 2021. This pattern is consistent with a regulatory selection mechanism, where investors reallocate their portfolios away from high-emission firms in response to both compliance requirements and reputational concerns. Importantly, these effects remain robust after balancing EU and US investors through propensity score matching, reinforcing the causal interpretation of the SFDR as the driver of the observed portfolio adjustments.

At the firm level, the SFDR induces substantial behavioral responses, particularly among the firms with the weakest environmental performance. Brown firms—initially the most disadvantaged relative to green firms—respond to the regulatory pressure by improving emissions performance, increasing green patenting, and enhancing environmental innovation. However, we also find that these positive transitions are dampened when institutional investors reduce their ownership stakes post-SFDR. Investor exit weakens the improvements in emissions management and innovation for brown firms, suggesting that divestment may constrain the very transition pathways the regulation aims to promote.

These findings contribute to the ongoing debate on whether sustainable finance regulation accelerates or hinders corporate transitions toward sustainability. Our results highlight a nuanced mechanism: while the SFDR incentivizes the firms most exposed to environmental risk to improve, sustained investor engagement is critical to maintain this momentum. Regulatory pressure alone can initiate change, but when combined with investor support rather than divestment, it more effectively facilitates the transition of high-emission firms.

Appendix

Appendix 1. Variable definitions.

Variable	Definition
Escore	Environmental performance score from LSEG ESG (formerly Refinitiv), scaled from 0 to 100, capturing emissions, resource use, innovation, and environmental controversies.
EmissionScore	Emission score reflects how well a firm manages and discloses its greenhouse gas (GHG) emissions. It evaluates a firm's performance on reducing emissions and its transparency in reporting them.
R&D	Research and Development expenditure, Natural logarithm of total research and development expenditure as a proxy for innovation activity.
GreenPatent	Green Patent is the number of environmentally related patents filed by a firm, extracted from the European Patent Office (EPO).
EnvInnovation	Environment innovation performance score from LSEG ESG (formerly Refinitiv), scaled from 0 to 100, captures a company's environmental innovation performance.
IOReduction	Dummy variable equal to 1 if a firm experiences a decline in institutional ownership compared to the previous year, and 0 otherwise.
Post	Dummy variable equal to 1 for years after the implementation of the SFDR (2021 onward), and 0 otherwise.
Green	Dummy variable equal to 1 if the firm is in the top tercile of the E score distribution in a given year; 0 otherwise.
Gray	Dummy variable equal to 1 if the firm is in the middle tercile of the E score distribution in a given year; 0 otherwise.
Brown	Dummy variable equal to 1 if the firm is in the bottom tercile of the E score distribution in a given year; 0 otherwise.
Size	Firm size: Natural logarithm of total assets of the firm.
ROA	Return on Assets: Net Income divided by the two fiscal period average of total assets multiplied by 100.
Tobin'sQ	The ratio that compares the market value of a firm to the replacement cost of its tangible assets.
Lev	Leverage: is calculated as total debt divided by total shareholders' equity.
BTM	Book to market value: Ratio of book value of equity to market value of equity.
Capex	Capital expenditure: Natural logarithm of total capital expenditures.

Variable	Definition
BrownPortfolio	The proportion of an institutional investor's EU equity holdings allocated to brown firms in a given year. Calculated as the total shareholdings in brown firms divided by the investor's total portfolio in EU-listed firms, where brown firms are identified based on the bottom tercile of the annual environmental score distribution.
EU	Dummy variable equal to 1 if the investor is domiciled in an EU country; 0 if the investor is domiciled in U.S.
InvSize	Investor size: Natural logarithm of the total value of an institutional investor's holdings in EU-listed firms in a given year.
PRI	Principle Responsible Investor is a binary variable equal to 1 if an institutional investor is a signatory to the UN Principles for Responsible Investment, and 0 otherwise.

Note: This table contains definitions for all variables employed in our empirical analysis.

Appendix 2. Number of institutional investors by sample year

Year	Freq.	Percent	Cum.
2018	1,859	13.08	13.08
2019	2,125	14.96	28.04
2020	2,710	19.07	47.11
2021	2,710	19.07	66.19
2022	2,447	17.22	83.41
2023	2,357	16.59	100.00
Total	14,208	100.00	

Note: This table presents the number of institutional investors in each year.

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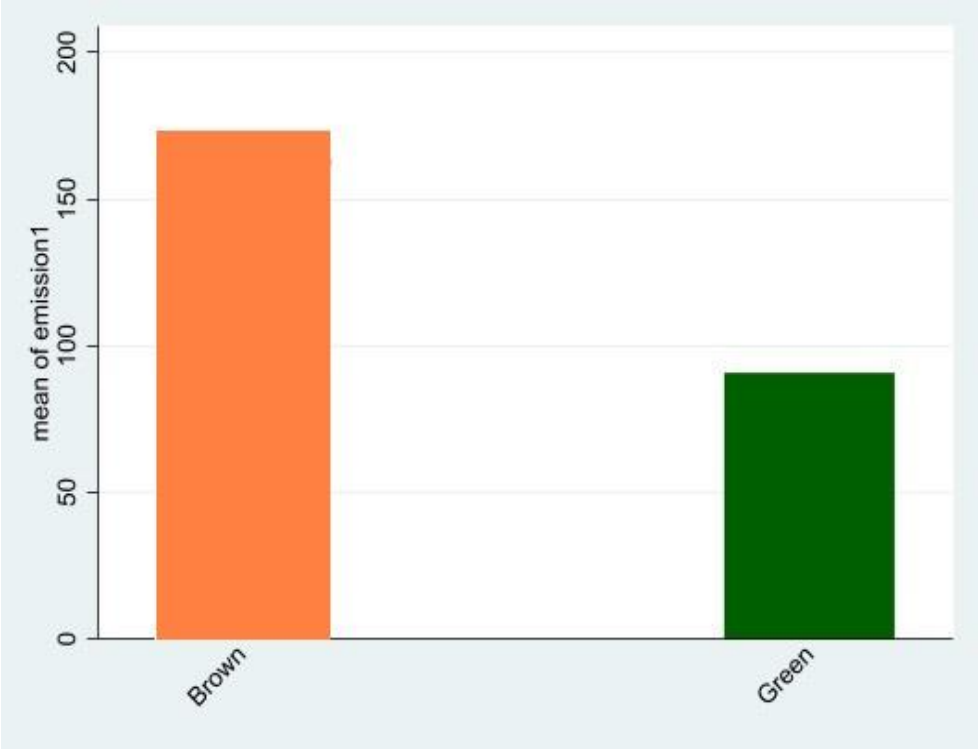
Figures

Figure 1. Average emissions of brown and green firms.



This figure plots the average Scope 1 CO_2 emissions of firms, scaled by firm size. Firms are classified into terciles each year based on their environmental (E) scores from LSEG ESG. The bottom tercile represents brown firms with the lowest environmental scores, and the top tercile represents green firms with the highest scores.

Table 1. Number of EU and US institutional investors

	Freq.	Percent	Cum.
US	10,858	76.37	76.37
EU	3,358	23.63	100.00
Total	14,208	100.00	

Note: This table presents the number of EU and US institutional investors in each year.

Table 2. Summary statistics

Panel A. Summary statistics at the institutional investor-level

	N	Mean	SD	Min	Max
BrownPortfolio	12,729	0.39	0.38	0	1
GrayPortfolio	12,729	0.38	0.35	0	1
GreenPortfolio	12,729	0.23	0.30	0	1
post	14,208	0.53	0.50	0	1
EU	14,208	0.24	0.42	0	1
PRI	14,208	0.12	0.33	0	1
InvSize	12,723	7.25	2.62	1.9	13.93

Panel B. Summary statistics at firm-level

	N	Mean	SD	Min	Max
EmissionScore	4,836	56.62	30.54	0	99.29
R&D	2,624	3.60	2.21	-2.14	8.76
GreenPatent	4,836	0.92	4.85	0	40
EnvInnovation	4,836	28.13	32.06	0	99.9
IOReduction	3,919	0.54	0.50	0	1
Post	4,836	0.56	0.50	0	1
Green	4,836	0.28	0.45	0	1
Gray	4,836	0.36	0.48	0	1
Brown	4,836	0.36	0.48	0	1
Size	4,809	7.74	1.93	2.71	11.99
ROA(%)	4,807	3.27	8.30	-22.86	27.48
Tobin's Q	4,802	2.10	2.54	0.36	51.46
Lev	4,809	0.58	0.19	0.10	1.10
BTM	4,802	0.62	0.57	-0.01	3.19
Capex	4,807	4.22	2.26	-2.91	9.02

Note: This table provides descriptive statistics for the variables used in our analysis over fiscal years 2018 to 2023. Panel A reports summary statistics of the ratings for institutional investors, while Panel B reports summary statistics for the main dependent and control variables at the firm level. All variables are defined in the Appendix 1.

Table 3. Correlations among variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) EmissionScore	1.00														
(2) *R&D*	0.44	1.00													
	0.00														
(3) *GreenPatent*	0.14	0.25	1.00												
	0.00	0.00													
(4) *EnvInnovation*	0.32	0.26	0.16	1.00											
	0.00	0.00	0.00												
(5) *IOReduction*	-0.02	-0.07	-0.01	0.01	1.00										
	0.34	0.00	0.52	0.39											
(6) *Post*	0.06	-0.06	-0.13	-0.15	-0.04	1.00									
	0.00	0.00	0.00	0.00	0.02										
(7) *Green*	0.61	0.40	0.15	0.47	-0.02	0.02	1.00								
	0.00	0.00	0.00	0.00	0.18	0.09									
(8) *Gray*	0.16	-0.01	-0.02	0.00	0.01	0.04	-0.47	1.00							
	0.00	0.45	0.16	0.78	0.69	0.01	0.00								
(9) *Brown*	-0.73	-0.37	-0.12	-0.45	0.01	-0.06	-0.47	-0.56	1.00						
	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00							
(10) *Size*	0.63	0.69	0.21	0.37	-0.02	-0.06	0.51	0.09	-0.56	1.00					
	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00						
(11) *ROA(%)*	0.17	0.08	-0.01	0.07	-0.09	0.02	0.06	0.08	-0.14	0.13	1.00				
	0.00	0.00	0.60	0.00	0.00	0.13	0.00	0.00	0.00	0.00					
(12) *Tobin's Q*	-0.17	-0.09	-0.04	-0.14	-0.11	-0.03	-0.12	-0.07	0.18	-0.30	0.19	1.00			
	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00				
(13) *Lev*	0.23	0.17	0.07	0.13	0.05	-0.02	0.15	0.07	-0.21	0.32	-0.19	-0.23	1.00		
	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00			
(14) *BTM*	0.02	0.01	0.07	0.09	0.13	0.06	0.03	0.03	-0.06	0.17	-0.11	-0.37	-0.08	1.00	
	0.09	0.50	0.00	0.00	0.00	0.00	0.07	0.03	0.00	0.00	0.00	0.00	0.00		
(15) *Capex*	0.30	0.41	0.28	0.25	-0.02	-0.01	0.33	-0.06	-0.25	0.56	0.02	-0.10	0.16	0.11	1.00
	0.00	0.00	0.00	0.00	0.17	0.55	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	

Note: This table displays the correlation coefficients matrix for the 15 variables analysed. All variables are defined in detail in Appendix 1.

Table 4. Portfolio allocation differences between EU and US investors following SFDR

	(1)	(2)
Subsamples	*EU*	*US*
VARIABLES	*BrownPortfolio*	
Post	-0.034***	0.013*
	(0.010)	(0.007)
InvSize	-0.001	0.022***
	(0.004)	(0.003)
PRI	-0.011	0.031
	(0.024)	(0.023)
Constant	0.754***	0.465***
	(0.107)	(0.031)
Observations	3,296	9,427
R-squared	0.022	0.117
Investor Style FE	YES	YES

Note: This table presents the Portfolio allocation differences between EU and US investors following SFDR. The analysis uses separate subsamples of institutional investors based in the EU and the US. Standard errors are clustered by investor and *t* statistics are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. The dependent variables is *BrownPortfolio*. *Post* is a dummy equal to 1 for period 2021 onward, 0 otherwise. *InvSize* is the natural logarithm of an institutional investor's holdings, *PRI* equals 1 if the institutional investor is a PRI (Principles for Responsible Investment) signatory and 0 otherwise.. All variables are defined in detail in Appendix 1.

Table 5. The impact of SFDR on the Brown portfolio of institutional investors

VARIABLES	(1) *BrownPortfolio*	(2) *BrownPortfolio*
Post	0.015**	0.015**
	(0.007)	(0.007)
EU	0.188***	0.195***
	(0.014)	(0.017)
Post× EU	-0.052***	
	(0.012)	
EU × Y2019		-0.023
		(0.014)
EU × Y2020		0.001
		(0.015)
EU × Y2021		-0.052***
		(0.017)
EU × Y2022		-0.055***
		(0.019)
EU × Y2023		-0.072***
		(0.019)
PRI	0.006	0.006
	(0.017)	(0.017)
InvSize	0.017***	0.017***
	(0.002)	(0.002)
Constant	0.503***	0.503***
	(0.028)	(0.028)
Observations	12,723	12,723
R-squared	0.123	0.123
Investor Style FE	YES	YES

Note: This table presents the result from estimating Equation (1), the impact of SFDR on the Brown portfolio of institutional investors. Standard errors are clustered by investor and year and *t* statistics are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. The dependent variable is *BrownPortfolio* in columns (1), (2) and (3) respectively. *Post× EU* is an interaction term equal to 1 for EU-based investors in the post-SFDR period (2021 onward), 0 otherwise. *EU × Y20*** is an interaction term equal to 1 for EU-based investors in the year 2019 to 2023, 0 otherwise. *InvSize* is the natural logarithm of an institutional investor's holdings, and *PRI* equals 1 if the institutional investor is a PRI (Principles for Responsible Investment) signatory and 0 otherwise. All variables are defined in detail in Appendix 1.

Table 6. The impact of SFDR on the firm sustainability transition

VARIABLES	(1) *EmissionScore*	(2) *R&D*	(3) *GreenPatent*	(4) *EnvInnovation*
Post	0.977**	0.006	-2.283***	-20.138***
	(0.498)	(0.027)	(0.451)	(1.033)
Gray	-14.196***	-0.032	-1.036**	-21.376***
	(1.011)	(0.032)	(0.461)	(1.926)
Brown	-35.734***	-0.217***	-1.790***	-41.083***
	(1.625)	(0.061)	(0.473)	(2.595)
Post× Gray	2.436***	0.055	1.222**	7.188***
	(0.891)	(0.045)	(0.535)	(1.460)
Post× Brown	6.411***	0.097**	2.140***	15.303***
	(0.953)	(0.048)	(0.466)	(1.252)
Constant	21.076**	0.523	2.776	40.288***
	(9.091)	(0.447)	(1.686)	(11.758)
Observations	4,787	2,589	4,787	4,787
R-squared	0.36	0.14	0.06	0.16
Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES

Note: This table presents the results from estimating Equation (2), examining the impact of the SFDR on firms' sustainability outcomes. Standard errors are clustered by firm, and t-statistics are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Dependent variables include *EmissionScore* (a firm's scope 1 and 2 greenhouse gas emissions management and disclosure), *R&D* (natural logarithm of research and development expenditure), *GreenPatent* (number of environmentally related patents filed), and *EnvInnovation* (environmental innovation performance score from LSEG ESG*). Post* × *Gray* and *Post* × *Brown* are interaction terms equal to 1 for gray and brown firms in the post-SFDR period (2021 onward), and 0 otherwise. Control variables include *Lev* (debt-to-equity ratio), *BTM* (book-to-market value), *Size* (natural logarithm of total assets), *ROA* (return on assets), *Capex* (capital expenditure scaled by total assets), and *Tobin's Q* (market-to-book ratio). All variables are defined in detail in Appendix 1.

Table 7. Institutional investor reduction and sustainability transitions

VARIABLES	(1) *EmissionScore*	(2) *R&D*	(3) *GreenPatent*	(4) *EnvInnovation*
Post× Gray× IOReduction	0.222	-0.063	0.253	-2.668
	(1.437)	(0.062)	(0.755)	(3.657)
Post× Brown× IOReduction	-3.811*	-0.272**	-0.275	-4.798
	(1.951)	(0.105)	(0.589)	(3.555)
Post× Gray	1.944	0.042	0.887	7.709***
	(1.182)	(0.053)	(0.773)	(2.580)
Post× Brown	6.761***	0.227***	2.222***	15.335***
	(1.569)	(0.071)	(0.622)	(2.516)
Gray× IOReduction	-0.145	0.020	0.090	-2.946
	(1.166)	(0.050)	(0.597)	(1.851)
Brown× IOReduction	3.482**	0.140*	0.245	-2.111
	(1.764)	(0.081)	(0.495)	(1.939)
Post× IOReduction	0.382	0.057	0.363	8.289***
	(0.864)	(0.040)	(0.572)	(3.008)
Post	0.593	0.008	-2.363***	-26.055***
	(0.636)	(0.032)	(0.597)	(1.966)
Gray	-13.095***	0.008	-1.146*	-19.247***
	(1.197)	(0.043)	(0.646)	(2.585)
Brown	-33.806***	-0.277***	-2.326***	-39.665***
	(2.128)	(0.080)	(0.632)	(3.464)
IOReduction	-0.584	-0.022	-0.245	-0.535
	(0.674)	(0.031)	(0.478)	(1.237)
Constant	42.754***	0.511	3.219	11.778
	(10.377)	(0.526)	(2.734)	(19.034)
Observations	3,866	2,105	3,866	3,866
R-squared	0.28	0.12	0.06	0.18
Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES

Notes: This table presents the results from estimating Equation (3), examining the impact of the SFDR and institutional investor reduction on firms' sustainability outcomes. The dependent variables are measured at the firm-year level: *EmissionScore* , *R&D*; *GreenPatent* , and *EnvInnovation*. *Post* × *Gray* and *Post* × *Brown* capturing the effect of SFDR on gray and brown firms relative to green firms, and *Post* × *Gray* × *IOReduction* and *Post* × *Brown* × *IOReduction* capturing whether institutional investor reduction after SFDR amplifies or dampens these effects. Control variables include *Lev* (debt-to-equity ratio), *BTM* (book-to-market value), *Size* (natural logarithm of total assets), *ROA* (return on assets), *Capex* (capital expenditure scaled by total assets), and *Tobin's Q* (market-to-book ratio). All regressions include firm and industry fixed effects. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. All variables are defined in detail in Appendix 1.

Table 8. The impact of SFDR on the Brown portfolio of institutional investors

VARIABLES	(1) *BrownPortfolio*	(2) *BrownPortfolio*
Post	0.021	0.021
	(0.018)	(0.018)
EU	0.154***	0.167***
	(0.026)	(0.028)
Post× EU	-0.097***	
	(0.022)	
EU × Y2019		-0.022
		(0.015)
EU × Y2020		-0.019
		(0.019)
EU × Y2021		-0.089***
		(0.028)
EU × Y2022		-0.131***
		(0.028)
EU × Y2023		-0.112***
		(0.028)
PRI	0.005	0.006
	(0.026)	(0.026)
InvSize	0.006	0.006
	(0.005)	(0.005)
Constant	0.662***	0.662***
	(0.062)	(0.062)
Observations	3,048	3,048
R-squared	0.072	0.073
Investor Style FE	YES	YES

Note: This table presents the result from estimating Equation (1), the impact of SFDR on the Brown portfolio of institutional investors. Standard errors are clustered by investor and year and *t* statistics are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. The dependent variable is *BrownPortfolio* in columns (1), (2) and (3) respectively. *Post× EU* is an interaction term equal to 1 for EU-based investors in the post-SFDR period (2021 onward), 0 otherwise. *EU × Y20*** is an interaction term equal to 1 for EU-based investors in the year 2019 to 2023, 0 otherwise. *InvSize* is the natural logarithm of an institutional investor's holdings, and *PRI* equals 1 if the institutional investor is a PRI (Principles for Responsible Investment) signatory and 0 otherwise. All variables are defined in detail in Appendix 1.

Table 9. The impact of SFDR on the firm sustainability transition

VARIABLES	(1) *EmissionScore*	(2) *R&D*	(3) *GreenPatent*	(4) *EnvInnovation*
Post	0.633	-0.039	-2.771***	-22.028***
	(0.552)	(0.034)	(0.626)	(1.091)
Gray	-20.354***	-0.313*	-1.491	-34.837***
	(2.033)	(0.184)	(0.973)	(3.010)
Brown	-55.005***	-0.491**	-2.654***	-57.662***
	(2.492)	(0.233)	(0.802)	(3.023)
Post× Gray	1.875	0.077	1.571*	13.367***
	(1.271)	(0.092)	(0.803)	(1.584)
Post× Brown	5.313***	-0.048	2.783***	20.718***
	(1.232)	(0.092)	(0.625)	(1.327)
Constant	62.892***	-2.587***	-0.498	63.408***
	(5.707)	(0.525)	(1.394)	(5.627)
Observations	2,777	1,553	2,777	2,777
R-squared	0.68	0.69	0.12	0.38
Controls	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO
Industry FE	YES	YES	YES	YES

Note: This table presents the results from estimating Equation (2), examining the impact of the SFDR on firms' sustainability outcomes. Standard errors are clustered by firm, and t-statistics are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Dependent variables include *EmissionScore* (a firm's scope 1 and 2 greenhouse gas emissions management and disclosure), *R&D* (natural logarithm of research and development expenditure), *GreenPatent* (number of environmentally related patents filed), and *EnvInnovation* (environmental innovation performance score from LSEG ESG*). Post* × *Gray* and *Post* × *Brown* are interaction terms equal to 1 for gray and brown firms in the post-SFDR period (2021 onward), and 0 otherwise. Control variables include *Lev* (debt-to-equity ratio), *BTM* (book-to-market value), *Size* (natural logarithm of total assets), *ROA* (return on assets), *Capex* (capital expenditure scaled by total assets), and *Tobin's Q* (market-to-book ratio). All variables are defined in detail in Appendix 1.

Table 10. Institutional investor reduction and sustainability transitions

VARIABLES	(1) *EmissionScore*	(2) *R&D*	(3) *GreenPatent*	(4) *EnvInnovation*
Post × *Gray* × *IOReduction*	-2.723	0.431	0.140	-2.312
	(3.297)	(0.326)	(1.591)	(6.230)
Post × *Brown* × *IOReduction*	-6.909**	-0.034	-0.701	1.352
	(3.507)	(0.322)	(1.005)	(5.523)
Post × *Gray*	1.918	-0.214	1.387	14.760***
	(2.181)	(0.182)	(1.313)	(3.804)
Post × *Brown*	6.433***	-0.138	3.305***	19.088***
	(2.480)	(0.189)	(0.875)	(3.364)
Gray × *IOReduction*	1.288	-0.298	-0.024	0.050
	(2.657)	(0.261)	(1.415)	(3.961)
Brown × *IOReduction*	5.231*	0.024	0.702	-5.840*
	(3.043)	(0.270)	(0.936)	(3.540)
Post × *IOReduction*	3.426**	-0.173	0.288	4.545
	(1.667)	(0.168)	(1.019)	(4.698)
Post	-1.570*	0.141	-3.048***	-25.057***
	(0.943)	(0.093)	(0.879)	(2.624)
Gray	-20.416***	-0.095	-0.844	-34.248***
	(2.398)	(0.231)	(1.391)	(3.731)
Brown	-55.827***	-0.414	-3.261***	-53.741***
	(3.289)	(0.298)	(0.984)	(3.700)
IOReduction	-1.565	0.112	-0.590	1.078
	(1.213)	(0.139)	(0.890)	(2.504)
Constant	65.448***	-2.886***	0.146	63.304***
	(6.124)	(0.550)	(1.473)	(5.774)
Observations	2,237	1,257	2,237	2,237
R-squared	0.67	0.69	0.12	0.35
Controls	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO
Industry FE	YES	YES	YES	YES

Notes: This table presents the results from estimating Equation (3), examining the impact of the SFDR and institutional investor reduction on firms' sustainability outcomes. The dependent variables are measured at the firm-year level: *EmissionScore* , *R&D*; *GreenPatent* , and *EnvInnovation*. *Post* × *Gray* and *Post* × *Brown* capturing the effect of SFDR on gray and brown firms relative to green firms, and *Post* × *Gray* × *IOReduction* and *Post* × *Brown* × *IOReduction* capturing whether institutional investor reduction after SFDR amplifies or dampens these effects. Control variables include *Lev* (debt-to-equity ratio), *BTM* (book-to-market value), *Size* (natural logarithm of total assets), *ROA* (return on assets), *Capex* (capital expenditure scaled by total assets), and *Tobin's Q* (market-to-book ratio). All regressions include firm and industry fixed effects. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. All variables are defined in detail in Appendix 1.