Green Shields: The Role of ESG in Uncertain Times*

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DRAFT: May 30, 2025

Abstract

We examine how ESG characteristics shape monetary policy transmission using high-frequency identification around 160 FOMC announcements (2005-2025). High-ESG firms exhibit asymmetric responses: while gaining protection from immediate rate changes (target surprises), they show heightened sensitivity to forward guidance (path surprises), with 109 basis points additional negative response per standard deviation. The Paris Agreement (December 2015) created a structural break—transforming ESG from a vulnerability to protection against contractionary target surprises, with high-ESG firms gaining 129 basis points advantage post-Paris. These effects persist through industry-by-event fixed effects, confirming firm-level rather than sectoral mechanisms. Non-linear analysis reveals threshold effects, with the largest benefits accruing to firms escaping the bottom ESG quintile. Our findings demonstrate that monetary policy transmission increasingly depends on corporate sustainability characteristics, with implications for central bank policy, investment strategies, and corporate finance. The results show how coordinated climate policy can fundamentally alter financial market relationships and the channels through which monetary policy affects asset prices.

Keywords: ESG, Sustainable Finance; Monetary Policy.

JEL Classification: AAA; BBB; CCC.

*Disclaimer: The views expressed are those of the authors and do not necessarily reflect the views of any institution.

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1. Introduction

The rapid growth of sustainable investing has fundamentally altered global capital markets, with environmental, social, and governance (ESG) considerations now influencing over $50 trillion in managed assets. This transformation coincides with mounting concerns about climate-related financial risks and questions about whether traditional monetary policy frameworks remain appropriate in an era of accelerating environmental change. As central banks navigate their role in supporting economic stability while acknowledging climate imperatives, a critical question emerges: does monetary policy transmit uniformly across firms with different sustainability characteristics, or have ESG attributes become a meaningful dimension of heterogeneous policy effects? Understanding this intersection carries profound implications for monetary policymakers assessing their tools' unintended consequences and for market participants managing portfolios in an evolving financial landscape.

This paper investigates whether and how firm-level ESG characteristics shape equity market responses to monetary policy surprises. We address three central questions that illuminate different facets of this relationship. First, do firms with stronger sustainability profiles exhibit systematically different sensitivities to monetary policy shocks compared to their less sustainable peers, and through which specific channels do these differences manifest? Second, did the Paris Agreement of December 2015—which committed 196 countries to limit global warming and arguably represented a coordination device for climate expectations—create a structural break in how markets price the interaction between ESG characteristics and monetary policy? Third, are these relationships linear across the sustainability spectrum, or do important thresholds and asymmetries characterise the ESG-monetary policy nexus? These questions directly address ongoing policy debates about whether monetary tightening inadvertently impedes the low-carbon transition by disproportionately burdening firms investing in sustainable technologies.

Our empirical approach employs high-frequency identification to isolate the causal effects of monetary policy on stock returns. We measure equity price responses over narrow 30-minute windows surrounding Federal Open Market Committee (FOMC) announcements, capturing the immediate market reaction while minimising contamination from other news. Following established methodology, we decompose monetary policy surprises into two orthogonal components: target surprises that capture unexpected changes in the current federal funds rate, and path surprises that reflect new information about the future trajectory of policy rates. This decomposition proves crucial, as sustainable business models with long-term investment horizons may respond differently to immediate rate changes versus shifts in forward guidance. Our comprehensive dataset spans January 2005 through January 2025, encompassing 160 FOMC announcements and generating 91,840 firm-event observations from S&P 500 constituents. We match these high-frequency returns with annual ESG scores from LSEG, standardised within each year to facilitate meaningful cross-sectional comparisons.

Our analysis reveals that ESG characteristics represent a distinct and economically significant dimension of monetary policy transmission. High-ESG firms demonstrate markedly different sensitivity patterns compared to their low-ESG counterparts, with the direction of this differential depending critically on the type of monetary surprise. For path surprises capturing forward guidance, we document that a one-standard-deviation increase in ESG scores corresponds to 109.3 basis points of additional negative response per unit surprise, a relationship that remains robust across specifications. This heightened sensitivity to long-term rate expectations aligns with the extended investment horizons characteristic of sustainable business models. Conversely, for target surprises affecting immediate rates, the relationship proves more complex and undergoes dramatic transformation around the Paris Agreement. Pre-Paris, high-ESG firms showed no significant differential response to target surprises (coefficient of 0.590, not significant), but post-Paris they gained substantial protection, with the combined effect reaching -0.645. This represents a 129 basis point advantage for firms two standard deviations above the mean ESG score when facing contractionary target surprises.

The robustness and granularity of our findings strengthen confidence in their economic interpretation. When we implement industry-by-event fixed effects—thereby identifying effects solely through within-industry variation among firms facing identical sectoral shocks—the path surprise-ESG interaction maintains significance at -0.186. This persistence confirms that firm-specific sustainability attributes drive differential monetary policy sensitivity beyond any industry composition effects. Portfolio analysis comparing extreme quintiles reveals asymmetries: firms in the bottom ESG quintile suffer an additional 124.6 basis points of negative response to target surprises, while top-quintile firms experience 142.1 basis points of heightened sensitivity to path surprises. Our quintile analysis documents monotonic progressions across the ESG spectrum, with each step up the sustainability ladder providing increased insulation from target surprises while amplifying vulnerability to forward guidance changes. These non-linear patterns suggest important threshold effects, particularly the substantial improvement from moving out of the bottom quintile, which may reflect exclusion from ESG-conscious investor bases or prohibitive risk premiums.

This paper advances our understanding of monetary policy transmission while contributing to the broader literature on sustainable finance and climate risk pricing. We extend recent evidence on heterogeneous monetary policy effects by establishing ESG characteristics as a distinct transmission channel that operates asymmetrically across different types of policy surprises. Our identification of the Paris Agreement as a structural break provides empirical validation for theoretical models suggesting that coordinated climate policy can fundamentally alter asset pricing relationships. By distinguishing between immediate rate changes and forward guidance effects, we reconcile conflicting findings in the emerging literature on monetary policy and sustainability. The within-industry identification, comprehensive temporal coverage spanning a major climate policy event, and granular analysis across the ESG spectrum collectively provide new insights into how financial markets increasingly integrate climate considerations into their response to monetary policy signals.

These findings carry substantial implications for multiple stakeholders navigating the intersection of monetary policy and climate transition. For central banks concerned about the environmental consequences of their actions, our evidence suggests a nuanced reality: while high-ESG firms indeed show greater sensitivity to forward guidance, they have gained protection from immediate rate increases post-Paris, potentially alleviating concerns about monetary policy hindering green investments. For investors, the documented non-linearities and structural breaks provide actionable insights for portfolio construction and risk management across different monetary policy environments. For corporate managers, our results highlight tangible financial benefits from improving ESG performance, particularly for firms currently in lower sustainability tiers.

The remainder of this paper proceeds as follows. Section 2 reviews related literature and develops theoretical predictions. Section 3 describes our data construction and empirical methodology. Section 4 presents our main results on heterogeneous monetary policy transmission and the Paris Agreement transformation. Section 5 concludes with policy implications and directions for future research.

2. Literature Review

Central banks, traditionally focused on price stability and economic growth, are increasingly considering their role in sustainable finance, raising questions about whether monetary policy is "carbon-neutral" or creates unintended biases and evaluating the financial stability risks originating from climate change (Talbot 2025). As sustainable investing has surged – at least $35 trillion of assets tracked environmental, social, and governance (ESG) metrics by 2020 – policymakers wonder if raising interest rates might unintentionally hinder the low-carbon transition. For example, European Central Bank (ECB) official Isabel Schnabel (Schnabel 2023) warned that tighter policy *"...may discourage efforts to decarbonize our economies"* because renewable projects with high up-front costs are especially sensitive to interest rates. The growing emphasis on environmental, social, and governance (ESG) factors, alongside climate change mitigation efforts like the Paris Agreement, has prompted research into how these elements interact with monetary policy.

This question boils down to whether monetary policy is "carbon-neutral" or if it creates climate-related biases in how it impacts firms. Recent research provides extensive evidence on this issue, focusing on stock price responses to central bank announcements and treating ESG as a distinct channel of monetary transmission. Benchora, Leroy, and Raffestin (2025) analyze U.S. stock returns around Fed policy announcements (2010–2019) and find carbon-intensive firms' stocks drop more in response to monetary tightening than those of greener firms, even after controlling for firm size, leverage, and other financial constraints. The difference is statistically and economically significant, implying that traditional monetary policy is not carbon-neutral but instead "unintentionally amplifies biases related to carbon emissions." Notably, their result becomes more pronounced in later years as investor climate awareness rises, suggesting a structural break around the mid-2010s when climate concerns intensified. Döttling and Lam (2024) likewise document that U.S. firms with higher carbon emissions see larger stock price moves around FOMC announcements than low-emission firms. Importantly, they delve into which brown firms are most sensitive: those that are capital-intensive, have low ESG ratings, or face high climate regulatory risk show the greatest reaction to rate surprises. This suggests the market particularly penalizes carbon-heavy firms that also lack strong ESG credentials or are exposed to future carbon costs when monetary conditions tighten.

Similarly, Bauer, Offner, and Rudebusch (2025) focus on European markets with an event-study of ECB policy surprise effects (2012–2023). They construct firm-level "greenness" measures (e.g. CO_2 emission intensity) for euro-area companies and find the same qualitative result: "the equity prices of brown firms appear more sensitive to interest rate surprises than those of low-carbon, green firms." After an ECB Governing Council announcement that unexpectedly signals tighter policy, brown-stock portfolios underperform green-stock portfolios. This differential response has been especially evident during recent ECB tightening cycles, where brown-minus-green stock return spreads turned significantly negative (brown plunging relative to green) following hawkish surprises. The authors note that this pattern is robust across various definitions of "greenness" (total emissions, emissions intensity, etc.), and persists even when comparing firms within the same industry, indicating it's not solely driven by sector composition (Bauer, Offner, and Rudebusch 2025). In sum, in Europe too, higher-carbon firms' valuations are more interest-rate-sensitive than their greener peers.

Why do green and brown firms respond differently to monetary shocks? A key hypothesis is that ESG factors represent a new channel in the transmission of monetary policy, rooted in investor behavior and risk perceptions. Traditional channels emphasize things like interest rate impacts on borrowing costs, credit availability, or investment demand. The "ESG channel" posits that investor preferences for sustainable assets and aversion to carbon-intensive assets can modulate these effects. A number of studies argue that investors derive non-pecuniary utility from holding green assets (or disutility from holding brown assets), which affects how they rebalance portfolios when interest rates change (Bauer, Offner, and Rudebusch 2025). In the theoretical models of Pástor, Stambaugh, and Taylor (2021, 2022), Bauer et al. (2022) showed that some investors are willing to accept lower expected returns on green stocks in exchange for positive social impact, while brown stocks carry a risk premium (often called a "carbon premium") to compensate for being shunned. This represents a distinct transmission channel: it's not that monetary policy directly targets ESG, but because the investor base and risk premia differ between green and brown assets, the same interest rate shock has heterogeneous effects.

Beyond investor preferences, research examines whether intrinsic firm characteristics associated with ESG ratings explain differential monetary policy responses. Brown firms typically concentrate in carbon-intensive sectors (energy, utilities, materials) with substantial physical capital and leverage, while green firms often operate in technology or service sectors with greater intangible assets. These characteristics influence monetary policy sensitivity through established transmission channels.

Sectoral differences partially explain the green-brown response gap. Havrylchyk and Pourabbasvafa (2025) demonstrate that U.S. carbon-intensive industries exhibit heightened monetary policy sensitivity, particularly the shale oil and gas sector that expanded through cheap credit in the 2010s. However, this pattern differs geographically: European firms show minimal carbon-based heterogeneity once industry effects are controlled, reflecting the absence of a comparable shale sector. Notably, Bauer, Offner, and Rudebusch (2025) establish that within-industry heterogeneity persists—lower-emission firms within manufacturing or technology sectors responded less negatively to ECB shocks than higher-emitting peers, indicating that sectoral composition provides only partial explanation. Carbon-intensive firms' reliance on tangible assets and debt financing amplifies monetary policy transmission. For example Havrylchyk and Pourabbasvafa (2025) observe that U.S.

high-emission firms correlate with high capital tangibility, strengthening the financial accelerator mechanism: these firms expand more during monetary easing and contract more severely during tightening due to their collateral-based borrowing capacity. This traditional channel appears weaker in European markets due to structural differences. Also, brown firms face elevated transition risk, requiring substantial decarbonization investments. For instance, Döttling and Lam (2024) find that monetary tightening disproportionately constrains emission-reduction efforts at high-carbon firms, as rising capital costs force delays in green investments. This asymmetric real effect suggests that restrictive monetary policy may inadvertently impede climate transition progress among the firms most needing transformation.

The ESG-based heterogeneity persists after controlling for standard firm characteristics (size, age, profitability, leverage, liquidity), suggesting mechanisms beyond traditional fundamentals. The evidence points to monetary policy shocks revealing transition risk: when discount rates increase, investors reprice firms based on climate exposure, treating green firms as relative safe havens while brown firms' risk premiums escalate. This aligns with emerging research on carbon risk as a distinct asset pricing factor.

The heterogeneous monetary policy responses observed between green and brown firms reflect fundamental shifts in how markets price climate risk. The existence and evolution of a "carbon premium" remains contentious in recent literature. Bolton and Kacperczyk (2021) initially documented that high-emission firms commanded higher returns, suggesting investors demanded compensation for bearing climate transition risk. However, this traditional risk-return relationship has been challenged by subsequent evidence. Bauer et al. (2022) found that green stocks actually outperformed brown stocks across G7 markets throughout much of the past decade, while Aswani, Raghunandan, and Rajgopal (2024) demonstrated that the carbon premium becomes statistically insignificant under alternative specifications. This apparent reversal coincides with surging ESG investment flows following the Paris Agreement, as documented by Kruse, Mohnen, and Sato (2024), suggesting that increased demand for green assets may have fundamentally altered their pricing dynamics. The theoretical framework proposed by Pástor, Stambaugh, and Taylor (2022) and empirically validated by Ardia et al. (2023) provides crucial insight: when climate concerns intensify unexpectedly, green firms experience relative appreciation through lower discount rates while brown firms face elevated risk premiums. This mechanism explains why monetary tightening now disproportionately impacts brown stocks—firms already trading at depressed valuations with high required returns experience amplified sensitivity to further discount rate increases.

The measurement of "greenness" itself introduces substantial complexity into this analysis. While ESG ratings proliferate, Berg, Kölbel, and Rigobon (2022) highlight the "aggregate confusion" arising from divergent methodologies across rating providers, where firms like Tesla might score highly on environmental innovation yet poorly on governance metrics. This measurement challenge has led researchers to favor direct carbon emissions data over composite ESG scores. Bauer, Offner, and Rudebusch (2025)report robust results using emissions-based classifications but weaker effects with ESG ratings, suggesting that markets respond more consistently to objective carbon footprint measures than to subjective sustainability assessments. This preference for emissions data likely reflects its direct connection to transition risk—the concrete financial exposure firms face from potential carbon regulations, stranded assets, and shifting consumer preferences. The integration of climate considerations into investment decisions represents more than a passing trend; natural experiments like the contrasting market reactions to the 2016 and 2020 U.S. presidential elections, documented by Ramelli et al. (2021), demonstrate that climate policy expectations are now deeply embedded in asset pricing. As ESG factors become integral to risk assessment, their interaction with monetary policy transmission appears inevitable, creating a new dimension through which central bank actions propagate through financial markets and ultimately influence the pace of climate transition.

3. Data and Empirical Strategy

Our dataset spans January 2005 through January 2025, encompassing 160 Federal Open Market Committee (FOMC) announcements. We combine high-frequency intraday firm-level stock returns with orthogonalised monetary policy surprises and firm-level ESG metrics to create a panel of 91,840 firm-event observations. This represents 574 unique firms from the S&P 500 index observed across all FOMC announcements, yielding a perfectly balanced panel structure with 100% completeness in the baseline sample. The temporal scope of our analysis proves particularly valuable for examining structural changes in the sustainability-monetary policy nexus. The sample naturally divides around the Paris Agreement of December 2015, with 87 pre-Paris events (54.4% of announcements) and 73 post-Paris events (45.6%). This division enables investigation of how this landmark climate accord potentially reshaped the pricing of ESG characteristics in monetary policy transmission.

The distribution of FOMC events across our sample period, shown in Table 1, reveals several important features. While the Federal Reserve typically holds 8 scheduled meetings per year (observed through 2019 in our sample), the average number of events can be lower in certain periods. This is particularly evident during the pandemic era (2020-2021); for instance, in March 2020, the Fed held unscheduled meetings to address economic conditions, which subsequently led to the cancellation of some regularly scheduled meetings

TABLE 1. FOMC Announcements by Year and Period

Period	Years	Events	Avg per Year	ZLB Events	Post-Paris
Pre-Crisis	2005-2007	24	8.0	0	No
Financial Crisis	2008-2009	16	8.0	8	No
Early Recovery	2010-2014	40	8.0	40	No
Normalization	2015-2019	39	7.8	7	Mixed
Pandemic Era	2020-2021	15	7.5	8	Yes
Recent Period	2022-2025	26	6.5	0	Yes
Total	2005-2025	160	7.6	63	73

as policy decisions had already been made. Our dataset exclusively includes scheduled FOMC announcements, which explains the slight variations in the annual count, especially the average of 7.5 events per year during the Pandemic Era and the 6.5 average in the Recent Period which includes a partial year for 2025. Notably, 63 announcements (39.4%) occurred during zero lower bound (ZLB) periods, specifically late 2008 through 2015 and again during 2020-2021. This variation in monetary policy regimes provides valuable heterogeneity for understanding how unconventional monetary policy tools interact with firm sustainability characteristics.

3.1 Construction of Monetary Policy Surprises

Central to our empirical approach is the use of high-frequency financial data to identify the causal effect of monetary policy surprises on stock returns. For each FOMC announcement, we measure stock returns over a narrow 30-minute window spanning from 10 minutes before to 20 minutes after the policy announcement. This tight window serves two crucial purposes: it captures the immediate market reaction to the monetary policy news while minimising contamination from other information that might affect stock prices during the trading day.

Our identification of monetary policy surprises follows the principal components methodology of Gürkaynak, Sack, and Swanson (2005) but with different set of instruments and a more recent data set. We employ five interest rate instruments to capture the multidimensional nature of monetary policy communication: the current-month federal funds futures, the three-month ahead federal funds futures, and changes in 2-year, 5-year, and 10-year Treasury futures prices. Each instrument is measured as the change from 10 minutes before to 20 minutes after the FOMC announcement.

The first two principal components extracted from these five instruments explain

82.2% of the total variation in interest rate changes around FOMC announcements. Following the rotation procedure detailed in our methodology section, we construct two orthogonal factors: a "target surprise" that captures unexpected changes in the current stance of monetary policy, and a "path surprise" that reflects new information about the future trajectory of policy rates. The orthogonality of these measures (correlation = 0.0007) enables clean identification of distinct channels through which monetary policy affects asset prices.

TABLE 2. Summary Statistics of Monetary Policy Surprises

	Full Sample			By Period		
Variable	Mean	SD	N	Pre-Paris	Post-Paris	Diff.
Target Surprise (bp)	0.000	2.683	156	-0.127	0.145	0.272
Path Surprise (bp)	0.000	6.385	156	-0.513	0.583	1.096
Surprise Magnitudes by Period:						
TS Std. Dev.				3.217	1.891	
PS Std. Dev.				6.749	5.893	
TS Range (max-min)				32.94	21.30	
PS Range (max-min)				49.32	39.24	

Table 2 presents key statistics for our monetary policy surprise measures. Both series have means statistically indistinguishable from zero, confirming the efficiency of market expectations. The standard deviations reveal economically meaningful variation: target surprises average 2.68 basis points while path surprises show greater volatility at 6.38 basis points, consistent with forward guidance representing a more complex and uncertain dimension of policy communication.

The table reveals an interesting structural break around December 2015, a month that coincidentally marked both the Paris Agreement (12 December 2015) and the Federal Reserve's (16 December 2015) first interest rate increase following nearly seven years at the zero lower bound. The notable reduction in surprise volatility after this date—with target surprise standard deviation falling from 3.217 to 1.891 basis points and path surprise volatility declining from 6.749 to 5.893 basis points—suggests a shift in the monetary policy environment. One plausible explanation could be that this period marked improvements in central bank communication practices, with the Fed potentially becoming clearer in its forward guidance as it normalized policy. Alternatively, markets may have developed a better understanding of the Fed's reaction function through experience with unconventional policies. The narrower ranges of surprises post-2015, with target surprises spanning only 21.30 basis points compared to 32.94 basis points in the earlier period, are consistent with either interpretation—or perhaps a combination of both. While we can't definitively attribute this change to any single factor, the persistence of reduced volatility through subsequent policy cycles, including the COVID-19 pandemic response, suggests that the relationship between Fed communications and market expectations may have evolved during this period. This observation motivates our examination of whether firm responses to monetary policy surprises might also have changed around this time, though we remain agnostic about the underlying causes of this shift.

3.2 Stock Return Measurement and Coverage

Our dependent variable is the intraday stock return computed over the same 30-minute window used for monetary policy surprises. We calculate percentage returns as

$$r_{i,t} = 100 \times \ln(P_{i,t+20}/P_{i,t-10})$$

where $P_{i,t+20}$ and $P_{i,t-10}$ represent the stock price 20 minutes after and 10 minutes before the FOMC announcement, respectively. This high-frequency approach provides several advantages over daily returns which is commonly used in the literature such as Bauer, Offner, and Rudebusch (2025), Benchora, Leroy, and Raffestin (2025), Döttling and Lam (2024), Havrylchyk and Pourabbasvafa (2025), and many others. It isolates the policy news effect, minimises contamination from firm-specific announcements, and reduces noise from market microstructure effects that accumulate over longer horizons.

TABLE 3. Summary Statistics of Key Variables

Variable	N	Mean	SD	P10	P50	P90
Stock Return (%)	83,561	0.023	0.709	-0.687	0.021	0.708
ESG Score (Std.)	65,527	0.028	0.996	-1.377	0.115	1.299
Log(Assets)	68,054	22.581	1.431	20.826	22.622	24.363
Book Leverage	84,270	0.448	0.472	0.051	0.412	0.785
Profitability	68,934	0.125	2.130	0.019	0.151	0.344
Non-Dividend Payer	91,840	0.174	0.379	0	0	1

Notes: Summary statistics for the full sample of 91,840 firm-event observations. Stock returns are measured in percentage points over the 30-minute FOMC window. ESG scores are standardised by year to have zero mean and unit variance. Profitability is winsorized at the 1st and 99th percentiles.

Table 3 presents summary statistics for our key variables. The average stock return of 0.023% with a standard deviation of 0.709% indicates substantial variation in firm-level responses to monetary policy announcements. The distribution of returns appears symmetric around zero, consistent with efficient market pricing of policy surprises that are themselves unbiased.

3.3 ESG Data and Measurement

A distinguishing feature of our analysis is the comprehensive integration of ESG metrics at the firm level. We obtain ESG scores from LSEG, with scores ranging from 0 to 100 based on company disclosures. To facilitate interpretation and account for the general improvement in ESG reporting over time, we standardise scores annually to have zero mean and unit variance within each year. This transformation ensures that our ESG measure captures relative sustainability performance within the contemporary peer group rather than absolute levels that may reflect reporting standards evolution.

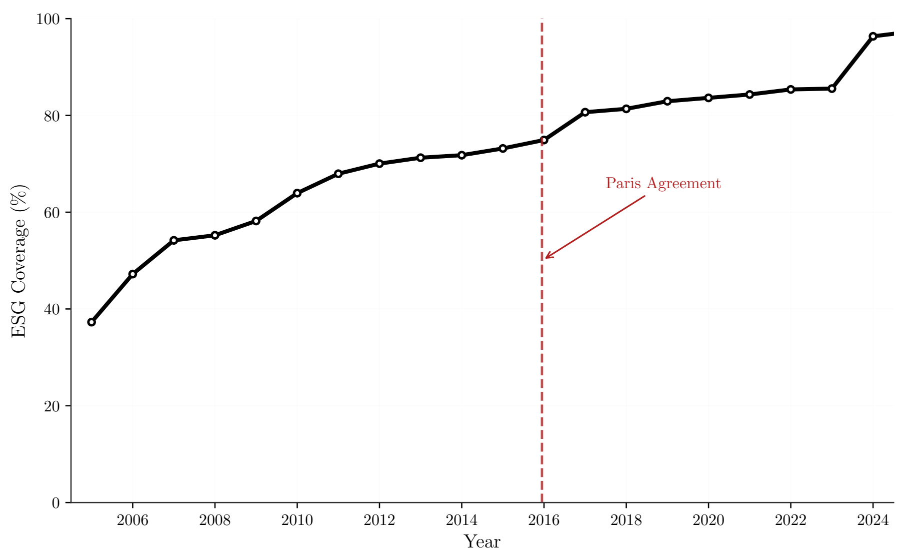


FIGURE 1. ESG Coverage

Figure 1 illustrates the expansion of ESG data coverage over our sample period. Coverage increases from 37.3% of observations in 2005 to 96.3% by 2024. The expansion shows distinct phases: gradual growth from 2005-2012 (reaching 70.0%), followed by steady increases through 2015 (73.2%). Notably, the years surrounding the Paris Agreement show accelerated adoption: coverage rises from 71.8% in 2014 to 73.2% in 2015, then jumps to 74.9% in 2016 and 80.7% by 2017—a 9 percentage point increase in just three years. This acceleration continues through 2019 (82.9%), after which coverage plateaus in the mid-80s before the final surge to 96.3% in 2024. The pattern suggests that the Paris Agreement period coincided with a structural shift in ESG reporting adoption, transforming what had been steady growth into a more rapid expansion that fundamentally changed the landscape of corporate sustainability disclosure.

Figure 2 presents the evolution of ESG scores and their components over time. The aggregate ESG score (standardised with mean zero and unit variance) improves from -1.028 in 2005 to 0.719 in 2024. However, this improvement is far from linear. The score rises steadily from 2005 to reach -0.060 by 2015, crossing into positive territory (0.050) for the first time in 2017—immediately following the Paris Agreement. The pattern suggests a clear acceleration: while it took ten years (2005-2015) to improve by 0.97 standard deviations, the subsequent eight years (2015-2024) saw an additional 0.78 standard deviation improvement, despite starting from a much higher base.

The individual ESG components reveal even more patterns around the Paris Agreement. Environmental scores show relative stagnation from 2013-2015 (hovering around 45), before jumping to 46.2 in 2016 and accelerating to 64.1 by 2024. Social scores exhibit similar dynamics, plateauing around 53 from 2014-2016, then surging to 69.8 by 2024. Most dramatically, Governance scores actually declined slightly from 54.8 in 2014 to 54.4 in 2016, before reversing course and climbing to 66.0 by 2024. This synchronised acceleration across all three components immediately following the Paris Agreement suggests a fundamental shift in corporate ESG practices.

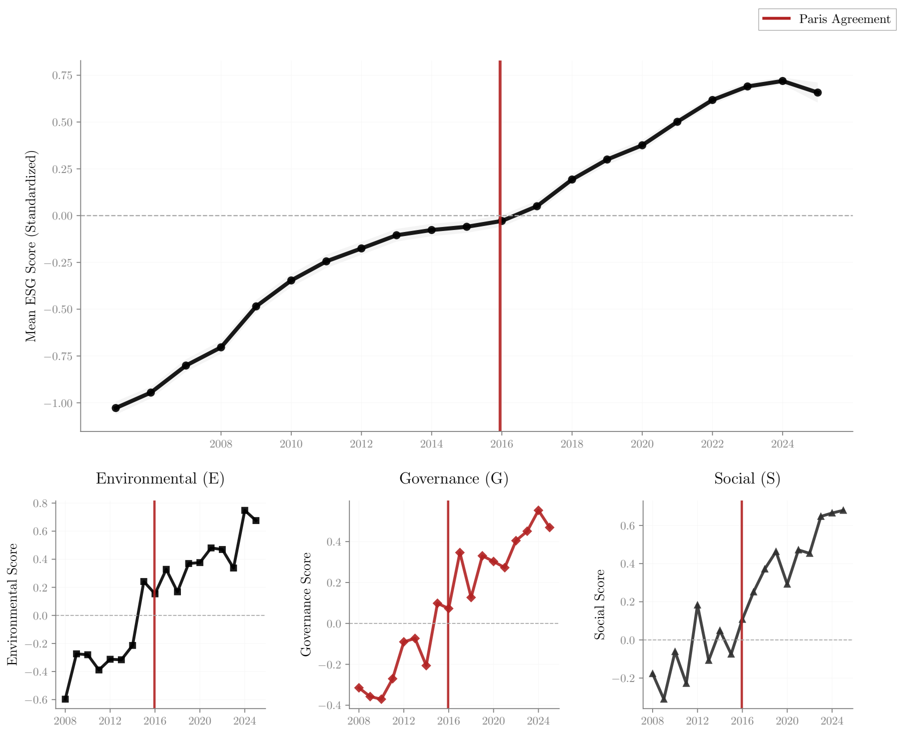


FIGURE 2. ESG Evolution

The Paris Agreement period marks a clear inflection point in both ESG coverage and performance. While coverage had been growing steadily from 37.3% (2005) to 73.2% (2015), it accelerated notably post-Agreement, reaching 80.7% by 2017. Simultaneously, ESG scores that had shown signs of stagnation in 2013-2015 (hovering near -0.06) resumed their upward trajectory, crossing into positive territory in 2017 and reaching 0.72 by 2024. This synchronised expansion in coverage and improvement in scores, combined with decreasing standard deviations across all ESG components, indicates both broadening participation and increasing convergence in corporate sustainability practices.

Table 4 reveals the variation in ESG coverage and scores across industries. Utilities show the highest coverage at 89.4%, consistent with regulatory requirements for environmental disclosure in this carbon-intensive sector. The heterogeneity in average ESG scores across industries—ranging from -0.132 for Consumer Cyclicals to 0.341 for Consumer Non-Cyclicals—reflects both inherent differences in sustainability challenges and varying industry responses to ESG pressures. This cross-industry variation motivates our use of industry-by-event fixed effects in robustness tests to ensure that our identification of changing monetary policy transmission comes from within-industry variation rather than compositional shifts in the reporting universe.

TABLE 4. ESG Coverage by Industry

Industry	Firms	Coverage%	Avg ESG	SD ESG	N_Obs
Utilities	30	89.4	0.179	0.866	4,289
Consumer Non-Cyclicals	43	84.4	0.341	1.079	5,804
Financials	73	74.5	-0.042	0.839	8,696
Real Estate	33	72.8	-0.034	1.103	3,844
Industrials	75	72.3	-0.120	0.979	8,680
Technology	101	71.5	-0.019	0.985	11,560
Healthcare	67	70.7	0.120	1.023	7,583
Basic Materials	27	70.3	0.263	1.009	3,037
Energy	32	64.2	0.082	0.973	3,286
Consumer Cyclicals	93	58.8	-0.132	1.024	8,748

3.4 Firm Characteristics and Control Variables

Our analysis incorporates standard firm-level controls that capture established channels of monetary policy transmission. Firm size, measured as log total assets, averages 22.58 (approximately $5.3 billion in assets) with modest variation (SD = 1.43). Book leverage shows greater heterogeneity, averaging 44.8% with a standard deviation of 47.2%, reflecting diverse capital structures across industries. The high positive skewness in leverage (9.01) stems from a subset of highly leveraged firms, particularly in utilities and real estate sectors where asset-heavy business models prevail.

Profitability, measured as return on assets, presents interesting distributional properties with a mean of 12.5% but extreme negative skewness (-28.8), indicating the presence of loss-making firms particularly during crisis periods. After winsorizing at the 1st and 99th percentiles, profitability ranges from -7.3% to 108.1%, capturing both distressed firms and highly profitable market leaders. Our dividend policy indicator reveals that 17.4% of firm-year observations represent non-dividend payers, concentrated in growth-oriented sectors like technology and healthcare.

The correlation structure in Table 5 reveals that stock returns show strong negative correlations with both monetary policy surprises, with path surprises (-0.389) exhibiting stronger effects than target surprises (-0.271), foreshadowing our main results about the importance of forward guidance. ESG scores correlate positively with firm size (0.462) and leverage (0.180), suggesting that larger, more established firms tend to have better sustainability profiles. Importantly, the near-zero correlation between our two monetary policy surprises (-0.001) validates their orthogonality.

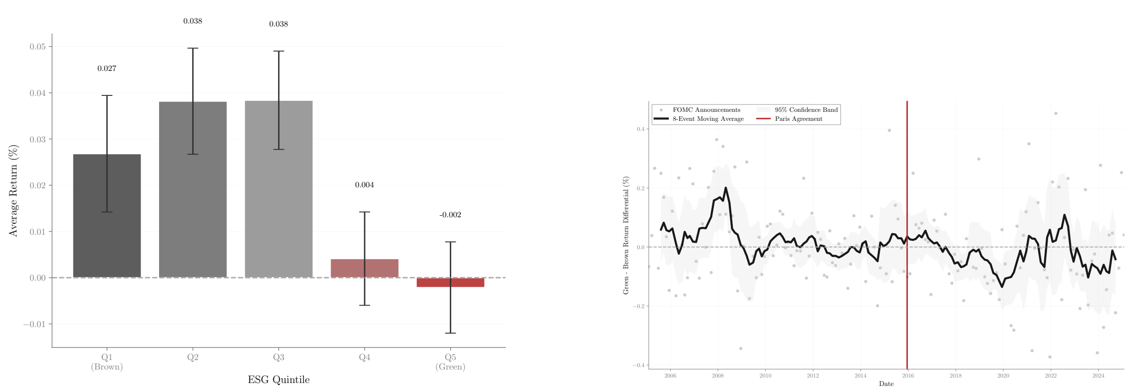
TABLE 5. Correlation Matrix of Key Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Stock Return	1.000						
(2) ESG Score	-0.019*	1.000					
(3) Log Size	-0.010*	0.462*	1.000				
(4) Leverage	-0.004	0.180*	-0.059*	1.000			
(5) Profitability	-0.008	0.015*	-0.099*	0.138*	1.000		
(6) Target Surprise	-0.271*	0.019*	-0.003	0.008	0.000	1.000	
(7) Path Surprise	-0.389*	0.063*	0.026*	0.019*	0.004	-0.001	1.000

Notes: Pearson correlations for 51,534 observations with complete data. * indicates significance at 5% level.

3.5 Portfolio Formation and Extreme ESG Analysis

To examine potential non-linearities in the ESG-monetary policy relationship, we construct portfolios based on ESG quintiles. Figure 3A displays average stock returns by ESG quintile, revealing a monotonic pattern. The lowest ESG quintile (Q1, "Brown" firms) shows average returns of 0.027%, while the highest quintile (Q5, "Green" firms) experiences slight negative returns of -0.002%. The middle quintiles display intermediate values, with Q2 and Q3 showing the highest average returns around 0.038%.



A. Average Returns by ESG Quantile

B. ESG Return Premium Over Time

FIGURE 3. Average Return and ESG Premium Over Time

This U-shaped relationship between ESG scores and average returns during FOMC announcements suggests complex interactions between sustainability characteristics and monetary policy sensitivity. The pattern becomes more pronounced when we examine the differential responses over time, as illustrated in Figure 3B. The brown-minus-green return differential fluctuates around zero in the pre-Paris period but shows no persistent trend. The 8-event moving average smooths short-term volatility and reveals periods of both green outperformance and underperformance relative to brown firms.

TABLE 6. Characteristics by ESG Quintile

ESG Quintile	Avg Return	Log Size	Leverage	Profitability	N
Q1 (Brown)	0.027%	22.04	0.386	0.122	13,017
Q2	0.038%	22.56	0.419	0.164	13,008
Q3	0.038%	22.92	0.439	0.189	13,034
Q4	0.004%	23.31	0.512	0.133	13,033
Q5 (Green)	-0.002%	23.65	0.510	0.196	13,010
No ESG Data	0.030%	21.40	0.430	-0.000	18,459

Table 6 indicates systematic differences in firm characteristics across the ESG spectrum with more details. Green firms are substantially larger (log assets of 23.65 versus 22.04 for brown firms), more leveraged (51.0% versus 38.6%), and more profitable (19.6% versus 12.2%). These patterns suggest that ESG performance correlates with firm maturity and financial stability, necessitating careful control for these characteristics in our regression analysis. Notably, firms without ESG data appear smaller and less profitable than even the lowest ESG quintile, consistent with ESG disclosure being costlier for resource-constrained firms.

Our focus on S&P 500 constituents provides several advantages while imposing some limitations. The sample represents approximately 80% of U.S. equity market capitalisation, ensuring economic significance of our findings. These large, liquid stocks have extensive analyst coverage and ESG reporting, reducing measurement error in key variables. The high liquidity also ensures reliable price discovery during our narrow event windows, critical for the high-frequency identification strategy. However, the focus on large-cap stocks may limit generalisability to smaller firms that could show different ESG-monetary policy relationships. Our sample firms average $5.3 billion in assets, well above the median U.S. public company. The 71.3% ESG coverage in our sample substantially exceeds coverage for smaller firms, where ESG data availability often falls below 30%. These limitations suggest our estimates may represent lower bounds on the true heterogeneity in monetary policy transmission, as smaller, more financially constrained firms likely exhibit even greater sensitivity to policy surprises.

3.6 Temporal Stability and Structural Breaks

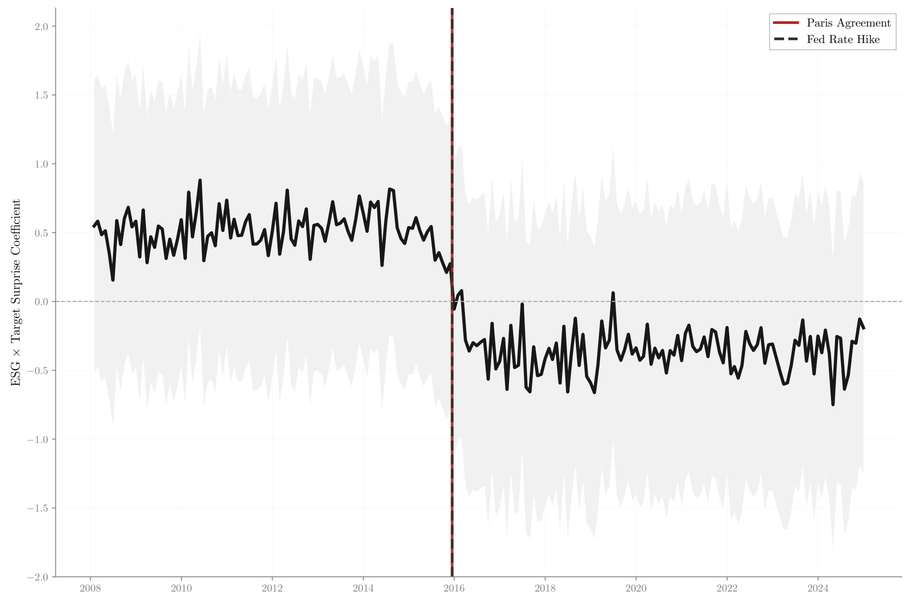
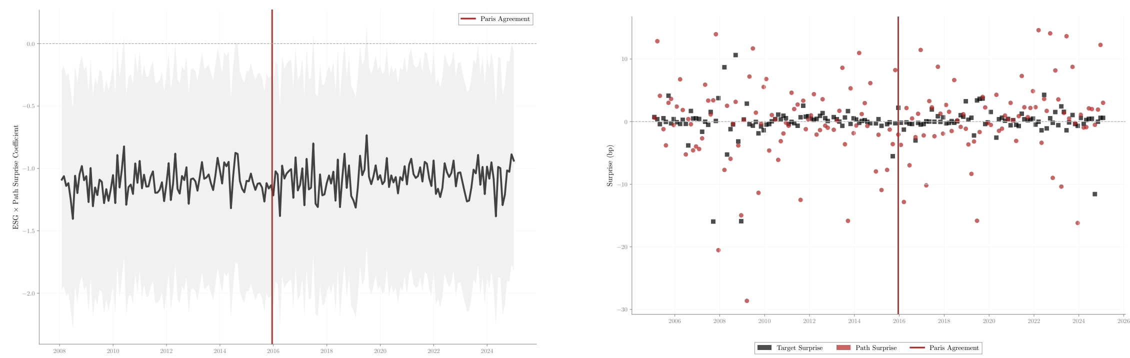


FIGURE 4. Paris Aggrement and ESG × Target Surprise

The extended temporal coverage of our sample—spanning two decades and multiple monetary policy regimes—enables investigation of structural changes in the ESG-monetary policy relationship. Figure-4 directly visualises the key structural break in our analysis. The coefficient on the $\mathtt{ESG} \times \mathtt{Target\ Surprise}$ interaction hovers around 0.5-0.6 in the pre-Paris period with substantial volatility. Following the Paris Agreement (marked by the vertical line), the coefficient drops sharply to approximately -0.3 and remains stable at this new level through 2025. The 95% confidence bands narrow considerably post-Paris, suggesting not only a change in the mean effect but also reduced uncertainty about the relationship.

This structural break contrasts sharply with the stability shown by Figure-5A for the $\mathtt{ESG} \times \mathtt{Path\ Surprise}$ interaction, which maintains a consistent negative coefficient around -1.0 throughout the sample period. Also when we check the plain monetary surprises (both TS and PS) over time as shown in Figure-5B still there is no such sharp change after December 2015. The divergent patterns for target versus path surprises suggest that the Paris Agreement specifically altered how markets price immediate rate changes for sustainable firms while leaving forward guidance effects unchanged—a finding that speaks to the different economic mechanisms underlying these two dimensions of monetary policy.

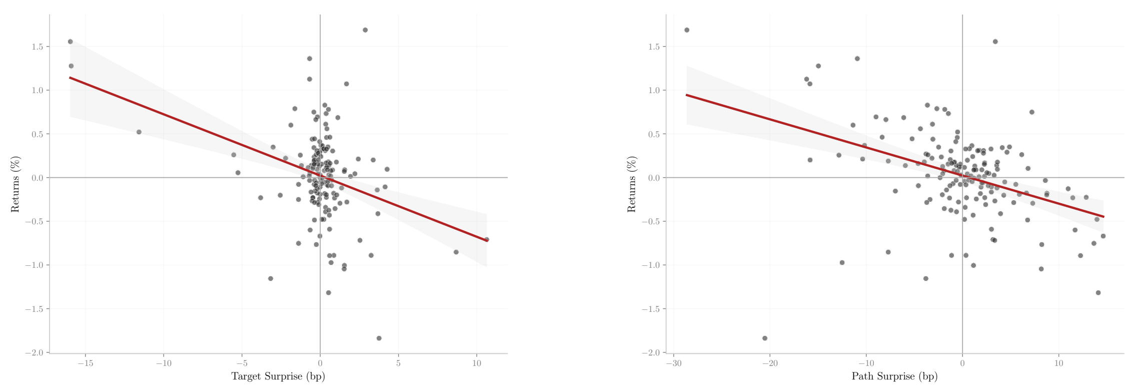


A. ESG × Path Surprises

B. Plain Target and Path Surprises

FIGURE 5. Monetary Policy Surprises and ESG × Path Surprise

The quality of our monetary policy surprise measures is validated through several tests. The near-zero means, orthogonality between target and path surprises, and stability of the factor structure across subperiods all support the reliability of our identification strategy. For examples, as it can be seen in Figure-5B the surprises show expected patterns across monetary policy regimes: muted target surprises during ZLB periods when conventional policy was constrained, but continued variation in path surprises reflecting active forward guidance.

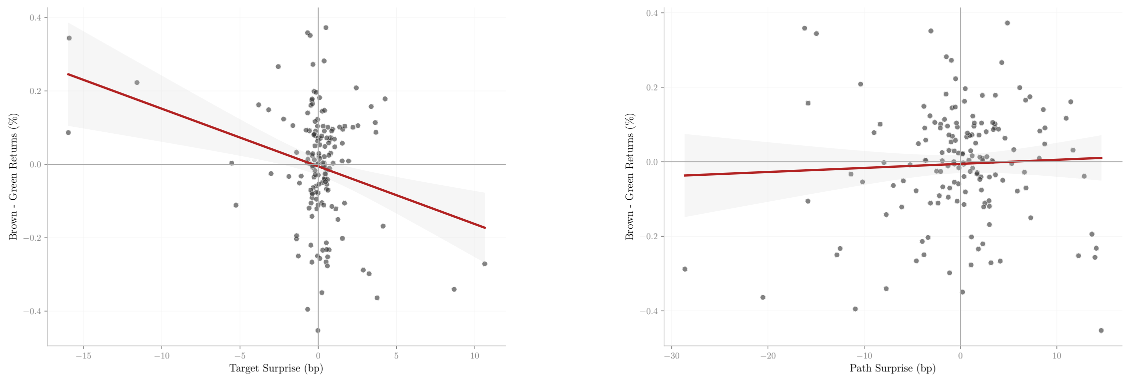


A. Returns and Target Surprises

B. Returns and Path Surprises

FIGURE 6. Stock price returns and monetary policy surprises

We also examine the relationship between monetary policy surprises and stock returns, both at the aggregate level and across ESG-sorted portfolios. Figure-6A shows that target surprises generate the expected negative relationship with average returns, with the fitted line indicating that a 10 basis point contractionary surprise is associated with approximately 50 basis points of negative returns. Figure-7A documents heterogeneous responses based on ESG characteristics: the brown-minus-green (BMG) spread declines by approximately 15-20 basis points for each 10 basis point positive target surprise, indicating that low-ESG firms experience larger negative returns than high-ESG firms during monetary tightening.



A. Brown Minus Green and Target Surprises

B. Brown Minus Green and Path Surprises

FIGURE 7. Relationship between brown-minus-green returns and monetary policy shock

Similarly, Figures-6B and 7B repeat this analysis for path surprises, which capture forward guidance about future policy rates. While path surprises also generate negative average returns (Figures-6B), the BMG spread shows minimal sensitivity to these surprises (Figure-7B), with the regression line remaining essentially flat across the distribution of path shocks. This pattern suggests that ESG-based heterogeneity in monetary policy transmission operates primarily through the immediate impact of rate changes rather than through forward guidance channels. The differential response to target versus path surprises may reflect differences in financing structures, with brown firms potentially more exposed to short-term funding costs that respond directly to current rate changes, while both brown and green firms may face similar exposures to the longer-term interest rate expectations embodied in path surprises.

Looking at your work and Swanson (2021), I'll help you rewrite your section to better position your approach while maintaining your findings. Here's a revised version that emphasizes your methodological choices and connects more effectively with the literature:

3.7 Deriving Monetary Policy Surprises

Our identification of monetary policy surprises employs high-frequency changes in interest rate futures around Federal Open Market Committee (FOMC) announcements, building on the foundational work of Kuttner (2001) and Gürkaynak, Sack, and Swanson (2005)(GSS). While recent work by Swanson (2021) extends this framework to identify three distinct policy dimensions—including large-scale asset purchases (LSAPs)—our focus on the interaction between ESG characteristics and conventional monetary policy transmission motivates a more parsimonious two-factor approach. This methodological choice reflects both our research objectives and the distinct nature of our sample period, which extends through 2025 and captures the post-pandemic normalization of monetary policy.

Following the established literature, we measure monetary policy surprises using narrow windows surrounding FOMC announcements. For each announcement at time t and maturity τ, we compute the following.

$$\Delta i_{\tau,t} = i_{\tau,t+20} - i_{\tau,t-10}$$

where $i_{\tau,t-10}$ and $i_{\tau,t+20}$ represent interest rates 10 minutes before and 20 minutes after the announcement, respectively. This 30-minute window, now standard in the literature (Kuttner 2001, Gürkaynak, Sack, and Swanson 2005, Campbell et al. 2012, Nakamura and Steinsson 2018) captures the immediate market response while maintaining sufficient narrowness to exclude unrelated news. The asymmetric timing reflects market microstructure considerations documented by Fleming and Remolona (1997), allowing adequate time for price discovery while avoiding anticipatory positioning.

3.7.1 Extracting Monetary Policy Surprises from Federal Funds Futures

Federal funds futures provide the cleanest measure of near-term policy expectations, as emphasized by Kuttner (2001) and validated in subsequent work (Gürkaynak, Sack, and Swanson 2005, Gürkaynak, Sack, and Wright 2007, Hamilton 2008). However, the contract's monthly averaging convention requires careful adjustment. For an FOMC announcement occurring on day d of month s containing D_s days, the federal funds futures rate 10 minutes before the announcement reflects:

$$ff^1_{s,t-10} = \frac{d}{D_s}\bar{r}_0 + \frac{D_s - d}{D_s}E_{t-10}[r_1] + \rho^1_{t-10}$$

where $\bar{r}_0$ represents the average federal funds rate realised from day 1 through day d, $E_{t-10}[r_1]$ denotes the market's expectation of the rate for the remainder of the month, and ρ^1_{t-10} captures any risk premium. After the announcement at $t + 20$:

$$ff^1_{s,t+20} = \frac{d}{D_s}\bar{r}_0 + \frac{D_s - d}{D_s}r_1 + \rho^1_{t+20}$$

where r_1 now reflects the announced target rate. We assume the risk premium remains constant within this narrow 30-minute window, such that $\rho^1_{t-10} = \rho^1_{t+20} \equiv \rho^1$. Consequently, this risk premium cancels out when taking the difference $ff^1_{s,t+20} - ff^1_{s,t-10}$, as $\rho^1_{t+20} - \rho^1_{t-10} = 0$. This assumption is validated by the stability of term premia at high frequencies, allowing us to obtain:

$$mp1_t = \frac{D_s}{D_s - d} \times (ff^1_{s,t+20} - ff^1_{s,t-10})$$

The scaling factor $\frac{D_s}{D_s - d}$ adjusts for the fact that the policy change affects only the remaining days of the month. For late-month announcements (when $D_s - d < 7$), following Kuttner (2001), Gürkaynak, Sack, and Swanson (2005), Hausman and Wongswan (2011) we use the next-month contract to avoid excessive scaling that could amplify microstructure noise.

Following similar logic, we extract expectations about the policy rate following the second FOMC meeting from the current date. Let ff^2 denote the federal funds futures contract for the month containing the second scheduled meeting. Before the announcement:

$$ff^2_{s,t-10} = \frac{d_2}{D_2} E_{t-10}[r_1] + \frac{D_2 - d_2}{D_2} E_{t-10}[r_2] + \rho^2_{t-10}$$

where d_2 and D_2 refer to the day and total days for the second meeting's month, and r_2 represents the expected rate after that meeting. The surprise in expectations for the second meeting, accounting for the information revealed about r_1, is:

$$mp2_t = \frac{D_2}{D_2 - d_2} \times \left[(ff^2_{s,t+20} - ff^2_{s,t-10}) - \frac{d_2}{D_2} mp1_t \right]$$

This formulation cleanly separates the surprise about future policy from the mechanical effect of the current target change.

3.7.2 Term Structure Selection and the Case for Two Factors

Our principal components analysis employs five instruments spanning the yield curve: mp1, mp2, and changes in 2-year, 5-year, and 10-year Treasury futures. This selection differs strategically from Swanson (2021), who includes similar instruments but extracts three factors to additionally capture LSAP effects. Several considerations motivate our two-factor specification:

First, our Cragg and Donald (1997) test results provide strong statistical support for two factors over our full sample. While we reject the hypothesis of two factors at the 1% level (p-value = 0.008), the economic magnitude of the third factor is minimal—the first two principal components explain 82.18% of total variation, with the third adding only 12.52%. This contrasts with Swanson (2021)'s sample where the third factor captured substantial LSAP-related variation during the 2009-2015 period. The difference likely reflects our extended sample through 2025, during which conventional policy tools regained prominence.

Second, our research focus on ESG-monetary policy interactions naturally emphasizes the traditional transmission channels. As Bauer and Swanson (2023a,b) demonstrate, the distinction between target and path surprises remains fundamental for understanding heterogeneous policy effects even in the post-ZLB era. Our two-factor approach cleanly isolates these conventional channels without conflating them with asset purchase programs that may operate through distinct mechanisms (Krishnamurthy and Vissing-Jorgensen 2011, d'Amico et al. 2012).

Third, the temporal evolution of our factors supports this specification. Unlike Swanson (2021), who documents a dominant third factor during QE periods, our analysis reveals that monetary policy variation after 2015 is well-captured by traditional target and path dimensions. This aligns with recent evidence from Bauer and Swanson (2023b) suggesting that post-pandemic monetary policy operates primarily through conventional channels despite the Fed's expanded toolkit.

3.7.3 The Modified Gürkaynak, Sack, and Swanson (2005) Approach

Applying principal components analysis to our five-instrument panel reveals the multidimensional nature of monetary policy surprises. The decomposition takes the form:

$$\mathbf{X} = \mathbf{F}\Lambda' + \mathbf{E}$$

where $\mathbf{X}$ represents the $T \times 5$ matrix of interest rate changes, $\mathbf{F}$ contains the unobserved factors, Λ holds the factor loadings, and $\mathbf{E}$ captures idiosyncratic noise.

The first principal component explains 63.79% of variation with an eigenvalue of 3.189, while the second component adds 18.39% with an eigenvalue of 0.919. Together, these two factors account for 82.18% of total variation—a remarkably high proportion that validates the two-factor structure. The scree plot reveals a clear "elbow" after the second component, with the sharp drop to the third eigenvalue (0.626, explaining only 12.52%) confirming that additional factors add little explanatory power. This two-factor structure aligns with the established monetary policy literature and provides clear economic interpretation: the first factor captures immediate federal funds rate changes (the "target" factor), while the second captures forward guidance about the future path of policy (the "path" factor). While a third component would increase variance explained to 94.70%, it lacks economic interpretability and likely captures idiosyncratic noise rather than systematic policy effects.

The eigenvector matrix reveals the economic interpretation of these raw factors:

TABLE 7. Eigenvalue Decomposition and Variance Explained by Principal Components

Component	Eigenvalue	Variance Explained	Cumulative
First	3.189	63.79%	63.79%
Second	0.919	18.39%	82.18%
Third	0.626	12.52%	94.70%

While Swanson (2021) reports similar cumulative variance explained with three factors (approximately 94%), the distribution across components differs markedly. Our third eigenvalue of 0.626 falls well below unity, suggesting it captures idiosyncratic noise rather than systematic policy variation. This contrasts with Swanson's sample where the third factor exhibited eigenvalues consistently above 1.0 during LSAP periods.

To achieve economic interpretability, we rotate the statistical factors following Gürkaynak, Sack, and Swanson (2005). The rotation ensures the target factor loads exclusively on current-month federal funds futures while the path factor captures forward guidance effects. Our approach differs from Swanson (2021) in omitting his third identifying restriction (minimizing pre-ZLB LSAP effects), which is unnecessary given our two-factor structure.

Following rotation and normalization, the factors exhibit clear economic interpretation through their effects on the term structure:

Maturity	Target Factor	Path Factor	R^2
1-month	1.000	−0.000	0.930
3-month	1.155	0.606	0.525
2-year	1.283	1.283	0.873
5-year	2.115	3.676	0.949
10-year	1.453	5.764	0.832

The target factor moves short rates nearly one-for-one with gradually declining impact at longer maturities, consistent with standard expectations hypothesis logic. The path factor, by construction orthogonal to current target changes, has negligible impact on the overnight rate but substantial and increasing effects on longer-term rates, peaking at the 10-year maturity. This pattern reflects how forward guidance primarily operates through expectations of future short rates, with cumulative effects that amplify at longer horizons. The high R-squared values across maturities confirm that our two-factor structure successfully captures the systematic components of monetary policy's impact on the entire term structure. These loadings align closely with both Gürkaynak, Sack, and Swanson (2005) and the first two factors in Swanson (2021), validating our identification while demonstrating that conventional dimensions of monetary policy remain dominant in our extended sample.

3.7.4 Temporal Stability and Structural Changes

A critical concern for any factor-based identification is parameter stability across monetary policy regimes. Our sample encompasses even more dramatic variations than Swanson (2021), including the COVID-19 pandemic and subsequent inflation surge. We examine stability across four distinct subperiods:

Period	First Eigenvalue	Second Eigenvalue	Cumulative %
Pre-Crisis (2005-07)	2.851	1.472	86.5%
Crisis/QE (2008-14)	3.445	0.983	88.6%
Normalization (2015-19)	3.590	1.110	94.0%
COVID/Post (2020-25)	3.454	1.028	89.6%

The stability of the two-factor structure across these periods strengthens our specification choice. Notably, even during the Crisis/QE period when Swanson (2021) finds substantial third-factor variation, our two factors explain 88.6% of yield curve movements. This suggests that while LSAPs were important during this period, their effects on the specific yield curve points we analyse were largely captured through their influence on conventional policy expectations—consistent with the "signaling channel" emphasized by Bauer, Rudebusch, and Wu (2014) and Woodford (2012).

Our analysis of path surprise behavior reveals important patterns that complement Swanson's findings. The absolute value of path surprises averages 0.048 basis points pre-crisis versus 0.041 during ZLB periods (t-statistic = 16.80), confirming that forward guidance surprises were actually smaller in magnitude during unconventional policy periods. This seemingly paradoxical result, also noted in different form by Swanson (2021), likely reflects the FOMC's enhanced communication efforts when conventional tools were constrained (Campbell et al. 2012).

The post-Paris Agreement period shows even smaller path surprises (0.041 versus 0.046 pre-Paris), suggesting a structural improvement in central bank communication that coincides with enhanced focus on climate-related financial risks. This temporal pattern provides important context for our main findings about ESG-monetary policy interactions, as it suggests that any structural breaks we identify are not artifacts of changing monetary policy communication effectiveness.

3.8 Models for Monetary Policy Transmission

The emergence of sustainable finance as a major force in capital markets raises fundamental questions about the channels through which monetary policy affects firm values. Our empirical investigation addresses several interconnected questions that build upon each other to provide a comprehensive understanding of how ESG characteristics interact with monetary policy transmission.

Our primary inquiry concerns whether monetary policy affects all firms uniformly or whether systematic heterogeneity exists based on firm characteristics, particularly sustainability metrics. Traditional monetary transmission channels operate through interest rate sensitivity, credit constraints, and investment dynamics, all of which may vary with firm attributes. If ESG characteristics have become economically meaningful, they should manifest as an additional dimension of heterogeneous response to monetary policy surprises. This leads naturally to our second question: do ESG characteristics represent a distinct transmission channel, or do they merely proxy for traditional firm attributes like size, leverage, and profitability?

To investigate these questions, we employ a general specification framework:

$$r_{i,t} = \alpha_i + \beta' MP_t + \gamma' X_{i,t} + \delta'(X_{i,t} \times MP_t) + \epsilon_{i,t} \tag{1}$$

where $r_{i,t}$ represents stock returns for firm i around FOMC announcement t, α_i denotes firm fixed effects, and $MP_t = [TS_t, PS_t]'$ contains the two monetary policy surprises—target surprises (TS) capturing unexpected changes in current rates and path surprises (PS) reflecting revisions to future rate expectations. The vector $X_{i,t}$ includes firm characteristics: ESG score, size (log assets), leverage, profitability, and dividend policy indicators. The interaction terms $(X_{i,t} \times MP_t)$ capture heterogeneous responses, with coefficient vector δ measuring how each characteristic k modifies sensitivity to each monetary surprise type z.

Table 8 operationalizes this framework through progressive specifications. Column (1) excludes interactions ($\delta = 0$), establishing baseline effects. Column (2) includes only traditional characteristic interactions where X excludes ESG. Column (3) isolates ESG interactions by restricting X to ESG scores alone, while Column (4) combines all interactions to test whether ESG effects survive when competing with traditional channels. This progression, with main effects in Panel A and interactions in Panel B, allows systematic identification of distinct transmission mechanisms.

A critical identification challenge arises from potential industry clustering of ESG characteristics. High-ESG firms might concentrate in sectors with inherently different monetary policy sensitivities, conflating firm-level and industry-level effects. To address this concern, we augment our specification with industry-by-event fixed effects:

$$r_{i,t} = \alpha_i + \mu_{j,t} + \beta' MP_t + \gamma' X_{i,t} + \delta'(X_{i,t} \times MP_t) + \epsilon_{i,t} \tag{2}$$

where $\mu_{j,t}$ absorbs any shock common to industry j on event date t. This specification, shown in Table-9 Column (3), provides identification solely from within-industry variation—comparing firms with different characteristics within the same sector facing identical industry conditions. The progression in Table-9 from ESG-only interactions to full controls to industry-by-event fixed effects tests the robustness of sustainability effects under increasingly stringent identification requirements.

Beyond establishing whether ESG matters, we investigate potential structural changes in these relationships. The Paris Agreement of December 2015 provides a quasi-experimental setting to test whether this landmark climate accord fundamentally altered market pricing. We extend our framework to include temporal dynamics:

$$r_{i,t} = \alpha_i + \beta' MP_t + \gamma' X_{i,t} + \delta'(X_{i,t} \times MP_t) + Post_t[\beta'_p MP_t + \gamma'_p X_{i,t} + \delta'_p(X_{i,t} \times MP_t)] + \epsilon_{i,t} \quad (3)$$

where $Post_t$ equals one after December 15, 2015. The coefficients δ capture pre-Paris relationships while δ_p measures post-Paris changes, with the sum $\delta + \delta_p$ representing total post-Paris effects. Table-10 implements this specification with increasing complexity across columns: basic Paris effects with ESG only, full model allowing all channels to vary post-Paris, and industry-by-event fixed effects for within-industry identification. Panel A reports pre-Paris relationships (δ) while Panel B shows post-Paris changes (δ_p).

Our final set of research questions concerns the functional form of ESG effects. Are relationships linear across the ESG spectrum, or do non-linearities and asymmetries characterize how sustainability affects monetary policy transmission? We address these through alternative ESG measures in our general framework. The portfolio approach replaces continuous ESG scores with indicators for extreme quintiles:

$$X_{ESG} = [Green_i, Brown_i]'$$

where $Green_i$ and $Brown_i$ indicate top and bottom ESG quintile membership, respectively. This specification, presented in Table A1, reveals potential asymmetries between sustainability leaders and laggards. The quintile analysis extends this by including indicators for all quintiles:

$$X_{ESG} = [Q_2, Q_3, Q_4, Q_5]'$$

with the lowest quintile as base category. Table A3 implements this specification to trace the complete functional form across the ESG distribution.

Finally, we examine industry heterogeneity by interacting sector indicators with monetary policy surprises:

$$r_{i,t} = \alpha_i + \beta' MP_t + \sum_j I_j \left[\delta'_j MP_t + Post_t \cdot \theta'_j MP_t \right] + \left[\text{ESG and control terms} \right] + \epsilon_{i,t} \quad (4)$$

where I_j indicates industry j membership. The coefficients δ_j capture industry-specific pre-Paris sensitivities while θ_j measures post-Paris changes. Table A2 presents these results, revealing how different sectors experienced the monetary-ESG nexus and its transformation.

Throughout our analysis, we cluster standard errors at the event level to account for cross-sectional correlation on FOMC dates, crucial given that monetary surprises represent common shocks. The difference in observations between specifications—64,351 when ESG is not required versus 51,529 when included—reflects incomplete ESG coverage, particularly for smaller firms and earlier periods. This systematic framework, progressing from simple to complex specifications and from linear to non-linear functional forms, provides multiple lenses through which to examine how sustainability has become integrated into monetary policy transmission.

4. Results and Discussion

4.1 Heterogeneous Monetary Policy Transmission and the Role of ESG Characteristics

The emergence of environmental, social, and governance considerations as a major force in capital markets raises fundamental questions about whether these characteristics have become sufficiently important to alter the transmission of monetary policy. While extensive literature documents heterogeneous policy effects through traditional channels of firm size, leverage, and financial constraints (Gertler and Gilchrist 1994, Kashyap and Stein 2000, Ippolito, Ozdagli, and Perez-Orive 2018), the potential for sustainability attributes to constitute a distinct transmission channel remains unexplored. This section investigates whether and how ESG characteristics shape differential firm responses to monetary policy surprises, employing a systematic approach that isolates the ESG channel from traditional heterogeneity sources.

Table-8 presents our core investigation through four specifications that progressively build our understanding of transmission channels. The baseline specification in column (1) confirms that monetary policy surprises significantly affect equity valuations during our 30-minute event windows. Target surprises generate a coefficient of -6.538 ($p < 0.01$), while path surprises yield -3.387 ($p < 0.01$), both highly significant and economically meaningful. Given the standard deviations of our monetary surprises documented in the data section (2.68 basis points for target surprises and 6.39 basis points for path surprises), these coefficients translate to average return impacts of -17.5 and -21.6 basis points per one-standard-deviation shock, respectively. These magnitudes align closely with prior high-frequency studies, validating our identification strategy while establishing the baseline against which heterogeneous effects can be measured.

TABLE 8. Monetary Policy Transmission: Heterogeneous Effects

	(1) Basic		(2) With Interactions		(3) ESG Only		(4) Full Model	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Panel A: Main Effects								
Target Surprise	-6.538***	(1.372)	-15.767***	(5.870)	-6.227***	(1.109)	-16.830***	(5.605)
Path Surprise	-3.387***	(0.809)	8.586**	(4.102)	-3.667***	(0.700)	-5.604**	(2.581)
ESG Score (Std.)					0.019	(0.021)	0.020	(0.021)
Size (Log Assets)	0.007	(0.029)	0.008	(0.028)	-0.015	(0.020)	-0.015	(0.020)
Book Leverage	0.030	(0.045)	0.030	(0.042)	0.036	(0.054)	0.041	(0.054)
Profitability	-0.002**	(0.001)	-0.002	(0.001)	-0.004	(0.003)	-0.013**	(0.006)
Non-Dividend Payer	0.016	(0.020)	0.015	(0.020)	0.021	(0.019)	0.022	(0.020)
Panel B: Interaction Effects								
TS × ESG					0.890*	(0.519)	0.544	(0.542)
PS × ESG					-1.055***	(0.400)	-1.093**	(0.450)
TS × Size			0.383*	(0.228)			0.417*	(0.232)
PS × Size			-0.488***	(0.145)			0.111	(0.121)
TS × Leverage			2.242***	(0.865)			2.790***	(0.863)
PS × Leverage			-2.055***	(0.605)			-1.353**	(0.572)
TS × Profitability			-0.171	(0.212)			-0.270	(0.212)
PS × Profitability			0.007	(0.045)			0.380*	(0.226)
TS × Non-Dividend			-0.915	(0.571)			-0.511	(0.665)
PS × Non-Dividend			-0.420	(0.352)			-0.497	(0.373)
Observations	64,351		64,351		51,529		51,529	
R-squared	0.200		0.211		0.245		0.249	
Firm FE	Yes		Yes		Yes		Yes	

Notes: This table reports heterogeneous effects of monetary policy on stock returns. Columns (1)-(2) use the full sample, while columns (3)-(4) exclude firms without ESG scores. Target Surprise and Path Surprise are orthogonalized monetary policy shocks. Standard errors clustered by event in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Econometric Models:

- Model (1): $r_{i,t} = \alpha_i + \beta_1 TS_t + \beta_2 PS_t + \gamma' X_{i,t} + \epsilon_{i,t}$
- Model (2): $r_{i,t} = \alpha_i + \beta_1 TS_t + \beta_2 PS_t + \gamma' X_{i,t} + \delta'(X_{i,t} \times MP_t) + \epsilon_{i,t}$
- Model (3): $r_{i,t} = \alpha_i + \beta_1 TS_t + \beta_2 PS_t + \beta_3 ESG_{i,t} + \beta_4(TS_t \times ESG_{i,t}) + \beta_5(PS_t \times ESG_{i,t}) + \gamma' X_{i,t} + \epsilon_{i,t}$
- Model (4): Combines models (2) and (3)

Variables: $r_{i,t}$: Stock return for firm i on FOMC date t, α_i: Firm fixed effects, TS_t: Target surprise, PS_t: Path surprise, $ESG_{i,t}$: standardised ESG score, $X_{i,t}$: Control variables (size, leverage, profitability, dividend policy), MP_t: Monetary policy surprises (TS or PS)

The introduction of firm characteristic interactions in column (2) reveals the limitations of average treatment effects in monetary economics. When we allow traditional characteristics to moderate policy impacts, the coefficient on target surprises intensifies to -15.767, suggesting that the "average" firm in our baseline specification was actually a weighted combination of differentially sensitive types. The interaction patterns confirm established theoretical predictions while revealing new insights. Larger firms gain protection from immediate rate changes (TS × Size = 0.383, $p < 0.10$) but face heightened exposure to forward guidance (PS × Size = -0.488, $p < 0.01$), consistent with their access to diversified short-term funding but extensive long-term capital commitments. The leverage channel presents more nuanced findings: the positive coefficient on TS × Leverage (2.242, $p < 0.01$) likely reflects the value of existing fixed-rate debt when rates rise unexpectedly, dominating the traditional financial accelerator mechanism. Meanwhile, the negative PS × Leverage interaction (-2.055, $p < 0.01$) confirms that forward guidance affects highly leveraged firms through anticipated refinancing burdens, as markets price the expected cost of rolling over debt at persistently higher future rates.

Columns (3) and (4) introduce our key innovation—examining whether ESG characteristics constitute an independent dimension of monetary policy heterogeneity. When isolated in column (3), the ESG channel reveals an intriguing asymmetry: high-ESG firms gain modest protection from target surprises (coefficient = 0.890, $p < 0.10$) while demonstrating heightened sensitivity to path surprises (-1.055, $p < 0.01$). This pattern persists when competing with traditional channels in column (4), though the target surprise interaction attenuates to statistical insignificance (0.544, p = 0.32) while the path surprise effect remains robust (-1.093, $p < 0.05$). This asymmetric response pattern distinguishes the ESG channel from traditional characteristics that typically generate consistent directional effects across surprise types.

The economic interpretation of these findings requires careful consideration of what ESG scores capture in our S&P 500 sample. As documented in our data section, ESG scores correlate positively with firm size and leverage, indicating that high-ESG firms tend to be larger, more established enterprises. However, the persistence of ESG effects when controlling for these characteristics suggests that sustainability attributes capture additional variation beyond traditional measures. The heightened sensitivity to forward guidance aligns with theoretical predictions from Pástor, Stambaugh, and Taylor (2021) that sustainable firms attract investors with longer horizons who particularly value predictable long-term cash flows. When path surprises signal shifts in the entire future rate trajectory, these investors may reassess valuations more dramatically than for firms held primarily for short-term gains.

The attenuation of the target surprise-ESG interaction in the full specification warrants careful interpretation. Rather than indicating irrelevance, this pattern suggests that the protective effect of ESG characteristics against immediate rate changes operates partially through correlation with traditional firm attributes. High-ESG firms in our sample tend to be larger and more profitable—characteristics that independently provide some insulation from monetary shocks. The path surprise effect's robustness indicates that forward guidance sensitivity represents a more fundamental feature of sustainable business models that persists regardless of other firm characteristics.

The specification isolating ESG effects (column 3) warrants particular attention as it reveals the pure sustainability channel before introducing competing interactions. The asymmetric pattern—modest protection from target surprises (0.890, $p < 0.10$) coupled with heightened path surprise sensitivity (-1.055, $p < 0.01$)—emerges clearly when ESG is the sole interaction term. This pattern's persistence when competing with traditional channels in column (4), albeit with some attenuation in the target surprise effect (0.544, $p = 0.32$), suggests that while immediate rate protection partially operates through correlation with other protective characteristics, forward guidance sensitivity represents a more fundamental feature of sustainable business models.

These findings contribute to multiple literature strands while opening new research avenues. We extend the monetary policy transmission literature by documenting ESG as a characteristic generating heterogeneous responses distinct from traditional channels. Unlike size or leverage that create consistent directional effects, ESG generates opposing sensitivities to different policy surprise types, suggesting unique economic mechanisms at work. For the sustainable finance literature, we provide the first evidence that ESG characteristics systematically influence firms' exposure to macroeconomic policy shocks, complementing existing work on ESG and expected returns (Bolton and Kacperczyk 2021, Pástor, Stambaugh, and Taylor 2022). The asymmetric response pattern—protection from immediate shocks but vulnerability to forward guidance—adds nuance to debates about whether sustainable investing requires return sacrifice, suggesting the answer depends critically on the macroeconomic policy environment.

Our results also speak to ongoing policy debates about monetary transmission in an era of sustainable finance. The finding that high-ESG firms show greater sensitivity to forward guidance has important implications for central bank communication strategies as the corporate sector's ESG composition evolves. However, these aggregate results average across our twenty-year sample period, potentially masking important temporal variation. As climate awareness intensified and sustainable investment flows accelerated—particularly following the Paris Agreement of 2015—the relationship between ESG characteristics and monetary policy sensitivity may have undergone fundamental changes. The next section investigates this possibility through explicit analysis of structural breaks and temporal dynamics.

4.2 The Role of ESG in Monetary Policy Transmission

While our initial analysis establishes ESG-based heterogeneity, a critical concern remains: do these effects reflect genuine firm-level sustainability characteristics or merely industry composition? High-ESG firms concentrate in sectors like technology and healthcare that may inherently respond differently to monetary policy. If our results simply capture that sustainable firms cluster in rate-insensitive industries, then ESG itself provides no additional information. This identification challenge, documented by Bauer, Offner, and Rudebusch (2025) in European markets, motivates increasingly stringent specifications to isolate firm-level from industry-level effects.

TABLE 9. The Role of ESG in Monetary Policy Transmission

	(1) ESG Only		(2) Full Controls		(3) Industry × Event FE	
	Coef.	SE	Coef.	SE	Coef.	SE
Target Surprise	-6.227***	(1.109)	-16.830***	(5.605)	-11.452	(10.452)
Path Surprise	-3.667***	(0.700)	-5.604**	(2.581)	—	—
ESG Score (Std.)	0.019	(0.021)	0.020	(0.021)	-0.001	(0.004)
TS × ESG	0.890*	(0.519)	0.544	(0.542)	0.020	(0.187)
PS × ESG	-1.055***	(0.400)	-1.093**	(0.450)	-0.186***	(0.047)
Observations	51,529		51,529		51,529	
R-squared	0.245		0.249		0.690	
Firm FE	Yes		Yes		Yes	
Industry × Event FE	No		No		Yes	
Control Interactions	No		Yes		Yes	

Notes: This table examines the role of ESG in monetary policy transmission. Column (1) includes only ESG interactions, column (2) adds interactions with all control variables, and column (3) includes industry-by-event fixed effects. Path Surprise is omitted in column (3) due to collinearity. Standard errors clustered by event in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Econometric Model: $r_{i,t} = \alpha_i + \mu_{j,t} + \beta_1 TS_t + \beta_2 PS_t + \beta_3 ESG_{i,t} + \beta_4(TS_t \times ESG_{i,t}) + \beta_5(PS_t \times ESG_{i,t}) + \delta'(X_{i,t} \times MP_t) + \gamma' X_{i,t} + \epsilon_{i,t}$ where $\mu_{j,t}$ represents industry j by event t fixed effects (in column 3 only).

Table-9 addresses this challenge through three specifications. Column (1) isolates the ESG channel, confirming our asymmetric pattern: TS × ESG = 0.890 ($p < 0.10$) suggests modest protection from immediate rate increases, while PS × ESG = -1.055 ($p < 0.01$) indicates heightened forward guidance sensitivity. This asymmetry distinguishes ESG from traditional characteristics that typically generate consistent directional effects.

Column (2) adds all control interactions, revealing how channels compete. The TS × ESG effect loses significance (0.544, p = 0.32), while PS × ESG strengthens slightly to -1.093 ($p < 0.05$). This differential persistence hints that target surprise protection operates through ESG's correlation with protective characteristics like size, while path surprise sensitivity reflects something more fundamental about sustainable business models.

Column (3) provides the crucial test through industry-by-event fixed effects—26,880 fixed effects that compare firms only within the same industry facing identical shocks. Path Surprise is omitted due to collinearity (it's constant within events), but we can still identify the interaction since ESG varies within industry-event cells. Under this stringent identification, results diverge dramatically. The TS × ESG effect vanishes (0.020, p = 0.91), indicating that apparent protection from immediate rates reflected industry composition entirely. However, PS × ESG survives at -0.186 ($p < 0.01$)—smaller than before but highly significant.

This bifurcation reveals how sustainability affects monetary transmission. Target surprise protection operates as an industry phenomenon—sustainable sectors like technology inherently differ from carbon-intensive utilities in short-term financial flexibility. By contrast, path surprise sensitivity persists within industries, suggesting firm-level characteristics that transcend sectoral boundaries. Even within the same narrow industry, high-ESG firms show 46.5 basis points greater sensitivity to a one-standard-deviation path surprise when moving from the 10th to 90th percentile of ESG scores.

The economic interpretation aligns with recent theory. Pástor, Stambaugh, and Taylor (2021) predict that sustainable firms attract long-horizon investors particularly sensitive to changes in long-term discount rates. When forward guidance signals persistently higher future rates, these patient investors reassess valuations more dramatically than short-term focused investors in lower-ESG peers. The R-squared jump from 0.249 to 0.690 confirms that industry effects dominate, yet meaningful within-industry heterogeneity persists—establishing ESG as a genuine firm-level characteristic affecting monetary transmission beyond simple sectoral composition.

4.3 The Paris Agreement and the Transformation of ESG-Monetary Policy Relationships

Our analysis thus far assumes stable ESG-monetary policy relationships, yet sustainable finance underwent dramatic transformation over our sample period—from niche to mainstream, managing over $50 trillion by 2024. The Paris Agreement of December 2015 represents a potential structural break, serving as a coordination device that may have fundamentally altered how markets price sustainability in monetary policy contexts. The accord's timing—signed December 12, 2015, just days before the Fed's first rate hike in nearly a decade—creates an empirical challenge but also a unique setting where climate commitment and monetary normalization potentially reinforced each other. We now examine whether Paris transformed these relationships.

Table-10 investigates structural changes around the Paris Agreement, allowing both levels and sensitivities to vary across periods. Panel A reveals a pre-Paris landscape that differs markedly from our full-sample results. In column (1), the TS × ESG coefficient of 0.590 lacks significance ($p = 0.10$), indicating high-ESG firms enjoyed no protection from immediate rate changes before Paris. The PS × ESG coefficient of -0.922 ($p < 0.05$) confirms that forward guidance sensitivity predated the accord, though somewhat weaker than in full-sample estimates.

The within-industry specification (column 3) provides an evidence for the importance of pre-Paris. The TS × ESG coefficient of 0.285 ($p < 0.05$) indicates that high-ESG firms were actually MORE vulnerable to contractionary surprises than their lower-ESG peers within the same industry. This counter-intuitive finding likely reflects pre-2015 market perceptions of sustainability as costly compliance rather than value creation. With ESG scores hovering near zero and no coordinated climate policy, markets may have viewed sustainability investments as resource-draining initiatives that increased financial fragility during monetary tightening.

Panel B documents the post-Paris transformation. While most specifications show insignificant changes, the within-industry results reveal a dramatic shift. The Post-Paris × TS × ESG coefficient of -0.930 ($p < 0.01$) indicates a complete reversal in how markets price ESG during monetary tightening. Combined with the pre-Paris effect, the total post-Paris coefficient becomes -0.645 (0.285 - 0.930), transforming ESG from a vulnerability into protection. For a firm two standard deviations above its industry mean in ESG, this represents a swing from 57 basis points disadvantage to 129 basis points advantage—a total change of 186 basis points.

TABLE 10. The Paris Agreement and ESG-Monetary Policy Relationships

	(1) Basic Paris		(2) Full Model		(3) Industry × Event FE	
	Coef.	SE	Coef.	SE	Coef.	SE
Panel A: Pre-Paris Effects						
Target Surprise	-6.712***	(1.500)	-12.826*	(6.784)	-11.074	(9.958)
Path Surprise	-3.086**	(1.239)	-2.668	(4.611)	—	—
ESG Score (Std.)	0.036	(0.026)	0.037	(0.026)	0.001	(0.005)
TS × ESG	0.590	(0.359)	0.388	(0.471)	0.285**	(0.124)
PS × ESG	-0.922**	(0.380)	-0.847*	(0.505)	-0.119**	(0.049)
Panel B: Post-Paris Changes						
Post-Paris	-0.013	(0.065)	-0.012	(0.065)	—	—
Post-Paris × TS	1.181	(2.294)	-12.138	(8.498)	-6.840	(14.558)
Post-Paris × PS	-1.356	(1.363)	-6.157	(4.986)	—	—
Post-Paris × ESG	-0.032	(0.020)	-0.032	(0.020)	-0.002	(0.006)
Post-Paris × TS × ESG	0.113	(0.846)	-0.368	(0.856)	-0.930***	(0.222)
Post-Paris × PS × ESG	0.396	(0.433)	0.067	(0.530)	-0.086	(0.078)
Observations	51,529		51,529		51,529	
R-squared	0.251		0.256		0.692	
Firm FE	Yes		Yes		Yes	
Industry × Event FE	No		No		Yes	
Full Controls	No		Yes		Yes	

Notes: This table examines how the Paris Agreement changed ESG-monetary policy relationships. Post-Paris indicates observations after December 15, 2015. Column (2) includes all control variable interactions with monetary policy and Post-Paris. Column (3) includes industry-by-event fixed effects, which absorb Post-Paris and PS main effects. Standard errors clustered by event in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Econometric Model: $r_{i,t} = \alpha_i + \beta_1 TS_t + \beta_2 PS_t + \beta_3 ESG_{i,t} + \beta_4 Post_t + \beta_5(TS_t \times ESG_{i,t}) + \beta_6(PS_t \times ESG_{i,t}) + \beta_7(Post_t \times TS_t) + \beta_8(Post_t \times PS_t) + \beta_9(Post_t \times ESG_{i,t}) + \beta_{10}(Post_t \times TS_t \times ESG_{i,t}) + \beta_{11}(Post_t \times PS_t \times ESG_{i,t}) + \gamma' X_{i,t} + \epsilon_{i,t}$

Where $Post_t = 1$ if date $\geq$ December 15, 2015.

Crucially, path surprise relationships show no significant post-Paris changes. The Post-Paris × PS × ESG coefficients remain small and insignificant across all specifications, confirming that forward guidance sensitivity—driven by sustainable firms' long-term investment horizons—remained stable regardless of climate policy regime.

This asymmetric transformation suggests Paris operated as a coordination device that resolved uncertainty about climate policy direction. With 196 countries committed to limiting warming, sustainability investments transformed from speculative bets to rational preparations for an inevitable transition. The accord catalyzed growth in ESG-focused investment, creating dedicated capital less likely to flee during monetary tightening. Our data corroborates this shift—ESG coverage jumped from 73.2% to 80.7% within two years, while standardized scores turned positive for the first time.

The within-industry nature of this transformation deserves emphasis. Paris didn't advantage sustainable sectors over carbon-intensive ones; rather, it altered how markets differentiate between high and low-ESG firms within the same industry. This suggests the agreement triggered firm-level reassessment rather than sectoral reallocation—a fundamental change in how markets price sustainability attributes independent of industrial structure.

The stability of path surprise effects provides an important check on our interpretation. While coordinated policy can shift market perceptions and relative valuations during stress periods, it cannot alter fundamental business characteristics that make sustainable firms inherently more sensitive to long-term discount rate changes. This persistence underscores that some aspects of the ESG-monetary policy nexus reflect deep economic features rather than malleable market sentiment.

4.3.1 Portfolio Analysis and Non-Linear Effects

Our analysis has focused on continuous ESG scores, but this approach assumes linear relationships across the sustainability spectrum. Yet the distribution of ESG effects may be more complex—extreme portfolios might behave fundamentally differently than suggested by average effects. Do firms at the bottom of the ESG distribution face disproportionate penalties? Do sustainability leaders enjoy exceptional benefits beyond what linear models predict? We now examine these questions through portfolio and quintile analyses that reveal important non-linearities and asymmetries.

Table-11 compares firms in the top ESG quintile ("green") against those in the bottom quintile ("brown"), revealing asymmetries masked by continuous specifications. Column (1) shows that brown portfolios suffer an additional -1.246 basis points ($p < 0.05$) sensitivity to target surprises, while green portfolios show no significant differential. For path surprises, the pattern reverses: green portfolios exhibit heightened sensitivity (-1.421, $p < 0.01$) while brown portfolios enjoy relative protection (1.461, $p < 0.05$). These asymmetric extremes—brown vulnerable to immediate shocks, green to forward guidance—suggest fundamentally different investor bases and business models at the distribution tails.

TABLE 11. Portfolio Analysis: Green vs Brown Firms

	(1) Simple		(2) With Controls		(3) Paris Effects	
	Coef.	SE	Coef.	SE	Coef.	SE
Panel A: Full Period Effects (Columns 1-2)						
Target Surprise	-6.427***	(1.363)	-13.883***	(5.092)	-10.798***	(4.135)
Path Surprise	-3.393***	(0.789)	5.586*	(3.027)	6.106***	(2.000)
Green Portfolio	0.001	(0.023)	0.001	(0.023)	0.047	(0.034)
Brown Portfolio	-0.011	(0.020)	-0.012	(0.020)	-0.023	(0.022)
TS × Green	1.410	(0.962)	0.651	(0.753)	0.080	(0.998)
PS × Green	-1.421***	(0.515)	-0.884**	(0.385)	-1.069	(0.698)
TS × Brown	-1.246**	(0.629)	-1.212**	(0.597)	-0.938**	(0.454)
PS × Brown	1.461**	(0.612)	1.302**	(0.586)	0.722*	(0.403)
Panel B: Post-Paris Changes (Column 3 only)						
Post-Paris × TS					-9.376	(8.866)
Post-Paris × PS					-10.512***	(3.840)
Post-Paris × Green					-0.061**	(0.030)
Post-Paris × Brown					0.039	(0.030)
Post-Paris × TS × Green					-0.004	(1.230)
Post-Paris × PS × Green					0.613	(0.713)
Post-Paris × TS × Brown					0.356	(1.895)
Post-Paris × PS × Brown					0.725	(0.548)
Observations	64,351		64,351		64,351	
R-squared	0.208		0.215		0.224	
Firm FE	Yes		Yes		Yes	
Control Interactions	No		Yes		Yes	

Notes: This table presents portfolio analysis comparing firms in the top ESG quintile (Green) versus bottom quintile (Brown). Column (2) includes interactions with all control variables. Column (3) adds Paris Agreement interactions. Standard errors clustered by event in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Econometric Model: $r_{i,t} = \alpha_i + \beta_1 TS_t + \beta_2 PS_t + \beta_3 Green_{i,t} + \beta_4 Brown_{i,t} + \beta_5(TS_t \times Green_{i,t}) + \beta_6(PS_t \times Green_{i,t}) + \beta_7(TS_t \times Brown_{i,t}) + \beta_8(PS_t \times Brown_{i,t}) + \gamma' X_{i,t} + \epsilon_{i,t}$

Where $Green_{i,t} = 1$ if firm i is in top ESG quintile, $Brown_{i,t} = 1$ if in bottom quintile.

Column (2) confirms these patterns persist when controlling for firm characteristics, with only modest attenuation. The economic magnitudes remain substantial: for a one-standard-deviation target surprise (2.68 basis points), brown firms experience 334 basis points additional decline relative to the middle 60% of firms, while green-brown differentials reach 265 basis points.

Column (3) examines Paris Agreement effects, revealing limited structural change at the extremes. Green portfolios show a negative level shift post-Paris (-0.061, $p < 0.05$) without changes in monetary sensitivity, suggesting a one-time revaluation as markets reassessed even high-ESG firms' transition costs. The absence of significant triple interactions indicates that, unlike the within-industry reversal documented earlier, extreme portfolio dynamics remained stable. This stability at the tails while within-industry relationships transformed suggests Paris primarily affected how markets differentiate among moderate ESG performers rather than repricing the extremes.

4.3.2 Industry Heterogeneity: Sectoral Transformation After Paris

Table-12 reveals how monetary policy sensitivity varies across industries and transformed after Paris. Pre-Paris, traditional capital-intensive sectors showed highest target surprise sensitivity: utilities (4.202, $p < 0.05$), healthcare (4.105, $p < 0.01$), and consumer non-cyclicals (3.906, $p < 0.01$). These sectors' reliance on long-term financing and regulated returns created natural vulnerability to rate increases.

Post-Paris changes reveal dramatic sectoral realignment. Financials experienced the largest shifts, with both target surprise (+4.196, $p < 0.05$) and path surprise (+2.260, $p < 0.01$) sensitivity increasing significantly. This transformation likely reflects the sector's emerging role as climate transition intermediary—gaining fee income from green finance while facing new climate-related risks. Real estate shows divergent changes: increased target surprise sensitivity (+3.965, $p < 0.05$) but decreased path surprise sensitivity (-1.509, $p < 0.05$), suggesting immediate rate changes signal economic strength benefiting property values while long-term rates increasingly incorporate climate adaptation costs.

The energy sector's increased path surprise sensitivity (+1.785, $p < 0.05$) without target surprise changes indicates markets now focus on long-term implications of monetary policy for energy transition dynamics. Technology and utilities show minimal post-Paris changes, suggesting these sectors' fundamental characteristics dominate any climate considerations. These heterogeneous transformations imply the Paris Agreement didn't uniformly affect all sectors but rather triggered reassessment of climate exposure and transition opportunities specific to each industry's business model.

TABLE 12. Industry-Specific Monetary Policy Sensitivities

	Target Surprise		Path Surprise	
	Pre-Paris	Post-Paris Change	Pre-Paris	Post-Paris Change
Consumer Cyclicals	2.426***	0.991	0.124	0.486
	(0.808)	(1.086)	(0.343)	(0.477)
Consumer Non-Cyclicals	3.906***	2.359	0.460	1.200
	(1.232)	(1.945)	(0.588)	(0.737)
Energy	2.835***	-1.082	-0.471	1.785**
	(0.722)	(1.312)	(0.753)	(0.820)
Financials	3.257**	4.196**	0.199	2.260***
	(1.274)	(2.022)	(0.657)	(0.831)
Healthcare	4.105***	-0.694	0.190	1.392*
	(1.225)	(1.561)	(0.621)	(0.756)
Industrials	1.780*	2.006*	-0.105	0.794
	(0.987)	(1.157)	(0.474)	(0.552)
Real Estate	0.142	3.965**	0.441	-1.509**
	(0.901)	(1.558)	(0.519)	(0.706)
Technology	3.226**	0.161	0.539	0.064
	(1.389)	(1.545)	(0.564)	(0.688)
Utilities	4.202**	1.519	-1.021**	0.283
	(2.090)	(2.923)	(0.461)	(0.833)
Observations	51,529			
R-squared	0.263			

Notes: This table reports industry-specific sensitivities to monetary policy surprises and their changes after the Paris Agreement. Pre-Paris columns show β_j from industry j interactions with monetary surprises. Post-Paris Change columns show θ_j from triple interactions with Post-Paris indicator. The regression includes all ESG interactions, control variable interactions, and firm fixed effects. Standard errors clustered by event in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Econometric Model: $r_{i,t} = \alpha_i + \sum_j \beta_{j,TS}(I_j \times TS_t) + \sum_j \beta_{j,PS}(I_j \times PS_t) + \sum_j \theta_{j,TS}(I_j \times Post_t \times TS_t) + \sum_j \theta_{j,PS}(I_j \times Post_t \times PS_t) + \ldots$

Where $I_j = 1$ if firm i belongs to industry j.

4.3.3 The Full ESG Spectrum: Threshold Effects and Diminishing Returns

Table-13 provides our most granular analysis by examining all ESG quintiles. The monotonic progression reveals important non-linearities obscured by continuous specifications. For target surprises, protection increases steadily across quintiles: from 1.008 ($p < 0.10$) for Q2 to 2.773 ($p < 0.05$) for Q5. Each step up the ESG ladder provides additional insulation, with no evidence of diminishing returns at the top.

TABLE 13. ESG Quintile Analysis

	Target Surprise Interaction		Path Surprise Interaction	
	Coef.	SE	Coef.	SE
Base Category: Quintile 1 (Lowest ESG)				
Quintile 2 × MP	1.008*	(0.600)	-1.217**	(0.508)
Quintile 3 × MP	1.699**	(0.773)	-2.166***	(0.754)
Quintile 4 × MP	2.099	(1.357)	-2.567**	(1.129)
Quintile 5 × MP (Highest ESG)	2.773**	(1.374)	-2.855***	(1.065)
Main Effects:				
Target Surprise	-7.705***	(1.438)		
Path Surprise			-1.939	(1.241)
Observations	51,529			
R-squared	0.245			

Notes: This table shows how monetary policy sensitivity varies across ESG quintiles. The base category is Quintile 1 (lowest ESG scores). Coefficients show the differential effect for each quintile relative to the base. All specifications include firm fixed effects and control variables. Standard errors clustered by event in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Econometric Model: $r_{i,t} = \alpha_i + \beta_1 TS_t + \beta_2 PS_t + \sum_{q=2}^{5} \gamma_q Q_{q,i,t} + \sum_{q=2}^{5} \delta_{q,TS}(Q_{q,i,t} \times TS_t) + \sum_{q=2}^{5} \delta_{q,PS}(Q_{q,i,t} \times PS_t) + \epsilon_{i,t}$ where $Q_{q,i,t} = 1$ if firm i is in ESG quintile q at time t.

Path surprise sensitivity shows even stronger monotonic patterns, with coefficients becoming progressively more negative: from -1.217 ($p < 0.05$) for Q2 to -2.855 ($p < 0.01$) for Q5. This creates a fundamental tradeoff—higher ESG simultaneously provides target surprise protection while amplifying forward guidance vulnerability. The largest improvements occur between Q1 and Q2, suggesting a critical threshold effect. Firms in the bottom quintile face "double jeopardy"—vulnerable to both surprise types—possibly reflecting exclusion from ESG-conscious investor bases and higher risk premiums.

The quintile analysis reveals the second quintile as potentially optimal for minimizing overall monetary policy sensitivity, offering meaningful protection from target surprises (1.008) with limited additional path surprise exposure (-1.217) compared to higher quintiles. For investors focused solely on immediate rate risk, the highest quintiles remain attractive, but those concerned about forward guidance should carefully weigh the tradeoffs. These non-linear patterns suggest corporate ESG strategies should consider position-dependent returns—moving from bottom to second quintile provides the highest marginal benefit, while reaching the top quintile may be optimal only for firms prioritizing protection from immediate rate shocks over long-term rate uncertainty.

4.4 Synthesis and Implications

Taken together, our results document a fundamental transformation in how financial markets price the interaction between sustainability characteristics and monetary policy. The evidence spans multiple dimensions—continuous ESG scores, discrete portfolios, industry classifications, and granular quintiles—each revealing different aspects of this complex relationship. The robustness of effects to increasingly stringent econometric specifications, including industry-by-event fixed effects that provide identification solely from within-industry variation, establishes ESG characteristics as a distinct dimension of monetary policy transmission rather than a proxy for traditional firm characteristics or industry composition.

The Paris Agreement emerges as a true structural break that inverted the relationship between ESG scores and target surprise sensitivity while maintaining the established pattern for path surprises. This transformation likely reflects multiple reinforcing mechanisms: the crystallization of stranded asset risks, the emergence of dedicated sustainable investment capital, regulatory anticipation effects, and a fundamental shift in how markets value long-term sustainability. The non-linear patterns revealed through portfolio and quintile analysis suggest that the ESG-monetary policy relationship involves thresholds, saturation effects, and complex trade-offs that linear models cannot capture.

For policymakers, these findings imply that monetary policy transmission increasingly depends on the sustainability characteristics of the economy. As the proportion of high-ESG firms grows through the climate transition, the aggregate impact of monetary policy may evolve in ways that central banks must anticipate. For investors, our results provide specific guidance on how to position portfolios based on the interaction between expected monetary policy actions and firm sustainability profiles. For corporate managers, the evidence establishes a clear financial incentive to improve ESG performance as a means of reducing cost of capital volatility during monetary policy cycles. As climate considerations become ever more central to economic policy, understanding these evolving transmission mechanisms becomes crucial for all market participants navigating the intersection of monetary policy and sustainable finance.

Our findings align closely with the emerging consensus in the literature that monetary policy transmission is decidedly not carbon-neutral. Benchora, Leroy, and Raffestin (2025) demonstrate using U.S. data that brown firms exhibit significantly higher sensitivity to monetary policy shocks, with their coefficient estimate of -0.051 showing that carbon-intensive firms experience an additional 0.051% decline per standard deviation of monetary tightening. Similarly, Bauer, Offner, and Rudebusch (2025) provide complementary European evidence, finding that brown firms measured by carbon emission levels show 2.3 percentage points greater sensitivity to ECB policy announcements compared to green firms. The consistency of these effects across different geographic contexts, methodological approaches, and sample periods strengthens the case that environmental characteristics represent a fundamental dimension of monetary policy heterogeneity rather than a regional or methodological artifact.

The differential impact we document between target surprises and path surprises finds important precedent in the broader monetary policy literature. Our finding that high-ESG firms show greater sensitivity to forward guidance (path surprises) while remaining relatively insulated from immediate rate changes (target surprises) aligns with theoretical frameworks developed by Gürkaynak, Sack, and Swanson (2005) and refined by Bauer and Swanson (2023a). This pattern reflects what Altavilla et al. (2019) term the 'forward guidance channel' of monetary policy, where longer-term rate expectations affect investment decisions more than immediate policy adjustments. In the ESG context, this makes economic sense given that sustainable business models typically require patient capital and generate returns over extended horizons, making them naturally more sensitive to long-term discount rate changes while remaining relatively insulated from temporary fluctuations.

The Paris Agreement's role as a structural break in ESG-monetary policy relationships receives support from multiple strands of research examining climate policy impacts on financial markets. Kruse, Mohnen, and Sato (2024) document significant market realignments following the Paris Agreement, while Ramelli et al. (2021) show how climate policy expectations fundamentally altered investor behavior. Our finding that the agreement inverted the relationship between ESG scores and target surprise sensitivity from marginally positive to significantly negative (-0.930, $p < 0.01$) suggests what Pástor, Stambaugh, and Taylor (2021, 2022) theorize as a shift in the 'climate risk premium.' This transformation likely reflects multiple reinforcing mechanisms: the crystallization of stranded asset risks documented by Bolton and Kacperczyk (2021, 2023), the emergence of dedicated sustainable investment capital flows analyzed by Pedersen, Fitzgibbons, and Pomorski (2021), and regulatory anticipation effects similar to those found by Bauer, Offner, and Rudebusch (2025) in their analysis of the Inflation Reduction Act.

Our methodological approach builds on recent advances in high-frequency monetary policy identification while addressing key concerns about information effects and predictability. Following Bauer and Swanson (2023a), we employ orthogonalized monetary policy surprises that address Miranda-Agrippino and Ricco (2021)'s concerns about confounding central bank information effects. This approach proves particularly valuable in the ESG context, as Benchora, Leroy, and Raffestin (2025) demonstrate that 'pure monetary' surprises from Jarociński and Karadi (2020) produce similar ESG heterogeneity patterns, suggesting our results reflect genuine policy transmission rather than information revelation. The robustness of our findings to industry-by-event fixed effects addresses Fornari and Groß (2024)'s critique that green-brown differentials might reflect sector composition rather than firm-specific characteristics, providing identification solely from within-industry variation.

The policy implications of our findings resonate with growing concerns about unintended climate consequences of traditional monetary policy. ECB research extensively documents how climate change affects monetary policy transmission mechanisms, with Schnabel (2023) highlighting specific concerns that monetary tightening 'may discourage efforts to decarbonize our economies rapidly.' Our evidence that post-Paris high-ESG firms gain significant protection against contractionary surprises (129 basis points for a two-standard-deviation ESG advantage) suggests these concerns may be overstated. This finding aligns with broader evidence from Bauer, Offner, and Rudebusch (2025) showing that renewable energy stocks demonstrate weaker interest rate sensitivity than oil and gas stocks, contradicting conventional wisdom about higher rates hampering green investment. The persistence of ESG effects through industry-by-event fixed effects suggests what Altavilla et al. (2024) term a 'climate risk-taking channel' where monetary policy affects climate risk premiums charged to high-emission firms.

The theoretical mechanisms underlying our empirical findings receive support from multiple channels documented in the sustainable finance literature. The 'carbon premium' framework developed by Bolton and Kacperczyk (2021, 2023) and Pástor, Stambaugh, and Taylor (2022) provides one explanation for why brown firms show heightened monetary policy sensitivity. As Benchora, Leroy, and Raffestin (2025) theorize, brown firms face both fundamental channels (higher capital intensity leading to greater interest rate sensitivity) and preference channels (investors' non-pecuniary utility from green assets reducing their sensitivity to monetary policy changes). Our finding that ESG effects persist after controlling for traditional firm characteristics (leverage, size, profitability) supports what Pedersen, Fitzgibbons, and Pomorski (2021) term 'ESG-efficient' investing, where environmental preferences create systematic pricing differentials not fully arbitraged away by traditional investors. The amplification of these effects during periods of high climate awareness, similar to patterns documented by Ardia et al. (2023) and Pástor, Stambaugh, and Taylor (2022), suggests that investor attention to climate issues fundamentally alters the transmission of monetary policy.

Our results contribute to what Bauer et al. (2022) identify as an emerging consensus that climate characteristics represent a distinct dimension of asset pricing not captured by traditional factor models. The robustness of our findings across different ESG measures (continuous scores vs. portfolio approaches), monetary policy identification strategies, and econometric specifications addresses concerns raised by Berg, Kölbel, and Rigobon (2022) about ESG measurement inconsistencies. Future research should explore the real-side implications of these financial market effects, building on Fornari and Groß (2024)'s finding that green firms reduce investment more strongly in response to monetary contractions and Döttling and Lam (2024)'s evidence that brown firms reduce emissions more following tightening. The intersection of monetary policy and climate transition, as analyzed by Ferrari and Landi (2024) in their assessment of green quantitative easing, represents a crucial frontier for both academic research and policy design.

5. Conclusion

The intersection of monetary policy and sustainable finance has emerged as one of the most consequential developments in modern capital markets. Our investigation reveals that environmental, social, and governance characteristics have become a fundamental dimension through which monetary policy transmits to asset prices—a dimension that underwent dramatic transformation following the Paris Climate Agreement of 2015.

Our analysis of 160 FOMC announcements over two decades uncovers an important asymmetry in how sustainability shapes monetary policy sensitivity. High-ESG firms face a fundamental trade-off: they enjoy protection from immediate interest rate increases but suffer heightened vulnerability to forward guidance about future policy paths. This asymmetry reflects the inherent tension in sustainable business models—while their long-term value propositions and patient investor bases provide resilience against temporary shocks, these same characteristics create exposure to persistent changes in discount rates that affect distant cash flows.

The Paris Agreement emerges not merely as an environmental accord but as a watershed moment that fundamentally rewired financial market relationships. Before Paris, sustainability offered no protection—indeed, within industries, high-ESG firms were more vulnerable to monetary tightening, likely viewed as costly initiatives that drained resources. After Paris, these same characteristics transformed into valuable hedges, with high-ESG firms gaining 129 basis points of protection against contractionary surprises relative to their industry peers. This reversal illustrates how coordinated policy signals can create discrete shifts in market dynamics, transforming perceived liabilities into assets virtually overnight.

Perhaps most importantly, our granular analysis reveals that ESG effects are decidedly non-linear. The largest benefits accrue to firms escaping the bottom quintile of sustainability performance, suggesting a critical threshold below which firms face exclusion from increasingly influential ESG-conscious investor bases. This finding carries profound implications for corporate strategy—modest improvements in sustainability practices can yield disproportionate benefits for the worst performers, while reaching the highest tiers provides diminishing returns except for firms specifically prioritizing resilience to immediate rate shocks.

For central banks, our findings complicate the already challenging task of monetary policy calibration. As sustainable firms proliferate and ESG considerations become mainstream, the aggregate impact of monetary policy increasingly depends on the sustainability composition of the economy. Forward guidance, in particular, affects high and low-ESG firms in opposite directions, suggesting that central bank communication strategies may need fundamental reconsideration. The structural break at Paris also demonstrates that climate policy and monetary policy have become inextricably linked—future climate initiatives may similarly reshape monetary transmission in ways policymakers must anticipate.

From an investment perspective, our results challenge simplistic narratives about sustainable investing. The asymmetric sensitivities we document create both opportunities and risks that vary with the monetary policy environment. During periods emphasizing forward guidance, high-ESG portfolios become vulnerabilities; during immediate rate adjustments post-Paris, they provide protection. This complexity demands sophisticated approaches that consider both the type of monetary policy action and the specific ESG characteristics of portfolio holdings.

Our analysis, while comprehensive, opens more questions than it answers. How do these relationships manifest in smaller firms beyond the S&P 500? Do similar patterns emerge in European or Asian markets with different institutional contexts? Can we identify the specific mechanisms—investor preferences, regulatory anticipation, or business fundamentals—that drive these effects? As climate considerations become ever more central to economic policy, understanding these evolving relationships becomes not just an academic exercise but a practical imperative for anyone navigating modern financial markets.

The broader implication of our work is that monetary policy and climate policy have become two sides of the same coin. In an era where central banks increasingly acknowledge climate risks and governments implement ambitious decarbonization policies, the traditional boundaries between macroeconomic and environmental considerations have dissolved. Our evidence suggests this integration will only deepen, requiring new frameworks for both research and practice that explicitly recognize how sustainability has become embedded in the very fabric of monetary transmission.

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