Green Transmission: Monetary Policy in the Age of ESG

ALBA PATOZI *

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Abstract

In this paper, I investigate how the Net-Zero transition affects the transmission of monetary policy. I first document an upward trend in environmental performance among US publicly listed companies over the last decade. Second, I evaluate the implications of firms becoming 'greener' for the transmission of monetary policy on asset prices, credit risk and firm-level investment. In response to a shock to monetary policy, 'green' firms (with high environmental scores) are significantly less impacted than their 'brown' counterparts (with lower environmental scores). The dependence of monetary policy responses on firm-level greenness is not explained by intrinsic differences in firms' characteristics. Instead, I show that the heterogeneous response is the result of investors' preferences for sustainable investing. Using a stylized theoretical framework, I illustrate how incorporating such preferences attenuates the semi-elasticity of 'green' asset prices with respect to monetary policy shocks.

Keywords: Monetary Policy, Heterogeneity, Sustainable Investing, ESG, Climate Change.

JEL Codes: E52, G12, G14, G30

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1 Introduction

Environmental objectives are increasingly becoming a key priority for business leaders and boards of directors. As of 2020, at least $35trn of institutional assets track firms' environmental, social and governance (ESG) ratings, and the value that investors place on ESG has more than tripled in the last four years (Baker et al., 2022). Driven in large part by their perception of shareholder interest, many firms are now racing to reduce their greenhouse gas emissions and to be more transparent about their environmental impact.

This trend did not go unnoticed by monetary policy makers who are assessing how climate change and the transition to Net-Zero may affect the macroeconomic landscape in which monetary policy operates. In a recent speech, Isabel Schnabel from the European Central Bank stated that in light of the current monetary policy tightening, green investments were relatively shielded from the impact of higher borrowing costs (Schnabel, 2023). In this paper, I ask: what are the implications of the drive toward 'greenification' for the firm-level transmission of monetary policy?

The contributions of this paper are two-fold. First, this is the first paper to characterise how firms' sensitivity to monetary policy shocks depends on firms' environmental performance. Using stock market, credit risk and investment data from a sample of US publicly listed firms, firm-level environmental performance data, and an exogenous monetary policy shock series, I show that green firms are considerably less sensitive to monetary policy than their brown counterparts. Second, I show that the dampened sensitivity of green firms to monetary policy is not driven by differences in firms' fundamentals. Instead, I develop a stylized theoretical model in which investors derive a non-pecuniary benefit from holding green stocks. I argue that this preference structure gives rise to weaker responses of green firms to monetary policy shocks, and show that the predictions of the model are consistent with the data.

My sample of US publicly listed firms spans the period between 2007 to 2020. To capture the unconventional nature of monetary policy that characterised this period, I use a series of monetary policy surprises from Bu et al. (2021).[1] I also collect environmental score data at the firm-level from MSCI ESG IVA Ratings, which are available at an annual frequency and span the period between 2007 to 2020.[2] Following a methodology proposed by Pástor et al. (2022), I extract the environmental performance (E) component from the ESG metrics and transform it to reflect a company's environmental friendliness in the cross-section (i.e how much greener a firm is compared to every other firm in the sample). This transformation is important because the original environmental scores measure how much better a firm performs on environmental issues *relative* to its peers in the same industry. In this ESG framework, MSCI considers a firm to be greener if it is more resilient to both long term physical and transitional climate change risks. For example, this includes publishing a carbon sustainability report, limiting emissions of harmful pollutants or chemicals, or seeking to lower its carbon footprint.

At first glance, it is not obvious whether the process of greennification should make green firms more (or less) responsive to monetary policy changes compared to their brown counterparts. On the one hand, I document that greener firms are smaller and younger on average, pay lower dividends and are mostly classified as 'growth' companies (i.e. companies whose future cash flows are anticipated to grow at a higher rate than the market). Existing literature suggests that young firms paying no dividends exhibit the largest and most significant change in capital expenditure following a monetary policy shock (Cloyne et al., 2018). This is driven by the fact that these firms' external finance is most exposed to the asset value fluctuations induced by monetary policy shocks. On the other hand, I also show that greener firms tend to be on average less leveraged, more liquid and exhibit larger distance to default compared to brown firms. In a model of heterogeneous firms which issue long-term debt subject to fixed issuance costs, Jeenas (2019) argues that a firm's liquid assets are a good predictor of lower future likelihood of debt issuance and insensitivity to borrowing rates. Similarly, Anderson and Cesa-Bianchi (2020) document that in response to monetary policy shocks firms

[1] For robustness I also test my results against a number of other unconventional series such as the ones constructed by Gürkaynak et al. (2005), Swanson (2021) and Rogers et al. (2018).

[2] MSCI is an ESG score provider which rates firms according to their environmental performance (E), social responsibility (S) and corporate governance (G).

with low leverage experience a less pronounced increase in credit spreads than firms with high leverage.

Given these two opposing forces, it is not clear what the relative sensitivity of green firms to monetary policy shocks should be. Without a clear prediction from theory, I proceed by addressing this question empirically. Using panel event study regressions, I look at stock price responses around FOMC announcements dates.

I find that an unanticipated monetary policy surprise of 100 basis points leads to an average reduction in stock prices of approximately 15%. However, this effect varies considerably with firm-level greenness. In particular, stock prices of green firms are considerably less responsive to monetary policy surprises: following a 100 basis point surprise in monetary policy, stock prices of green (quintile 5) firms fall by around 10%, whereas the stock prices of their brown (quintile 1) counterparts fall by around 21%. The heterogeneous results based on firm-level greenness are robust to a battery of tests. Specifically, they are robust to: (i) using alternative interest rate surprises; and (ii) assessing firm-level greenness based on other ESG score metrics, such as Sustainalytics. Additionally, they are relatively symmetric and equally significant across contractionary and expansionary monetary policy episodes and they hold in the ZLB as well as in the post-ZLB period. Further, they are consistent with the relative effects of monetary policy on CDS spreads, whereby green CDS spreads appear less sensitive to monetary policy shocks compared to their brown counterparts. Moreover, they are also consistent with the relative response of investment for green vs. brown firms in the aftermath of a monetary policy shock, with green firms' investment reacting less strongly than that of brown firms.

In order to better understand the underlying drivers of the differential responses of green vs. brown asset prices to monetary policy shocks, I assess whether the observed heterogeneity can be explained by intrinsic differences in firm-level characteristics of green and brown firms. To do this, I double-sort firms by their greenness and other financial characteristics.[3] I

[3]I augment my baseline specification with an additional double interaction term that controls for the heterogenous effect that monetary policy may have on leverage, liquidity, age, size, market-to-book ratio, among other things.

find that while some of these characteristics are important drivers of monetary policy heterogeneity on their own, they cannot explain the dampened sensitivity of green firms (compared to brown) to monetary policy shocks.

To rationalise the unexplained heterogeneity in firms' responses to monetary policy, I look at investors' preferences for sustainable investing. I consider a stylized theoretical framework where investors derive additional utility from their holdings of green assets and find that accounting for such preferences can generate a dampened semi-elasticity of green asset prices to monetary policy shocks. This is because the effect of an increase in interest rates to green stock prices is a composite of two forces. The pecuniary force that is common across both green and brown asset prices, and results in a reduction of both of these asset prices (i.e as the interest rate increases, investors substitute away from equities and towards bonds). The non-pecuniary force, which is only present in the case of green stocks, attenuates the first force, as investors derive an additional utility from holding green assets.

I then take this hypothesis to the data and find supporting evidence that the dampened sensitivity of green stock prices with respect to monetary policy shocks is driven by investors' preferences for sustainable investing. In particular, the dampened sensitivity is even more pronounced in (i) regions that are highly exposed to natural disaster risk; (ii) US counties where more people believe climate change personally affects them; and (iii) times of heightened climate change concerns. In addition, the theoretical framework implies a re-weighting of the fraction of green stocks in investors' portfolios. This is because a contractionary monetary policy shock depresses the valuation of green stocks to a larger extent than that of brown stocks. This increases the share of investors' portfolio that consists of green securities. Using quarterly data from institutional stock ownership, I find supporting evidence of a rise in green portfolio weights in the aftermath of a monetary policy shock.

To summarise, the empirical results are consistent with the predictions of the stylized model. They support the view that the differential sensitivity of green firms (compared to brown) to monetary policy is driven by investors' preferences for sustainable investing.

Literature Review. This paper is related to two different strands of literature. The first focuses on the role of financial frictions for the transmission of monetary policy. The second investigates the effect of climate change on asset prices and financial markets.

The literature on monetary policy transmission has typically looked at proxies for financial constraints such as firm size, indebtedness, age, liquidity and distance to default (Ottonello and Winberry, 2020; Cloyne et al., 2018; Jeenas, 2019; Ozdagli and Velikov, 2020). However, there has not yet been any work on whether monetary policy affects firms differently conditional on firm-level greenness. Additionally, this literature has typically focused on the response of firm-level quantities, such as investment and employment in the aftermath of a surprise in monetary policy. As these quantities are usually available at a quarterly frequency, assessing the impact of monetary policy on these variables involves aggregating surprises around Federal Open Market Committee (FOMC) announcements to a quarterly level.[4] Different from these papers, I use panel event study regressions based on high-frequency stock market data. The high-frequency approach is particularly useful for three reasons. First, it is free of aggregation bias.[5] Second, endogeneity concerns are minimised with high-frequency data.[6] Third, due to their forward-looking nature, stock prices are likely to reflect future changes in real outcomes such as investment and employment (more quickly than the variables themselves). The high frequency approach therefore delivers a much cleaner identification (Anderson and Cesa-Bianchi, 2020).

With respect to the second strand of the financial effects of climate change, Barnett et al. (2020) provide novel theoretical insights into this topic by drawing from decision theory and tools from asset pricing under uncertainty to estimate the social cost of carbon. Under this framework, asset prices reflect the environmental damage of carbon emissions due to the un-

[4]Three notable exceptions are Anderson and Cesa-Bianchi (2020), Gürkaynak et al. (2019) and Lakdawala and Moreland (2021).

[5]Lower-frequency analysis, which usually is conducted at a quarterly or annual frequency, requires aggregating interest rate surprises over the relevant quarter. Ramey (2016) argues that such aggregation might induce serial correlation in the series of the aggregated surprises. Additionally, Gazzani et al. (2019) and Chudik and Georgiadis (2022) show that such aggregation results in inconsistent estimates of aggregated impulse responses.

[6]Research shows that at lower frequencies, FOMC decisions may be influenced by stock market movements (Rigobon and Sack, 2004; D'Amico and Farka, 2011).

certainty related to both the transmission mechanism and the resultant social damage of climate change. The empirical evidence supports these theoretical predictions and establishes that there is a risk premium associated with long-run climate change risks (Engle et al., 2020). However, it is not clear whether climate risks are priced in correctly. Several studies show that investors do not pay attention to climate change risks and underreact to long-term climate trends (see for instance Hong et al. (2019); Krueger et al. (2020); Painter (2020)). Consequently, salient climate change events, such as abnormally hot days attract investors' attention and result in firms with low carbon emissions underperforming those with high carbon emissions. The characteristics of investors who hold the stock can also determine how climate change risks are priced in. For example Alok et al. (2020) show that fund managers based in regions with frequent climate change disasters overreact to negative climate change events and underweight stocks affected by climate change more heavily. Similarly, Pastor et al. (2021) develop a theoretical model where agents' taste for green holdings affects asset prices. In their model green assets outperform their brown counterparts when consumers' tastes for green products and investors' tastes for sustainable investing are hit by positive shocks. In a similar vein, Baker et al. (2022) found that investors are, on average, willing to pay an additional 0.2% annually when investing in a fund with an ESG mandate. My paper contributes to this literature by identifying how preferences for sustainable investing do not just affect how climate change risks are priced in, but also play an important role in the transmission of shocks in financial markets. In particular, my findings highlight how attitudes towards sustainable investing can lead to heterogeneous capital flow responses to macro-financial shocks.

The remainder of the paper is structured as follows: Section 2 describes the data. Section 3 presents the main results alongside several robustness checks and additional results. Section 4 assesses the extent to which the observed heterogeneity is driven by differences in firm characteristics. Section 5 provides theoretical and empirical evidence in support of the investors' preferences for sustainable investing channel. Finally, Section 6 concludes.

2 Data

I compile my firm-level dataset by combining the following sources: annual firm-level environmental performance scores from MSCI ESG IVA Ratings; daily monetary policy surprise series from Bu et al. (2021); daily firm-level equity prices from the Centre for Research in Security Prices (CRSP); quarterly firm-level balance sheet data from Compustat; daily CDS spreads data from IHS Markit; quarterly forecasts on future company earnings from the Institutional Brokers' Estimate System (I/B/E/S) dataset; quarterly county-level natural hazard risk data from the US Federal Emergency Management Agency (FEMA); county-level data on climate change beliefs from the Yale Climate Opinion Survey (YCOS); daily data on news about climate change by Ardia et al. (2020); quarterly institutional ownership data from Thomson Reuters 13F database.

The final dataset combines all the firm-level data into an 'event study' dataset centered around FOMC announcement days. Specifically, I collect all available environmental performance data on a FOMC announcement day (t) and select all firms for which I can match both equity price and balance sheet data. The final dataset includes 102 FOMC announcements over the 2008 - 2020 period, has information on 1,361 firms and a total of 38,037 observations.

2.1 Environmental Performance

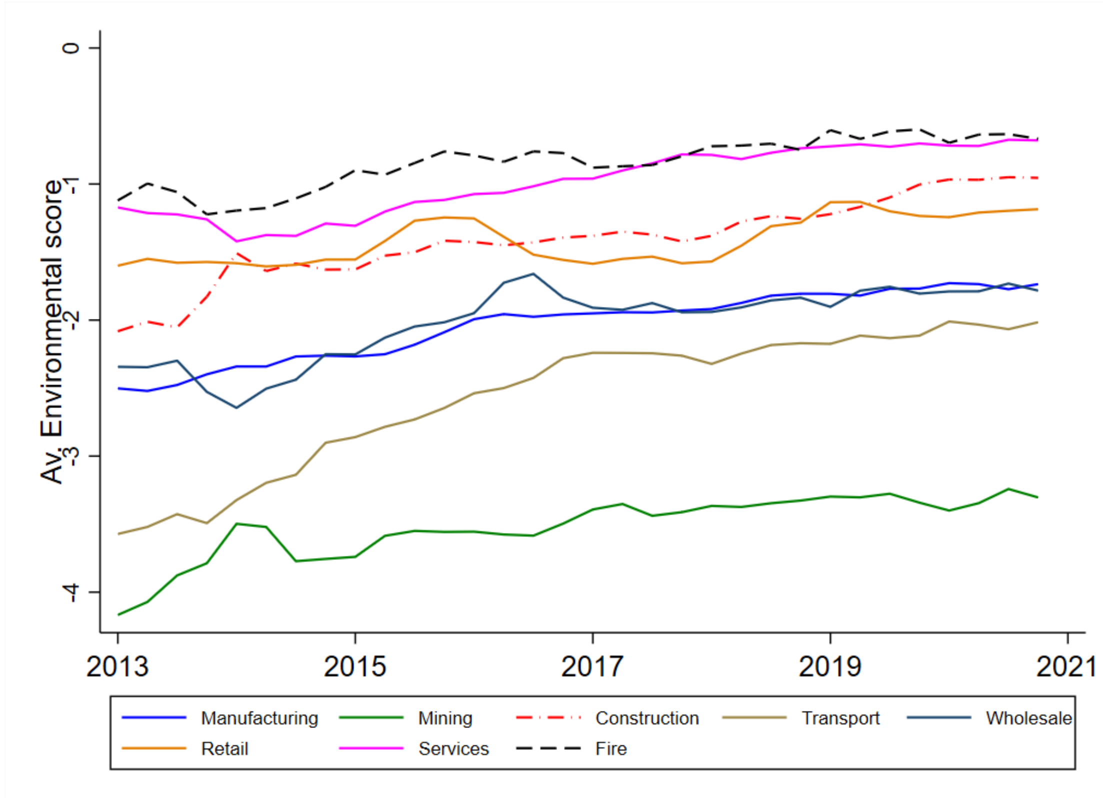
I compute stock-level environmental scores based on MSCI ESG IVA (Intangible Value Assessment) Ratings. The MSCI dataset stands out for both the breadth of its coverage and the depth of its analysis. MSCI ESG IVA rates and analyzes over 5,500 companies, thus covering more firms than any of its competitor ESG rating providers. To assess companies' exposure to and management of ESG risks and opportunities, MSCI collects data from multiple sources, which include macro data, company disclosures and government databases. It updates these ratings at least annually and provides a granular dissagregated score for each of the subcategories that make up the individual E, S, and G pillars. The availability of the dissagregated scores is exactly what I will explore to construct industry-unadjusted Environmental scores at the firm level as outlined by Pástor et al. (2022).

For this analysis, it is important to make use of industry-unadjusted environmental scores, because with industry adjustment, a heavy polluting (brown) firm may be classified as green simply because it pollutes less than its peers in the same industry. MSCI's granular data allows us to compute a measure of firm-level greenness score that characterises that firm irrespective of which industry the firm belongs to. Following Pástor et al. (2022), I start with MSCI variables 'Environmental Pillar Score' (E_score) and 'Environmental Pillar Weight' (E_{weight}). E_{score} is a number between 0 and 10, measuring a firm's weighted average score across 13 environmental issues related to climate change, natural resources, pollution and waste and environmental opportunities. The scores are designed to measure a firm's resilience to both physical and transitional long-term climate change risks. E_{weight}, which is typically constant across firms in the same industry is a number between 0 and 100 measuring the importance of environmental issues relative to social and governance issues. To convert the industry-adjusted scores to unadjusted scores, I transform the MSCI (adjusted) environmental scores according to the following equation:

$$G_{i,t} = -(10 - E_{score,i,t}) \times E_{weight,i,t})/100 \tag{1}$$

where $E_{score,i,t}$ and $E_{weight,i,t}$ are from company i's most recent MSCI ratings date. The quantity $10 - E_{score,i,t}$ measures how far the company is from a perfect environmental score of 10. The product $(10 - E_{score,i,t}) \times E_{weight,i,t}$ measures how brown the firm is, by interacting how poorly the firm scores on environmental issues with how large the environmental concerns are for the industry it is part of (i.e. $E_{weight,i,t}$). The minus sign at the beginning converts the brown score to a greenness score.

Figure 1. Upward trend in environmental performance across industries



Notes: Time evolution of the cross-sectional average firm environmental scores by industry, constructed using MSCI ESG IVA ratings, following the green score construction methodology proposed by Pástor et al. (2022).

My sample extends from January 2007 to December 2020, consistent with MSCI ESG data availability. Figure 1 details average firm unadjusted environmental scores over time on a per industry basis.[7] Two important stylized facts emerge. First, the lowest ranked industries appear to be mining and transport and the highest ranked industries include services, financial, insurance and real estate (Fire).[8] This pattern is quite reassuring, as it shows that the environmental ranking that emerges after the transformation laid out in equation (1), is in line with what are generally viewed as high (low) polluting industries. The second stylized fact that Figure 1 makes apparent is the upward trend in average firm level-greenness. This upward trend is common across all major industries, thus showing that the composition of firms in

[7]Figure 1 begins in November 2012 because MSCI's coverage increases substantially in October 2012, when MSCI began covering small U.S. stocks.

[8]Table 12 lists the top (bottom) five companies based on firm-level environmental scores for every industry.

the economy has changed in a way that is indicative of a larger proportion of green firms than a decade ago.

To be entirely consistent with Pástor et al. (2022), the environmental score I use in my analysis is:

$$\text{Env score}_{i,t} = G_{i,t} - \bar{G}_t \tag{2}$$

where $\bar{G}_t$ is the value-weighted average of $G_{i,t}$ across all firms i. Since I subtract $\bar{G}_t$, $\text{Env score}_{i,t}$ measures a company's cross-sectionally demeaned greenness score as in Pastor et al. (2021).[9] If w_t and Env score_t denote the vectors containing stocks' market weights and $\text{Env score}_{i,t}$ values in period t, then:

$$w_t' \, \text{Env score}_t = 0, \tag{3}$$

a condition imposed by Pastor et al. (2021)[10].

2.2 Monetary Policy Surprises

The literature on identification of monetary policy shocks typically uses high frequency identification techniques. Monetary policy surprises are measured as the difference in market participants' expectations of the federal funds rate around FOMC press releases, as pioneered by Kuttner (2001). The high frequency identification ensures that monetary policy surprises are orthogonal to the state of the economy and unrelated to contemporaneous macro-financial conditions. This is because changes in expectations about monetary policy in a narrow window around a press release should be mainly influenced by new information on monetary policy, that could not have been anticipated before the announcement.

However, while the Kuttner surprise is really effective at capturing the monetary policy stance in the pre-GFC crisis period, it not as relevant in the post-GFC period. This is because the post-GFC period is characterised by monetary policy surprises concerning the fu-

[9] Engle et al. (2020) argue that cross-sectionally demeaning the ESG scores minimises errors arising from discontinuous breaks in ESG scores due to ESG model changes.

[10] I have chosen to perform this additional transformation for an exact comparison to Pástor et al. (2022), but this has no effect on the final results as it gets absorbed by the time fixed effects.

ture course of policy rates, and not changes in the immediate policy (Gürkaynak et al., 2019). To capture the unconventional nature of the conduct of monetary policy in the post-GFC period, I use Bu et al. (2021) measures, henceforth BRW. BRW shocks utilise information on interest rates at different maturities and are constructed using a Fama and MacBeth (1973) two-step regression procedure to estimate the unobservable component of monetary policy.[11]

The application of this methodology gives rise to three appealing features that differentiate these shocks from other shocks in the literature. First, these shocks bridge periods of conventional and unconventional monetary policy-making, allowing for a good comparison with studies that focus on the pre-GFC period only. Second, they are largely unpredictable, which is key for ensuring exogeneity to macroeconomic outcomes. Third, they contain no central bank information effects. Romer and Romer (2000); Nakamura and Steinsson (2008); Miranda-Agrippino (2016); Jarociński and Karadi (2020) show that the existence of central bank information effects not only confounds identification, but also reveals a tendency for private sector expectations to go in the opposite direction of what economic models would predict. [12]

The monetary policy surprise series begins in January 2008, when the (one-year lagged) ESG data becomes available and ends in December 2020. During this time, there were 102 monetary policy surprises with a mean of approximately zero and standard deviation of approximately 5 basis points. Table 1 also details the number of instances when the BRW monetary policy surprises were contractionary vs. expansionary (i.e. positive vs negative). Their occurrence appears to be relatively symmetric with 43 contractionary episodes and 59 expansionary episodes.

[11]First step involves running time series regressions to estimate the sensitivity of interest rates at different maturities to FOMC announcements. In the second step, all outcome variables are regressed onto the estimated sensitivity index from step one, for each time period.

[12]The presence of central bank information effects may lead to instances where a contractionary monetary policy surprise drives asset prices up.

Table 1. Summary Statistics of Monetary Policy Surprises

	Mean	Median	Std. dev.	Min	Max	Observations
MP surprise	-0.005	-0.007	0.051	-0.189	0.186	102
Contractionary MP surprise	0.037	0.027	0.037	0.000	0.186	43
Expansionary MP surprise	-0.036	-0.029	0.034	-0.189	-0.001	59

Notes: Summary statistics of monetary policy surprises for the period 31/01/2008 to 31/12/2020. Monetary policy surprises are collected from Bu et al. (2021) and expressed in percentage points.

2.3 Investors' Preferences and Environmental Concerns

Following existing literature that examines the link between asset prices and investors' environmental preferences, I account for investors' propensity for sustainable investing by employing three measures of climate concerns.[13] Namely, (i) the National Risk Index from the Federal Emergency Management Agency in the US, (ii) the Media Climate Change Concern Index by Ardia et al. (2020) and (iii) the Yale Climate Change Opinion Survey.

The National Risk Index (NRI) is a composite measure of natural hazard risk at the county level in the US, which combines hazard exposure, frequency and historic loss data for 18 different natural hazards with social vulnerability and community resilience data to calculate a standardized risk value for every U.S. county.[14] The NRI is publicly available and its granularity is quite useful for our analysis as it helps identify those counties which are particularly vulnerable to natural disaster risk. I think of NRI as a proxy for exposure to physical risks that emerge due to climate change. This is because the most recent IPCC reports find strong evidence of a link between climate change, heat waves, wildfires, Atlantic hurricanes and extreme precipitation (IPCC, 2022).

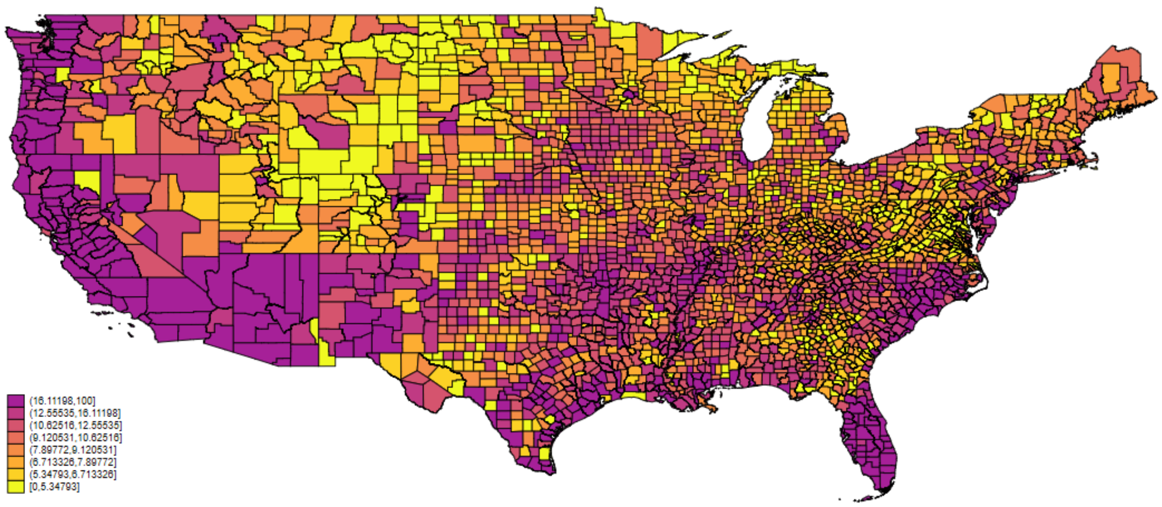
While I acknowledge that not all of the natural disasters encompassed by the National Risk Index are climate change–related disasters, I use this measure as a first-pass to control-

[13] A non-exhaustive list includes Pástor et al. (2022); Baldauf et al. (2020); Engle et al. (2020); Correa et al. (2020).

[14] The 18 natural hazards include Avalanche, Coastal Flooding, Cold Wave, Drought, Earthquake, Hail, Heat Wave, Hurricane, Ice Storm, Landslide, Lightning, Riverine Flooding, Strong Wind, Tornado, Tsunami, Volcanic Activity, Wildfire, and Winter Weather.

ling for county-level heterogeneities that might be related to climate change. Figure 2 shows considerable variation across counties in their exposure to natural disaster risk.

Figure 2. National Risk Index



Notes: Map of the National Risk Index by Zuzak et al. (2022) at the county level.

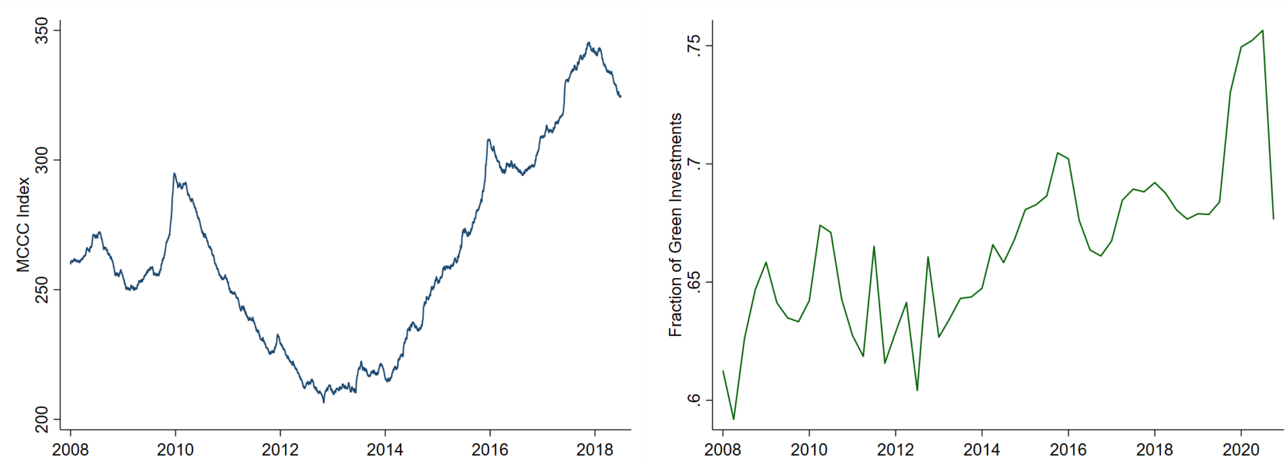
The Media Climate Change Concerns (MCCC) Index by Ardia et al. (2020) is a daily index of news about climate change published by major U.S. newspapers and newswires.[15] This index captures the number of climate news stories each day, associated with a negative sentiment (i.e, articles that focus on present and future risks from climate change). Drawing from previous work by Pástor et al. (2022), I measure the cumulative level of climate change concerns using a distributed lag model that assumes individuals' memory of climate news stories decays gradually over time. Let MCCC_t denote the daily MCCC index. I define the level of climate concerns at the end of day t as:

$$MCCC_t^{cumulative} = \sum_{\tau=0}^{T} \rho^{\tau} MCCC_{t-\tau} \tag{4}$$

[15]These include the Los Angeles Times, New York Times, Wall Street Journal,and USA Today, and two major newswires: Associated Press Newswires and Reuters News.

where ρ measures how long climate change news persists in investors' memories. I set the half-life of news stories to one year, which implies $\rho = 0.9981$. [16] T is set to 36 months (1095 days) following Pástor et al. (2022). Panel A of Figure 3 plots the time series of these concerns, which have increased significantly since 2013.

Figure 3. Media Climate Change Concern Index vis-à-vis the Green Portfolio Weight



(A) Climate Concerns

(B) Portfolio Green Weight

Notes: Panel A depicts the Cumulative Media Climate Change Concerns Index by Ardia et al. (2020), constructed using a distributed lag model as defined in equation (4). Panel B graphs the cross-sectional average of institutional investors' fraction of green security holdings over time, constructed using institutional ownership data from Thomson Reuters 13F database.

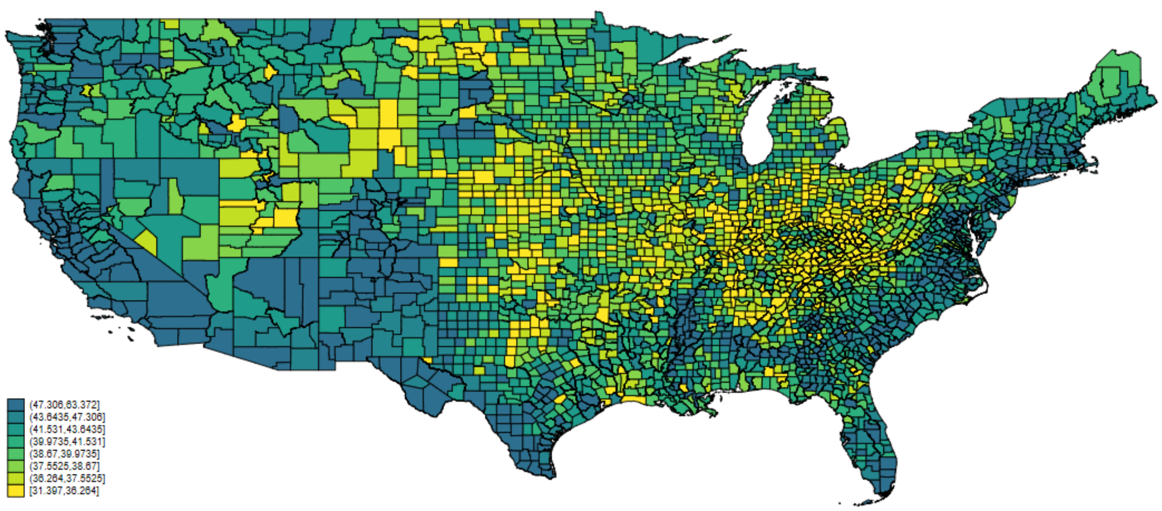
Additionally, to assess the degree to which investors' preferences play a role in the transmission of monetary policy, I use institutional ownership data from Thomson Reuters 13F database. I merge the 13F investors holding data with the security-level greenness scores I constructed in Section 2.1. I then split the sample of securities data into two groups, based on where each security lies in the greenness distribution. Specifically, I define a dummy variable: $g_{i,t}^{high}$, which equals 1 when the greenness score of firm i, lies above the median of the greenness score distribution (and zero otherwise). I then compute for every institutional investor j the weight of green securities held in their portfolio at each point in time. In other words, I look at the fraction of total investments by market value that is associated with green secu-

[16] I experiment with other half-life durations, such as 6 months, 3 months, 1 month and 15 days to ensure that my results are not driven by the choice of ρ.

rities. Panel B of Figure 3 presents the cross-sectional average of this fraction over time. It shows a clear upward trend in sustainable investing over the past decade, which is consistent with the intensified level of climate change concerns in Panel A.

The Yale Climate Change Opinion Survey (2021) is a public opinion survey that aims to estimate how climate change beliefs, risk perceptions, and policy support vary widely depending on where people live. One of the benefits of using this dataset is its geographic high resolution, which provides us with climate change beliefs data at the county level. I look at a variable called 'personal', which measures the degree to which the respondents of the Yale Climate Opinion Survey (YCOS) believe to be personally affected by climate change.[17] The map in Figure 4 shows considerable variation in beliefs about climate change across counties.

Figure 4. Climate Change Beliefs



Notes: Map of Climate Change Beliefs at county level provided by the Yale Climate Opinion Survey (2021), following Howe et al. (2015).

2.4 Firm-Level Data

To provide evidence on how FOMC announcements affect financial markets' assessments of individual firms' exposures to long-term risks associated with climate change, I construct a

[17]This represents the fraction of respondents in each county who answered 'Yes' to the following question. "Global warming will harm me personally. How much do you think global warming will harm you personally? (i) Not at all, (ii) Only a little, (iii) A moderate amount, (iv) A great deal, (v) Don't know".

panel data set. The cross-sectional dimension of the panel corresponds to a sample of Compustat US publicly listed firms. The time (event) dimension of the panel is represented by the FOMC announcement dates. Appendix A summarises variable definitions. The sample comprises of Compustat firms, whose environmental performance is covered by MSCI ESG IVA Ratings and spans the time period from 1 January 2007 to 31 December 2019. This gives a total of 1361 firms. The stock return data is obtained from the Center for Research in Security Prices (CRSP) database. I define the stock return around an FOMC announcement as the percentage change of the closing quotes of stock prices between the day before and the day after an FOMC announcement.

In addition to stock returns, I also collect data on CDS spreads at the firm level. This data comes from IHS Markit and covers 313 firms during the period of 2008 - 2020. The main variables of interest are conventional CDS spreads and the implied probability of default (for the underlying bond). The conventional CDS spread (or CDS premium) is the market price of credit risk, as it denotes the amount paid by the Protection Buyer to the Protection Seller to insure against the risk of default by a reference entity.

The standard balance sheet items, explained in detail in Table A.1, come from the Compustat database. In line with previous research on monetary policy transmission and firm heterogeneity, I control for differences in financial constraints across firms (Ottonello and Winberry, 2020; Cloyne et al., 2018; Anderson and Cesa-Bianchi, 2020; Chava and Hsu, 2020). Hence I compute size, book leverage, distance to default and age, which proxy for financial constraints. Size is constructed as the logarithm of total assets and deflated by the implicit price deflator. Book leverage is computed as the ratio of total debts to total assets. Distance to default follows Gilchrist and Zakrajšek (2012). Age represents the period since incorporation of a firm into the CRSP database. Consistent with research on firm balance sheet heterogeneity and monetary policy shocks, I also account for differences in firm profitability, cash holdings (liquidity), market-to-book ratio (growth vs. value stocks), asset maturity. retained earnings, short term and long term debt and dividends per share (Cloyne et al., 2018; Gürkaynak et al., 2019; Ippolito et al., 2018; Lakdawala and Moreland, 2021).

Additionally, following research that suggest that socially responsible firms commit to a higher standard of transparency and provide more financial disclosure, I proceed by computing a measure of financial transparency (Kim et al., 2014). In order to obtain a measure of financial transparency, I leverage information on firm earnings' announcements from the Institutional Brokers' Estimate System (I/B/E/S). This dataset collects quarterly forecasts made by financial analysts on future earnings for publicly traded companies. Following Casella et al. (2022), under the assumption that more transparent firms have less disagreements among financial analysts, I define firm financial transparency as:

$$\text{transparency}_{i,t} \equiv \frac{1}{std.\,dev.(EPS_{i,t})} \tag{5}$$

where $std.\,dev.(EPS_{i,t})$ is the standard deviation of analysts' forecasts on firm i's earnings per share in the last 30 calendar days before the earnings announcement.

3 Monetary Policy and Green Firms

In this section, I test the joint hypothesis that monetary policy affects green firms differently from their brown counterparts and that this heterogeneity is reflected in asset prices at high frequency windows. First, I estimate the heterogenous impact on stock prices using event-study panel regressions. Second I investigate whether a similar finding is supported using firm-level CDS spreads and investment data. Third, I report a battery of robustness test, where I make use of an alternative measure of firm level greenness and/or alternative measures of monetary policy shocks.

3.1 Empirical Design

I proceed by employing panel event-study regressions based on high-frequency data. The high-frequency approach is particularly useful for my analysis for two reasons. First, it is free of aggregation bias.[18] Second, unlike at lower frequencies where FOMC decisions may be influenced by stock market movements, no such endogeneity concerns exist with daily data (Rigobon and Sack, 2004; D'Amico and Farka, 2011). The model I estimate is:

$$\Delta p_{i,t} = \alpha_i + \alpha_{st} + \beta(\varepsilon_t^m \times g_{i,t-1}) + \delta g_{i,t-1} + \Gamma' Z_{i,t-1} + e_{i,t} \quad (6)$$

where i indexes firm, s indexes major economic sectors and t indexes the FOMC announcements. $\Delta p_{i,t}$ denotes the percentage change in the stock price of firm i at time t (log difference of the closing quotes of stock prices the day before and the day after an FOMC announcement), ε_t^m is the BRW monetary policy shock, $g_{i,t-1}$ is a firm i's environmental score computed as described in Section 2.1. Drawing from previous work by Gürkaynak et al. (2019) and Ottonello and Winberry (2020), $Z_{i,t-1}$ is a vector of controls that include size, profitability, book leverage, market-to-book ratio, cash holdings, short term liabilities, retaining earnings, dividend per share and distance to default.

All variables in the regression other than the monetary policy shock and the stock price change are lagged by one quarter to ensure that the relevant variables are in the market participants' information set. The environmental score is lagged by one year, since the the MSCI ESG IVA Ratings are usually updated at an annual frequency. Equation (6) includes both firm level fixed effects and industry-by-time fixed effects. The firm level fixed effects, α_i control for any firm-specific time invariant unobservables, whereas the sector-by-time fixed effects, α_i will capture differences in how economic sectors respond to aggregate shocks. The main coefficient of interest is β, which measures how the sensitivity of stock returns with respect to monetary shocks depends on firms' environmental performance. Throughout, I cluster standard errors at the FOMC event level to account for correlation across FOMC events.

[18] Lower-frequency analysis, which usually is conducted at a quarterly or annual frequency, requires aggregating interest rate surprises over the relevant quarter. Ramey (2016) argues that such aggregation might induce serial correlation in the series of the aggregated surprises. Additionally, Gazzani et al. (2019) and Chudik and Georgiadis (2022) show that such aggregation results in inconsistent estimates of aggregated impulse responses.

3.2 Results

Table 2 presents the baseline findings of this paper. The first column shows that a contractionary monetary policy shock of 100 basis points reduces stock prices by 16%. Column (2) shows that stock prices of firms with better environmental performance are less affected. Adding sector-by-time fixed effects in column (3) further demonstrates that this result is not driven by differences in how economic sectors respond to aggregate shocks. Overall, I find strong and robust evidence that an increase in environmental performance dampens the effect that monetary policy has on stock prices.

Table 2. Baseline Results

	(1)	(2)	(3)	(4)
	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$
MP shock (ε_t^m)	-16.04***	-14.66***		
	(3.950)	(3.878)		
MP shock × Env. score ($\varepsilon_t^m \times g_{i,t-1}$)		2.411***	2.587***	2.209***
		(0.604)	(0.550)	(0.506)
Env. score ($g_{i,t-1}$)		0.0217	0.0199	0.0471
		(0.0506)	(0.0380)	(0.0320)
Firm FE	Yes	Yes	Yes	Yes
Time FE	No	No	Yes	Yes
Industry_time FE	No	No	No	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.0775	0.0790	0.314	0.359
Observations	38037	38037	38037	37928

Notes: The dependent variable is the two-day stock return bracketing an FOMC announcement (in percent). The sample covers 102 FOMC announcements between 31 January 2008 and 31 December 2019. Env. score is the unadjusted firm-level environmental score as described in Section 2.1. Control variables are size, profitability, book leverage, market-to-book ratio, short term liabilities, retaining earnings, dividend per share and distance to default. ε_t^m is the BRW monetary policy shock (in percent). The regression coefficients of controls variables are not shown here for brevity. The numbers in parenthesis are standard errors, which are clustered at the event-level. The asterisks denote statistical significance (*** for p < 0.01, ** for p < 0.05, * for p < 0.1).

One concern is that the results in Table 2 may be driven by the speed with which information is incorporated by financial market participants, which may vary across large versus small firms. For example Peng (2005) argues that there is a faster rate of information incorporation for large firms compared to small firms. To the extent that green firms tend to be younger and smaller in size than their brown counterparts, this would imply that monetary policy shocks may affect green firms at a slower speed than their brown counterparts.[19] To assess whether the differential response of green firms to monetary policy shocks is not just a result of investor inattention, but persists at longer horizons, I consider a specification with cumulative stock price changes up to 10 days after an FOMC announcement. Columns (1) - (11) of Table 3 show that the differential response of green firms compared to their brown counterparts is not just a transitionary adjustment in prices, but this effect is rather persistent and statistically significant for up to 15 days after the FOMC announcement.

Table 4 presents the regression results without imposing linearity in the interaction of monetary policy and firms' environmental performance. Here I estimate equation (6) for different 'bins' of the distribution of firms based on firm level greenness, which allows for estimation of separate slopes for each group. Cloyne et al. (2018) argues that this is a non-parametric way of estimating the heterogeneous effects of monetary policy by different firm characteristics. I split the distribution of firms in the dataset into five groups, based on the five quintiles of firm-level greenness. While there is no conceptual reason to prefer one specific greenness cutoff over another, the results are not sensitive to the precise cutoff. The stock price responses by firm-level greenness are reported in Table 4. Quintile 1 refers to firms whose environemntal score falls in the bottom quintile (i.e. brown firms), whereas Quintile 5 refers to firms whose environmental score falls in the upper quintile (i.e. green firms). The results reported in Table 4 make it clear that stock prices of green firms are considerably less responsive to monetary policy surprises: following a 1 percentage point surprise in monetary policy, stock prices of quintile 5 (green) firms fall by around 10%, whereas the stock prices of their quintile 1 (brown) counterparts fall by around 21%.

[19] Table 11 provides summary statistics on the differences in financial characteristics between green and brown firms.

Table 3. Cumulative Returns

	(1) $\Delta_0 p_{i,t}$	(2) $\Delta_1 p_{i,t}$	(3) $\Delta_2 p_{i,t}$	(4) $\Delta_3 p_{i,t}$	(5) $\Delta_4 p_{i,t}$	(6) $\Delta_5 p_{i,t}$	(7) $\Delta_6 p_{i,t}$	(8) $\Delta_7 p_{i,t}$	(9) $\Delta_8 p_{i,t}$	(10) $\Delta_9 p_{i,t}$	(11) $\Delta_{10} p_{i,t}$
MP shock × Env. score ($\varepsilon_t^m \times g_{i,t-1}$)	1.706***	2.213***	1.391***	0.943	0.962	1.410**	1.781***	1.916**	2.336***	2.265***	1.938**
	(0.432)	(0.507)	(0.506)	(0.652)	(0.601)	(0.636)	(0.639)	(0.852)	(0.761)	(0.810)	(0.806)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry_time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.344	0.358	0.344	0.362	0.323	0.308	0.310	0.314	0.310	0.288	0.307
Observations	37902	37863	37860	37451	37649	37847	37840	36289	37829	37821	37819

Notes: The dependent variable is the two-day stock return bracketing an FOMC announcement (in percent). The sample covers 102 FOMC announcements between 31 January 2008 and 31 December 2020. Env. score is the unadjusted firm-level environmental score as described in Section 2.1. Control variables are size, profitability, book leverage, market-to-book ratio, short term liabilities, retaining earnings, dividend per share and distance to default. ε_t^m is the BRW monetary policy shock (in percent). The regression coefficients of controls variables are not shown here for brevity. The numbers in parenthesis are standard errors, which are clustered at the event-level. The asterisks denote statistical significance (*** for $p < 0.01$, ** for $p < 0.05$, * for $p < 0.1$).

Table 4. Quintiles: Firm level

Dep. variable: $\Delta p_{i,t}$	(1) Quintile 1	(2) Quintile 2	(3) Quintile 3	(4) Quintile 4	(5) Quintile 5
MP shock (ε_t^m)	-20.95***	-20.32***	-15.42***	-13.54***	-9.626***
	(3.986)	(4.585)	(4.221)	(3.889)	(3.293)
Firm FE	Yes	Yes	Yes	Yes	Yes
Industry_time FE	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes
R-squared	0.0940	0.117	0.117	0.116	0.0740
Observations	9388	8014	6984	7117	6420

Notes: The dependent variable is the two-day stock return bracketing an FOMC announcement (in percent). The sample covers 102 FOMC announcements between 31 January 2008 and 31 December 2020. Env. score is the unadjusted firm-level environmental score as described in Section 2.1. Control variables are size, profitability, book leverage, market-to-book ratio, short term liabilities, retaining earnings, dividend per share and distance to default. ε_t^m is the BRW monetary policy shock (in percent). The regression coefficients of controls variables are not shown here for brevity. The numbers in parenthesis are standard errors, which are clustered at the event-level. The asterisks denote statistical significance (*** for p < 0.01, ** for p < 0.05, * for p < 0.1).

Table 5. Portfolio Event Study - Equally-weighted

Dep. variable: Δp_t	(1) Quintile 1	(2) Quintile 2	(3) Quintile 3	(4) Quintile 4	(5) Quintile 5	(6) Green-minus-Brown
MP shock (ε_t^m)	-15.87***	-14.61***	-11.02***	-8.725**	-5.965*	9.906***
	(3.466)	(3.751)	(3.592)	(3.450)	(3.155)	(1.977)
mktrf	0.612***	0.786***	0.868***	0.863***	0.818***	0.206*
	(0.193)	(0.184)	(0.198)	(0.210)	(0.181)	(0.112)
smb	0.930**	0.887*	0.755*	0.638	0.462	-0.469**
	(0.454)	(0.455)	(0.408)	(0.414)	(0.337)	(0.181)
hml	0.307	0.193	0.0827	0.128	-0.0494	-0.356***
	(0.484)	(0.494)	(0.462)	(0.481)	(0.427)	(0.131)
rmw	0.426	0.602	0.782	0.723	0.611	0.184
	(0.554)	(0.554)	(0.564)	(0.584)	(0.489)	(0.262)
cma	0.976	1.088	0.962	0.666	0.286	-0.689*
	(0.685)	(0.767)	(0.710)	(0.702)	(0.628)	(0.357)
R-squared	0.492	0.485	0.473	0.438	0.403	0.426
Observations	102	102	102	102	102	102

Notes: The dependent variable is the two-day stock return bracketing an FOMC announcement (in percent). The sample covers 102 FOMC announcements between 31 January 2008 and 31 December 2020. Columns (1) to (5) split the distribution of firms in the dataset into 5 groups, based on the 5 quintiles of firm-level environmental performance. Column (6) constructs a portfolio that goes long in quintile 5 firms and short in quintile 1 firms. Control variables are the Fama-French factors mktrf, smb, hml, rmw and cma. ε_t^m is the BRW monetary policy shock (in percent). The numbers in parenthesis are standard errors, which are clustered at the event-level. The asterisks denote statistical significance (*** for p < 0.01, ** for p < 0.05, * for p < 0.1).

Next, to ensure that the panel-level results are not driven by any firm-specific outliers, I proceed by taking a cross-sectional average of returns for each FOMC announcement at the quintile level of the environmental score distribution. This is equivalent to constructing 5 different equally-weighted portfolios that consist of, in order from Columns (1) to (5), Quintile 1, 2, 3, 4 and 5 firms. I then run a simple time series OLS regression to examine the impact of FOMC surprises on portfolio returns. Results in Table 5 are based on the Fama-French 5 Factor model, where returns of each portfolio are regressed onto the unanticipated BRW monetary policy shocks and the Fama-French 5 factors. Next, I construct a portfolio that goes long in Quintile 5 (green) firms and short in Quintile 1 (brown) firms (i.e. Green-minus-Brown). Consistent with the differential response in stock prices from the baseline regressions, the Green-minus-Brown portfolio delivers high returns during periods of contractionary monetary policy innovations.[20]

3.3 Robustness of the Baseline Results

Alternative interest rate surprises. The first set of additional results contains a number of robustness checks of the baseline result reported in Table 2. Table 6 shows that the heterogeneity identified in the baseline results is robust to using alternative interest rate surprises. Columns (2) to (6) of Table 6 report the coefficient estimates from specification (6), with alternative monetary policy shocks following Kuttner (2001), Gürkaynak et al. (2005), Jarociński and Karadi (2020), Swanson (2021) and Rogers et al. (2018), respectively. In Column (7) I report the result from an instrumental variable (IV) approach, where I use the BRW monetary policy surprise as an instrument for the change in the 2-year US Treasury yield around FOMC announcements. The results are largely unchanged.

[20]Results are quantitatively and qualitatively unchanged when considering a value-weighted Green-minus-Brown portfolio.

Table 6. Robustness: Alternative monetary policy shock measures

Dep. variable: $\Delta p_{i,t}$	(1) Baseline	(2) Kuttner	(3) GSS	(4) JK	(5) Swanson	(6) RSW	(7) IV
MP shock × Env. score ($\varepsilon_t^m \times g_{i,t-1}$)	2.209***	3.272**	0.824***	2.565*	0.867**	2.395***	2.776***
	(0.506)	(1.317)	(0.278)	(1.392)	(0.352)	(0.898)	(0.756)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry_time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.359	0.358	0.329	0.358	0.325	0.349	0.000239
Observations	37928	37928	30761	37928	32758	26536	37928

Notes: The dependent variable is the two-day stock return bracketing an FOMC announcement (in percent). The sample covers 102 FOMC announcements between 31 January 2008 and 31 December 2020. Env. score is the unadjusted firm-level environmental score as described in Section 2.1. Control variables are size, profitability, book leverage, market-to-book ratio, short term liabilities, retaining earnings, dividend per share and distance to default. ε_t^m is the BRW monetary policy shock (in percent). The regression coefficients of controls variables are not shown here for brevity. The numbers in parenthesis are standard errors, which are clustered at the FOMC event-level. The asterisks denote statistical significance (*** for p < 0.01, ** for p < 0.05, * for p < 0.1).

Alternative metrics of firm-level environmental performance. The second set of results contains robustness checks regarding the firm-level greenness measure by investigating other metrics of environmental performance. Table 7 reports the results obtained from running specification (6) with alternative proxies for firm-level greenness. The result in column (2) suggests that monetary policy heterogeneity conditional on firm-level greenness is not specific to the Pástor et al. (2022) methodology, but is also observed when one uses the raw environmental scores from MSCI IVA Metrics. The raw firm-level environmental score adjusts for environmental considerations at the sector level and assigns firms an environmental score relative to their sectoral peers (i.e. A high E (raw) score describes a firm whose environmental performance is high within a particular sector, but not necessarily in the cross-section). In column (3) I look at a subcategory of the aggregate MSCI score, which is particularly relevant for climate change. Specifically, column (3) reports the results from measuring firm-level greenness based on a firm's emissions score, where a higher score indicates lower levels of GHG emissions.[21] The

[21] Here I have applied the same greenness score construction methodology that was proposed by Pástor et al. (2022) and is detailed in Section 2.1. The aim of this transformation is to assign firms a score that reflects their 'true' greenness regardless of which sector they operate in.

interaction coefficient (measuring the relative responsiveness of low polluting firms relative to high polluting firms) is still positive and significant.

Columns (3) to (6) use firm-level environmental performance scores from a different ESG database provider called Sustainalytics. This database has been used in previous research and comes with the advantage that the environmental scores are updated at a monthly frequency, thus potentially providing more variation in firm-level greenness (Engle et al., 2020). To determine a firm's environmental performance, Sustainalytics evaluates firms on a number of indicators, including efforts to reduce greenhouse gas emissions, increase renewable energy use, and reduce water use. Columns (4) to (6) in Table 7 report that the heterogeneous sensitivity to monetary policy shocks is also observed when using Sustainalytics based scores of environmental performance instead of MSCI. Additionally, Table A.2 in the Appendix shows that the heterogeneous impact of monetary policy on firm-level returns is only the case for firms with high environmental scores, but does not arise in the case of firms with higher social responsibility or corporate governance scores. These results lend additional support to the idea that firm-level environmental performance plays a significant role in the transmission of monetary policy.

Table 7. Robustness: Alternative metrics of environmental performance

Dep. variable: $\Delta p_{i,t}$	(1) MSCI Baseline	(2) MSCI Raw Score	(3) MSCI Emissions	(4) SUS Env. Policy	(5) SUS Env. Mgmt.	(6) SUS Renew. Energy
MP shock × Env. score ($\varepsilon_t^m \times g_{i,t-1}$)	2.209***	1.157***	0.830**	0.0261*	0.0318**	0.0583**
	(0.506)	(0.323)	(0.329)	(0.0140)	(0.0155)	(0.0268)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry_time FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.359	0.358	0.373	0.362	0.362	0.381
Observations	37928	37928	33508	32630	32630	19412

Notes: The dependent variable is the two-day stock return bracketing an FOMC announcement (in percent). The sample covers 102 FOMC announcements between 31 January 2008 and 31 December 2020. Env. score is the unadjusted firm-level environmental score as described in Section 2.1. Control variables are size, profitability, book leverage, market-to-book ratio, short term liabilities, retaining earnings, dividend per share and distance to default. ε_t^m is the BRW monetary policy shock (in percent). The regression coefficients of controls variables are not shown here for brevity. The numbers in parenthesis are standard errors, which are clustered at the event-level. The asterisks denote statistical significance (*** for p < 0.01, ** for p < 0.05, * for p < 0.1).

Additional analysis of the data. The third set of results includes some additional analysis of the data. First, Columns (2) and (3) in Table 8 show that the heterogeneous response of green vs. brown firms to monetary policy shocks is relatively symmetric across episodes of expansionary and contractionary monetary policy shocks.[22] In other words, while contractionary monetary policy depresses average asset prices, this reaction tends to be less pronounced for greener firms as shown in column (2). While expansionary monetary policy increases average asset prices, this positive reaction is slightly dampened in the case of greener firms as shown in column (3). Column (4) shows that the results are robust to only considering the post GFC period, which alleviates concerns that the results are driven by a handful of influential events, such as the unscheduled FOMC meetings during the GFC. Columns (5) and (6) split the sample between ZLB announcements and post ZLB announcements. The ZLB is the period starting on 16 December 2008, when FOMC lowered the federal funds rate to zero and ending in 16 December 2015, when FOMC raised the federal funds rate for the first time since the GFC.

Results in Columns (5) and (6) indicate that the dampened sensitivity of green asset prices with respect to monetary policy shocks remains intact both in the ZLB and post ZLB period. Interestingly, column (6) reports a higher coefficient on the interaction between the MP shock and firm-level greenness in the post ZLB period. This could be because conventional monetary policy was constrained in the ZLB period, which may have led to less powerful responses in asset prices.[23]

Second, Table 9 performs a falsification test in line with Gürkaynak et al. (2019), which looks at the two-day asset price changes up to 10 days before the FOMC announcements and finds no relationship between monetary policy shocks and firm-level greenness. Thus, it is not the case that green firms always behave differently from their brown counterparts for some

[22] Removing the industry-by-time fixed effects reveals that in response to a contractionary monetary policy shock of 100 bp average asset prices fall by 19%, whereas in response to an expansionary monetary policy shock of 100 bp the average stock prices increase by 16%.

[23] Removing the industry-by-time fixed effects in order to estimate the average monetary policy effect on asset prices, reveals that a contractionary surprise of 100 basis points led to a 13% reduction in average asset prices in the ZLB period, compared to 21% reduction in post-ZLB period. These average results are significant at the 5% and 1% significance level, respectively.

reason unrelated to monetary policy. Rather, it is the unexpected change in monetary policy that generates the heterogenous response.

Table 8. Robustness: Additional analysis of the data

Dep. variable: $\Delta p_{i,t}$	(1) Baseline	(2) Contractionary	(3) Expansionary	(4) Post GFC	(5) ZLB	(6) Post ZLB
MP shock × Env. score ($\varepsilon_t^m \times g_{i,t-1}$)	2.209***	2.520**	- 2.702**	1.933***	1.334***	3.228***
	(0.506)	(0.971)	(1.245)	(0.540)	(0.490)	(1.008)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry_time FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.359	0.434	0.304	0.356	0.408	0.351
Observations	37928	17526	20231	35964	16513	19684

Notes: The dependent variable is the two-day stock return bracketing an FOMC announcement (in percent). The sample covers 102 FOMC announcements between 31 January 2008 and 31 December 2020. Env. score is the unadjusted firm-level environmental score as described in Section 2.1. Control variables are size, profitability, book leverage, market-to-book ratio, short term liabilities, retaining earnings, dividend per share and distance to default. ε_t^m is the BRW monetary policy shock (in percent). The regression coefficients of controls variables are not shown here for brevity. The numbers in parenthesis are standard errors, which are clustered at the event-level. The asterisks denote statistical significance (*** for p < 0.01, ** for p < 0.05, * for p < 0.1).

Table 9. Robustness: Falsification Test

Dep. variable: $\Delta p_{i,\tau}$	(1) $\tau-1$	(2) $\tau-2$	(3) $\tau-3$	(4) $\tau-4$	(5) $\tau-5$	(6) $\tau-6$	(7) $\tau-7$	(8) $\tau-8$	(9) $\tau-9$	(10) $\tau-10$
MP shock × Env. score ($\varepsilon_t^m \times g_{i,t-1}$)	0.602	0.394	-0.402	-0.983**	-0.199	0.461	0.371	0.110	-0.473	-0.802
	(0.397)	(0.450)	(0.486)	(0.447)	(0.454)	(0.421)	(0.453)	(0.434)	(0.585)	(0.598)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry_time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.299	0.351	0.288	0.246	0.337	0.319	0.269	0.333	0.325	0.343
Observations	37736	37923	37724	37914	37909	37389	37901	36927	37900	35944

Notes: The dependent variable is the two-day stock return bracketing an FOMC announcement (in percent). The sample covers 102 FOMC announcements between 31 January 2008 and 31 December 2020. Env. score is the unadjusted firm-level environmental score as described in Section 2.1. Control variables are size, profitability, book leverage, market-to-book ratio, short term liabilities, retaining earnings, dividend per share and distance to default. ε_t^m is the BRW monetary policy shock (in percent). The regression coefficients of controls variables are not shown here for brevity. The numbers in parenthesis are standard errors, which are clustered at the event-level. The asterisks denote statistical significance (*** for p < 0.01, ** for p < 0.05, * for p < 0.1).

3.4 Evidence from credit default swap spreads

In this subsection, I document that the heterogeneous impact of monetary policy on green vs. brown firms goes beyond equity markets, and also affects firms' external financing costs. Combining a dataset on CDS spreads from IHS Markit with firm-level balance sheet information, I show that monetary policy has heterogeneous effects on firms' external funding costs conditional on firm-level greenness. I consider the following event study specification:

$$\Delta CDS_{i,t} = \alpha_i + \beta_1(g^{high}_{i,t-1} \times \epsilon^m_t) + \beta_2(g^{low}_{i,t-1} \times \epsilon^m_t) + \delta_1 g^{high}_{i,t-1} + \delta_2 g^{low}_{i,t-1} + \Phi' Z_{i,t-1} + e_{i,t} \quad (7)$$

where $\Delta CDS_{i,t}$ denotes the change in the CDS spread of firm i at time t (difference of the CDS spread the day before and the day after an FOMC announcement, in basis points), ϵ^m_t is a monetary policy shock. $g^{high}_{i,t-1}$ and $g^{low}_{i,t-1}$ are two dummy variables. Specifically, $g^{high}_{i,t-1}$ equals 1 when the environmental score of firm i lies above the median of the greenness distribution in the year proceeding the monetary policy surprise (and zero otherwise), and $g^{low}_{i,t-1}$ equals 1 when the environmental score of firm i lies below the median of the greenness distribution (and zero otherwise). $Z_{i,t-1}$ is a vector of controls that include size, profitability, book leverage, market-to-book ratio, cash holdings, short term liabilities, retaining earnings, dividend per share and distance to default. Coefficients β_1 and β_2 capture the impact of monetary policy on CDS spreads for green and brown firms respectively. The results are reported in column (2) of Table 10. They show that CDS spreads rise in response to contractionary monetary policy shocks. This is because an interest rate rise reduces a firm's net present value, which increases its likelihood of default. However, the response of CDS spreads for green firms is smaller compared to the response in CDS spreads for their brown counterparts. In particular, a monetary policy surprise of 100 basis points increases CDS spreads by around 15 basis points in the case of green firms and 29 basis points in the case of brown firms. Analogously, column (4) shows that in the aftermath of a monetary policy surprise of 100 basis points the implied probability of default for green firms increases to a lesser extent than for brown firms.

Table 10. Event Study - Credit Default Swap Spreads

	(1) ΔCDS	(2) ΔCDS	(3) $\Delta prob^{default}$	(4) $\Delta prob^{default}$
MP shock (ε_t^m)	22.25**		1.683**	
	(10.14)		(0.751)	
MP shock × Green ($\varepsilon_t^m \times g_{i,t-1}^{high}$)		15.01		1.297*
		(9.843)		(0.778)
MP shock × Brown ($\varepsilon_t^m \times g_{i,t-1}^{low}$)		29.10***		2.067***
		(11.05)		(0.763)
Firm FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.0425	0.0434	0.0496	0.0503
Observations	15026	15026	14106	14106

Notes: The dependent variable in columns (1) and (2) is the two-day change in CDS spreads bracketing an FOMC announcement (in basis points). The dependent variable in columns (2) and (3) is the two-day change in the implied probability of default over the next 5 years (in percentage points). The sample covers 102 FOMC announcements between 31 January 2008 and 31 December 2020. Env. score is the unadjusted firm-level environmental score as described in Section 2.1. ε_t^m is the BRW monetary policy shock (in percent). Control variables are size, profitability, book leverage, market-to-book ratio, short term liabilities, retaining earnings, dividend per share and distance to default. The regression coefficients of controls variables are not shown here for brevity. The numbers in parenthesis are standard errors, which are clustered at the event-level. The asterisks denote statistical significance (*** for p < 0.01, ** for p < 0.05, * for p < 0.1).

3.5 Real Effects of Monetary Policy

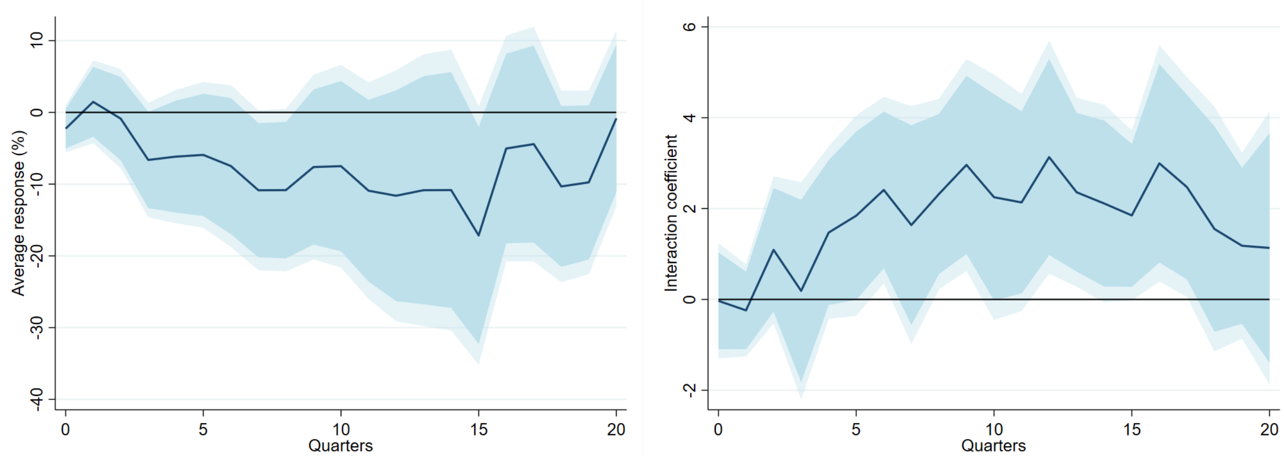
So far, I have only focused on the short-term reaction of stock market outcomes to monetary policy surprises. This is because the high frequency approach allows for a more credible identification of the impact of monetary policy on firm-level outcomes, as well as a more precise estimation of its effects (Anderson and Cesa-Bianchi, 2020). However, the impact of monetary policy on equity prices and CDS spreads documented so far could be reflecting a temporary adjustment in asset prices. It is also possible that the identified monetary policy surprises are temporary disruptions to market interest rates that do not have long-lasting effects on a company's performance. In light of these concerns, I extend the daily event-study panel regressions of Section 3.1 to a quarterly frequency.

I proceed by collecting quarterly data on firm-level investment from Compustat and aggregating the monetary policy surprises to a quarterly frequency. With this dataset, I use panel local projection methods a la Jordà (2005), to examine whether the investment response to monetary policy depends on firm-level greenness. Specifically, I estimate the following specification:

$$\Delta_h logk_{i,t} = \alpha_i^h + \alpha_{s,t}^h + \beta^h(\varepsilon_t^m \times g_{i,t-1}) + \delta^h g_{i,t-1} + \Gamma'^h Z_{i,t-1} + e_{i,t,h} \tag{8}$$

where $\Delta_h log(k_{i,t}) \equiv log(k_{i,t+h}) - log(k_{i,t-1})$ denotes the response variable of interest (i.e. the cumulative change in capital stock between quarter t-1 and quarter t+h over varying prediction horizons h = 0,2...10), α_j^h are firm FE, $\alpha_{s,t}^h$ are sector-by-time FE, ε_t^m and denotes the Bu et al. (2021) monetary policy surprise aggregated to a quarterly level. $Z_{j,t-1}$ is a vector of (lagged) firm-level controls (size, real sales growth, leverage and distance to default) and g_{jt-1} is firm i's greenness score, computed from MSCI ESG IVA ratings.

Figure 5. Impulse Response Function of Investment



(A) Average Effect

(B) Interaction Effect

Notes: In line with local projection methods, each horizon is estimated separately. The dependent variable is $\Delta logk_{i,t+h}$, over the horizons considered. The independent variable in Panel (A) is ε_t^m. The independent variable in Panel (B) is $\varepsilon_t^m \times g_{i,t-1}$. The light blue shaded areas denote the 95% and 90% confidence intervals around point estimates constructed with standard errors clustered at the time level.

Panel (B) in Figure 5 graphs the marginal impulse response for investment when increasing firm-level greenness by one unit, as captured by the coefficient β^h. Environmentally responsible firms react less strongly to a tightening in monetary policy: increasing firm-level greenness by one unit dampens the response in investment by around 3 percentage points, with a peak effect reached approximately 3 years after the monetary policy shock. Panel (A) estimates a dynamic version of the specification in (8) without the sector-time fixed effects and shows that the average firm reduces investment by around 10% in response to a contractionary monetary policy surprise of 1 percentage point. To summarise, the results in this Section show that the heterogeneous responses uncovered with the high frequency event study regressions also hold at business cycle frequency, with brown firms responding more strongly to monetary policy shocks compared to green firms.

4 Characteristics of Green and Brown Firms

In this section, I test the hypothesis that monetary policy affects green firms differently from their brown counterparts because of intrinsic differences in firm-level financial characteristics. Table 11 provides the summary statistics for different financial variables conditional on firm level greenness. Green (brown) firms are thought to be those whose environmental score falls in the top (bottom) quintile of the firm level greenness distribution. Table 11 shows that green firms are on average smaller, younger, less leveraged, more liquid and less riskier than their brown counterparts. Existing literature looks at how these firm characteristics may amplify or dampen the investment channel of monetary policy.

For instance, Cloyne et al. (2018) provides evidence that young firms paying no dividends exhibit the largest and most significant change in capital expenditure following a monetary policy shock. This is driven by the fact that these firms' external finance is mostly exposed to the asset value fluctuations induced by monetary policy shocks. Jeenas (2019), on the other hand, assesses the role of firms' liquidity management in the transmission of monetary policy.

Table 11. Summary Statistics

	Green Firms (Quintile 5)				
	Mean	Median	Std. dev.	P25	P75
Env. performance	-0.291	-0.190	0.269	-0.420	-0.140
Size	8.074	7.962	1.758	6.840	9.222
Leverage	0.454	0.402	1.220	0.236	0.608
Short term financing	0.029	0.011	0.074	0.002	0.033
Long term debt share	0.871	0.953	0.208	0.852	0.990
Profitability	0.028	0.030	0.041	0.019	0.042
Retained earnings to assets	-0.028	0.158	1.191	-0.114	0.390
Divs. per share	0.134	0.000	0.322	0.000	0.185
Cash to assets	0.171	0.100	0.184	0.038	0.235
Market to book ratio	2.175	1.534	2.058	1.025	2.484
Age (since CRSP incorp)	25.262	21.750	17.089	12.500	33.500
D2default	9.067	8.187	5.853	4.960	12.257
Transparency	49.251	37.500	39.560	20.000	75.000
Observations	11388				

	Brown Firms (Quintile 1)					
	Mean	Median	Std. dev.	P25	P75	**Difference**
Env. perfomance	-4.089	-3.975	0.882	-4.489	-3.519	3.798***
Size	8.170	8.138	1.540	7.052	9.243	-0.096***
Leverage	0.485	0.470	0.677	0.309	0.601	-0.031*
Short term financing	0.030	0.012	0.069	0.002	0.037	-0.001
Long term debt share	0.888	0.955	0.185	0.871	0.992	-0.017***
Profitability	0.027	0.027	0.037	0.018	0.039	0.002**
Retained earning to assets	0.055	0.146	1.359	-0.002	0.331	-0.083***
Divs. per share	0.227	0.140	0.401	0.000	0.345	-0.093***
Cash to assets	0.073	0.039	0.094	0.010	0.098	0.098***
Market to book ratio	1.316	1.046	0.995	0.811	1.490	0.859***
Age (since CRSP incorp)	33.397	27.500	23.204	13.500	50.500	-8.135***
D2Deafult	7.161	6.356	5.343	3.516	9.917	1.905***
Transparency	28.766	20.000	29.066	10.345	33.333	20.486***
Observations	11368					

Notes: Green (Brown) firms are classified according to the top (bottom) quintiles of the environmental score distribution. Sample spans from 2007Q1 to 2020Q4. Difference refers to the difference in the means between Green and Brown firms. The asterisks denote statistical significance (*** for $p < 0.01$, ** for $p < 0.05$, * for $p < 0.1$).

In a model of heterogeneous firms, which issue long-term debt subject to fixed issuance costs, Jeenas (2019) argues that a firm's liquid assets are a good predictor of lower future likelihood of debt issuance and insensitivity to borrowing rates. Thus, in response to a contractionary monetary policy shock, firms with more liquid assets reduce investment less relative to others. Additionally, Ottonello and Winberry (2020) find that investment of firms with low default risk and debt burdens, as measured by firm's leverage and 'distance to default' are the most responsive to monetary policy shocks. This is because these firms face a flatter marginal cost curve for financing investment.

To investigate whether the differential sensitivity of green firms to monetary policy surprises is the result of any of the firm characteristics outlined above, I augment equation (6) with an additional term:

$$\Delta p_{i,t} = \alpha_i + \alpha_{st} + \beta(\varepsilon_t^m \times g_{i,t-1}) + \delta g_{i,t-1} + \gamma(\varepsilon_t^m \times c_{i,t-1}) + \Gamma' Z_{i,t-1} + e_{i,t} \tag{9}$$

where $\varepsilon_t^m \times c_{i,t-1}$ is a double interaction term of monetary policy surprises and firm-level characteristics as summarized in Table 11. The interpretation of the β coefficient now changes slightly. Consider the case of $c_{i,t-1}$ being firm leverage. Then β captures the relative response of asset prices for greener firms, controlling for the interaction of monetary policy with firm leverage. In effect, I am double sorting firms based on their firm-level performance, as well as their book leverage ratio. If the dampened sensitivity of green firms to monetary policy surprises is driven by underlying differences in firm characteristics, then we should expect the addition of these double interaction terms to render the β coefficient insignificant.

Table 12 shows the degree to which green firms' differential response to monetary policy shocks may be driven by underlying firm financial characteristics. For comparison with the baseline results, column (1) of Table 12 reports the results from specification (9), i.e. the specification including time-sector fixed effects, firm-level controls and a single interaction based on firm-level greenness score. Columns (2) to (9) report the results from specification (9), where $c_{i,t-1}$ is based on firm-level proxies for financial constraints, typically used in the literature. In particular, I consider book leverage, firm size, age (measured as time since CRSP incorporation), distance to default, liquidity ratio, profitability and short-term debt share, respectively.[24] Results in Table 12 show that the estimated β coefficient is similar and statistically significant in all columns. This result suggests that firm level greenness is not simply capturing the effect of other firm-level characteristics. Moreover, the interaction effects of firm-level characteristics with monetary policy generally have the expected sign. I find that larger firms react less strongly to monetary policy shocks. Additionally, consistent with Cloyne et al. (2018), results in column (4) show that younger firms are less responsive to monetary policy shocks. Similar to Anderson and Cesa-Bianchi (2020), but in contrast to Ottonello and Winberry (2020), I find that distance to default dampens a firm's sensitivity to monetary policy shocks.

Following research that suggests that socially responsible firms commit to a higher standard of transparency and provide more financial disclosure, I proceed by assessing whether the differential response to monetary policy shocks is driven by differences in valuation uncertainty across green versus brown firms. Column (9) of Table 12 presents the results from the inclusion of the double interaction term, $\varepsilon_t^m \times 1/\text{std.(EPS)}$.[25] The coefficients before this terms in column (9) suggest that, while it is true that monetary policy affects financially transparent firms less than their financially opaque counterparts, this is not enough to justify the dampened sensitivity of green firms to monetary policy surprises. In addition to the double interaction terms shown in Table 12, I have also double sorted firms according to their firm-level greenness and market-to-book ratio, cyclicality, long term debt ratio, retained-earnings and dividends per share. The baseline result remains largely unchanged, suggesting that the heterogeneous effect of monetary policy conditional on firm-level greenness is not explained by intrinsic differences in financial characteristics between green and brown firms.

[24]See Appendix A for a detailed description on how these variables were computed.

[25]Section 2 describes how previous research has used this variable as a proxy for firm financial transparency.

Table 12. Double-sorting based on firm-level environmental performance and financial characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$
MP shock × Env. score ($\varepsilon_t^m \times g_{i,t-1}$)	2.209***	2.209***	2.110***	2.325***	1.852***	2.279***	2.003***	2.211***	2.129***	1.887***
	(0.506)	(0.506)	(0.499)	(0.514)	(0.479)	(0.469)	(0.499)	(0.506)	(0.527)	(0.461)
MP shock × Leverage ($\varepsilon_t^m \times c_{i,t-1}$)		0.00398								0.178
		(0.449)								(0.428)
MP shock × Size ($\varepsilon_t^m \times c_{i,t-1}$)			0.740*							0.328
			(0.440)							(0.399)
MP shock × Age ($\varepsilon_t^m \times c_{i,t-1}$)				0.0892***						0.0704**
				(0.0309)						(0.0274)
MP shock × D2default ($\varepsilon_t^m \times c_{i,t-1}$)					0.677***					0.564***
					(0.219)					(0.199)
MP shock × Liquidity ($\varepsilon_t^m \times c_{i,t-1}$)						-3.870				-3.968
						(5.396)				(5.679)
MP shock × Profitability ($\varepsilon_t^m \times c_{i,t-1}$)							81.30**			33.71
							(33.29)			(28.70)
MP shock × Short-term debt ($\varepsilon_t^m \times c_{i,t-1}$)								7.923		17.36**
								(7.702)		(8.353)
MP shock × Transparency ($\varepsilon_t^m \times c_{i,t-1}$)									0.0556***	0.0430***
									(0.0133)	(0.0120)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry_time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.359	0.359	0.359	0.359	0.360	0.359	0.359	0.359	0.365	0.367
Observations	37928	37928	37928	37928	37928	37928	37928	37928	34959	34959

Notes: The dependent variable is the two-day stock return bracketing an FOMC announcement (in percent). The sample covers 102 FOMC announcements between 31 January 2008 and 31 December 2019. Env. score is the unadjusted firm-level environmental score as described in Section 2.1. Control variables are size, profitability, book leverage, market-to-book ratio, asset maturity, short term liabilities, retaining earnings, dividend per share and distance to default. ε_t^m is the BRW monetary policy shock (in percent). The regression coefficients of controls variables are not shown here for brevity. The numbers in parenthesis are standard errors, which are clustered at the event-level. The asterisks denote statistical significance (*** for p < 0.01, ** for p < 0.05, * for p < 0.1).

5 Investors' Green Preferences

In this section, I assess whether the dampened sensitivity of green firms to monetary policy shocks can be explained by developments in investors' preferences for sustainable investing. The key idea is that investors might value green assets for non-pecuniary reasons other than expected return or risk. This has the general implication that such preferences can become important in asset price determination, as investors require compensation for changing their asset holdings in response to shocks. In the case of contractionary monetary policy shocks, all else equal, higher interest rates lower security prices because expected future returns are discounted by a larger factor. This results in a fall of the present value of any given future income stream, which is typically associated with a portfolio rebalancing channel away from equities and towards bonds.

Accounting for investors' preferences for sustainable investing in a simple stylized model can help justify the differential response of green vs. brown equity prices to monetary policy shocks. Section 5.1 illustrates how incorporating green preferences in investors' utility function can have three important implications: (i) the semi-elasticity of equity prices to interest rates is lower for green firms compared to their brown counterparts; (ii) the differential response of green-vs-brown firms to interest rates gets amplified in states of the world with stronger preferences for sustainable investing; (iii) a contractionary monetary policy shock generates an increase in the portfolio weight of green securities.

5.1 A simple 2-period model with green preferences

Time is discrete and there are only two periods. There is no aggregate or idiosyncratic uncertainty. The household can invest in three riskless assets, namely bonds, green securities and brown securities, $b_1, s_{G,1}, s_{B,1}$ respectively. One unit of bonds purchased in period one returns with certainty (1+r) units of the consumption good in period two. One unit of green (brown) stocks purchased in period one at a price $q_{G,1}$ ($q_{B,1}$), returns with certainty a payoff π_G (π_B) in period two. The household is endowed with income y in period one and receives no income in period two. The household makes portfolio decisions in period one, subject to a budget constraint. In addition, I assume investors exhibit a preference for sustainable investing. In other words, investors derive a utility of $f(s_{G,1})$ from their holdings of green securities. The household/investor then maximizes the following utility function:

$$\max_{c_t, b_1, s_G s_B} E_1\left(\sum_{t=1}^{2} \beta^{t-1}\big(u(c_t) + f(s_{G,1})\big)\right), \text{ subject to,}$$

$$c_1 + b_1 + q_{G,1}s_{G,1} + q_{B,1}s_{B,1} \leq y \text{ in period one,} \tag{10}$$

$$c_2 \leq (1+r)b_1 + \pi_G s_{G,1} + \pi_B s_{B,1} \text{ in period two.} \tag{11}$$

The internal solution of the utility maximisation problem yields the following no-arbitrage conditions:

$$q_{B,1} = \frac{\pi_B}{1+r}; \quad q_{G,1} = \frac{\pi_G}{1+r} + \frac{(1+\beta)f'(s_{G,1})}{u'(c_1)} \tag{12}$$

Assuming for simplicity that green and brown securities give an equal payoff in period two (i.e. $\pi_G = \pi_B$), the expressions above reveal that 'green' preferences result in higher prices for green securities compared to their brown counterparts. Another way to think about this result is in terms of returns, whereby with 'sustainable investing' preferences investors require a lower return (compensation) for holding green stocks.

With the main conditions of the model specified, now I seek to demonstrate how a change in the real interest rate, proxying for a change in monetary policy, affects investors' portfolio choice between green and brown stocks, as well as their equilibrium prices. For exposition purposes, I now focus on a model with a log utility function, where $u(c_t) = log(c_t)$ and a linear preference for 'green' investing, where $f(s_{G,1}) = \alpha s_{G,1}$. A more general specification is provided in Appendix B. Solving for equilibrium prices, I can derive an expression for both $q^*_{B,1}$ and $q^*_{G,1}$ in terms of pre-determined parameters:

$$q^*_{B,1} = \frac{\pi_B}{1+r}, \quad q^*_{G,1} = \frac{\pi_G}{1+r} + \frac{\alpha}{1+\alpha}y \tag{13}$$

These expressions show that investors do not value green stocks purely for their pecuniary benefit (i.e. the discounted present value of future payoff), but also because they derive an additional utility from their holdings of green assets. In contrast to green securities, brown assets are only valued for their pecuniary benefit (i.e. price of brown securities is equivalent to the discounted present value of their future payoffs).

The question I now want to address is the extent to which these asset prices change in response to monetary policy shocks. Empirically, I address this by looking at the percentage change in the stock prices of an average firm in the aftermath of an unanticipated monetary policy surprise (where the dependent variable is defined as the log difference of the closing quotes of stock prices the day before and the day after an FOMC announcement). By taking logs to the expressions in (13) I provide the theoretical analogue to my empirical specification in Section 3.1. In line with the empirical design, I next differentiate these log expressions with respect to the real interest rate (with proxies for the unanticipated monetary policy shock in Section 3.1). This derivation allows us to compare the semi-elasticity of green-vs-brown asset prices with respect to real interest rates.

PROPOSITION 1: *Green security prices have a lower semi-elasticity with respect to monetary policy shocks, given* $\alpha > 0$.[26]

$$|\frac{dln(q^*_{G,1})}{dr}| < |\frac{dln(q^*_{B,1})}{dr}| \tag{14}$$

To make sense of this proposition, note that investors value green stocks both for their pecuniary returns, but also because they derive some additional utility from holding them. Assuming for simplicity that $\pi_G = \pi_B$, changes in interest rates affect the pecuniary returns for green and brown assets to the same degree. However, since investors also value green stocks because of their 'sustainable' preferences, which are unaffected by the interest rate,

[26] $|\frac{dln(q_{B,1})}{dr}| = \frac{1}{1+r}$; $\quad |\frac{dln(q_{G,1})}{dr}| = \frac{1}{1+r} - \frac{(q^*_{G,1} - q^*_{B,1})}{q^*_{G,1}} \frac{1}{1+r}$, assuming $\pi_B = \pi_G$. The differential response in the semi-elasticities of green-vs-brown stocks is: $\left(|\frac{dln(q_{G,1})}{dr}| - |\frac{dln(q_{B,1})}{dr}|\right) = -\frac{\frac{\alpha}{1+\alpha}y}{\frac{\pi_G}{1+r} + \frac{\alpha}{1+\alpha}y} \frac{1}{1+r} < 0$

then this leads to an attenuated effect on the semi-elasticity of green stocks with respect to interest rates.

In other words, the effect of an increase in interest rates to green stock prices is a composite of two forces. The (pecuniary) force that is common across both green and brown assets results in a reduction of both of these asset prices (i.e. as the interest rate increases, investors substitute away from equities and towards bonds). The non-pecuniary force, which is only present in the case of green stocks, dampens the first force because investors derive an additional utility from holding green assets.

COROLLARY 1: *The differential response of green-vs-brown firms to interest rates gets amplified in states of the world with stronger preferences for sustainable investing (given $\alpha > 0$)).*

$$\frac{d\left(\left|\frac{dln(q^*_{G,1})}{dr}\right| - \left|\frac{dln(q^*_{B,1})}{dr}\right|\right)}{d\alpha} < 0 \tag{15}$$

Corollary 1 is the result of differentiating the difference in the semi-elasticites of green vs. brown asset prices in equation (14) with respect to the sustainable preference parameter α. Equation (15) shows that the non-pecuniary force intensifies with the degree of environmental consciousness. In other words, the semi-elasticity of green asset prices with respect to an increase in interest rates is lower in states of the world with stronger preferences for sustainable investing.

Let us define the portfolio weight of green securities in equilibrium as the fraction of green securities to total securities (i.e. $w^*_{G,1} = \frac{q^*_{G_1} s^*_{G,1}}{q^*_{G,1} s^*_{G,1} + q^*_{B,1} s^*_{B,1}}$). Let us also assume for simplicity that the supply of both green and brown securities is fixed (i.e. $s^*_{G,1} = s^*_{B,1} = 1$).

COROLLARY 2: *A contractionary monetary policy shock generates an increase in the portfolio weight of green securities.*

$$\frac{dln(w_{G,1})}{dr} > 0 \tag{16}$$

An implication of Proposition 1 is that the relative weight of green stocks compared to their brown counterparts increases in the aftermath of a monetary policy shock. This is because a contractionary monetary policy shock depresses the valuation of green stocks to a lesser extent than that of brown stocks. Therefore, in relative terms the (log) prices of green securities react less to monetary policy shocks than (log) prices of brown securities. This has the effect of increasing the share of investors' portfolio that consists of green securities.

5.2 Evidence from institutional stock ownership

In this subsection I leverage information from institutional investors' portfolio holdings to uncover whether the dampened sensitivity of greener firms to monetary policy is related to investors' preferences for sustainable investing. The institutional holdings data is obtained from Securities and Exchange Commission Form 13F and includes quarterly security holdings of institutions with assets under management of over $100 million dating back to 1980.[27] Together, these institutions manage approximately 63% of the US market, with the remaining 37% being held by households and non-13F institutions (Koijen and Yogo, 2015). I use this rich dataset to address the following two questions: (i) What type of investors are responsible for the dampened sensitivity of greener firms to monetary policy?; (ii) How does the green weight in institutional investors' portfolios change in the aftermath of monetary policy?

To address the first questions, I first classify investors into types based on the environmental performance score of their security holdings. Specifically, let $w_{j,i,t}$ denote institutional investor j's holdings share of security i at time t and $g_{i,t}$ denote firm i's environmental performance score at time t as defined in Section 2.1. The overall greenness score for each fund j at time t is computed as:

$$\text{Investor Greenness}_{j,t} = \sum_{i \in \Theta(j)} w_{j,i,t} \times g_{i,t} \tag{17}$$

where $\Theta(j)$ denotes the set of securities held by fund j.

I then use these investor greenness scores to proxy for the type of investor that is likely to hold firm i at time t. In other words, I compute an investor-based environmental performance

[27] The 13F institutions include banks, insurance companies, investment advisors (including hedge funds), mutual funds, pension funds, and other institutions such as endowments, foundations, and nonfinancial corporations.

score for each firm i as a weighted average of its investors' revealed preferences. Specifically, let $\tilde{w}_{i,j,t}$ denote the fraction of total investments in firm i that are made by institutional investor j at time t. The investor-based greenness score for every firm i at time t is given by:

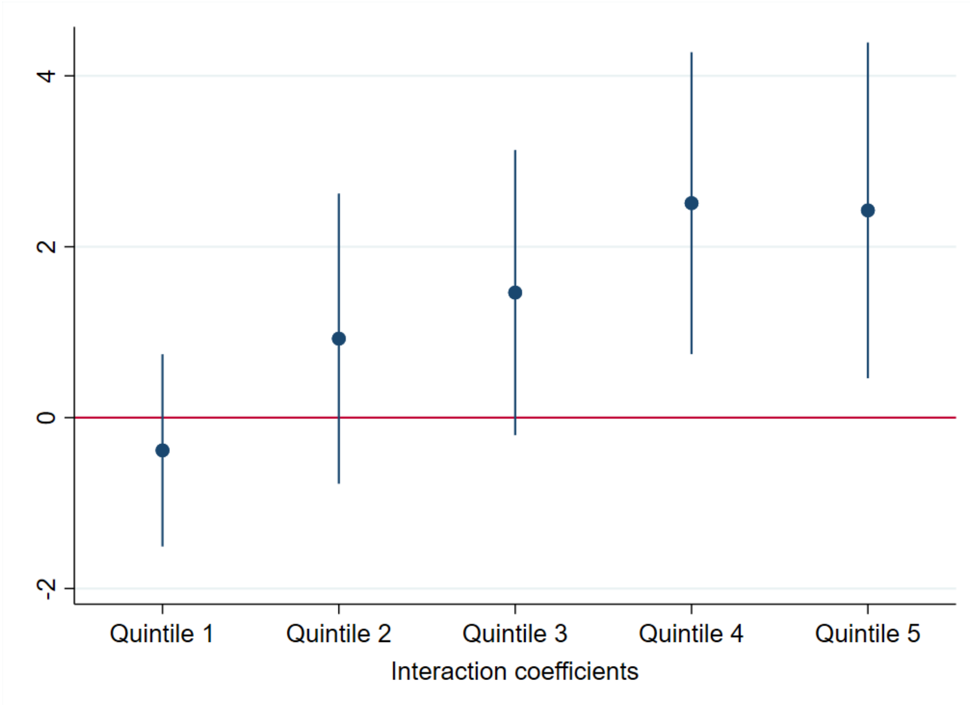
$$\text{Investor-based Greenness}_{i,t} = \sum_{j \in \Gamma(i)} \tilde{w}_{i,j,t} \times \text{Investor Greenness}_{j,t} \tag{18}$$

where $\Gamma(i)$ denotes the set of institutional investors that hold firm i in their portfolio.

As a last step, I split the distribution of firms into five different bins based on the revealed green preferences of their investors (i.e. the Investor-based Greenness$_{i,t}$). This allows me to assess how investors' preferences affect the sensitivity of green asset prices to monetary policy. To minimise endogeneity concerns, I look at the Investor-based Greenness scores as of a year before the monetary policy shock. Quintile 1 refers to securities that a year before the monetary policy shock were held by investors with a preference for browner firms. Quintile 5 refers to securities that a year before the monetary policy shock were held by environmentally conscious investors. I proceed by estimating the baseline specification in equation (6) for the five different bins of investor types.

Figure 6 plots the beta coefficients before the interaction term of firm-level greenness with monetary policy for 5 different bins of the investor greenness distribution. Greener firms are even less sensitive to monetary policy when they are being held by investors with a preference for sustainable investing. Crucially, the beta coefficients for firms being held by 'brown' investors (Quintiles 1 and 2) are not statistically different from zero. Conversely, the dampened sensitivity of greener firms to monetary is only observed for firms held by environmentally conscious investors (Quintiles 4 and 5). To summarise, these results confirm the theoretical predictions implied by Proposition 1 in Section 5.1. They show that the differential response of green firms (compared to brown) to monetary policy can be explained by investors' preferences for sustainable investing.

Figure 6. Investors' Preferences Channel



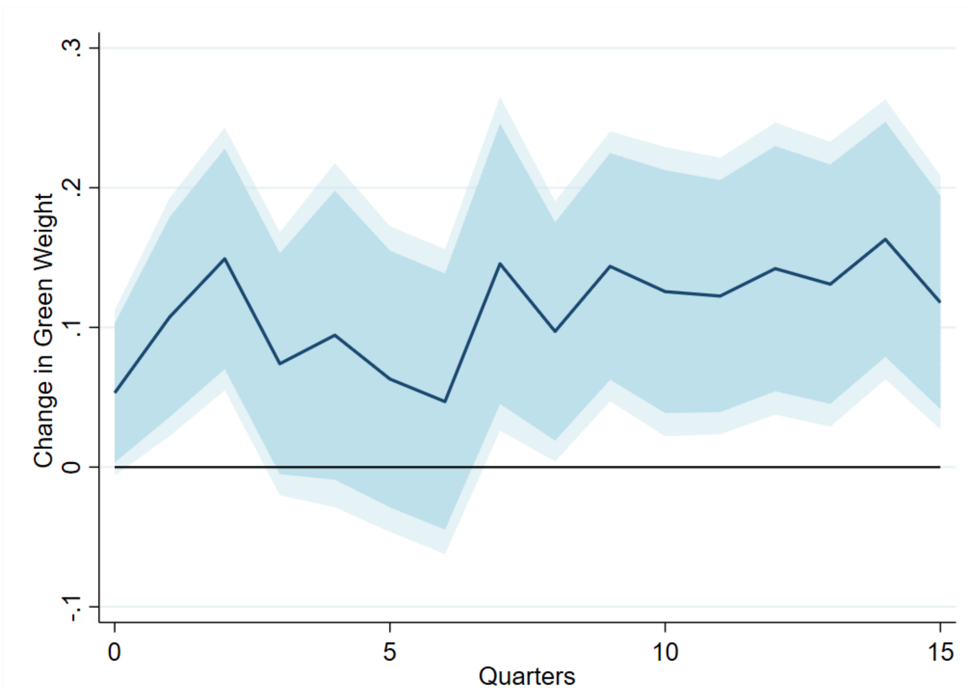
Notes: This graph plots the beta coefficients from the following specification: $\Delta p_{i,t} = \alpha_i + \alpha_{st} + \beta(\varepsilon_t^m \times g_{i,t-1}) + \delta g_{i,t-1} + \Gamma' Z_{i,t-1} + e_{i,t}$, for the five different quintiles of the Investor-based greenness distribution. Quintile 1 refers to securities that are held by investors with 'brown' preferences, as of a year before the monetary policy shock. Quintile 5 referes to securities that were held by investors with 'green' preferences, as of a year before the monetary policy shock. Confidence intervals are reported at the 95% level.

Next, I look at how the green weight in institutional investors' portfolio changes in the aftermath of monetary policy. An implication of Proposition 1 in Section 5.1 is that this weight must increase following an increase in interest rates. This is because, a contractionary monetary policy shock depresses the valuation of green stocks to a larger extent than that of brown stocks. Therefore in relative terms, the (log) prices of green securities react less to monetary policy shocks than (log) prices of brown securities. This has the effect of increasing the share of investors' portfolio that consists of green securities. To assess the empirical validity of Corollary 2 in Section 5.1, here I utilise data from institutional stock ownerships and employ the following specification:

$$\Delta_h w_{j,t}^G = \alpha_j^h + \beta^h \epsilon_t^m + \delta t + e_{j,t+h} \tag{19}$$

where $\Delta_h w_{j,t} \equiv$ Green weight$_{j,t+h}$ − Green weight$_{j,t-1}$. Green weight$_{j,t}$ denotes the proportion of securities held by institutional investor j with a greenness score above the median of the environmental score distribution.[28] ε_t^m is the monetary policy surprise by Bu et al. (2021), t is a linear time trend, α_j^h is a fixed effect that captures time-invariant characteristics at the institutional investors' level and h denotes the estimation horizon, with h = 0, 1, 2, ..., H. The coefficient of interest β^h measures the change in the green portfolio weight held by an average institutional investor in response to a monetary policy surprise of 100 basis points. The resulting impulse response captured by coefficient β^h is reported in Figure 7.

Figure 7. Impulse Response Function of Green Portfolio Weight



Notes: In line with local projection methods, each horizon is estimated separately. The blue solid line represents the $\{\beta^h\}_{h=0}^{20}$ estimates in percent. The dependent variable is $\Delta_h log(Green\ weight_{j,t})$, over the horizons considered. The independent variable is ε_t^m. The light blue shaded areas denote the 95% and 90% confidence intervals around point estimates constructed with standard errors clustered at the time level.

Figure 7 shows that in the face of contractionary monetary policy surprises, institutional investors respond by increasing the fraction of green assets held in their portfolio by 6 percent-

[28]Here, a security is considered 'green' if its environmental performance score falls above the median of the environmental score distribution in the *previous* year.

age points. This response is statistically significant on impact, pointing to a sizable portfolio rebalancing effect.

To summarise, these results confirm the theoretical predictions implied by Corollary 2 detailed in Section 5.1. They show that the differential sensitivity of green firms (compared to brown) to monetary policy is driven by investors' preferences for sustainable investing.

5.3 Environmental concerns

In this subsection, I run a series of triple interaction terms to test whether the differential response of green asset prices (compared to brown) gets amplified in states of the world with stronger preferences for sustainable investing. That is, I augment the baseline specification (6) with a triple interaction term:

$$\Delta p_{i,t} = \alpha_i + \alpha_{st} + \beta(\varepsilon_t^m \times g_{i,t-1}) + \delta g_{i,t-1} + \gamma(\varepsilon_t^m \times g_{i,t-1} \times s_i) + \Gamma' Z_{i,t-1} + e_{i,t} \quad (20)$$

where s_i is a variable that aims to capture investors' preference for sustainable investing. $Z_{i,t-1}$ includes a set of firm-level controls as before, and all the double interactions of s_i with monetary surprises and firm-level greenness. The first variable I consider is the natural risk score index, which measures whether firm i is located in a county with high exposure to natural disaster risk.[29] The coefficient before the triple interaction term, MP shock $\times$ Env. Score $\times$ NRI in column (2) of Table 13 indicates that the dampened response of green firms to monetary policy surprises is only the case for firms headquartered in counties that are highly exposed to natural disaster risk. If the following two conditions hold: (i) climate concerns are more elevated in regions that are highly exposed to natural disasters and (ii) investors exhibit local bias, the significance of the triple interaction term is indicative of an investor 'green' preference channel.

[29] See Section 2.3 for more detail on this variable.

Table 13. Environmental Concerns

	(1)	(2)	(3)	(4)
	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$
MP shock × Env. score ($\varepsilon_t^m \times g_{i,t-1}$)	2.209***	1.418**	-2.953	2.154***
	(0.506)	(0.628)	(1.786)	(0.507)
MP shock × Env. score × NRI ($\varepsilon_t^m \times g_{i,t-1} \times s_i$)		0.0306*		
		(0.0175)		
MP shock × Env. score × Beliefs ($\varepsilon_t^m \times g_{i,t-1} \times s_i$)			0.107***	
			(0.0396)	
MP shock × Env. score × MCCC ($\varepsilon_t^m \times g_{i,t-1} \times s_t$)				0.0312**
				(0.0145)
Firm FE	Yes	Yes	Yes	Yes
Industry_time FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.304	0.304	0.303	0.264
Observations	51415	50704	43966	38223

Notes: The dependent variable is the two-day stock return bracketing an FOMC announcement (in percent). The sample covers 102 FOMC announcements between 31 January 2008 and 31 December 2020. Env. score is the unadjusted firm-level environmental score as described in Section 2.1. Control variables are size, profitability, book leverage, market-to-book ratio, asset maturity, short term liabilities, retaining earnings, dividend per share and distance to default. ε_t^m is the BRW monetary policy shock (in percent). The regression coefficients of controls variables are not shown here for brevity. The numbers in parenthesis are standard errors, which are clustered at the event-level. The asterisks denote statistical significance (*** for p < 0.01, ** for p < 0.05, * for p < 0.1).

However, not all natural disasters are the result of climate change. Hence the national risk index may not necessarily be capturing climate change concerns. To address this concern, I consider another measure, which proxies for beliefs related to climate change in different counties in the US.[30] Column (3) in Table 13 presents the results from the inclusion of the climate perception variable 'personal', which measures the degree to which respondents in the Yale Climate Opinion Surveys believe to be 'personally' affected by climate change. While column (1) points to a dampened sensitivity of green firms to monetary policy shocks, column (3) shows how the differential response turns insignificant once climate change beliefs are taken into account. The coefficient before the triple interaction term, MP shock × Env. score × Beliefs indicates that the dampened response of green firms to monetary policy surprises

[30] See Section 2.3 for more detail on this variable.

is only the case for those firms, which are headquartered in counties where residents believe climate change 'personally' affects them.

I acknowledge that both of the measures considered in columns (2) and (3) are only indirectly linked to investors preferences (i.e. if investors exhibit strong local bias). Therefore, I consider a third measure of climate change awareness that comes from news articles about climate change published by major U.S. news outlets.[31] In so far as the arrival of such news increases environmental awareness, one would expect investors' propensity to hold green assets (above and beyond risk-return considerations) to strengthen in periods when news coverage of climate change events is amplified. Results in column (4) show that the differential response of green stocks to monetary policy shocks is exacerbated in periods when climate concerns are heightened. Coefficient before MP shock $\times$ Env. score $\times$ MCCC thus serves as evidence that sustainable investing preferences can have a significant impact on the transmission of monetary policy.

6 Conclusion

This paper shows that environmental performance and investors' preferences for sustainable investing matter for the transmission of monetary policy on firm-level outcomes. First, evidence from stock price, credit risk and investment data at the firm-level, shows that greener firms are considerably less responsive to monetary policy shocks than their brown counterparts. Second, stock holdings data at the institutional investor level, suggests that the dampened sensitivity of green firms to monetary policy shocks is the result of investors' preferences for sustainable investing. This is because investors are more reluctant to substitute away from green stocks following a contractionary monetary policy shock, when they derive a non-pecuniary benefit from holding green assets.

These results have important implications for the transmission of monetary policy during the Net-Zero transition: monetary policy may be less powerful in a world where the share of

[31] I use the Cumulative Media Climate Change Concerns variable defined in Section 2.3, detrended linearly.

greener firms in the economy increases, or when preferences for sustainable investing amplify. An important task for future work is to study how monetary policy should be carried out in light of the green transition.

My findings highlight that attitudes towards sustainable investing play an important role in how capital is allocated in financial markets. In particular, green preferences lead to heterogeneous capital flow responses to macro-financial shocks, which improves the ability of green firms to withstand these shocks. These distributional effects have important implications for firms' cost of capital, their investment potential and their resilience to future shocks. My research informs the current policy debate on whether the recent monetary policy tightening may discourage firms' efforts to decarbonise. While green investments have relatively large upfront costs, my results suggest that green firms may not be as vulnerable to higher interest rates as previously believed.

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A Appendix

Table A.1. Variable Definitions.

Variables	Description
Return	Percentage change of stock price between the day before and the day after an FOMC announcement, $log(P_{i,\tau+1}) - log(P_{i,\tau-1})$
Environmental score	The annual environmental score from MSCI ESG IVA ratings, following the green score construction methodology proposed by Pástor et al. (2022).
Firm Size	The logarithm of quarterly total assets (ATQ) deflated by US Implicit Price Deflator
Book leverage	The ratio of total debts (DLCQ + DLTTQ) to the sum of total debts and the book value of equity (DLCQ + DLTTQ + CEQQ)
Short-term debt	Short-term debt (DLCQ), expressed as a fraction of total assets (ATQ)
Long-term debt	Share of long term debt (DLTTQ) to total debt (DLCQ + DLTTQ).
Profitability	Operating income before depreciation (OIBDPQ), expressed as a fraction of total assets (ATQ)
Retained earnings	Retained earnings (REQ), expressed as a fraction of total assets (ATQ).
Dividend per share	Dividend per share (DVPSPQ).
Cash holdings	Cash holding (CHEQ), expressed as a fraction of total assets (ATQ).
Market-to-book ratio	The sum of the market value of equity and total debts (PRCCQ*CSHOQ + DLCQ + DLTTQ), expressed as a fraction of total assets (ATQ).
Age	Age since incorporation in CRSP (BEGDAT).
Distance to default	Distance to default measure following Gilchrist and Zakrajšek (2012).
	and (ii) the product of current assets as a fraction of total assets and as a fraction of cost of goods sold, respectively, respectively, ((PPEGTQ/ATQ)*(PPEGTQ/DPQ)) +((ACTQ/ATQ)*(ACTQ/COGSQ)).
1/std.(EPS)	1/standard deviation of the analysts' forecasts of EPS from Institutional Brokers' Estimate System (I/B/E/S)
NRI score	The US National Risk Index from the Federal Emergency Management Agency (FEMA), which measures natural hazard risk at the county level.
MCCC	Media Climate Change Concerns Index by Ardia et al. (2020)
Personal	Percentage of residents at the county level in the US who answered "Yes" to the Yale Climate Opinion Survey question: "Do you think that global warming is having a personal effect on you?

Table A.2. The 'E' in ESG

	(1)	(2)	(3)	(4)
	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$	$\Delta p_{i,t}$
MP shock × Env. score	2.209***	2.523***	2.373***	3.004***
	(0.506)	(0.512)	(0.579)	(0.624)
MP shock × Soc. score		0.604		0.533
		(0.653)		(0.655)
MP shock × Gov. score			0.353	1.047
			(1.032)	(1.240)
Firm FE	Yes	Yes	Yes	Yes
Industry_time FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.359	0.358	0.358	0.314
Observations	37928	36999	36999	37108

Notes: The dependent variable is the two-day stock return bracketing an FOMC announcement (in percent). The sample covers 102 FOMC announcements between 31 January 2008 and 31 December 2019. Env. score, Soc. score and Gov. score are the unadjusted firm-level environmental scores, social responsibility scores and corporate governance scores constructed from the E, S and G pillars of ESG using a methodology detailed in Section 2.1. Control variables are size, profitability, book leverage, market-to-book ratio, short term liabilities, retaining earnings, dividend per share and distance to default. ε_t^m is the BRW monetary policy shock (in percent). The regression coefficients of controls variables are not shown here for brevity. The numbers in parenthesis are standard errors, which are clustered at the event-level. The asterisks denote statistical significance (*** for p < 0.01, ** for p < 0.05, * for p < 0.1).

B A simple 2-period model with green preferences

Time is discrete and there are only two periods. There is no aggregate or idiosyncratic uncertainty. The household can invest in three riskless assets, namely bonds, green securities and brown securities, $b_1, s_{G,1}, s_{B,1}$ respectively. One unit of bonds purchased in period one, returns with certainty (1+r) units of the consumption good in period two. One unit of green (brown) stocks purchased in period one at a price $q_{G,1}$ $(q_{B,1})$, returns with certainty a payoff π_G (π_B) in period two. The household is endowed with income equivalent to y in period one and makes portfolio decisions in period one, subject to a budget constraint. In addition, I assume investors exhibit a preference for sustainable investing. In other words, investors derive a utility of $f(s_{G,1})$ from their holdings of green securities. The household/investor then maximizes the following utility function:

$$\max_{c_t,b_1,s_G s_B} E_1(\sum_{t=1}^{2}\beta^{t-1}\big(u(c_t)+f(s_{G,1})\big), \text{ subject to,}$$

$$c_1+b_1+q_{G,1}s_{G,1}+q_{B,1}s_{B,1}\leq y \text{ in period one} \tag{21}$$

$$c_2\leq(1+r)b_1+\pi_G s_{G,1}+\pi_B s_{B,1} \text{ in period two.} \tag{22}$$

The internal solution of the utility maximisation problem yields the following no-arbitrage conditions:

$$q_{B,1}=\frac{\pi_B}{1+r};\ \ q_{G,1}=\frac{\pi_G}{1+r}+\frac{(1+\beta)f'(s_{G,1})}{u'(c_1)} \tag{23}$$

As a theoretical analogue to the empirical specification laid out in Section 3.1, I proceed by computing the semi-elasticity of these asset prices with respect to the risk-free interest rate. In this set-up, the risk-free rate can be thought of as a proxy for the unanticipated shock to the policy rate in Section 3.1:

$$\frac{dln(q_{B,1})}{dr}=-\frac{1}{1+r} \tag{24}$$

$$\frac{dln(q_{G,1})}{dr}=-\frac{1}{1+r}+\frac{(1+\beta)f'(s_{G,1})}{u'(c_1)}\frac{\left[1-(1+r)\frac{u''(c_1)}{u'(c_1)}\frac{\partial c_1}{\partial r}+(1+r)f''(s_{G,1})\frac{\partial s_{G,1}}{\partial r}\right]}{(1+r)q_G} \tag{25}$$

Assuming in a tight window around a monetary policy announcement the equilibrium supply of both green and brown assets is fixed, and therefore insensitive to interest rates, I can equate $\frac{\partial s_{G,1}}{\partial r}$ to 0. Under this assumption equation (25) can be re-written as:

$$\frac{dln(q_{G,1})}{dr}=-\frac{1}{1+r}+\frac{(1+\beta)f'(s_{G,1})}{u'(c_1)}\frac{\left[1-(1+r)\frac{u''(c_1)}{u'(c_1)}\frac{\partial c_1}{\partial r}\right]}{(1+r)q_G} \tag{26}$$

Assuming for simplicity $\pi_G=\pi_B$, and recognizing that $\frac{dln(q_{G,1})}{dc_1}=-\frac{1}{q_G}\frac{(1+\beta)f'(s_{G,1})}{u'(c1)}\frac{u''(c_1)}{u'(c_1)}$, I can simplify equation (25) further:

$$\frac{dln(q_{G,1})}{dr} = \underbrace{-\frac{1}{1+r}}_{\text{Pecuniary effect}} + \underbrace{\frac{(q_{G,1} - q_{B,1})}{(1+r)q_{G,1}}}_{\text{Green preferences effect}} + \underbrace{\frac{dln(q_{G,1})}{dc_1}\frac{\partial c_1}{\partial r}}_{\text{Wealth effect}} \tag{27}$$

Equation (27) shows that the effect of an increase in interest rates on green asset prices is a composite of three forces. The 'pecuniary' force that is common across both green and brown assets, results in a reduction of both of these asset prices (i.e. as the interest rate increases, investors substitute away from equities and towards bonds). The 'green preferences' force, which is only present in the case of green stocks, attenuates the first force because investors derive an additional utility from holding green assets. The third force, which I call the 'wealth effect', captures the idea that investors' propensity to hold green assets is proportional to their wealth in period one. While the pecuniary force is always negative and the green preferences force is always positive, the sign and magnitude of the wealth effect will vary depending on $\frac{\partial c_1}{\partial r}$ (i.e. the interplay between income and substitution effects).

Case 1: Green security prices have a lower semi-elasticity with respect to monetary policy shocks compared to their brown counterparts if higher interest rates have a net zero effect on period 1 consumption (i.e. $\frac{\partial c_1}{\partial r} = 0$).

$$\left(|\frac{dln(q_{G,1})}{dr}| - |\frac{dln(q_{B,1})}{dr}|\right) = -\frac{(q_{G,1} - q_{B,1})}{(1+r)q_{G,1}} < 0 \tag{28}$$

Case 2: Green security prices have a lower semi-elasticity with respect to monetary policy shocks compared to their brown counterparts if higher interest rates have a net positive effect on period 1 consumption (i.e. $\frac{\partial c_1}{\partial r} > 0$).

$$\left(|\frac{dln(q_{G,1})}{dr}| - |\frac{dln(q_{B,1})}{dr}|\right) = -\frac{(q_{G,1} - q_{B,1})}{(1+r)q_{G,1}} - \frac{dln(q_{G,1})}{dc_1}\frac{\partial c_1}{\partial r} < 0 \tag{29}$$

Case 3: Green security prices have a lower semi-elasticity with respect to monetary policy shocks compared to their brown counterparts if $\frac{\partial c_1}{\partial r} < 0$ and the following condition holds:

$$\frac{(q_{G,1} - q_{B,1})}{(1+r)q_{G,1}} > -\frac{dln(q_{G,1})}{dc_1}\frac{\partial c_1}{\partial r} \tag{30}$$

When the substitution effect dominates the income effect, an increase in interest rates results in a net-negative effect on period-1 consumption. This effect is captured by the term $\frac{\partial c_1}{\partial r} < 0$ in equation (30). Because investors' propensity to hold green assets is proportional to their wealth in period 1, this puts downward pressure on the demand for holding green securities. The magnitude of the wealth effect is captured by the product $\frac{dln(q_{G,1})}{dc_1}\frac{\partial c_1}{\partial r}$. When the 'green preferences' effect dominates the 'wealth' effect, I can show that green asset prices are less sensitive to monetary policy shocks compared to their brown counterparts.

Case 4: Green security prices have a higher semi-elasticity with respect to interest rates compared to brown security prices, if and only if $\frac{\partial c_1}{\partial r} < 0$ and the wealth effect dominates the green preferences effect.