Green Stocks and Monetary Policy Shocks: Evidence from Europe

Michael Bauer[1] Eric Offner[2] Glenn Rudebusch[3]

[1]Federal Reserve Bank of San Francisco and CEPR

[2]European Central Bank and University of Hamburg

[3]Brookings Institution, CEPR, New York University

7th Annual Research Conference at Banco de España

Macroeconomic and Financial Aspects of Climate Change

Madrid, November 14, 2024

The views expressed here are our own and do not necessarily represent those of others in the Federal Reserve System or the Eurosystem.

Monetary policy, higher interest rates, and the green transition

- To reduce inflation, central banks pushed up real interest rates in 2022–23.
- Many worry that higher interest rates will unduly slow the green transition. Schnabel (2023): monetary tightening "may discourage efforts to decarbonize our economies rapidly."
- Substantial upfront financing costs of renewable energy infrastructure and minimal future fuel costs result in long-duration cash flow investments that are sensitive to interest rates. (Production cost of clean electricity rises with level of interest rates more than fossil fuel power, e.g., Schmidt et al., 2019.)
- A European perspective: "Action taken by central banks to fight inflation is widely considered to be in tension with their role in supporting the transition to a sustainable, low-carbon economy." (Monnet and van 't Klooster, 2023)

This paper

- How different are the green/brown equity price responses to interest rates?
- We use the intraday changes in interest rates around ECB Governing Council monetary policy announcements as monetary policy surprises.
  - These surprises are exogenous drivers of asset prices at policy announcements, so they can identify causal effects of monetary policy on equity markets.
- Our event study examines daily firm-level stock price responses to all ECB monetary policy surprises from 2012 to 2023.
- We compare responses of green and brown stocks. Greenness measured using firm-level data on environmental measures—primarily, emission intensity.
- We use two methodologies to distinguish green and brown responses: panel regressions and portfolio sorts.

Preview of results

- In contrast to received wisdom, ECB policy surprises have stronger negative effects on brown stocks than green stocks.
- This difference is robust to different specifications, methodologies, sample choices, monetary policy surprises, and measures of greenness.
- This heterogeneity also appears independent of other firm characteristics—market risk, book-to-market ratio, leverage, profitability, age—that may cause heterogeneous stock market responses.
- Recent tightening episode is no exception to historical patterns.
- Cross-validation: Renewable energy and fossil fuel industry equity indices show heterogeneous reactions consistent with our firm-level results.

(Closely) Related literature

- Four studies find that equity prices of U.S. brown firms respond more than green ones to Fed monetary policy announcements: Döttling and Lam (2024), Havrylchyk and Pourabbasvafa (2023), Patozi (2024), and Benchora et al. (2023). However, there is less agreement as to the relevant causal mechanisms. Our results for Europe are qualitatively and quantitatively consistent with these earlier results for the United States
- By contrast, Fornari and Gross (2024) find a similar response for green and brown stocks for U.S. and a stronger *green* response for Euro area. Their contrary results reflect use of a binary green/brown classification that also labels firms without emissions data as brown.

Euro-area results are very interesting complement to U.S.

Relevant differences between U.S. and Europe:

- Overarching difference: Much more climate policy agreement in Europe. Uncertainty about a U.S. green transition path can affect firms' green capital spending commitments and investors' pricing of climate equity risk.
- Different environment for investors: greater acceptance of ESG investing in Europe and likely greater share of green investors
- Different environment for firms: a skew towards carbon tax versus subsidy; fossil fuel production sector is much smaller

Such differences can help uncover sources of a green/brown policy heterogeneity.

Data

Firm-level data from LSEG (London Stock Exchange Group)

- ESG database for emissions and scores (formerly Refinitiv ESG, ASSET4)
  - Covers firms with more than 90% of global stock market capitalization
- Worldscope for annual accounting data
- LSEG Datastream for daily stock returns
  - Apply commonly used filters (penny stocks, non-common equity, etc.)

$\Rightarrow$ Final sample of 916 euro-area public companies

$\Rightarrow$ Sample period: Jan-2010 to Oct-2023. But we account for publication lags: Stock returns and ECB announcements matched with accounting and ESG variables from two years earlier.

Measuring emissions and greenness

- Emissions: sum of scope 1 (direct) and scope 2 (indirect) GHG emissions in metric tons of total CO_2 equivalents
  - We omit scope 3 emissions because very large and imprecisely estimated
  - We use samples with *all* emissions data or only *reported* emissions data (Bauer et al., 2022; Aswani et al., 2024)
- We consider five measures of greenness:
  - Emission intensity: emissions/sales (baseline; widely used)
  - Emission intensity 2: emissions/market cap
  - Log level of emissions (e.g., Bolton and Kacperczyk, 2023)
  - E score: environmental score based on emissions, innovation, and resource use
  - Emission score: based on various emissions-related metrics

Seven measures of intraday ECB monetary policy surprises

- Monetary event window covers press release and press conference. Source: Euro Area Monetary Policy Event-Study Database (see Altavilla et al., 2019).
- Three measures based on OIS rate changes over total event window
  - *Baseline* — One-year OIS rate. Includes rate surprise and forward guidance, as in Nakamura and Steinsson (2018), Bauer and Swanson (2023).
  - Three-month OIS rate. Focuses on rate surprise as in Gertler and Karate (2015).
  - "*PC*" — First principal component of seven OIS rates also used by Altavilla et al.
- Surprises from Altavilla et al. (2019)
  - "*Target*" rate surprise over press release window
  - "*Forward Guidance*" surprise over press conference window
- Surprises that try to remove "information effects"
  - "*KTW*" surprise from Krusell, Thurwachter and Weiss (2023) uses 3m OIS rate surprise only for meetings with negative stock market reaction
  - "*JK*" from Jarocinski and Karadi (2020) uses Bayesian VAR and sign restrictions on stock market response

Effects of ECB monetary policy on green and brown stocks

Panel regressions of firm-level returns on policy shocks

Estimate sensitivity of green/brown stocks to ECB surprises using panel regression:

$$r_{it} = \beta_1 \, mps_t + \beta_2 \, mps_t \, g_{it} + \beta_3 \, g_{it} + \gamma' X_{it} + FE + \varepsilon_{it},$$

- r_{it}: stock return of firm i on ECB announcement day t.
- mps_t: intraday monetary policy surprise on ECB announcement day t (e.g., p.p. change in 1Y OIS from ECB press release to just after press conference)
- g_{it}: greenness measure for firm i on day t (e.g., emission intensity)
- X_{it}: other firm-level controls: size, market to book equity, leverage, profitability, sales growth, investment, and log properties, plants and equipment (PP&E)
- FE: fixed effects; alternative specifications with firm, time, sector-by-time, or country-by-time fixed effects.

Panel regressions of firm-level returns on policy shocks

Estimate sensitivity of green/brown stocks to ECB surprises using panel regression:

$$r_{it} = \beta_1 \, mps_t + \beta_2 \, mps_t \, g_{it} + \beta_3 \, g_{it} + \gamma' X_{it} + FE + \varepsilon_{it},$$

- β_1 expected to be negative, i.e., higher interest rates lower equity prices
- β_2 shows how greenness alters sensitivity of firm-level returns to mps_t:

$$r_{it} = (\beta_1 + \beta_2 \, g_{it}) \, mps_t + \ldots$$

- For emission intensity, high values of g_{it} correspond to brown stocks. Therefore, if β_1 is negative, a negative β_2 implies that brown stocks have a stronger negative reaction to policy surprises than green stocks.

Effects of ECB policy surprises on green and brown stocks

	(1)	(2)	(3)	(4)	(5)
mps (β_1)	-9.87^{*}	-9.87^{*}			
	(5.39)	(5.42)			
mps $\times$ *g* (β_2)		-2.02^{***}	-2.07^{***}	-2.22^{***}	-2.13^{***}
		(0.57)	(0.22)	(0.32)	(0.31)
g	0.17^{***}	0.15^{***}	0.14^{***}	0.14^{***}	0.15^{***}
	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
Firm FE	Y	Y	Y	Y	Y
Time FE	N	N	Y	N	N
Industry-by-time FE	N	N	N	Y	N
Country-by-time FE	N	N	N	N	Y
Observations	30,504	30,504	30,504	30,504	30,504
Adjusted R^2	0.04	0.04	0.35	0.37	0.37

$\Rightarrow$ Robust, economically meaningful difference: brown (-11.9) vs. green (-7.9)

$\Rightarrow$ Same β_2 in (4), even though FE captures cross-industry heterogeneity

Portfolio approach to investigate green/brown heterogeneity

- Sort firms into five portfolios (quintiles) based on their emission intensity.
- Brown-minus-green (BMG) portfolios subtract highest-emission quintile returns from lowest quintile returns (using equal- or value-weighted returns).
- BMG daily returns are then regressed on monetary policy surprises.
- Investors could have formed BMG portfolios in real time (financial strategy of going long in brown stocks and short in green)
- To control for the influence of very large firms, we also double-sort: first by size and then by greenness (e.g., green portfolio return is average of returns for portfolios of large green firms and small green firms).

Response of brown-minus-green portfolios to ECB policy surprises

	Equal-weighted			Value-weighted		
mps	−0.97	−2.98*	−3.32**	−4.14	−6.27	−8.69*
	(1.40)	(1.71)	(1.58)	(3.64)	(5.15)	(4.98)
Observations	107	107	107	107	107	107
R^2	0.01	0.04	0.21	0.04	0.07	0.35
Double-sorted	N	Y	Y	N	Y	Y
Year FE	N	N	Y	N	N	Y
Month FE	N	N	Y	N	N	Y

$\Rightarrow$ Negative response of BMG return to policy surprise shows that brown stocks exhibit a stronger response to monetary policy than green stocks.

Robustness of panel regressions to different greenness measures

(A) All emissions (estimated and reported)

	Emissions/sales	Emissions/market cap	Log emissions
$mps \times g$ (β_2)	-2.22^{***}	-1.08^{***}	-1.45^{**}
	(0.32)	(0.05)	(0.64)
Observations	30,504	30,504	30,504
Adjusted R^2	0.37	0.37	0.37

(B) Only reported emissions

	Emissions/sales	Emissions/market cap	Log emissions
$mps \times g$ (β_2)	-0.03	-1.02^{***}	-1.5^{***}
	(0.22)	(0.38)	(0.59)
Observations	23,928	23,928	23,928
Adjusted R^2	0.41	0.38	0.41

$\Rightarrow$ Across all measures, effect is negative and generally statistically significant.

(Regressions include firm and industry-by-time fixed effects.)

Robustness of panel regressions to different greenness measures

(C) Scores		
	Emission score	E score
$mps \times g$ (β_2)	-0.9	-1.24
	(0.66)	(0.78)
Observations	31,720	30,497
Adjusted R^2	0.38	0.34

$\Rightarrow$ Using E scores, no statistically significantly different green/brown response

$\Rightarrow$ Caveats: ESG ratings can be inconsistent across providers. They are revised extensively over time, so were not available to investors in real time.

(Regressions include firm and industry-by-time fixed effects.)

Robustness of panel results to different monetary policy surprises

	Simple changes		Principal components			No info. effects	
	OIS 3m	OIS 1y	PC	Target	FG	KTW	JK
$mps \times g$ (β_2)	-1.76^{***}	-2.22^{***}	-1.82^{***}	-1.13^{***}	-0.78^{*}	-6.81^{***}	-3.14^{***}
	(0.23)	(0.32)	(0.25)	(0.17)	(0.46)	(1.89)	(0.65)
Observations	30,504	30,504	30,504	30,504	30,504	18,977	30,504
Adjusted R^2	0.37	0.37	0.37	0.37	0.37	0.44	0.37

$\Rightarrow$ Stocks of high-carbon firms respond more strongly to monetary policy surprises, independent of how this surprise is measured.

(Regressions use emission intensity and include firm and industry-by-time fixed effects.)

Underlying sources of heterogeneous monetary policy effects

Green-vs-brown heterogeneity and other firm characteristics

- Does the differential sensitivity to monetary policy of green and brown stocks represent a separate dimension of heterogeneity, or is it a reflection of other firm characteristics (leverage, age, size, liquidity, and profitability)?
- Much research on how U.S. firms' equity price responses to Fed monetary policy surprises vary with firm-level characteristics. (Ozdagli, 2018; Ippolito et al., 2018; Gürkaynak et al., 2022; Döttling and Ratnovski, 2023)
- Usual panel regression specification:

$$r_{it} = \delta_1 \, mps_t \, z_{it} + \delta_2 \, z_{it} + \gamma' X_{it} + \alpha_i + \alpha_{st} + \varepsilon_{it}.$$

  - Unconditional effects of mps_t are negative (in sector-by-time fixed effect, α_{st})
  - If δ_1 is *negative*, firms with higher characteristic z_{it} have *stronger* mps_t sensitivity.
- What firm characteristics account for the varying impact of ECB surprises on stock returns? Apparently, no previous analysis of this issue for euro area!

New European results on monetary policy heterogeneity

- Firms are more sensitive to ECB policy surprises if they have
  - High leverage (high debt/assets)
  - Young age (more recent IPO)
  - High book-to-market ratio
  - Higher market beta (more exposed to market risk)
  - Lower profitability
- These firms likely face a higher risk premium for further external finance (or a larger interest rate burden from existing debt).
- Our euro-area results are generally consistent with U.S. estimates from earlier monetary policy and climate-finance papers.

Panel regressions with greenness and other firm characteristics

We control for various dimensions of heterogeneity in estimating the sensitivity of equity returns to ECB surprises:

$$r_{it} = \beta_2\, mps_t\, g_{it} + \beta_3\, g_{it} + \delta_1\, mps_t\, z_{it} + \delta_2\, z_{it} + \gamma' X_{it} + \alpha_i + \alpha_{st} + \varepsilon_{it},$$

Or, to rearrange the terms of interest:

$$r_{it} = (\beta_2\, g_{it} + \delta_1\, z_{it})\, mps_t + \ldots$$

- Does *green-brown heterogeneity*, captured by estimates of β_2, change when we include various firm characteristics, either individually or jointly?
- Does the inclusion of z_{it} account for systematic differences between green and brown firms and account for our headline result?

Example: Leverage and green/brown heterogeneity

	(table 2)	(table 6)	(table 8)
mps $\times$ *g* (β_2)	-2.22^{***}		-2.18^{***}
	(0.32)		(0.33)
mps $\times$ *Leverage* (δ_1)		-0.65^{**}	-0.62^{*}
		(0.33)	(0.34)
Firm FE	Y	Y	Y
Industry-by-time FE	Y	Y	Y
Observations	30,504	55,730	30,504
Adjusted R^2	0.35	0.30	0.37

$\Rightarrow$ Firms with higher carbon intensity are more sensitive to interest rates.
$\Rightarrow$ Firms with higher leverage are more sensitive to interest rates.
$\Rightarrow$ But the influence of greenness and leverage on firms' equity price responses to monetary policy shocks are effectively orthogonal.

Other firm characteristics also unrelated to green heterogeneity

Interactions	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CO_2 intensity	−2.24***	−2.20***	−2.18***	−2.21***	−2.28***	−2.21***	−2.22***	−2.10***	−2.22***	−2.12***
	(0.36)	(0.33)	(0.33)	(0.32)	(0.42)	(0.33)	(0.32)	(0.32)	(0.32)	(0.50)
Size	−0.69									−0.89
	(1.32)									(1.23)
B/M		−0.84***								−0.91**
		(0.29)								(0.46)
Leverage			−0.62*							−0.48*
			(0.34)							(0.28)
Profitability				1.82						−0.88
				(3.11)						(2.32)
Tangibility					0.30					
					(0.85)					
Liquidity						0.70				0.50
						(0.79)				(0.79)
Age							0.42			0.66**
							(0.34)			(0.33)
Beta								−1.61**		−1.52**
								(0.64)		(0.74)
Cash flow									0.09	−2.93
									(5.17)	(4.33)
Observations	30,504	30,504	30,504	30,504	23,029	30,492	29,869	30,481	30,504	29,834
Adjusted R^2	0.37	0.37	0.37	0.37	0.40	0.37	0.38	0.37	0.37	0.38

Possible channels and candidate explanations

Possible channels for stronger brown response to monetary policy

1. Differences in firm characteristics, such as variation in tangible capital
   - But controlling for capital tangibility does not change our results
2. Industry differences: For example, high-carbon oil and gas sector has sizable consumer demand interest rate sensitivity
   - But we find similar results within and across industries
3. Carbon premium I (risk)
   - *Brown stocks have higher risk premium, which drives stronger response*
4. Carbon premium II (aversion)
   - *Green stocks preferred by investors, which lowers interest-rate sensitivity*

Carbon risk premium and risk-taking channel

- Brown stocks more exposed to transition risk, investors require a larger risk premium (Pastor et al., 2021)
- Monetary policy can affect *quantity of transition risk*
  - In the model of Döttling and Lam (2024), tighter monetary policy causes brown firms to delay replacing carbon-intensive assets, increasing their exposure of transition risk
- Monetary policy can affect *price of risk*
  - According to *risk-taking channel of monetary policy*, tightening increases effective risk aversion and risk premia across the board (Bauer, Bernanke, Milstein, 2023)
  - In the model of Benchora et al. (2023), this channel arises from a search-for-yield motive
- Evidence from Altavilla et al. (2023) on "climate risk-taking channel of monetary policy" supports this explanation

“Carbon aversion premium” and yield-inelastic investors

- Green investor preferences drive up prices of green stocks and expected returns of brown stocks (Pastor et al., 2021)
- Non-pecuniary motive makes green investors less sensitive to expected returns (or: marginal investor less sensitive for green assets)
  - Models of Benchora et al. (2023) and Patozi (2024) show role of green preferences for interest-rate sensitivity of stocks
- Evidence in Patozi (2024) shows that stocks held by ESG index funds are less sensitive to monetary policy (also leverages regional and time variation in risk exposure)
- Although Europe has stronger public climate concerns and considerations for climate risk in financial decisions, green-brown heterogeneity is not stronger than in the U.S.

Caveats to explanations based on the carbon premium

- Contradictory evidence on returns in green and brown stocks
  - Brown stocks had higher returns, confirming carbon premium hypothesis. (Bolton and Kacperczyk (2021, 2023); Delmas et al. (2015); Busch et al. (2022); Görgen et al. (2020), Bansal et al. (2021), …)
  - Green stocks had higher returns. (Garvey et al. (2018); In et al. (2019); Huij et al. (2024); Paastor et al. (2022); Bauer et al. (2022))
  - Brown outperformance due to mismeasurement or mispricing (Atilgan et al. (2023); Aswani et al. (2024); Zhang (2024))
- Methodological challenges: realized vs. expected returns; short time series; noisy measures of greenness.
- But recent evidence with new data sets and methodologies supports carbon premium hypothesis: (Eskildsen et al. (2024), Bauer et al. (2024)).

Renewable energy vs. fossil fuel sectors

Cross-validate our results with a narrow focus on energy sector

- So far, we have explored monetary policy green/brown heterogeneity across a wide range of firms with higher and lower carbon emissions.
- Narrow companion question: Will higher interest rates slow the adoption of renewable energy production over fossil fuels (e.g., Schnabel, 2023).
- View that tighter monetary policy will hinder a green transition prompts proposal for dual interest rates with a lower rate for renewable energy loans.
  - "The cost of investment must be higher for players in the fossil-fuel sector. We need a green interest rate and a brown interest rate." (Macron, 2023)
  - For example, ECB could set up a green targeted lending operation that would provide banks with a lower interest rate that incentivizes green loans.

Interest rate effect: solar & wind versus oil & gas energy indexes

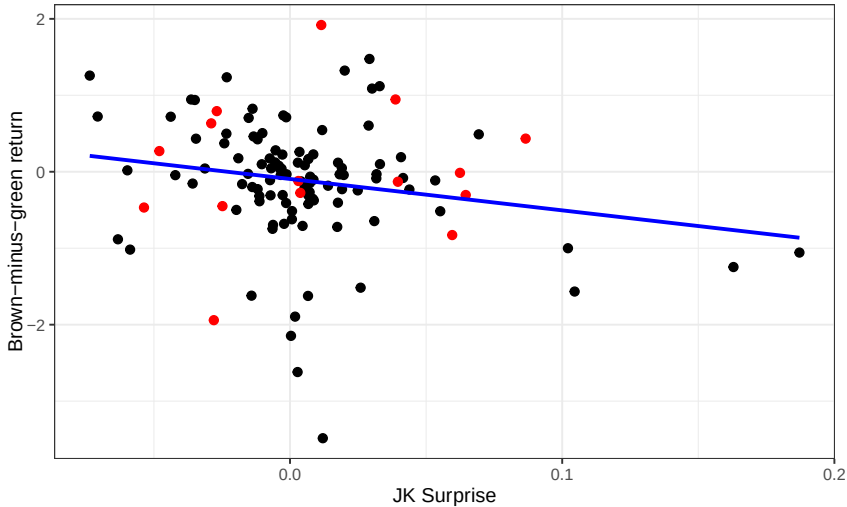
- Renewable energy facilities have upfront construction financing and low future operating costs. With higher interest rates, they should be at a cost disadvantage relative to fossil fuels.
- We use prominent stock market indexes representing global energy sectors:
  - Green indexes: Wilderhill Clean Energy, S&P Global Clean Energy, ISE Global Wind Energy, and MAC Global Solar Energy.
  - Brown indexes: FTSE All World Oil & Gas & Coal, S&P 500 Integrated Oil & Gas.
- For each group, the first principal component is the green or brown common factor. We also calculate a brown-minus-green (BMG) factor (i.e., the return on going long in oil and gas and short in renewable energy).
- Event study regressions uncover the sensitivities of these factors to three different measures of ECB policy shocks (OIS 3m, OIS 1y, JK).

Effect of monetary policy surprises on BMG energy sector indexes

	OIS 3m	OIS 1y	JK
MPS	-3.17^{*}	-0.62	-4.10^{**}
	(1.87)	(1.78)	(1.61)
Observations	124	124	124
Adjusted R^2	0.02	0.00	0.04

- BMG portfolio responses are negative for all three measures of monetary policy shocks. That is, the brown factor is more sensitive to monetary policy than the green factor.

Reaction of BMG energy portfolio to JK ECB surprises



- Recent ECB surprises (2022-23, red dots) are consistent with full sample.

Conclusion

- Our three euro-area results:
  - Green stocks are less affected by monetary policy surprises than brown stocks
  - Difference not due to firm-level characteristics (e.g., leverage, size, etc.)
  - Interest rate reaction of renewable energy industry weaker than oil & gas sector
- Broadly in line with U.S. research—despite Europe/U.S. differences
- Future research in several areas:
  - Understanding the underlying causal channel—a carbon risk/carbon aversion premium may be responsible, but no definitive evidence yet
  - Reconciling with earlier consensus view that higher interest rates unduly limit renewable energy production and green transition
  - Understanding the green/brown real-side consequences of monetary policy, which would clarify the heterogeneous effects on the green transition.