Where is the Carbon Premium?
Global Performance of Green and Brown Stocks

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Climate change and financial markets

> *"Achieving [1.5 degrees] requires a whole economy transition. Every company, bank, insurer, and investor will need to adjust their business models, develop credible plans for the transition to a low-carbon, climate-resilient future, and then implement those plans." (Glasfow Financial Alliance for Net Zero)*

How can financial markets help address climate change?

- Efficiently allocate *funding* to enable transition to low-carbon economy
- Manage and share climate-related *risks* (hedging, financial stability, resilience)
- Provide *information* for climate policy and economic decisions

How are climate risks priced in financial markets?

- Two broad categories of financial risks due to climate change
  - *Physical risks*: direct effects of climate change on economic activity and asset values
  - *Transition risks*: policies and regulations required for transition to low-carbon economy
- Different risks relevant for equity, bond, real-estate, and other asset markets
- Key challenge: measure the *exposure* of firms/assets to climate risks
- Shifting financial landscape: increasing public awareness of climate change, growing political/corporate activism, evolving investor preferences
- Empirical literature growing quickly with substantial progress, but many open questions remain

Climate risk and equity markets: conflicting views and evidence

- How is climate/transition risk priced in the stock market? Do “green” or “brown” (sustainable or carbon-dependent) stocks provide higher returns?
- ESG industry predicts *green outperformance*
  - Larry Fink (2020) “*our investment conviction is that sustainability- and climate-integrated portfolios can provide better risk-adjusted returns to investors*”
  - Supported by several papers showing higher green returns in the U.S.
- *Carbon premium* hypothesis: brown stocks have higher expected returns
  - Consistent with asset pricing theory: e.g., brown firms face higher risks (e.g., Pastor, Stambaugh, Taylor, 2021)
  - Some evidence supports carbon premium hypothesis (e.g., Hong & Kacperczyk, 2009, and Bolton & Kacperczyk, 2021, 2022)
- No clear answer in the literature to a basic question in climate finance

Methodological choices are partly responsible for differing results

- How to measure a stock's/firm's greenness?
  - ESG ratings are judgemental, noisy, subject to revisions (Berg et al., 2022; Gibson Brandon et al., 2021).
  - CO_2 emissions easier to measure, but estimates can be problematic (Aswani et al., 2022)
  - Emissions level/intensity/growth can yield different results (Bolton and Kacperczyk, 2021)
- How to measure green and brown stock market performance?
  - Panel regressions of Bolton and Kacperczyk (2021, 2022) suggest carbon premium, but quite sensitive to specification (Aswani et al., 2022)
  - Most portfolio-based methods suggest green outperformance (e.g., Huij et al., 2021; Pastor et al., 2022)
- Sample choice: time period and geography
  - Different short sample periods may account for some of the divergent results
  - Most studies focus on the U.S. market (except for Bolton and Kacperczyk, 2022)

This paper: new global evidence on climate pricing in stock markets

- Contribute along all three methodological dimensions
- Our methodology
  - Focus on reported scope 1+2 emissions (levels and intensity)
  - Use tools from empirical asset pricing: portfolios and green factors
  - Report green performance over time, since 2010, for G7 countries
  - Reconcile results with panel regressions
- Our key findings
  - Substantial green outperformance in U.S., extends to most G7 countries
  - Robust to choice of factor method or measure of greenness
  - Risk-adjusted outperformance smaller but still positive
  - Importance of (a) publication lag and (b) cross-sectional comparison of greeneness

Related literature

- **Asset pricing theory on sustainable/green investing:** Heinkel et al. (2001), Albuquerque et al. (2019), Baker et al. (2018), Pedersen et al. (2021), Pastor, Stambaugh, Taylor (2021), Lontzek et al. (2022)
- **Empirical evidence for outperformance of green/ESG stocks:** Kempf and Obsthoff (2007), Garvey et al. (2018), In et al. (2019), Görgen et al. (2020), Cheema-Fox et al. (2021), Huij et al. (2021), Pastor, Stambaugh, Taylor (2022), Ardia et al. (2022)
- **Evidence for carbon/pollution/sin premium:** Hong & Kacperczyk (2009), El Ghoul et al. (2011), Delmas et al. (2015), Busch et al. (2020), Alessi et al. (2021), Bolton & Kacperczyk (2021, 2022), Hsu, Li, Tsou (2022)

Some theory: carbon premium vs. green outperformance

Why would there be a carbon premium?

- Pastor-Stambaugh-Taylor (2021, JFE) provide model to build intuition
- Two theoretical reasons for additional demand for sustainable/green stocks
  - Investors have preference for green stocks (utility depends on ESG score)
  - Green stocks hedge climate risk, brown stocks are more risky
    (e.g., exposure to a carbon tax depends on ESG score)
- Some evidence in support of both of these channels (e.g., Engle et al., 2020)
- Strong demand translates into higher prices and lower expected returns and cost of capital for green stocks

Could there be green outperformance despite a carbon premium?

- *Realized returns* (during transition) may differ from *expected returns* (in eqbm.)
- Increased ESG/climate change concerns raise green stock prices:
  - *Customer channel*: stronger demand for goods and services from green firms
  - *Investor channel*: stronger preference for holding green stocks
  - *Risk channel*: better green hedging properties in face of higher climate risk
- "If ESG concerns strengthen unexpectedly and sufficiently, green assets outperform brown ones despite having lower expected returns." (PST 2021)
- In long samples, we can accurately measure expected returns, but ESG data available only for a short sample.
  - Violation of common assumption that avg. realized returns $\approx$ expected returns

Why this matters: financial and real effects

- Why do we care whether investors earn more with green or brown stocks?
- Lower expected returns mean *lower cost of capital* for green firms, which can provide important incentives for funding the transition:
  - Green firms would tend to invest more
  - All firms would try to become greener
- Can inform us whether are markets are appropriately assessing climate risks, e.g., for financial stability concerns.

Data and methodology

Data

- Firm-level data from Thomson Reuters Refinitiv
  - Accounting data: Worldscope
  - Market data: Datastream
  - Carbon emissions: ESG database (formerly Asset4)
- United States and other G7 countries
  - Canada, France, Germany, Italy, Japan, and the United Kingdom
  - ESG data coverage deteriorates outside G7

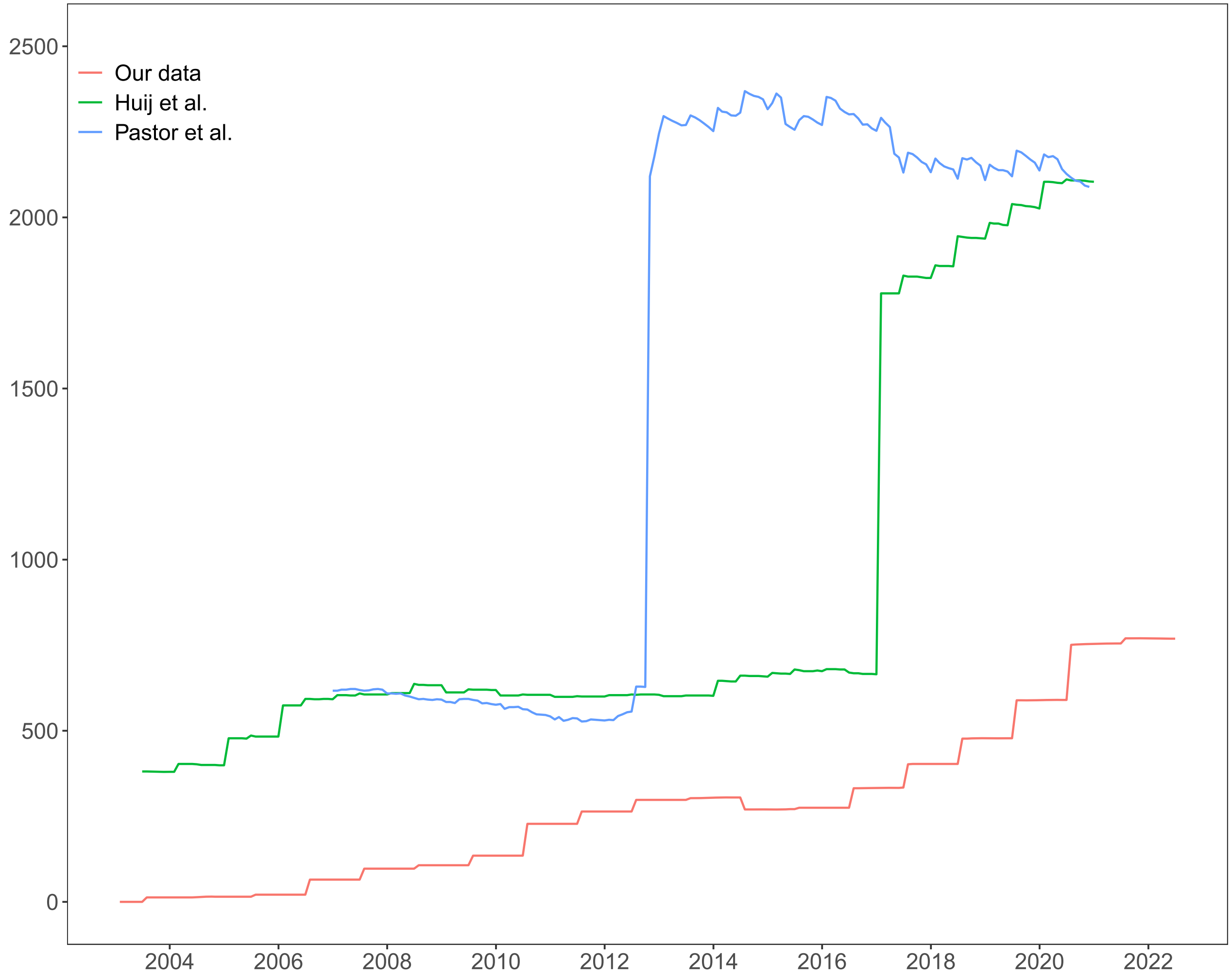
Measuring greenness and climate risk exposure: CO_2 emissions

- Scope 1+2 emissions
  - Scope 1: direct emissions from company- owned and controlled resources
  - Scope 2: indirect emissions from the power generation of the energy purchased by the company
  - Exclude scope 3: emissions generated by company's upstream and downstream activities—hardest to monitor, voluntary to report, very large in magnitude
- Emission levels and intensities
  - Total level of scope 1+2 emissions. Downside: depends on scale/size
  - Intensity: normalize by size of company. *Emissions / Sales*

Reported vs. estimated emissions

- Substantial share of companies in the “ESG universe” actually report CO_2 emissions
- For companies without disclosed emissions, data providers estimate emissions using various different proprietary models
- Using estimated/imputed emissions data can bias empirical results
  - “Vendor-estimated emissions systematically differ from firm-disclosed emissions and are highly correlated with [...] sales” (Aswani et al., 2022)
- We use only disclosed/reported emissions
- Reduces number of firms but makes our results more reliable

Number of firms



Summary statistics for the G7 countries (total).

	Mean	Median	25th	75th	Obs.
Scope 1	2,921,550	66,653	9,008	526,035	12,674
Scope 2	561,833	97,130	21,327	402,473	12,458
Scope 1+2 level	3,425,962	222,858	42,860	1,193,117	12,851
Scope 1+2 intensity	0.31	0.03	0.00	0.12	12,820
Market cap	20,535	6,810	2,326	19,006	12,673

Emissions measured in tons of CO2; emission intensity measured in tons of CO2 divided by thousands of USD in firm revenues; market cap measured in millions of USD.
Sample period: January 2010 to December 2021

Methodology: portfolio sorts

- Goal: classify firms and measure performance in line with what investors could have done in real time
- Sort firms into green and brown portfolios based on emission levels or intensities
- Account for publication lags
  - At the end of June, build new portfolios using accounting and emission data from previous year (18-month publication lag)
  - For example, use 2020 emissions for returns from July 2021 to June 2022
  - Avoid look-ahead bias, similar to Ardia et al. (2022) and Ilhan et al. (2021)
- Focus on brown-minus-green (BMG) spread portfolio and its returns

Three different spread portfolios

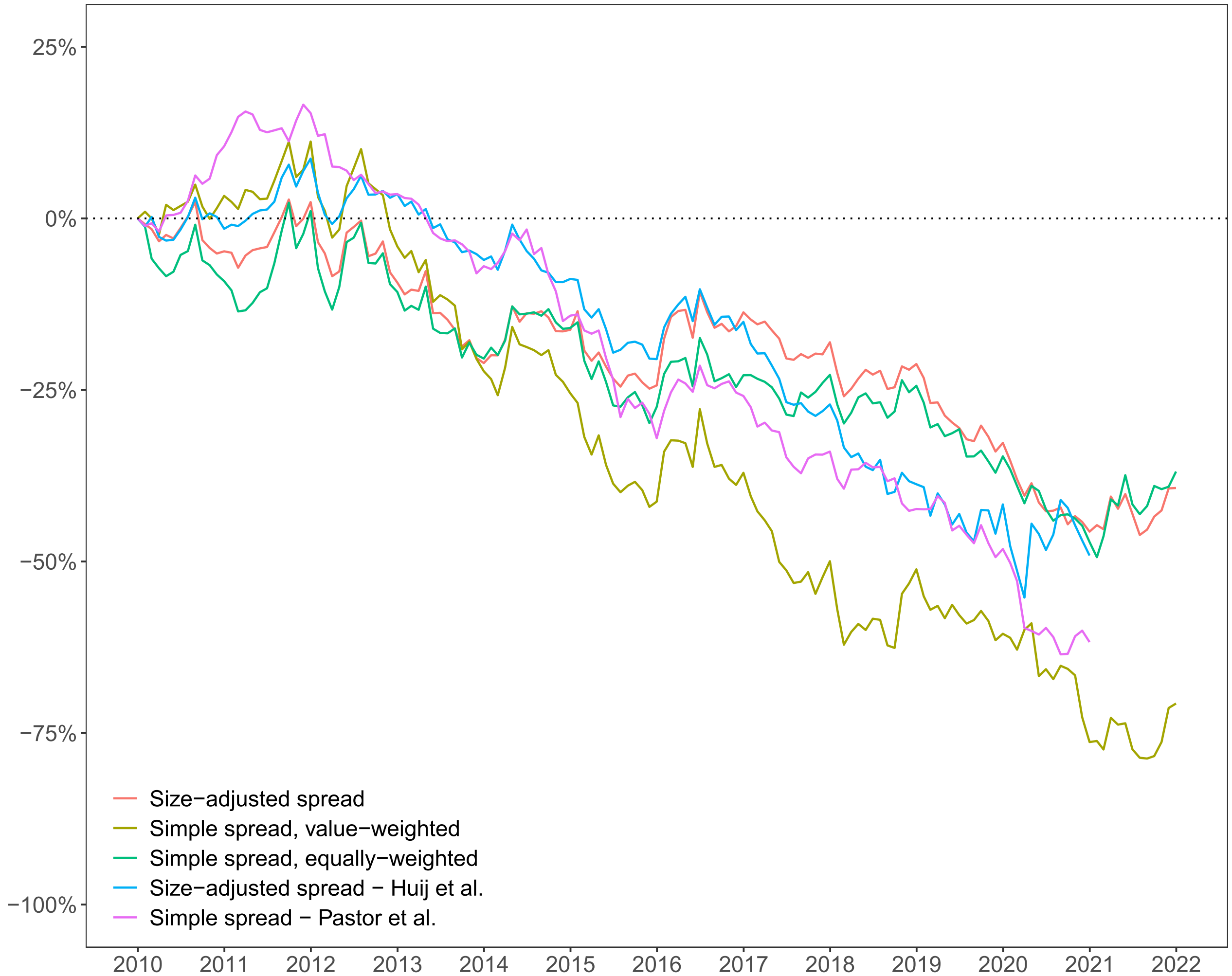
- (1) “Simple spread”
  - Sort stocks into quintile portfolios based on emission levels or intensities
  - Calculate value-weighted portfolio returns
  - BMG spread is brownest minus greenest quintile portfolio
  - Standard method in anomaly literature, similar to Pastor et al. (2022)
- (2) “Simple spread, equal-weighted”
  - Similar but use equal-weighted portfolio returns

Three different spread portfolios (cont'd)

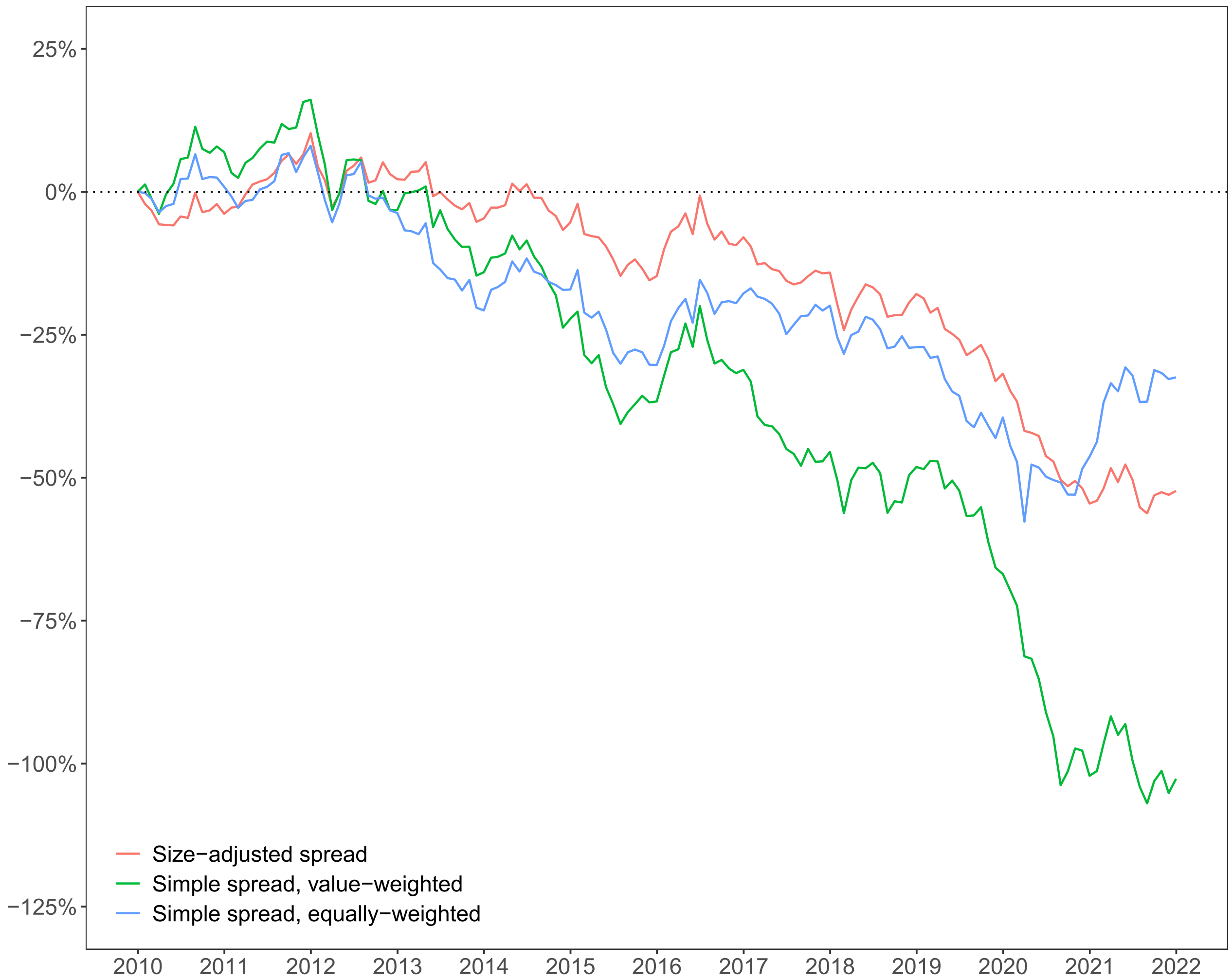
- (3) "Size-adjusted spread"
  - Two-way sort by (market cap) and greenness (emission levels or intensity), following Fama and French (1993) and Huij et al. (2021)
  - Categorize big and small firms based on market cap
  - Categorize "low/green", "medium", and "high/brown" based on the 30th and 70th percentiles of the emissions variable
  - Value-weighted returns for each of the six portfolios
  - Spread return is difference in average returns between two brown and two green portfolios

Results for the United States

Brown vs. green performance in the U.S., total emissions



Brown vs. green performance in the U.S., emission intensity



Average monthly returns

Factor/Portfolio	brown	green	BMG
Emission level			
Size-adjusted spread	1.15	1.40	-0.25
	(3.17)	(3.45)	(-1.30)
Simple spread, value-weighted	1.02	1.47	-0.45
	(3.27)	(3.63)	(-1.84)
Simple spread, equally-weighted	1.15	1.37	-0.22
	(2.93)	(3.06)	(-1.00)
Spreads from the literature			
Size-adjusted spread - Huij et al.	1.22	1.57	-0.34
	(2.75)	(3.51)	(-1.64)
Simple spread - Pastor et al.	0.84	1.28	-0.45
	(2.13)	(3.49)	(-2.61)
Emission intensity			
Size-adjusted spread	1.04	1.37	-0.33
	(2.68)	(3.27)	(-1.70)
Simple spread, value-weighted	0.79	1.45	-0.65
	(2.11)	(3.38)	(-2.37)
Simple spread, equally-weighted	1.24	1.43	-0.18
	(2.65)	(3.25)	(-0.75)

Mean portfolio returns and Sharpe ratios

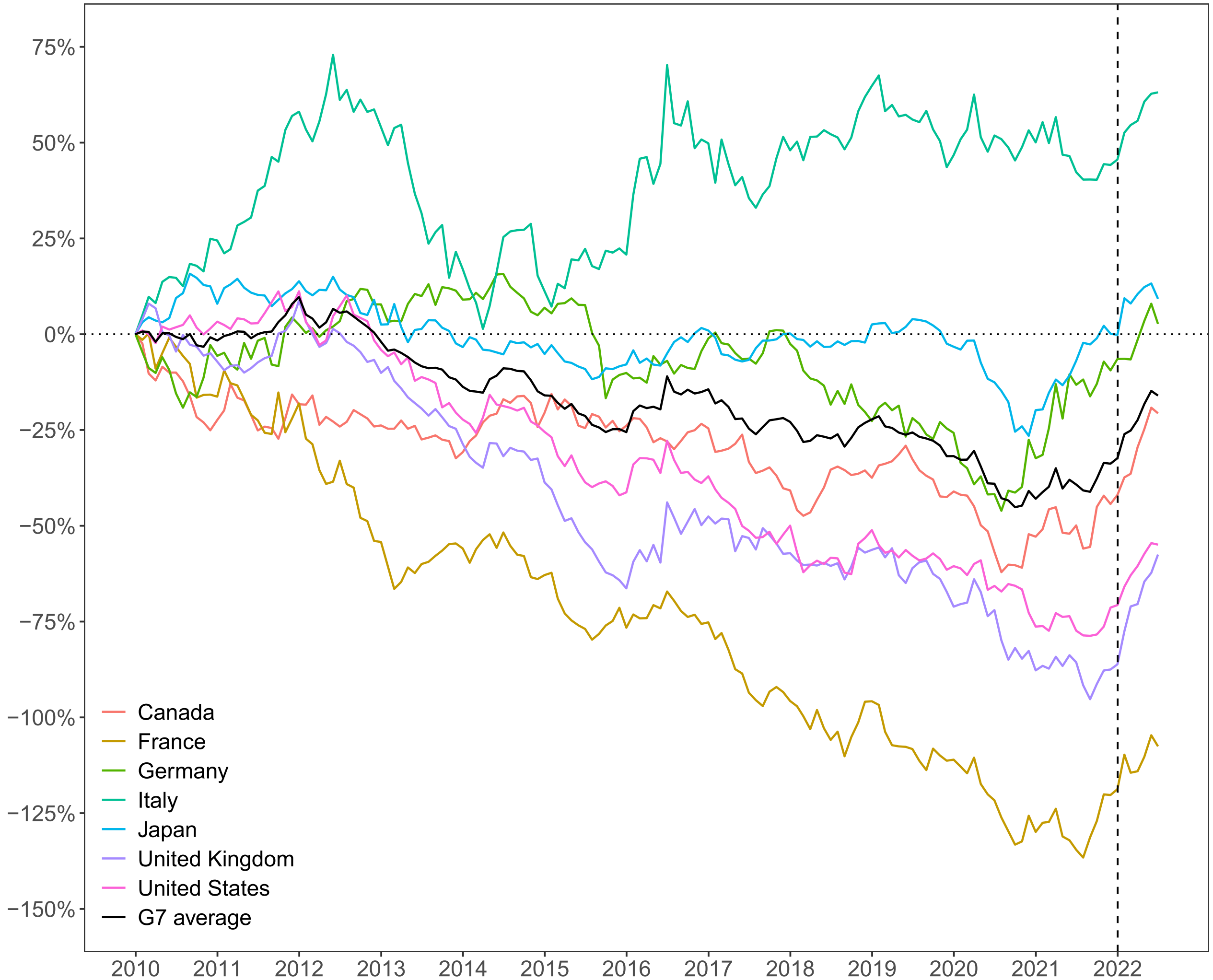
	Quintiles					BMG	Market
	1(green)	2	3	4	5 (brown)		
Level of emissions							
Mean return	1.47	1.26	1.32	1.31	1.02	-0.45	1.27
	(3.63)	(3.27)	(3.60)	(3.87)	(3.27)	(-1.84)	(3.69)
Volatility	4.86	4.66	4.41	4.07	3.75	2.92	4.13
Sharpe ratio	0.29	0.26	0.29	0.31	0.26	-0.17	0.30
Emission intensity							
Mean return	1.45	1.31	1.17	1.04	0.79	-0.65	1.27
	(3.38)	(4.08)	(3.96)	(3.05)	(2.11)	(-2.37)	(3.69)
Volatility	5.16	3.86	3.57	4.10	4.53	3.33	4.13
Sharpe ratio	0.27	0.33	0.32	0.24	0.17	-0.21	0.30

Correlations of monthly spread returns

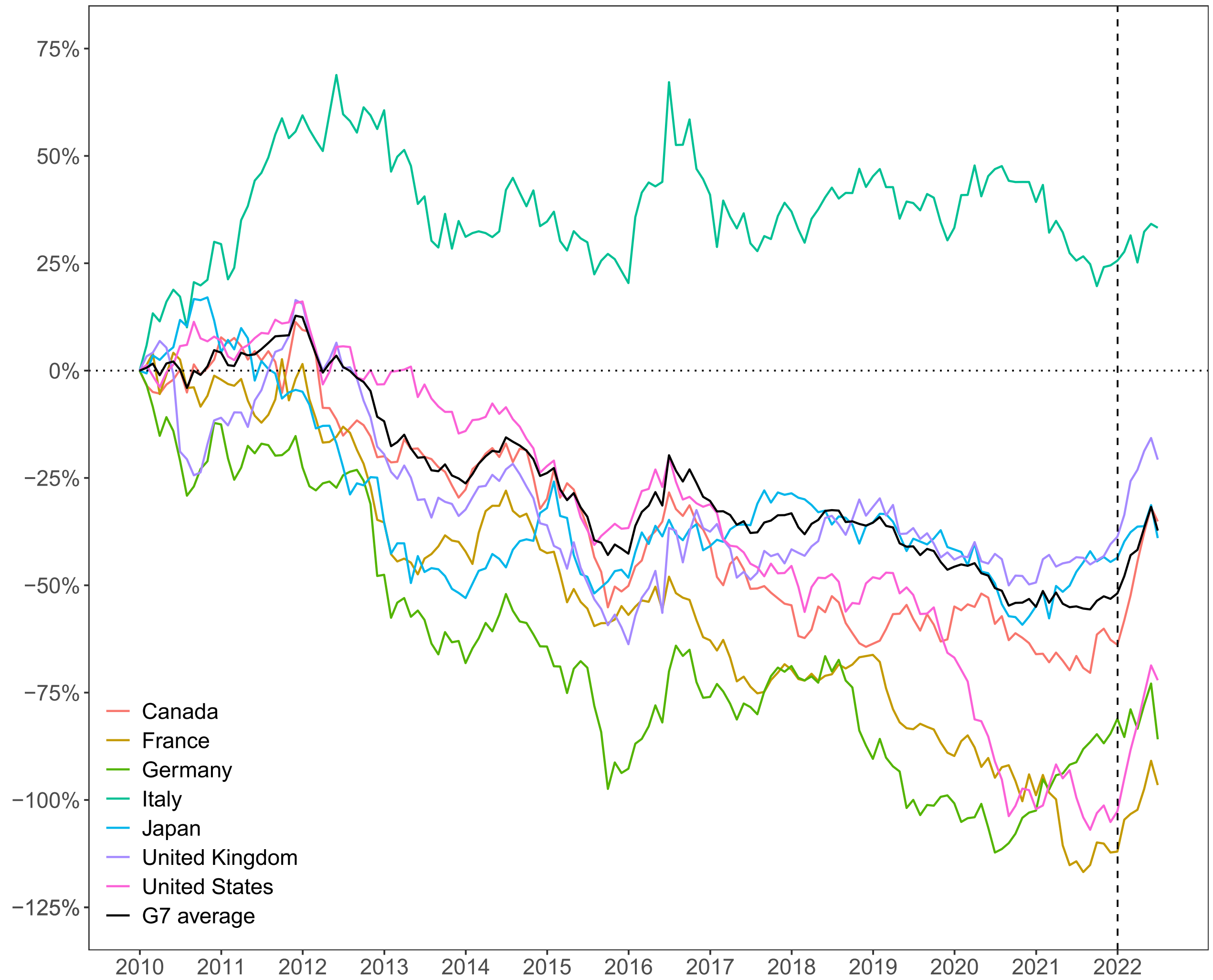
	Size-adjusted spread	Simple spread value-weighted (VW)	Simple spread equal-weighted (EW)
Correlations among spreads based on emission levels			
Size-adjusted spread	1		
Simple spread, VW	0.82	1	
Simple spread, EW	0.87	0.76	1
Correlations with spreads from literature			
Huij et al.	0.72	0.62	0.71
Pastor et al.	0.46	0.32	0.31
Correlations with spreads based on emission intensity (EI)			
Size-adjusted spread, EI	0.84	0.64	0.77
Simple spread, VW, EI	0.67	0.57	0.64
Simple spread, EW, EI	0.77	0.50	0.77

Results for G7

Brown vs. green performance — total emissions



Brown vs. green performance — emission intensity



Mean portfolio returns and Sharpe ratios

	Quintiles					BMG	Market
	1(green)	2	3	4	5 (brown)		
G7 avg., level of emissions							
Mean return	0.80	0.91	0.82	0.75	0.59	-0.20	1.05
	(1.84)	(2.21)	(1.98)	(1.83)	(1.54)	(-1.20)	(3.07)
Volatility	5.22	4.97	4.96	4.93	4.66	2.05	4.11
Sharpe ratio	0.15	0.18	0.16	0.14	0.12	-0.12	0.25
G7 avg., emission intensity							
Mean return	0.80	0.86	0.74	0.71	0.48	-0.33	1.05
	(1.71)	(2.10)	(2.01)	(1.86)	(1.16)	(-1.60)	(3.07)
Volatility	5.66	4.93	4.45	4.61	4.93	2.48	4.11
Sharpe ratio	0.14	0.17	0.16	0.15	0.09	-0.15	0.25

Average monthly returns

	Level of emissions			Emission intensity		
Factor/Portfolio	brown	green	BMG	brown	green	BMG
Canada	0.65	0.89	-0.24	0.46	0.84	-0.38
	(1.38)	(1.98)	(-0.93)	(0.93)	(1.86)	(-1.25)
France	0.31	1.06	-0.75	0.40	1.12	-0.71
	(0.64)	(1.91)	(-2.45)	(0.82)	(1.91)	(-2.43)
Germany	0.49	0.45	0.04	0.09	0.56	-0.47
	(0.85)	(0.96)	(0.11)	(0.16)	(1.05)	(-1.34)
Italy	0.64	0.15	0.49	0.68	0.35	0.33
	(1.16)	(0.19)	(0.99)	(1.18)	(0.44)	(0.71)
Japan	0.61	0.58	0.03	0.42	0.66	-0.24
	(1.84)	(1.50)	(0.14)	(1.15)	(1.53)	(-0.83)
United Kingdom	0.44	0.98	-0.54	0.47	0.65	-0.18
	(1.15)	(2.05)	(-1.91)	(0.96)	(1.19)	(-0.52)
United States	1.02	1.47	-0.45	0.79	1.45	-0.65
	(3.27)	(3.63)	(-1.84)	(2.11)	(3.38)	(-2.37)
G7 average	0.59	0.80	-0.20	0.48	0.80	-0.33
	(1.54)	(1.84)	(-1.20)	(1.16)	(1.71)	(-1.60)

Energy crisis of 2022 and the importance of shocks

- Substantial *brown outperformance* in 2022 mainly due to Ukraine war and global energy crisis
  - Consistent pattern across all G7 countries
  - High demand and profitability for oil and gas (energy) companies, and for defense sector
  - Green investor demand likely has declined: shifts in climate concerns/transition risks; sustainable investing is a luxury good (Bansal et al., 2021)
- Illustrates the empirical importance of shocks with short samples
  - Energy crisis partly reverses earlier gains of green assets
- Need long samples and/or methods to parse out shocks

Panel Regressions

Bridging the gap: from portfolios to panel regressions

- Why do panel regressions tend to find higher returns for brown stocks?
- Steps from portfolio results to panel estimates:
  - Starting point: Sample average of equal-weighted simple spread
  - Equivalent: Average monthly regressions of returns on *brown-green-indicator*
  - Panel regressions pool firm-month observations (different no. of firms/month)
  - Panel regressions add controls and (time/industry) fixed effects
  - Panel regressions typically use "global" measure instead of "cross-sectional" measure of greenness
- Following are panel regressions for the United States

Starting point: simple, EW spread returns

Factor/Portfolio	brown	green	BMG
Emission level	1.15	1.37	-0.22
	(2.93)	(3.06)	(-1.00)
Emission intensity	1.24	1.43	-0.18
	(2.65)	(3.25)	(-0.75)

Panel regressions using brown-green indicator

	Emission level			Emission intensity		
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	1.537***			1.535***		
	(0.05)			(0.05)		
Brown-green indicator	-0.130*	-0.146	-0.046	-0.062	-0.315***	-0.194*
	(0.07)	(0.10)	(0.11)	(0.08)	(0.10)	(0.11)
Observations	47418	47418	47418	47400	47400	47400
R^2	0.00	0.27	0.27	0.00	0.27	0.27
Controls	No	Yes	Yes	No	Yes	Yes
Time FEs	No	Yes	Yes	No	Yes	Yes
Industry FEs	No	No	Yes	No	No	Yes

Controls: Book-to-market, sales growth, log(PPEGT), leverage, last month return, last year return, log(market cap), ROE, investment-to-assets

Panel regressions using CO_2 emissions

	Emission level			Emission intensity		
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	2.775***			1.530***		
	(0.27)			(0.05)		
Emissions	-0.094***	-0.057*	-0.022	0.000	-0.019	0.054
	(0.02)	(0.03)	(0.04)	(0.06)	(0.05)	(0.06)
Observations	47388	47388	47388	47388	47388	47388
R^2	0.00	0.27	0.27	0.00	0.27	0.27
Controls	No	Yes	Yes	No	Yes	Yes
Time FEs	No	Yes	Yes	No	Yes	Yes
Industry FEs	No	No	Yes	No	No	Yes

Controls: Book-to-market, sales growth, log(PPEGT), leverage, last month return, last year return, log(market cap), ROE, investment-to-assets

What explains the differences with Bolton & Kacperczyk?

- Measuring greenness in the cross section of firms
  - We focus on the comparison across firms at each point in time
  - Brown-green indicators based on portfolio sort; could use “greenness rank”
  - Corresponds to investor/portfolio perspective
  - BK (and others) use panel regressions with emissions variable
- Publication lags
  - We use 18-month publication lag (common practice in empirical asset pricing)
  - BK show results for publication lag from 0 to 12 months—evidence for carbon premium gets weaker with length of lag

Conclusion

- Substantial green outperformance in U.S., extends to most G7 countries
  - Robust to choice of factor method or measure of greenness
  - Risk-adjusted outperformance smaller but still positive
  - Importance of portfolio perspective and publication lag
- No evidence for carbon premium (higher expected brown returns)
  - Brown stocks have lower *average realized* returns than green stocks
- Shocks unusually important because of short samples
  - Results consistent with initially small carbon premium and large, unexpected, persistent increase in climate change concerns favoring green stocks

Outlook: open issues and ongoing/future research

- How should we measure greenness?
- How does greenness change over time? Which firms try to become greener?
- How can we disentangle expected and realized returns?
  - Estimate surprise returns using changes in climate change concerns (Ardia et al., 2022; Pastor et al., 2022)
  - Event studies of political news (Ramelli et al., 2022) or climate policy news (work in progress)
- Climate risks priced in equity markets, but are they priced *correctly*?
  - What is the "right" carbon premium? Are brown stock prices low enough?
  - Model-based valuation of brown and green assets
  - Holy grail of climate finance?