Sectoral Green Risk Premia and Transition Risk

M. Bondesan[*,‡] A. Flori[†] L. Regis[*,‡] L. Trapin[||]

[*] University of Turin
[‡] Collegio Carlo Alberto
[†] Politecnico di Milano
[||] University of Bologna

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Motivation

- The Paris Agreement was signed in 2015 and aimed at limiting global warming to 1.5°C above pre-industrial levels.
- Objective: by 2050, the world must reach net zero emissions to avoid extreme weather and rising sea levels.
- Implementation path: full of uncertainty, ups and downs: e.g. withwdrawal of the U.S. from the agreement; regional differences (EU vs. US commitment...).
- Ex-ante commitments to reduce carbon emissions, and their uncertain implementation, generate **climate-transition risk** for corporations which derives both from their own environmental performance, but also, more external factors, such as regulation and connected firms' compliance to it.

Research Questions and related literature

- **What is the impact of firms' environmental performance on (their own) equity returns?** Bolton and Kacperczyk (2021), Bolton and Kacperczyk (2023), Aswani et al. (2024), Zhang (2025),
- **Do investors price climate-transition risk?** Lots of papers, among which theoretical papers (Pástor et al. (2021), (Alessi et al. (2021), Lioui and Tarelli (2022)), green vs. brown portfolios approaches.
- **Results**: negative market price of risk $\implies$ "greener firms" are a hedge against climate-related risks; "brown firms" are riskier (since Edmans, 2011) and investors need to be compensated to hold them; empirically, results depend on the measures, datasets,...

Contribution of our PNRR project

- Idea: transition risk effects come (also) from the exposure to the environmental performance of other firms/the economy (scope3 emissions, Coqueret and Tran (2022),...)
- In this presentation: explore whether these exposures (measured in a particular way) constitute a risk and are priced in the equity market... using standard asset pricing factor models and methods (Gagliardini et al. (2016)).
  - study the behavior of a portfolio ("factor") that incorporates the sectoral dimension by combining sectoral green vs. brown portfolios using information from the input-output tables, disentangling direct and indirect effects of changes in greenness;
- Within the project, more generally, we study whether the environmental performance of/shocks to the supply chain influence/s directly firms' profitability/stock returns.
- Take a European perspective (see De Angelis and Monasterolo (2024)).

Systemic Green Factor

- Our main object of study is a portfolio, which is a weighted average of green vs. brown portfolios that are:
  1. **sectoral**;
  2. **long-short: sorted into quartiles using an environmental performance indicator**;
  3. **value-weighted**;
  4. **combined using output multipliers as weights**;
- We treat this portfolio as a factor, aimed at capturing economy-wide (systemic) exposure to transition risk.
- Sectoral green vs. brown portfolios capture the relative effect of being greener in a specific sector; output multipliers capture sectoral effects on total output.
- We refer to the factor as to the Systemic Green vs. Brown Factor.

Output Multipliers (EU 28)

Preview of the results

- We construct our proposed portfolio for a sample of European large listed companies.
- Our factor displays a significant negative α, after controlling for standard Fama-French factors.
- Firms' stock returns display a negative significant β wrt our Systematic factor.
- βs change over time (with a recent decreasing trend).
- Although the associated risk factor is significantly priced in the cross-section of returns in 2011-2022, there is evidence of strong period and sectoral effects.

Dataset

- We focus on the constituents of the EUROSTOXX600 index, see (De Angelis and Monasterolo (2024)), excluding sector K, and use monthly data on returns from January 2011 to December 2022.
- Portfolios are sorted into quartiles using the Refinitiv ESGC Score (annually updated) ("Robustness": emissions, emission intensity, but data limitations!).

Eurostat Industry	Description	Distinct Security	Panel Observations
C	Manufacturing	195	26140
D	Energy and Electricity	23	3177
F	Construction	18	2550
G	Wholesale and retail trade	43	5663
H	Transporting and storage	14	1814
J	Information and communication	49	6041
K	Financial and insurance activities	99	13106
L	Real estate activities	27	3559
M	Professional	17	2353
Total		485	64403

ESG Combined Score ESG Score ESG Grades

Green vs. brown portfolios

Descriptive Statistics

Factor/Portfolio	Mean	Std	Kurt	Skew	Sharpe
Manufacturing	-0.18	3.54	3.26	0.20	-0.02
Energy	0.49	4.51	4.02	-0.45	0.14
Construction	0.03	5.25	4.84	-0.15	0.03
Wholesale and retail trade	-0.52	6.17	9.76	-1.50	-0.07
Transport	-0.54	7.37	4.46	-0.11	-0.06
I & C	-2.89	8.94	4.51	-0.60	-0.31
Real Estate	-0.46	4.25	4.59	-0.41	-0.08
Professional	-0.42	7.32	4.04	-0.25	-0.04
Systemic Green vs. Brown	-0.39	1.63	3.16	-0.13	-0.24

Correlation Matrix: ESGC Score
2011-14 2015-18 2019-22 Descriptive statistics: FF factors

Linear Asset-Pricing Factor Model

1. The tool we use in our analysis is the linear asset pricing factor model.

$$\left(r_{i,t} - r_t^f\right) = a + \sum_{k=1}^{K} b_k f_{t,k} + \varepsilon_{i,t}.$$

where:

- $r_{i,t} - r_t^f$ is the return of a portfolio/stock in excess of the risk-free rate[1];
- a is an intercept, b_k are factor loadings, $f_{t,k}$ represents the return of the k-th "observable factor" with $k = 1, \dots, K$, at time $t = 1, \dots, T$, $\varepsilon_{i,t}$ is an error term.
  1. $r_{i,t} - r_t^f = f_{t,SG}$;
  2. $r_{i,t}$ are the returns of firms in the EUROSTOXX 600 and $f_{t,k}$'s are Fama-French factors and the Systemic Green vs. Brown factors.

[1] The European risk-free rate is constructed as a combination of the Eonia rate, until 2019-09, and STR rate from 2019-10 onwards.

Baseline Factor Models

Model	Reference	Abbreviation	Factors	K
Six-Factor	Fama and French (2015); Carhart (1997)	6FF	$f_{m-\text{EUrf},t}$, $f_{smb,t}$, $f_{hml,t}$, $f_{rmw,t}$, $f_{cma,t}$, $f_{wml/mom,t}$	6
Five-Factor	Fama and French (2015)	5FF	$f_{m-\text{EUrf},t}$, $f_{smb,t}$, $f_{hml,t}$, $f_{rmw,t}$, $f_{cma,t}$,	5
Three-Factor	Fama and French (1993)	3FF	$f_{m-\text{EUrf},t}$, $f_{smb,t}$, $f_{hml,t}$,	3
Capital Asset Pricing	Sharpe (1964); Lintner	CAPM	$f_{m-\text{EUrf},t}$	1

Baseline models

Fama-French factors

Systemic Green vs. Brown portfolio excess return

Factor	Green	Brown	Green vs. Brown
6FF model			
$\hat{\alpha}$	0.311 **	0.595 ***	-0.284 **
$\hat{\beta}_{m-EUrf}$	0.496 ***	0.577 ***	-0.081 **
$\hat{\beta}_{smb}$	-0.219 ***	0.067	-0.286 ***
$\hat{\beta}_{hml}$	0.055	-0.000	0.056
$\hat{\beta}_{rmw}$	0.375 ***	0.408 **	-0.033
$\hat{\beta}_{cma}$	0.061	-0.034	0.095
$\hat{\beta}_{wml/mom}$	-0.061	-0.064	0.003
R^2_{adj}	0.7407	0.7048	0.1703

- Significant negative α.
- Brown portfolio is more exposed to the market; Green is negatively exposed to small minus big (in line with other similar greenness factors, e.g. Alessi et al. (2021)).

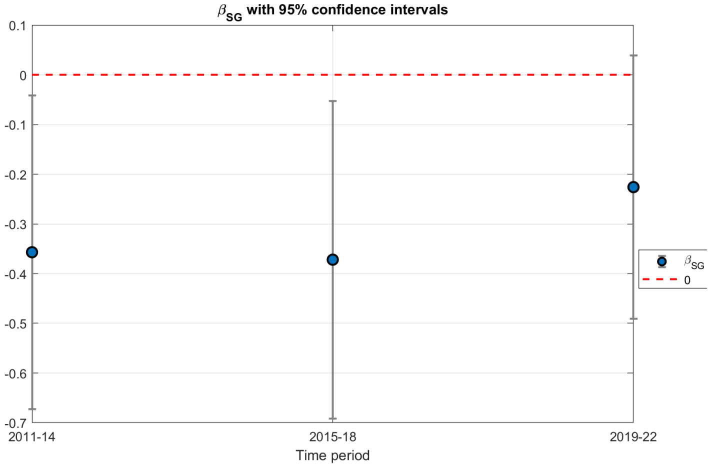
Beta estimates

FF factors and Systemic Green vs. Brown, 2011-2022

	CAPM	3FF	5FF	6FF
$\hat{\alpha}$	0.494 ***	0.499 ***	0.424 **	0.548 ***
$\hat{\beta}_{SG}$	-0.321 ***	-0.317 ***	-0.308 ***	-0.305 ***
$\hat{\beta}_{m-EUrf}$	0.791 ***	0.785 ***	0.762 ***	0.741 ***
$\hat{\beta}_{smb}$		0.043	0.040	0.059
$\hat{\beta}_{hml}$		0.028	0.234	0.114
$\hat{\beta}_{rmw}$			0.287	0.260
$\hat{\beta}_{cma}$			-0.171	-0.076
$\hat{\beta}_{wml/mom}$				-0.140
R^2_{adj}	0.2211	0.2212	0.2223	0.2239

- SEs are clustered by time/firm.
- Returns display significant negative β with the Systemic Green Factor across the whole period.
- The value of β decreases in the last period (2019-22).

Evolution of βs over time



Risk-Premium Estimation

1. To try and assess whether our factor is priced in the cross-section of stock returns, we follow Gagliardini et al. (2016)'s two-stage procedure, with constant β's. We set a trimming threshold to 25% of the total observations in the first-pass.

   A) First-pass - Time-Series OLS, $\hat{\beta} = (X'X)^{-1} X'Y$:

   $$\left(r_{i,t} - r_t^f\right) = a + \sum_{k=1}^{K} b_k f_{t,k} + \varepsilon_{i,t}, \quad \text{where } k = 1, \ldots, K, \text{ and } t = 1, \ldots, T.$$

   B) Repeated $\forall$ asset $i = 1, \ldots, N \implies \hat{a}_i$ and $\hat{b}_{i,k}$

Risk-Premium Estimation/2

- (C) Second-pass - Cross-Section with WLS to address heteroscedasticity, $\hat{\beta} = (X'WX)^{-1} X'WY$, where W is a diagonal matrix, $\omega_i = \frac{1}{\sigma_i^2}$, and σ_i^2 is the residuals' estimated variance:

$$\hat{a}_i = \alpha + \sum_{k=1}^{K} \nu_k \hat{b}_{i,k} + \varepsilon_i.$$

$\Longrightarrow$ $\hat{\nu}_k$ is a factor-specific cross-sectional estimated parameter, with

$$CI_{\hat{\nu}_k}^{corrected} = \left(\hat{\nu}_k - \frac{1}{T}\hat{B}_{\nu,k}\right) \pm z\frac{\hat{\sigma}_{\nu,k}}{\sqrt{NT}},$$ where $\hat{B}_{\nu,k}$ is the bias vector.

- (D) Bias-corrected risk-premia:

$\hat{\lambda}_k = \left(\hat{\nu}_k - \frac{1}{T}\hat{B}_{\nu,k}\right) + \mathbb{E}\left[f_{t,k}\right]$, where $\mathbb{E}\left[f_{t,k}\right]$ is the factor's expected return, with

$$CI_{\hat{\lambda}_k} = \hat{\lambda}_k \pm z\frac{\hat{\sigma}_{f,k}^{\text{HAC(Newey-West)}}}{\sqrt{T}}.$$

Risk-Premium Results

Full period 2011-2022

		90% CI		95% CI		99% CI	
Factor	Estimate	90% Lower	90% Upper	95% Lower	95% Upper	99% Lower	99% Upper
$\hat{\lambda}_{m-EUrf}$	16.681 ***	14.360	19.002	13.915	19.447	13.046	20.316
$\hat{\lambda}_{smb}$	0.462	-0.345	1.269	-0.500	1.424	-0.802	1.726
$\hat{\lambda}_{hml}$	-7.495 ***	-8.956	-6.034	-9.236	-5.755	-9.783	-5.208
$\hat{\lambda}_{rmw}$	3.591 ***	2.771	4.411	2.613	4.568	2.306	4.875
$\hat{\lambda}_{cma}$	-3.540 ***	-4.325	-2.755	-4.475	-2.605	-4.769	-2.311
$\hat{\lambda}_{wml/mom}$	3.537 ***	2.040	5.034	1.754	5.321	1.193	5.881
$\hat{\lambda}_{SG}$	-1.356 ***	-2.159	-0.553	-2.313	-0.399	-2.613	-0.099

Time-period 2011-2022. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively.

$\Longrightarrow$ Negative and significant risk premium in the cross-section.

- Risk premium seems to disappear over time.

Risk-Premium Results

2011-2014

		90% CI		95% CI		99% CI	
Factor	Lambda	90% Lower	90% Upper	95% Lower	95% Upper	99% Lower	99% Upper
$\hat{\lambda}_{m-EUrf}$	12.585***	8.542	16.628	7.768	17.402	6.254	18.916
$\hat{\lambda}_{smb}$	0.746	-0.698	2.191	-0.974	2.467	-1.515	3.008
$\hat{\lambda}_{hml}$	1.226	-0.977	3.428	-1.399	3.850	-2.223	4.674
$\hat{\lambda}_{rmw}$	-2.074***	-3.537	-0.612	-3.817	-0.331	-4.365	0.216
$\hat{\lambda}_{cma}$	3.353***	2.430	4.276	2.254	4.452	1.908	4.798
$\hat{\lambda}_{wml/mom}$	7.681***	5.046	10.316	4.541	10.821	3.555	11.807
$\hat{\lambda}^{LS}_{synth}$	-5.995***	-7.034	-4.955	-7.233	-4.756	-7.623	-4.367

Time-period 2011-2014. *, ** and * denote significance at 1%, 5% and 10% levels, respectively.**

Risk-Premium Results

2015-2018

		90% CI		95% CI		99% CI	
Factor	Lambda	90% Lower	90% Upper	95% Lower	95% Upper	99% Lower	99% Upper
$\hat{\lambda}_{m-EUrf}$	11.335***	8.386	14.284	7.821	14.849	6.716	15.954
$\hat{\lambda}_{smb}$	0.447	-0.662	1.556	-0.874	1.769	-1.290	2.184
$\hat{\lambda}_{hml}$	-9.457***	-11.205	-7.710	-11.540	-7.375	-12.195	-6.720
$\hat{\lambda}_{rmw}$	6.095***	4.727	7.464	4.465	7.726	3.953	8.238
$\hat{\lambda}_{cma}$	-5.230***	-6.236	-4.224	-6.429	-4.032	-6.805	-3.655
$\hat{\lambda}_{wml/mom}$	6.782***	4.979	8.586	4.633	8.931	3.958	9.606
$\hat{\lambda}^{LS}_{synth}$	-2.253***	-3.343	-1.163	-3.552	-0.955	-3.960	-0.54

Bias-Corrected λ (annualized) with 90%, 95% and 99% CIs

Time-period 2015-2018. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively.

Risk-Premium Results

2019-2022

		90% CI		95% CI		99% CI	
Factor	Lambda	90% Lower	90% Upper	95% Lower	95% Upper	99% Lower	99% Upper
$\hat{\lambda}_{m-EUrf}$	15.098***	10.269	19.927	9.344	20.852	7.536	22.661
$\hat{\lambda}_{smb}$	0.568	-1.013	2.150	-1.316	2.453	-1.908	3.045
$\hat{\lambda}_{hml}$	-11.028***	-14.376	-7.681	-15.017	-7.040	-16.270	-5.787
$\hat{\lambda}_{rmw}$	6.331***	4.929	7.733	4.661	8.002	4.136	8.527
$\hat{\lambda}_{cma}$	-5.317***	-7.198	-3.436	-7.559	-3.076	-8.263	-2.372
$\hat{\lambda}_{wml/mom}$	-2.094	-5.251	1.063	-5.855	1.668	-7.037	2.850
$\hat{\lambda}^{LS}_{synth}$	-0.437	-2.074	1.200	-2.388	1.513	-3.001	2.126

Time-period 2019-2022. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively.

Sectoral Analysis: Comparing Risk-Premia across Sectors

- We repeat the risk premium estimation exercise for the sub-samples of firms belonging to the different sectors, finding sectoral heterogeneity.

Industry	**Description**	$\hat{\lambda}_{SG}$
C	Manufacturing	-1.578 ***
D	Energy and Electricity	2.773 ***
F	Construction	-2.127 ***
G	Wholesale and retail trade	0.940 *
J	Information and communication	0.050

Risk-Premium Estimates across Sectors (6F model) over the Full-Period 2011-2022

- Positive and significant risk premium for energy companies! Exposure to Green is compensated!

Conclusions

- Sectoral green vs. brown factors can capture interesting heterogeneity.
- Our estimates point to a negative (average) linear relation between stock returns and our Systemic factor and to a negative risk premium in the cross-section.
- Risk premium seems to disappear over time: settling regulation reduces uncertainty? This is supported by an analysis on the sub-sample of firms participating to the EU-ETS market, which shows an insignificant risk premium, in particular in the period 2015-18, characterized by stability in regulation.
- Next steps: enlarging the dataset, direct vs. indirect effects; construction of a factor based on the environmental performance of the supply chain.

Thank You

Thank you for your attention!!!

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Background Slides

Background Slides

The EU Emissions Trading System (EU ETS)

- Requires polluters to pay for their greenhouse gas (GHG) emissions.
- Launched in 2005, it is the world's first carbon market and among the largest ones globally. Effective in 2015 (Phase III).
- Helps bring overall EU emissions down while generating revenues to finance the green transition.
- "Cap and trade" principle: the cap is expressed in emission allowances with one allowance giving right to emit one tonne of CO2 eq (i.e., carbon dioxide equivalent). Allowances are sold in auctions and may be traded.
- As the cap decreases annually in line with the EU's climate target, so does the supply of allowances to the EU carbon market.
- Operates in all EU countries plus Iceland, Liechtenstein and Norway, and is linked to the Swiss ETS (since 2020).
- Source: European Commission / Climate Action

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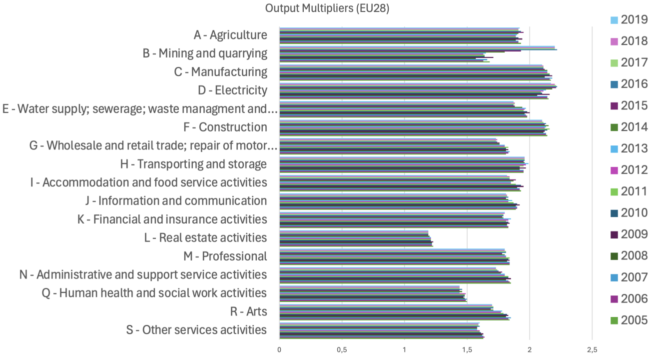
Output Multipliers (Eurostat Input-Output Tables)



Output Multipliers (EU 28)

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ESG Combined Score

ESG performance score discounted by negative media stories (controversies)

ESG Combined Score. Source: LSEG Refinitiv's ESG data and scores.

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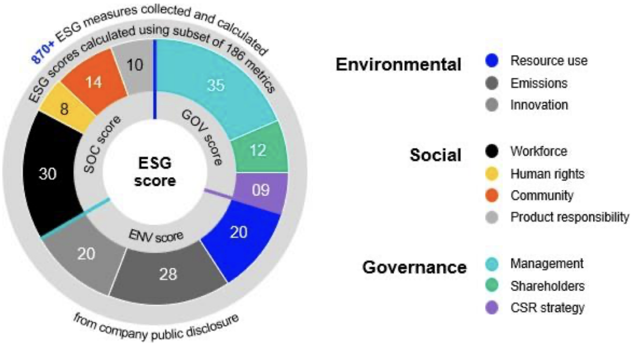
ESG Score



ESG Score. Source: Environmental, Social and Governance scores from LSEG

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ESG Grades

Score range	Grade	Description
0.0 <= score <= 0.083333	D -	'D' score indicates poor relative ESG performance and insufficient degree of transparency in reporting material ESG data publicly.
0.083333 < score <= 0.166666	D	
0.166666 < score <= 0.250000	D +	
0.250000 < score <= 0.333333	C -	'C' score indicates satisfactory relative ESG performance and moderate degree of transparency in reporting material ESG data publicly.
0.333333 < score <= 0.416666	C	
0.416666 < score <= 0.500000	C +	
0.500000 < score <= 0.583333	B -	'B' score indicates good relative ESG performance and above- average degree of transparency in reporting material ESG data publicly.
0.583333 < score <= 0.666666	B	
0.666666 < score <= 0.750000	B +	
0.750000 < score <= 0.833333	A -	'A' score indicates excellent relative ESG performance and high degree of transparency in reporting material ESG data publicly.
0.833333 < score <= 0.916666	A	
0.916666 < score <= 1	A +	

ESG laggards

ESG leaders

ESG Grades. Source: Environmental, Social and Governance scores from LSEG

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Fama-French Factors

Baseline models

1. Mkt-RF: Market excess return as market minus risk-free return $\Longrightarrow$ **CAPM**
2. SMB (Small Minus Big market capitalization): Average return of the difference between the nine small and big stock portfolios
3. HML (High Minus Low book-to-market ratio): Average return of the difference between the two value and growth portfolios $\Longrightarrow$ **3FF model**
4. RMW (Robust Minus Weak): Average return of the difference between the two robust and weak operating profitability portfolios
5. CMA (Conservative Minus Aggressive): Average return of the difference between the two conservative and aggressive investment portfolios $\Longrightarrow$ **5FF model**
6. WML/MOM (Winners minus Losers or Momentum): Equal-weight average return of the difference between the two winner and loser regional portfolios $\Longrightarrow$ **6FF model**

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Factor Analysis

Descriptive Statistics: Fama-French Factors (Baseline)

Factor	Mean	Std	Kurt	Skew	Sharpe	Tstat
$f_{m-\text{EUrf},t}$	0.49	4.93	3.82	-0.25	0.12	1.48
$f_{smb,t}$	0.10	1.67	3.35	-0.01	0.13	1.56
$f_{hml,t}$	-0.13	2.93	6.25	0.60	-0.00	-0.05
$f_{rmw,t}$	0.35	1.66	3.35	-0.51	0.28	3.40
$f_{cma,t}$	-0.11	1.53	4.01	0.08	0.01	0.07
$f_{wml/mom,t}$	0.76	3.27	10.52	-1.31	0.27	3.21

Descriptive statistics for the returns from January 2011 to December 2022 of Fama-French factors (baseline).
Note:
The table reports the monthly mean (Mean) and standard deviation (Std), kurtosis (Kurt) and skewness (Skew), the Sharpe ratio (Sharpe), and the t-stat (Tstat) for the null hypothesis that the mean return is zero.

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Factor Analysis

Descriptive Statistics: Factors 2011-14

Factor	Mean	Std	Kurt	Skew	Sharpe	Tstat
f_t^C	-0.74	3.15	4.63	0.74	-0.24	-1.64
f_t^D	0.38	4.05	2.46	0.46	0.10	0.66
f_t^F	-1.25	4.79	2.53	0.12	-0.26	-1.81
f_t^G	0.57	4.73	2.76	0.11	0.12	0.84
f_t^H	-0.44	5.80	2.35	-0.16	-0.08	-0.52
f_t^J	-0.95	4.12	1.93	-0.16	-0.23	-1.59
f_t^K	0.40	4.72	2.57	-0.08	0.08	0.59
f_t^L	0.21	3.22	3.23	-0.23	0.06	0.44
f_t^M	-0.33	5.04	2.52	0.05	-0.07	-0.46
f_t^{SG}	-0.23	1.22	2.11	0.26	-0.19	-1.29

Descriptive statistics for the returns from January 2011 to December 2014 of sectoral green vs. brown and systemic portfolio.

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Factor Analysis

Descriptive Statistics: Factors 2015-18

Factor	Mean	Std	Kurt	Skew	Sharpe	Tstat
f_t^C	0.09	3.77	2.44	0.29	0.03	0.17
f_t^D	0.66	3.92	3.59	-0.72	0.17	1.17
f_t^F	1.53	5.13	3.49	0.47	0.30	2.07
f_t^G	-1.19	4.20	2.52	0.09	-0.28	-1.97
f_t^H	-0.94	6.90	1.80	-0.05	-0.14	-0.94
f_t^J	-1.97	6.58	2.95	0.40	-0.30	-2.08
f_t^K	-0.05	3.19	2.54	0.23	-0.02	-0.11
f_t^L	-0.50	4.13	3.30	-0.43	-0.12	-0.84
f_t^M	-1.22	6.57	2.94	-0.46	-0.19	-1.28
f_t^{SG}	-0.33	1.41	2.71	0.09	-0.24	-1.65

Descriptive statistics for the returns from January 2015 to December 2018 of sectoral green vs. brown and systemic portfolios.

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Factor Analysis

Descriptive Statistics: Factors 2019-22

Factor	Mean	Std	Kurt	Skew	Sharpe	Tstat
f_t^C	0.11	3.66	3.23	-0.37	0.03	0.21
f_t^D	0.43	5.48	3.79	-0.64	0.08	0.55
f_t^F	-0.20	5.53	6.53	-0.89	-0.04	-0.25
f_t^G	-0.95	8.60	6.89	-1.59	-0.11	-0.77
f_t^H	-0.24	9.14	4.61	-0.15	-0.03	-0.18
f_t^J	-5.74	13.03	2.37	-0.07	-0.44	-3.06
f_t^K	0.03	7.05	7.81	-1.64	0.00	0.03
f_t^L	-1.09	5.16	4.21	-0.18	-0.21	-1.46
f_t^M	0.29	9.66	3.12	-0.30	0.03	0.21
f_t^{SG}	-0.62	2.13	2.4	-0.05	-0.29	-2

Descriptive statistics for the returns from January 2019 to December 2022 of sectoral green vs. brown and systemic portfolio.

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Factor Analysis

Descriptive Statistics: Fama-French factors 2011-2022

Factor	Mean	Std	Kurt	Skew	Sharpe	Tstat
$f_{m-\text{EUrf},t}$	0.66	4.94	3.75	-0.31	0.13	1.59
$f_{smb,t}$	0.10	1.67	3.30	-0.01	0.06	0.72
$f_{hml,t}$	-0.13	2.93	6.16	0.60	-0.04	-0.53
$f_{rmw,t}$	0.35	1.66	3.31	-0.51	0.21	2.56
$f_{cma,t}$	-0.11	1.52	4.01	0.07	-0.07	-0.84
$f_{wml/mom,t}$	0.76	3.27	10.37	-1.30	0.23	2.78

Descriptive statistics for the returns from January 2011 to December 2022 of Fama-French portfolios.

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Factor Analysis

Descriptive Statistics: Correlation Matrix (ESGC score criterion)

	$f_{SG,t}$	$f_{m,t}$	$f_{smb,t}$	$f_{hml,t}$	$f_{rmw,t}$	$f_{cma,t}$	$f_{wml/mom,t}$
$f_{SG,t}$	1.00						
$f_{m,t}$	-0.23	1.00					
$f_{smb,t}$	-0.36	0.11	1.00				
$f_{hml,t}$	0.10	0.28	-0.03	1.00			
$f_{rmw,t}$	-0.08	-0.20	-0.04	-0.83	1.00		
$f_{cma,t}$	0.25	-0.15	-0.23	0.71	-0.55	1.00	
$f_{wml/mom,t}$	0.04	-0.47	-0.01	-0.53	0.41	-0.15	1.00

Correlation matrix for the returns from January 2011 to December 2022 on various portfolios and factors. Value-weighted portfolios are constructed according to the ESGC score criterion.

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Pooled OLS Results: Sector C - Manufacturing

Baseline

	CAPM	3FF	5FF	6FF
$\hat{\alpha}$	0.854 ****	0.803 ****	0.710 ****	0.798 ****
$\hat{\beta}_m$	0.788 ****	0.818 ****	0.777 ****	0.761 ****
$\hat{\beta}_{smb}$		0.103 ****	0.087 ***	0.101 ****
$\hat{\beta}_{hml}$		-0.213 ****	0.091 **	-0.002
$\hat{\beta}_{rmw}$			0.390 ****	0.369 ****
$\hat{\beta}_{cma}$			-0.277 ****	-0.202 ****
$\hat{\beta}_{wml/mom}$				-0.106 ****
R^2_{adj}	0.2033	0.2087	0.2098	0.2107

Benchmark estimates of monthly excess returns on Fama-French factors $\hat{\beta}_i$, where $i = \{m, smb, hml, rmw, cma, wml/mom\}$, estimated via pooled OLS. Time-period 2011-2022. Sector C - Manufacturing. ****, ***, ** and * denote significance at 0.1%, 1%, 5% and 10% levels, respectively, and R^2_{adj} indicates the adjusted R-squared.

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Pooled OLS Results: Sector C - Manufacturing

Synthetic Long-Short (ESGC score criterion)

	CAPM	3FF	5FF	6FF
$\hat{\alpha}$	0.750 ****	0.733 ****	0.641 ****	0.728 ****
$\hat{\beta}^{LS}_{synth}$	-0.302 ****	-0.235 ****	-0.229 ****	-0.228 ****
$\hat{\beta}_{m}$	0.761 ****	0.797 ****	0.758 ****	0.743 ****
$\hat{\beta}_{smb}$		0.022	0.011	0.025
$\hat{\beta}_{hml}$		-0.190 ****	0.105 ***	0.012
$\hat{\beta}_{rmw}$			0.387 ****	0.366 ****
$\hat{\beta}_{cma}$			-0.260 ****	-0.185 ***
$\hat{\beta}_{wml/mom}$				-0.106 ****
R^2_{adj}	0.2067	0.2105	0.2115	0.2124

Estimates of monthly excess returns on the synthetic factor, $\hat{\beta}_{synth}$, and Fama-French factors, $\hat{\beta}_i$, where $i = \{m, smb, hml, rmw, cma, wml/mom\}$, estimated via pooled OLS. Value-weighted long-short portfolios (green-brown), constructed according to the ESGC score criterion. Time-period 2011-2022. Sector C - Manufacturing. ****, ***, ** and * denote significance at 0.1%, 1%, 5% and 10% levels, respectively, and R^2_{adj} indicates the adjusted R-squared.

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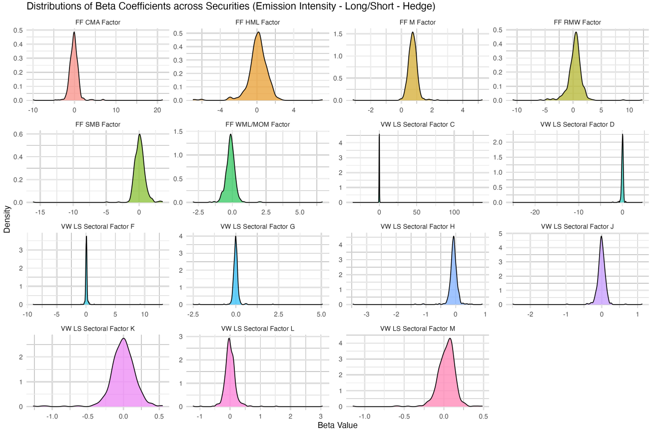
Factor Exposures (Individual Securities - Emission Intensity)

Time-Series Regressions of Excess Returns on Sectoral and Fama-French Factors



Beta distributions for Emission Intensity criterion, long-short (hedge)

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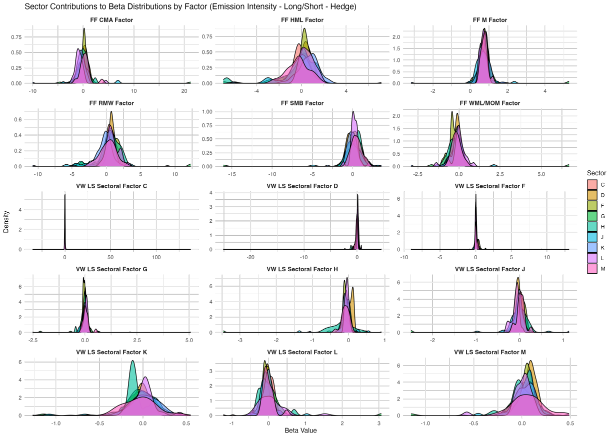
Factor Exposures by Sector - Emission Intensity

Time-Series Regressions of Excess Returns on Sectoral and Fama-French Factors



Beta distributions by sector for Emission Intensity criterion, long-short (hedge)

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Risk-Premium Results

Synthetic and Fama-French factors - Long/Short (Emission Intensity) - Full period 2011-2022 (Excluding Financial Firms)

		90% CI		95% CI		99% CI	
Factor	Lambda	90% Lower	90% Upper	95% Lower	95% Upper	99% Lower	99% Upper
$\hat{\lambda}_{m-EUrf}$	14.742 ***	12.421	17.063	11.977	17.508	11.107	18.377
$\hat{\lambda}_{smb}$	0.515	-0.292	1.322	-0.447	1.477	-0.749	1.779
$\hat{\lambda}_{hml}$	-9.772 ***	-11.233	-8.311	-11.513	-8.031	-12.060	-7.484
$\hat{\lambda}_{rmw}$	4.886 ***	4.066	5.706	3.909	5.864	3.602	6.171
$\hat{\lambda}_{cma}$	-4.002 ***	-4.786	-3.217	-4.937	-3.067	-5.231	-2.773
$\hat{\lambda}_{wml/mom}$	0.454	-1.043	1.951	-1.329	2.238	-1.890	2.799
$\hat{\lambda}^{LS}_{synth}$	5.120 ***	4.213	6.027	4.040	6.201	3.700	6.541

Bias-Corrected λ (annualized) with 90%, 95% and 99% CIs

Estimated annualized risk premia λ for factors $k = \{$m-EUrf, smb, hml, rmw, cma, wml/mom, g$\}$, for value-weighted long-short portfolios (green-brown), constructed according to the **Emission intensity** criterion. **Time-period 2011-2022**. **Excluding financial firms (Eurostat sector K)**. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively.

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