ESG Policy Uncertainty*

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Abstract

We examine whether the uncertainty related to developments in environmental, social and governance (ESG) regulation is reflected in asset prices. We proxy the sensitivity of firms to ESG regulation uncertainty by the disparity between the components of their ESG ratings. Firms with high ESG disparity have a higher option-implied cost of protection against downside tail risk. The impact of the misalignment across the different dimensions of the ESG score is distinct from that of the level of the ESG score itself. Aggregate downside risk bears a negative price for firms with low ESG disparity.

JEL Classification: G12, G18, G32

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1 Introduction

There has been an increasing number of environmental, social and governance (ESG) related regulatory developments around the world.[1] In the last decade, the volume of ESG topics in US regulatory documents has increased dramatically, especially after the adoption of the Paris agreement in 2015.[2] This surge in regulatory activity has been marked by significant changes and rollbacks, as policy turnarounds have been prompted by societal pressure, political motives or short-term economic concerns.[3] As a result, ESG-related regulation has been particularly volatile, reflecting a dynamic and evolving policy landscape. In turn, both firms and investors in their financing or investment decisions are faced with uncertainty about how new, updated, and proposed ESG-related regulation will shape the regulatory framework in the future.

In this paper, we explore the uncertainty that stems from the development of ESG regulations and the firm's ability to manage its exposure to this regulatory development. We proxy the latter by the observed disparity across the three dimensions of a firm's ESG standing: its environmental, social and governance performance. We conjecture that the degree of divergence across different aspects of a firm's ESG qualities reflects its ability to adapt to ESG regulatory requirements or its vulnerability to unexpected ESG policy changes, as perceived by the market. We therefore consider the deviation in a firm's performance across its "E", "S" and "G" ratings, which we term *ESG disparity*, as a measure of the firm's exposure to unexpected changes in ESG regulation. Although a firm's ESG rating could also be

[1] At the global level, there exist the International Sustainability Standards Board (ISSB), the Carbon Disclosure Project (CDP), the Climate Disclosure Standard Board (CDSB), the Global Reporting Initiative (GRI), the Task Force on Climate-related Financial Disclosures, and the Value Reporting Foundation, among others. In Europe, there is the Corporate Sustainability Reporting Directive (CSRD), the Sustainable Finance Disclosure Regulations (SFDR), and the Green/EU taxonomy, among others. In mainland China, there is the EU-China Common Ground Taxonomy (CGT), and the China Securities Regulatory Commission (CSRC) ESG risk disclosure rules. In the US, there are the following proposed regulations related to ESG: the SEC climate-related disclosure rules, the Climate Risk Disclosure Act, and the ESG Disclosure Simplification Act. For example, the European Commission has delayed the implementation of the SFDR several times, contributing to the uncertainty with respect to the final regulation. Once in place as of January 2023, the SFDR has outlined a set of 14 core indicators comprising Level 2's mandatory reporting template with a focus on adverse environmental and social impacts. However, the implementation of Level 2 requirements has raised confusion among investors, leading the European Supervisory Authorities to call for the European Commission to clarify what defines a sustainable investment. See https://www.esginvestor.net/sfdr-level-2-uncertainty-unnerves-managers/

[2] See `https://eqm.ai/wp-content/uploads/2023/05/2023-05-25-ESG-Regs-Report-2023-2.pdf`

[3] For instance, the U.S. withdrew from the Paris Accord in 2017, and rejoined in 2021.

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indicative of the firm's ability to address changes in ESG regulation, as arguably higher-rated firms would be less exposed to new or changed regulation compared to lower-rated peers, the level of the ESG rating does not reveal the degree to which a higher rating on one component of the score compensates for a lower rating on another component. Therefore, we argue that it is important to consider the divergence within components of a firm's ESG rating.

As investors cannot fully anticipate the nature or scope of new ESG-related policies, asset prices can be affected as investors learn about the costs of these new policies. In this paper, we investigate whether ESG policy uncertainty—at the aggregate economy level and at the firm level—is priced in the option market. Specifically, we explore whether the aggregate cost of protection against downside tail risk that investors require on the market varies with the ESG regulatory uncertainty they face. At the firm level, we examine the relationship between the degree of firms' exposure to ESG regulatory uncertainty and the cost of option protection against the occurrence of tail events on the downside. We also study the pricing of the uncertainty related to a firm's ESG performance to determine whether investors pay a premium to hedge against this risk.

In a first step, we examine whether uncertainty related to ESG regulation developments is reflected in the options market. In the model of Pastor and Veronesi (2013), investors are uncertain whether the current government policy will change or not. Potential new policies are heterogeneous ex ante, as different policies are expected to have different impacts on firms. When choosing a new policy, the government maximizes investors' welfare, while also considering non-economic objectives, reflected in the political costs of adopting a new policy. These political costs are uncertain, and as investors learn about them by observing political signals, they revise their expectations about the likelihood that future policies will be chosen. Stock prices are affected because political uncertainty leads investors to demand compensation. In addition, firms that are likely to be impacted more by changes in government policy command an additional premium for investors.

We focus here on the specific case of ESG regulatory policies within the broader set of government regulations. Both investors and firms are uncertain about the choice of new ESG regulations and about the impact of these regulations on the firm. We examine the impact of ESG regulatory uncertainty on the stock market by investigating whether investors seek option protection when the ESG regulatory uncertainty is higher in the economy. In the cross-section, we also examine whether investors demand additional compensation against large price drops from holding

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firms that are more exposed to changes in ESG regulation.

Ilhan et al. (2021) and Cao et al. (2022) consider firms' ESG ratings to proxy for the sensitivity of firms to ESG regulation. Arguably, firms with high ESG performance are less sensitive to ESG regulatory developments compared to firms with low ESG performance. However, the combined ESG score of a firm hides any potential disparity between its environmental, social or governance performance. A high disparity in the different dimensions that make up the sustainability footprint of a firm would reflect an increased operational or regulatory uncertainty facing the firm. Therefore, in addition to the level of a firm's ESG rating, we consider the disparity across the firm's environmental, social, and governance performance to proxy for its sensitivity to unexpected changes in ESG regulation. We interpret ESG disparity as a signal of the management's ability to manage its ESG regulatory development. Firms may struggle to identify the ESG regulatory standards to follow and align their reports with various ESG-related reporting frameworks, resulting in disparity in their reported environmental, social and governance performance.[4]

We focus on the options market to investigate whether investors account for the ESG uncertainty reflected in the disparity across the different components of a firm's ESG rating and whether investors are willing to pay in order to hedge it. Options are a natural asset class to study pricing and hedging of downside tail risk, as their prices reflect the forward expectations of investors and do not require a realization of the state. Considering that investors may care more about downside losses than upside gains (Roy, 1952; Kahneman and Tversky, 1979; Gul, 1991), we focus on downside risk. We estimate the cost of protection against downside risk for each US firm following Ilhan et al. (2021) and Kelly et al. (2016).

At the aggregate economy level, the cost of protection against downside risk is higher when the ESG regulatory uncertainty is greater, especially under worse economic conditions. This result is similar to Pastor and Veronesi (2012, 2013) where they find that political uncertainty is priced. At the firm level, firms with high ESG performance have a lower option-implied cost of protection against downside risk

[4]For instance, Coca-Cola claims to align its 2021's ESG report to the following reporting framework and standards: Global Reporting Initiative (GRI), Task Force on Climate-related Financial Disclosures, Sustainability Accounting Standards Board (SASB), United Nations Global Compact (UNGC), UN Guiding Principles Reporting Framework (UNGPRF), and United Nations Sustainable Development Goals (SDGs). Pepsico, on the other hand, claims to align its 2021's ESG report to Global Reporting Initiative (GRI), Sustainability Accounting Standards Board (SASB), Task Force on Climate-related Financial Disclosures (TCFD), and Carbon Disclosure Project (CDP). Of course, while there are some similarities in their reporting framework and standards, any difference therein could impact their environmental, social, and governance performance assigned by third-party ESG raters such as Thomson Reuters or MSCI.

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compared to firms with low ESG scores. This evidence is in line with Ilhan et al. (2021)'s findings on carbon-intense firms. Interestingly, while all three components of the ESG score contribute significantly to the price of downside risk, the implications of the governance score have the opposite sign. Firms that score highly on governance also have a higher option protection against downside tail risk. However, regardless of their level of ESG performance, firms with high ESG disparity, or as we conjecture, with a low ability to manage ESG regulatory developments, have a consistently higher cost of option protection against downside risk.

Second, we investigate the effect of ESG treatment (or labeling) on the cost of option protection against downside tail risk. We find that the cost is lower for firms that receive ESG scores in a given year relative to firms without a score and with similar fundamental characteristics. In addition, to further address endogeneity concerns, we exploit the introduction of an ESG-based equity index. In April 2019, SPGlobal launched the S&P 500 ESG Index which includes only firms that are ESG top performers. This event presents a unique opportunity to estimate the effect of the inclusion of a firm in ESG membership on its associated cost of protection against downside risk. We find that index inclusion significantly lowers the firm's cost of protection against downside tail risk. As uncertainty in relation to the ability of a firm to manage ESG regulation is reduced for investors with the publication of an ESG rating or inclusion in an ESG-based equity index, the cost of protection against tail risk reflected in the options market is reduced.

Third, we examine the pricing of aggregate downside risk conditioned on the two aspects of firms' ESG performance: the level of a firm's overall ESG score and the disparity across its components. We extract both the firm-specific and aggregate downside risk measures from the option market which captures the forward expectation of all future events (including rare events). We estimate each US firm's downside risk (FDR) following Gao et al. (2018) and extract an aggregate downside risk measure using principal component analysis (PCA) based on the correlation of monthly estimates of firm downside risk measures (Siriwardane, 2015). We find that there is a one-factor structure driving the time series variation in FDR across all firms. This single factor represents the aggregate downside risk (ADR) measure in our study. Given this aggregate option-implied measure of tail risk, we investigate whether downside risk is priced in the cross-section of stock returns conditional on the level of the ESG score of firms or on the disparity across the different components of the score. We find that aggregate downside risk bears a negative price of risk for firms with high or low levels of ESG performance. When we condition on the

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disparity across the E, S and G dimension of sustainability scores, we find that the cross-sectional relationship between expected stock returns and downside risk betas is significant in the cross-section of firms with low ESG disparity.

To the best of our knowledge, this is the first paper to examine ESG uncertainty as captured by the disparity between the different components of the ESG profile of a firm and to relate it to downside risk in the options market. Focusing on a specific ESG aspect—that of carbon emission performance—Ilhan et al. (2021) find that climate policy uncertainty is priced in the options market. More carbon-intense firms are associated with a higher cost of protection against downside risk. Our results corroborate these findings, documenting that firms with high emission reduction scores have lower downside tail risk. Cao et al. (2022) is the closest to our paper. They examine whether firms' ESG scores are related to the expensiveness of their options, as captured by implied volatility. Our paper is in line with their baseline result in that firms' ESG performance is reflected in options prices. However, we focus on the disparity across the different components of firms' ESG performance and find that it is reflected in firms' downside tail risk.

Other studies have attempted to study the relationship between ESG-related performance and risk in other markets other than the options market. Glossner (2017) examines the relationship between ESG risks and long-run stock returns. He finds that the portfolio of firms with high ESG risk generates a negative alpha and attributes the negative alpha to unexpected costly ESG incidents and negative earnings surprises. He et al. (2021) examine the implications of shareholder votes in environmental and social (ES) proposals and find that higher support in failed ES proposals predicts subsequent ES incidents. They also document a negative relation between ES incidents and risk-adjusted performance. Hoepner et al. (2023) find that ESG engagement reduces a firm's exposure to downside risk.

Previous literature examines the divergence in ESG ratings across different ESG raters, the cause of the divergence across raters (Christensen et al., 2022; Berg et. al., 2024; Gibson et al., 2021; Eccles et al., 2020), and whether rating divergence is priced in the cross-section of stock returns ((Gibson et al., 2021)). Christensen et al. (2022) document that greater ESG disclosure leads to greater disagreement between ESG rating agencies. They observe that rating disagreement is greater when firms have relatively high or low average ESG ratings. They also find that the environmental and social pillars of ESG, rather than governance, drive more of the positive relationship between ESG disclosures and ESG disagreement. Berg et. al. (2024) investigate the sources of divergence in environmental, social and governance (ESG)

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ratings. Gibson et al. (2021) analyze the level and nature of disagreement about a firm's ESG rating and study the impact of ESG rating disagreement on stock returns. They find a positive relationship between environmental rating disagreement and stock returns, and a negative one for social and governance rating disagreement.

We contribute to this literature by considering a different dimension of disagreement: the uncertainty in the ESG performance of a firm as captured by the divergence across its different environmental, social and governance scores. We find that the uncertainty in the ESG performance related to such disagreement is priced in the options market. Although there is literature on the pricing of aggregate downside risk, little is understood about the pricing of downside risk in relation to the ESG performance or profile of the firm. Ang et al. (2006) show that the cross-section of stock returns reflect a risk premium for bearing downside risk. Huang et al. (2012) estimate the firm-specific extreme downside risk and document that there is a positive premium on firm-specific extreme downside risk. They find that high extreme downside risk stocks outperform low extreme downside risk stocks. Siriwardane (2015) also finds that downside risk obtained from the option market is priced in the cross-section of equity returns. Kelly and Jiang (2014) show that tail risk has strong predictive power for aggregate market returns. We contribute to this stream of literature by relating the pricing of the aggregate downside risk to the firms' ESG performance.

The remainder of this paper is organized as follows. Section 2 describes the data and the different option-implied risk measures. Section 3 presents empirical analyses of the relationship between ESG uncertainty and the cost of protection against downside tail risk. Section 4 examines ESG uncertainty and aggregate downside risk. Section 5 concludes.

2 Data

We obtain ESG ratings for the sample of US firms covered by Thomson Reuters for the period from December 2002 (the earliest year in the database) to December 2021. Sustainability scores are provided at an annual frequency. The ESG scores of individual firms incorporate ratings along three dimensions: environmental (E), social (S) and governance (G). The overall ESG combined score is discounted for significant ESG controversies that impact the company being rated. Thomson Reuters provides a second level of disaggregation of the sustainability scores along the E, S and G dimensions: Resource Use, Emissions, and Innovation scores for the environ-

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mental category; Workforce, Human Rights, Community, and Product responsibility for the social category; Management, Shareholders, and Corporate Social Responsibility (CSR) strategy for the governance category. The ESG metrics are reported as percentile rank scores. Scores in the environmental and social categories, as well as the controversies score are benchmarked against industry groups according to the Thomson Reuters Business Classifications (TRBC). The scores in the governance categories are measured against the country of incorporation of the firm.

In Panel A of Table 1, we report descriptive statistics of the firms' ESG scores, as well as of the individual components of the aggregate score. The average ESG score across firms is 42. The governance component generally attains higher levels relative to E and S, with a G score of 53.4 for the average firm; it is also the least volatile of the three. Over the years, the number of US firms' ESG scores in our sample has grown significantly from 59 firms with ESG scores in 2002 to 3,113 US firms in 2021. The average firm's ESG performance has also increased over the years. From 2002 to 2013, the ESG combined score increased from 26.21 in 2002 to 40.42 in 2013. Thereafter, the average ESG performance decreased slightly. A similar pattern is observed for the environmental, social and governance scores, where the environmental ratings have increased almost threefold over the entire period. In general, the governance pillar score has the highest average performance over time.

We extract daily options data on U.S. individual stocks from OptionMetrics over the period from January 2001 to December 2021. Specifically, we obtain volatility surface data for standardized options with an expiration of 30 calendar days, the zero-coupon yield curve, and the forward and spot rates. We use the filtered options data to compute different measures of downside risk.

The measure of downside risk that we use for our baseline analysis is the implied volatility slope (IVSDn), obtained following Kelly et al. (2016) and Ilhan et al. (2021). The IVSDn relates the left-tail implied volatility to the moneyness measured by the Black Scholes delta of out-of-the-money (OTM) standardized put options with a 30-day maturity. We also process the surface data to make it less discrete in moneyness and interpolate the observed implied volatilities as a function of moneyness.[5] We regress the implied volatility of OTM standardized put options on the corresponding delta (ranging between -0.5 and -0.1) and a constant to extract the IVSDn for each individual firm in our sample. The slope of the function that relates implied volatility to moneyness quantifies the relative cost of option protection

[5]See Kelly et al. (2016) and Ilhan et al. (2021) for more information on the computation procedures.

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Table 1: **Descriptive Statistics**

This table reports descriptive statistics covering the period from 2002 to 2021. Panel A reports descriptives of the sustainability metrics of the firms in the sample. ESG is the firm's environmental (E), social (S) and governance (G) combined score which incorporates ESG controversies. The ten category scores are also reported. Panel B reports descriptives of the risk measures used in the analysis. IVSDn represents the firm's cost of protection against downside risk. It relates the left-tail implied volatility to the moneyness measured by the option's Black Scholes delta for the out-of-the-money (OTM) standardized put options with a 30-day maturity. The remaining risk measures in Panel B are defined in Table A1 in the Appendix. Panel C provides descriptives of firms' monthly returns and a number of controls. The CAPM beta and volatility are estimated over a 12-month period. For the CAPM beta, the firms' monthly returns are regressed on the S&P 500 returns and a constant. *logassets* measures firm size and is computed as the natural logarithm of firm's assets. *divnetinc* is the ratio of the firm's gross dividend to net income. *ebitassets* is the ratio of the firm's earnings before interest and tax (EBIT) to assets. *capexassets* is the ratio of the firm's capital expenditure (capex) to assets. *booktomar* is the ratio of the firm's equity book value to the market value. *debtassets* is the ratio of total debt to total assets. *N* states the number of firm-month observations.

Statistic	N	Mean	St. Dev.	Min	Max
Panel A: Sustainability Measures					
ESG	119,406	41.979	17.873	0.869	92.516
E	119,406	32.755	28.620	0.000	98.546
S	119,406	45.804	21.726	0.741	97.963
G	119,406	53.417	21.722	0.292	98.599
Resource use	119,070	35.010	34.747	0.000	99.884
Emissions reduction	119,070	33.763	33.591	0.000	99.807
Innovation	119,070	21.267	30.017	0.000	99.367
Workforce	119,070	49.165	26.737	0.162	99.835
Human rights	119,070	21.701	30.953	0.000	99.206
Community	119,070	68.124	23.363	0.362	99.900
Product responsibility	119,070	40.423	30.413	0.000	99.780
Management	119,070	57.773	27.436	0.052	99.983
Shareholders	119,070	55.924	27.484	0.051	99.969
CSR strategy	119,070	28.278	34.151	0.000	99.804
Panel B: Risk Measures					
IVSDn	119,406	0.444	0.436	−2.112	4.308
smfiv	119,406	0.201	0.286	0.012	8.059
mfiv_bkm	119,406	0.213	0.296	0.012	7.535
mfiv_bjn	119,406	0.204	0.273	0.012	6.779
smfivd	119,406	0.091	0.105	0.006	2.110
mfivd_bkm	119,406	0.137	0.211	0.007	5.651
mfivd_bjn	119,406	0.119	0.165	0.006	4.042
mfis	119,406	−0.617	0.498	−3.786	4.200
mfik	119,406	5.281	2.024	1.832	29.022
cvix_sigma2	119,406	0.206	0.294	0.011	7.543
cvix_sigma5	119,406	0.213	0.296	0.012	7.542
cvix_mnes20	119,406	0.163	0.158	0.012	2.574
cvix_mnes25	119,406	0.178	0.185	0.012	3.149
rix	119,406	0.018	0.047	0.0002	1.609
rixnorm	119,406	0.081	0.037	0.021	0.288
Panel C: Controls					
return	119,111	1.225	10.767	−84.353	305.691
volatility	119,028	8.903	5.720	1.310	96.651
beta	117,147	1.199	1.010	−9.380	12.198
logassets	119,394	22.941	1.582	17.766	28.620
divnetinc	118,206	0.792	43.731	−162.716	4,300.375
ebitassets	106,927	0.100	0.090	−0.843	0.917
capexassets	115,722	0.044	0.052	0.000	0.865
booktomar	119,096	1.025	48.868	−5.945	4,868.352
debtassets	119,370	0.264	0.211	0.000	3.892

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against downside tail risk. It is a relative measure as it captures the cost of protection against extreme downside events relative to the cost of protection against less extreme events on the downside.

Panel B of Table 1 presents the descriptive statistics of the measures of option-implied (downside) risk estimated over the period 2002-2021. In line with Ilhan et al. (2021), the IVSDn estimate is typically positive, which indicates that deeper OTM puts are more expensive. The average cost of protection against downside risk among firms is 0.44. For robustness, we also estimate an array of different measures of option-implied downside risk offered in the literature. We obtain the model-free implied volatility measures of Britten-Jones and Neuberger (2000), Bakshi et al. (2003), and Martin (2011, 2017), including measures of implied volatility on the downside. We also consider the model-free implied skewness and kurtosis measures of Bakshi et al. (2003), the corridor volatility index of Andersen and Bondarenko (2007) and Andersen et al. (2015), and the rare disaster concern index (RIX) of Gao et al. (2018). The descriptions of these measures can be found in Table A1 in the Appendix.

We obtain monthly returns for the firms and the S&P 500 index, as well as firm characteristics from Thomson Reuters for the period from 2002 to 2021. Specifically, we obtain total assets, total debt, normalized EBIT, net income after taxes, gross dividends on common stocks, capital expenditure, company market capitalization, book value per share, and total common shares outstanding. For each firm, we also obtain 12-month rolling window CAPM betas and return volatility. Descriptive statistics of these control variables are reported in Panel C of Table 1.

3 ESG Policy Uncertainty and Downside Tail Risk

In this section, we examine the relationship between ESG policy uncertainty and the value of option protection against downside risk. First, we investigate whether ESG policy uncertainty is reflected in the option market. We interpret policy uncertainty as the inability to predict how the regulation on environmental, social and governance issues will evolve in the future. Second, we examine the relationship between individual firms' sustainability performance and the value of option protection against downside risk. We consider two aspects of firm ESG performance: the level of a firm's ESG score and the disparity across the E, S and G scores within each firm. Firms with low ESG scores, as well as firms with diverging performance along the environmental, social and governance dimensions are more likely to be affected

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by unanticipated changes in ESG regulation. We incorporate both measures of firm-level ESG performance to evaluate the expensiveness of protection against left-tail events for firms with high or low levels of sensitivity to ESG policy uncertainty captured by those measures. Third, we investigate the implications of receiving an ESG score on the cost of option protection against downside tail risk. The uncertainty relative to a firm's ability to adapt to unanticipated changes in ESG regulation is reduced for investors with the publication of ESG ratings. We therefore investigate the effects of ESG labeling on the cost that investors pay in order to hedge against downside risk.

3.1 ESG Policy Uncertainty

We examine the aggregate ESG regulatory uncertainty within the framework of Pastor and Veronesi (2012, 2013) which explains why political uncertainty about regulation may have an impact on asset prices. Within that framework, regulatory uncertainty is viewed as the uncertainty whether the current government policy will change. It derives from the political costs of a given policy that are unknown to investors and who as a result cannot fully anticipate which policy the government will choose. A second source of uncertainty in their framework is related to the uncertain impact of any given policy on firm profitability. As investors learn about the costs of the new policy by observing political signals, they revise their beliefs about expected future policies, generating an effect on asset prices.

In this study, we narrow down to a specific subset of government policies: those related to ESG aspects of economic activity. We seek to determine whether uncertainty associated with ESG regulation is priced in the option market. An implication of the Pastor and Veronesi (2013) model also exploited in Kelly et al. (2016) is that the option protection against downside tail risk becomes more valuable when regulatory uncertainty is higher.

We proxy aggregate ESG regulatory uncertainty with the US environmental and climate policy uncertainty index of Noailly et al. (2022), the US environmental and Renewable energy policy uncertainty index of Noailly et al. (2022), and the US climate policy uncertainty index of Gavriilidis (2021). Our measure of the aggregate cost of protection against downside risk is obtained as the implied volatility slope (IVSDn), relating volatility to moneyness for standardized OTM put options with 30 days to expiration, aggregated across the firms in our sample. In order to investigate whether the effects of ESG policy uncertainty are more pronounced when the

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economy is weaker, we also account for aggregate economic conditions. In particular, we use the following variables: the National Bureau of Economic Research (NBER) recession dummy, the cyclically adjusted PE ratio (CAPE ratio) of Bob Shiller, the Chicago Fed National Activity Index (CFNAI), the industrial production growth (IPG) in percent, and the real gross domestic product (GDP) growth in percent.

Table 2 shows the result of the regression of aggregate IVSDn—which represents the aggregate cost of protection against downside tail risk—on ESG regulatory uncertainty. Across all specifications, the aggregate cost of protection against downside risk increases with ESG regulatory uncertainty, especially when the economic conditions are weak.

3.2 ESG Performance and Firm's Downside Tail Risk

The evidence in Table 2 suggests that an increase in the ESG regulatory uncertainty (as proxied by its environmental component) is associated with more valuable option protection against downside risk in the aggregate. In the following, we examine the cross-sectional implications of ESG policy uncertainty. The effect could be differentiated depending on the firm's level of exposure to ESG regulations.

A first proxy for such firm-level sensitivity towards ESG regulation is the level of the ESG score of the firm. Arguably, firms with high ESG scores are expected to be impacted by unexpected changes in ESG regulation to a lesser extent than their peers that fare worse on ESG. To investigate the relationship between a firm's ESG score and its cost of protection against downside risk, we estimate the following baseline regression:

$$IVSDn_{i,m,t+1} = \alpha_0 + \beta_1 ESGrating_{i,t} + \delta X_{i,t} + \epsilon_{i,m,t+1}, \tag{1}$$

where $IVSDn_{i,m,t+1}$ denotes the implied volatility slope of firm i in month m of year $t+1$, $ESGrating_{i,t}$ is the $ESG_{i,t}$, $E_{i,t}$, $S_{i,t}$ or $G_{i,t}$ of firm i sustainability score in year t, and $X_{i,t}$ is a vector of controls for firm i at time t. We average on a monthly basis the daily implied volatility slope for each firm. We match the firm's IVSDn in year $t+1$ to the firm's sustainability score in year t since Thomson Reuters updates its sustainability score when they receive the firm's annual report, therefore, resulting in a delay in ESG score update. As controls, we include firm's monthly return, CAPM *beta*, *volatility*, based on a 12-month rolling estimate, *logassets*, the

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Table 2: **Aggregate Environmental Policy Uncertainty Indices and Cost of Protection Against Downside Risk**

The dependent variable is the aggregate of the firms' Implied Volatility Slope(IVSDn) which relates the implied volatility to the moneyness (measured by delta) for the standardized OTM put options with 30 days to expiration; this captures the cost of protection against downside risk. The main independent variable is the aggregate US Environmental Policy Uncertainty Indices. Panel A reports results for the aggregate US Climate Policy Uncertainty (measured by Gavriilidis (2021)), multiplied by 100. Panel B reports results for the aggregate US Environmental and Climate Policy Uncertainty (measured by Noailly et al. (2022)), multiplied by 100. Panel C reports results for the aggregate US Environmental and Renewable Energy Policy Uncertainty (measured by Noailly et al. (2022)), multiplied by 100. We use the following measures of aggregate economic conditions: the National Bureau of Economic Research (NBER) recession dummy, equal to one during recession months and zero otherwise, the cyclically adjusted PE (CAPE) ratio of Bob Shiller, the Chicago Fed National Activity Index (CFNAI), the industrial production growth (in percentage), and the real Gross Domestic Product (GDP) growth (in percentage). Standard errors are reported in parentheses. $*p < 0.1; **p < 0.05; ***p < 0.01$.

	(1)	(2)	(3)	(4)	(5)
Panel A: Climate Policy Uncertainty					
CPU Index	0.076^{***}	0.070^{***}	0.075^{***}	0.071^{***}	0.078^{***}
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
NBER recession	0.068^{***}				
	(0.026)				
CAPE		0.005^{***}			
		(0.002)			
CFNAI			-0.009		
			(0.006)		
Industrial Production Growth (%)				-0.005^{**}	
				(0.002)	
Real GDP Growth (%))					0.001
					(0.004)
Constant	0.236^{***}	0.115^{**}	0.242^{***}	0.250^{***}	0.239^{***}
	(0.013)	(0.046)	(0.013)	(0.014)	(0.017)
Observations	252	252	252	252	252
Adjusted R^2	0.215	0.219	0.201	0.213	0.194
Panel B: Environmental and Climate Policy Uncertainty					
EnvPolicy Uncertainty Index	0.030^{**}	0.031^{**}	0.013	0.025^{*}	0.012
	(0.013)	(0.014)	(0.013)	(0.013)	(0.014)
NBER recession	0.084^{***}				
	(0.018)				
CAPE		-0.006^{***}			
		(0.001)			
CFNAI			-0.083^{***}		
			(0.011)		
Industrial Production Growth				-0.008^{***}	
				(0.001)	
Real GDP Growth					-0.021^{***}
					(0.004)
Constant	0.237^{***}	0.393^{***}	0.256^{***}	0.258^{***}	0.313^{***}
	(0.018)	(0.044)	(0.017)	(0.018)	(0.023)
Observations	219	219	219	219	219
Adjusted R^2	0.116	0.098	0.240	0.169	0.145
Panel C: Environmental and Renewable Energy Policy Uncertainty					
EREPU Index	0.021^{***}	0.016^{***}	0.014^{***}	0.018^{***}	0.013^{**}
	(0.005)	(0.006)	(0.005)	(0.005)	(0.005)
NBER recession	0.085^{***}				
	(0.018)				
CAPE		-0.005^{***}			
		(0.002)			
CFNAI			-0.079^{***}		
			(0.010)		
Industrial Production Growth (%)				-0.008^{***}	
				(0.001)	
Real GDP Growth (%))					-0.019^{***}
					(0.004)
Constant	0.235^{***}	0.376^{***}	0.246^{***}	0.257^{***}	0.299^{***}
	(0.011)	(0.045)	(0.011)	(0.011)	(0.016)
Observations	219	219	219	219	219
Adjusted R^2	0.160	0.108	0.265	0.201	0.165

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natural logarithm of total assets, *divnetinc*, gross dividends divided by net income after taxes, *ebitaseets*, normalized earnings before interest and taxes, standardized by total assets, *capexaseets*, obtained as capital expenditure divided by total assets, *debtassets*, total debt divided by total assets, and *booktomar*, book value of equity divided by firm's market capitalization. Beta, volatility, and return are measured at a monthly level while the sustainability scores and the rest of the control variables are available at annual frequency.

Table 3 presents the result of the firm-month level regression of the implied volatility slope (IVSDn)—our option-implied measure of the cost of protection against downside risk—on firms' overall ESG score as well as its three components reflecting firms' environmental (E), social (S) and governance (G) performance. The findings show that there is a negative and significant relationship between the cost of protection against downside tail risk and the overall sustainability performance of the firms. This result becomes more nuanced when we narrow down to the three pillar scores. The higher the firm's E and S performance, the lower the cost of protection against downside risk. However, governance performance exhibits a negative relationship, which implies that firms with higher governance performance have a higher cost of protection against downside risk. The coefficients of the control variables have the expected signs: the higher the CAPM beta, the higher the cost of protection against downside risk. Larger, more profitable, high capital expenditure and lower financial leverage firms have lower cost of protection against downside risk.

We also consider the second level of ESG score disaggregation through the category scores along the following dimensions: Resource Use, Emissions, and Innovation scores which constitute the environmental pillar score; Workforce, Human Rights, Community, and Product Responsibility, contributing towards the social score; and Management, Shareholders, and CSR Strategy for the governance dimension. Table 4 reports the firm-month level regression to examine the relationship between each of the category scores and the cost of option protection against downside tail risk.

The findings in Table 4 indicate that for the category scores along the environmental and social dimensions, all underlying components have a negative and significant relationship with the cost of protection against downside risk. Firms with better efficient use of resources, lower emissions, and better innovation to reduce environmental costs and burdens have a lower cost of protection against downside risk. The same holds for firms with a better workforce, human rights, community, and product responsibility score. The pattern is more nuanced along the governance

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Table 3: **Firm's ESG Performance and the Cost of Protection Against Downside Risk**

This table reports the regression output corresponding to the model in Equation (1). The main dependent variable is the Implied Volatility Slope on the downside (IVSDn) which relates the implied volatility to the moneyness (measured by delta) for the standardized OTM put options with 30 days to expiration. Column (1) presents the specification in which $ESGrating_{i,t}$ corresponds to the ESG score of firm i at time t. Columns (2) through (4) have the E, S and G pillar scores as the $ESGrating_{i,t}$ measure. All specifications include the same set of control variables. Those include firms' monthly return, the CAPM beta, obtained by regressing the firm's monthly return on the S&P 500 Index return, a constant using a 12-month rolling period, and volatility, estimated over a 12-month period. *logassets* measures firm size and is computed as the natural logarithm of a firm's assets. *divnetinc* is the ratio of the firm's gross dividend to net income. *ebitassets* is the ratio of the firm's earnings before interest and tax (EBIT) to assets. *capexassets* is the ratio of the firm's capital expenditure (capex) to assets. *booktomar* is the ratio of the firm's equity book value to the market value. *debtassets* is the ratio of total debt to total assets. All specifications include year fixed effects. The sample includes all US firms with ESG scores from Thomson Reuters and covers the period from 2002 to 2022. Standard errors, clustered by firm and year, are reported in brackets. $*p < 0.1; **p < 0.05; ***p < 0.01$.

	(1)	(2)	(3)	(4)
ESG	−0.00117***			
	(0.0001)			
Environmental		−0.00103***		
		(0.0001)		
Social			−0.00141***	
			(0.0001)	
Governance				0.0002***
				(0.0001)
beta	0.008***	0.007***	0.008***	0.007***
	(0.001)	(0.001)	(0.001)	(0.001)
volatility	−0.011***	−0.011***	−0.011***	−0.011***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
return	−0.0002	−0.0002	−0.0002	−0.0002
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
logassets	−0.077***	−0.071***	−0.072***	−0.084***
	(0.001)	(0.001)	(0.001)	(0.001)
divnetinc	0.0001**	0.0001***	0.0001**	0.0001**
	(0.00002)	(0.00002)	(0.00002)	(0.00002)
ebitassets	−0.374***	−0.365***	−0.355***	−0.399***
	(0.014)	(0.014)	(0.014)	(0.013)
capexassets	−0.091***	−0.081***	−0.109***	−0.075***
	(0.023)	(0.023)	(0.023)	(0.023)
debtassets	0.078***	0.073***	0.076***	0.084***
	(0.006)	(0.006)	(0.006)	(0.006)
booktomar	0.00001	0.00001	0.00001	0.00001
	(0.00002)	(0.00002)	(0.00002)	(0.00002)
Constant	2.146***	1.980***	2.035***	2.258***
	(0.024)	(0.027)	(0.025)	(0.023)
Year FE	Yes	Yes	Yes	Yes
Observations	103,051	103,051	103,051	103,051
Adjusted R^2	0.257	0.258	0.259	0.256

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Table 4: **Firm's ESG Performance and the Cost of Protection Against Downside Risk: Second Level of Disaggregation**

This table displays the results of the regressions of the monthly cost of protection against downside risk (IVSDn) on the sustainability performance based on Equation (1). This table reports only the parameter estimates of β_1 on sustainability performance. The control variables are CAPM beta, volatility, return, logassets, divnetinc, ebitaseets, capexaseets, debtassets, and booktomar. All specifications control for fixed-year effects. Panel A reports the parameter estimates along the environmental dimension: where *ESGrating* corresponds to firm's scores on Resource use, Emission reduction, and Innovation. Panel B reports the parameter estimates along the social dimension: Workforce, Human rights, Community, and Product responsibility. Panel C reports the parameter estimates along the governance dimension: Management, Shareholder, and CSR strategy. Standard errors, clustered by firm and year, are reported in parentheses. $*p < 0.1; **p < 0.05; ***p < 0.01$.

Dimension	Environmental	Social	Governance
Panel A: Environmental			
Resource use	-0.001^{***}		
	(0.00004)		
Emissions reduction	-0.001^{***}		
	(0.00004)		
Innovation	-0.0001^{***}		
	(0.00004)		
Panel B: Social			
Workforce		-0.001^{***}	
		(0.0001)	
Human rights		-0.001^{***}	
		(0.00004)	
Community		-0.001^{***}	
		(0.0001)	
Product responsibility		-0.0004^{***}	
		(0.00004)	
Panel C: Governance			
Management			0.0004^{***}
			(0.00004)
Shareholder			-0.0001^{***}
			(0.00004)
CSR strategy			-0.001^{***}
			(0.00004)

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components. There, higher shareholder and CSR strategy scores are associated with a lower cost of option protection. However, higher management scores imply the opposite. Firms with better board structure, compensation policy, and board functions have a higher cost of protection against downside risk. Given that the weighting methodology of Thomson Reuters attributes substantially higher weight to management in their governance score, the positive association with a firm's downside risk is also reflected in the governance dimension of a firm's score.

3.3 ESG Disparity and Firm's Downside Tail Risk

In the following, we examine the relationship between the disparity across a firm's sustainability profile (i.e., environmental, social and governance performance) and its cost of option protection against downside risk. We conjecture that the observed disparity across the components of a firm's sustainability metric proxies for its ability to manage ESG regulatory developments. A firm with high ESG disparity signals a low ability to manage ESG regulatory requirements.

For each firm in our sample, we compute the disparity across its E, S and G scores as the mean absolute deviation (MAD) between the different components and sort firms into deciles. We estimate the baseline regression in Equation (1) for firms within each MAD decile. Table 5 presents the β_1 estimates for firms in the 10th decile (representing those with the highest disparity) and in the 1st decile (representing those with the lowest disparity). We find that both high- and low-disparity firms associate a higher cost of downside option protection with low ESG scores. However, when the disparity is low, the individual components of the sustainability score are not significantly associated with the cost of option protection.

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Table 5: **The Cost of Protection Against Downside Risk and Firms' ESG Ratings: Across Deciles of ESG Disparity**

For each firm in our sample, we compute the mean absolute deviation (MAD) for the E, S and G scores. Next, we sort the firms into deciles based on the computed mean absolute deviation and extract those that belong to the 10th decile (highest disparity) and 1st decile (lowest disparity). Regressions are estimated at the firm-month level. The main dependent variable is the Implied Volatility Slope on the downside (IVSDn) which relates the implied volatility to the moneyness (measured by delta) for the standardized OTM put options with 30 days to expiration. The row "ESG" reports parameter estimates for β_1 from a regression of IVSDn on the ESG score with controls and year fixed effects for the firms in the 90th and the 10th deciles. The rows "E", "S" and "G" report parameter estimates for β_1, where the variable *ESGrating* is represented by the environmental, social and governance scores, respectively. The "High Disparity" column denotes the regression result column for firms' in the 10th decile based on the mean absolute deviation (MAD). The "Low Disparity" column denotes the regression result column for firms' in the 1st decile based on the MAD. The sample includes all US firms with E, S and G scores and covers the period from 2002 to 2022. The t-statistics are reported in parentheses. $*p < 0.1; **p < 0.05; ***p < 0.01$.

	High Disparity		Low Disparity	
ESG	-0,00379	***	-0,00044	***
	(-8,93974)		(-2,80907)	
E	-0,00198	***	-0,00009	
	(-6,84420)		(-0,57762)	
S	-0,00162	***	-0,00008	
	(-7,72468)		(-0,47048)	
G	0,00070	***	-0,00006	
	(2,49038)		(-0,40209)	

We introduce the ESG disparity as an independent continuous variable to the baseline regression. The (augmented) baseline regression equation is as follows:

$$IVSDn_{i,m,t+1} = \alpha_0 + \beta_1 ESGrating_{i,t} + \lambda_1 ESGdisparity_{i,t} + \delta X_{i,t} + \epsilon_{i,m,t+1}. \quad (2)$$

$IVSDn_{i,m,t+1}$ is the implied volatility slope of firm i at month m in year $t+1$, and $ESGrating_{i,t}$ is the $ESG_{i,t}$, $E_{i,t}$, $S_{i,t}$, or $G_{i,t}$ of firm i sustainability score in year t. $X_{i,t}$ is a vector of controls for firm i at time t. The ESG disparity is the firm's mean absolute deviation across its environmental, social and governance performance which captures the ability of the firm to manage its ESG regulatory development.

Table 6 presents the estimates of a firm-month level regression of IVSDn on the sustainability performance and the ESG disparity of firms based on Equation (2). The model is estimated for the overall ESG score as well as its various components. Throughout all specifications and for all levels of disaggregation of the ESG score, we find that a high ESG disparity is consistently and significantly associated with a higher cost of option protection against left-tail risk. Investors in firms with poor ESG performance (in the aggregate or along most of the different dimensions of the

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score) would typically pay a higher cost to protect against extreme left-tail events in the option market. However, they would do so consistently when the uncertainty associated with the firm's ability to manage its exposure to ESG regulation is high.

Next, we examine whether the ability of companies to manage the ESG disparity differs between sectors. We link the firms in our sample to their various sectors based on the Global Industry Classification Standard (GICS). The GICS classifies firms into 12 sectors: Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care, Financials, Information Technology, Communication Services, Utilities, and Real Estate. Table A2 presents the results of the regressions of the monthly cost of protection against downside risk (IVSDn) on the sustainability performance and ESG disparity based on Equation (2) for each sector. For most of the industry sectors, the relationship between $IVSDn$ and ESG performance that we document for the overall sample still holds and remains significant. Exceptions are Materials, Utilities, and Communication Services, where the direction of the relationship reverses or becomes insignificant. The option value of protection against downside tail risk is higher for firms with large ESG disparity for all industries but two: Communication Services and Real Estate. For Materials and Utilities, the λ_1 estimate is not discernible from zero. The pattern persists across the E, S and G dimensions of sustainability.

3.4 ESG Labeling and Downside Risk

In our analyses so far, we have established a relationship between a firm's ESG profile and the costs that investors face to protect themselves against extreme events on the downside. In this section, we consider the implications for a firm receiving an ESG score in the first place, regardless of its level, relative to a firm that has not yet been rated on its sustainability performance. To estimate the causal effect of the availability of a sustainability score on the cost of protection against downside risk, we consider two groups of firms: firms with ESG scores (treated firms) and firms without ESG scores that are otherwise comparable to the treated firms based on a set of firms' observed characteristics (our control group). We apply the matching technique for panel data developed by Imai et al. (2023), which allows simple diagnostics to check covariates' balance and to estimate the short-term and long-term causal effects or the average treatment effect.

For each treated observation, we find a set of control observations that have

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Table 6: **ESG Disparity**

This table summarizes the results of regressions of the monthly cost of protection against downside risk (IVSDn) on firm's ESG ratings and its individual components, and the ESG disparity measure based on Equation (2). The table reports only the coefficient estimates on the ESG rating variable (β_1) and on ESG disparity (λ_1). The control variables are beta, volatility, return, logassets, divnetinc, ebitaseets, capexaseets, debtassets and booktomar. All specifications include year fixed effects. Panel A reports parameter estimates where the ESG rating variable is the firm's ESG score. Panel B reports estimates for specifications in which the ESG rating variable is the E, S or the G score. Panel C reports estimates for specifications where the ESG rating variable is either one of the category scores: Resource use, Emission reduction, Innovation, Workforce, Human rights, Community, Product responsibility, Management, Shareholder, or CSR strategy. Standard errors are reported in parentheses. $*p < 0.1; **p < 0.05; ***p < 0.01$.

Coefficients	ESG rating - β_1	ESG disparity - λ_1
Panel A: Aggregate		
ESG	-0.001^{***}	0.001^{***}
	(0.0001)	(0.0001)
Panel B: First level:		
Environmental	-0.001^{***}	0.001^{***}
	(0.0001)	(0.0001)
Social	-0.001^{***}	0.001^{***}
	(0.0001)	(0.0001)
Governance	0.0001	0.001^{***}
	(0.0001)	(0.0001)
Panel C: Second level:		
Environmental:		
Resource use	-0.001^{***}	0.001^{***}
	(0.00004)	(0.0001)
Emissions reduction	-0.001^{***}	0.001^{***}
	(0.00005)	(0.0001)
Innovation	-0.00001	0.001^{***}
	(0.00004)	(0.0001)
Social:		
Workforce	-0.001^{***}	0.001^{***}
	(0.0001)	(0.0001)
Human rights	-0.001^{***}	0.001^{***}
	(0.00004)	(0.0001)
Community	-0.001^{***}	0.001^{***}
	(0.0001)	(0.0001)
Product responsibility	-0.0004^{***}	0.001^{***}
	(0.00004)	(0.0001)
Governance:		
Management	0.0003^{***}	0.001^{***}
	(0.00004)	(0.0001)
Shareholder	-0.0002^{***}	0.002^{***}
	(0.00004)	(0.0001)
CSR strategy	-0.001^{***}	0.001^{***}
	(0.00004)	(0.0001)

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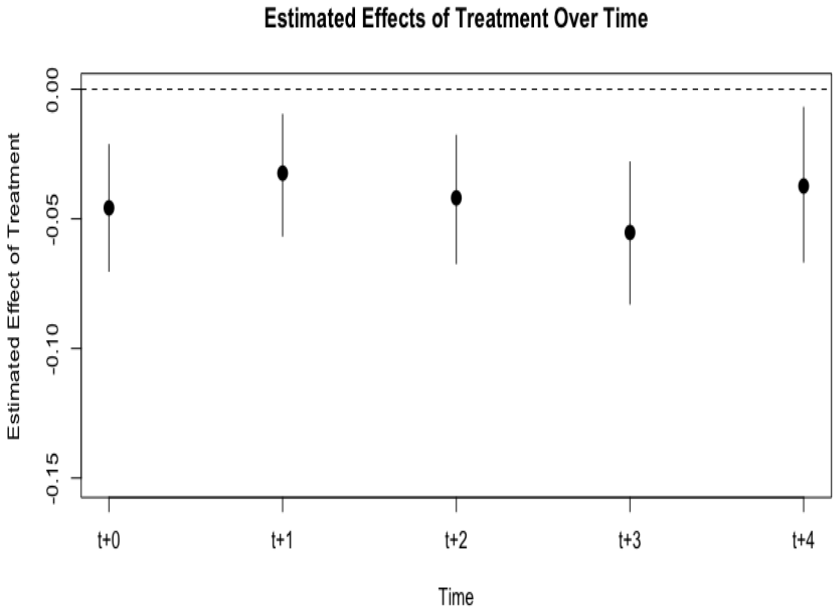
identical treatment histories over a 12-month period.[6] We apply the covariate balancing propensity score (CBPS) weighting technique to ensure that the treated and control observations have similar covariate values. The observed confounders we consider are the quick ratio, firm size, financial leverage, hard spending, intangibles, growth, cash ratio, profitability, and dividend yield. We also consider several other weighting and matching techniques. For matching techniques, we apply 'up-to-five matching', where each treated firm can only match a maximum of five control firms. We then apply the difference-in-difference estimator to estimate the causal effect of ESG treatment on the cost of protection against downside risk.

Figure A1 presents the distribution of the treatment across firms and time. At the beginning of our sample period, most of the companies were not assigned ESG scores. The number of companies treated with a score increases with time. We note that it is also very rare that a firm switches treatment status, facilitating the estimation of long-term causal effects of ESG treatment. In addition, we have a reasonably high number of matched control firms to estimate the average effects of treatment and therefore make causal inferences (see Figure A2). Next, we refine the matched set of Figure A2 to adjust for confounders. We apply two refinement weighting methods, the CBPS and the Propensity Score weighting method. Figure A3 plots the standardized mean difference between the treated observations and the matched control group over a 12-month pre-treatment period based on both weighting methods. The standardized mean difference is close to zero and reasonably constant during the pretreatment period. This suggests that there is no imbalance in confounders and that the parallel trend assumption for the difference-in-difference estimator used to estimate the average treatment effect seems appropriate.

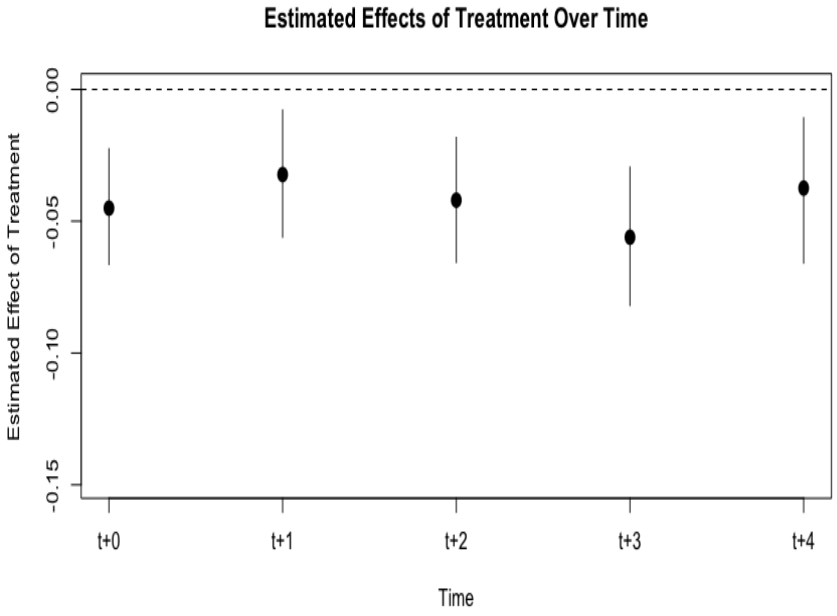
We estimate the causal effect of ESG treatment on the cost of protection against downside risk. For any two firms that are the same in their fundamental characteristics but one receives ESG treatment (ESG score) and the other does not, we estimate the impact of the treatment on the value of option protection against the tail risk. Figure 1 presents the estimated average treatment effect based on the two matching and weighting methods. For the immediate effect, the average treatment is negative, which implies that the cost of protection is lower for firms that receive ESG scores compared to firms with the same fundamental characteristics that have not been assessed. For the long-term (cumulative) effect over the next four months,

[6]The length of the treatment histories period represents a bias-variance trade-off. Increasing its length improves the credibility of the unconfoundedness assumption but reduces the efficiency of the estimates (Imai et al. (2023).

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(a) CBPS Weighting



(b) PS Weighting

Figure 1: **Estimated Average Treatment Effect of ESG Status (Treatment) on the Cost of Protection Against Downside Risk.** The estimates are based on the Covariates Balance Propensity Score (CBPS) weighting method (Panel (a)) and the Propensity Score weighting method (Panel (b)) that adjusts for treatment and covariates histories during the 12-month period prior to the treatment. Estimates for the average effects of ESG treatment are shown for the four-month period after the immediate effect, with 95% asymptotic confidence intervals as vertical bars. The bootstrap method is used for the standard error calculation.

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the average effect of the treatment remains negative. The results are statistically significant at the 95% confidence level, where we use the bootstrap method to obtain standard errors. Overall, we find that ESG treatment lowers the cost of protection against downside risk for the firm.

We also consider an alternative empirical strategy to estimate the causal effect of ESG treatment on the value of option protection against tail risk by exploiting a quasi-natural experiment setting. In April 2019, SPGlobal launched the S&P 500 ESG Index. The index comprises more than 300 of the original S&P 500 companies, included on the basis of their ESG score. According to SPGlobal, the S&P 500 ESG Index is a broad-based market cap-weighted index that is designed to measure the performance of securities that meet sustainability criteria, while maintaining similar overall industry group weights as the S&P 500. Inclusion in the index is a signal of the good ESG performance of a firm. We use a difference-in-difference (DiD) approach to compare changes in the cost of protection against downside risk between firms that are included in the S&P 500 ESG Index (treatment group) and those that are not included (control group). Table 7 presents the results.

Table 7: **Average ESG Treatment Effect on the Cost of Protection Against Downside Risk**

This table presents the result of the DiD estimates of the effect of the inclusion of a S&P 500 company in the S&P 500 ESG Index on the cost of protection against downside risk, proxied by the IVSDn. *Treated* is a dummy variable that is equal to 1 if a firm is included in the S&P 500 ESG Index. *Post* is a dummy variable that takes the value of 1 for the period after the launch of the S&P 500 ESG Index in April 2019. Controls include firm's market beta, volatility, return, log assets, dividends standardized by net income, EBIT, CAPEX, and debt, all standardized by total assets, as well as its book-to-market ratio. The main variable of interest is the interaction term of *Treated* * *Post* that indicates the average effect of ESG membership treatment on the cost of protection against downside risk. Standard errors are reported in parentheses. $*p < 0.1; **p < 0.05; ***p < 0.01$.

	Dependent variable:		
	IVSDn		
	(1)	(2)	(3)
Treated	-0.159^{***}	-0.092^{***}	-0.064^{***}
	(0.003)	(0.003)	(0.003)
Post	0.355^{***}	0.345^{***}	0.103^{***}
	(0.004)	(0.004)	(0.006)
Treated * Post	-0.144^{***}	-0.117^{***}	-0.145^{***}
	(0.006)	(0.006)	(0.006)
Year FE	No	No	Yes
Controls	No	Yes	Yes
Observations	118,855	102,799	102,799
R^2	0.132	0.179	0.269
Adjusted R^2	0.132	0.179	0.268
Residual Std. Error	0.406	0.387	0.366
	(df = 118851)	(df = 102786)	(df = 102769)
F Statistic	$6{,}012.186^{***}$	$1{,}863.433^{***}$	$1{,}301.243^{***}$
	(df = 3; 118851)	(df = 12; 102786)	(df = 29; 102769)

We find that in all specifications, the coefficient of the interaction term ($Treated*$

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Post) is negative and statistically significant. Our results show that the inclusion into 'ESG membership' as represented by inclusion in the S&P 500 ESG Index lowers the firm's cost of protection against downside risk. We note that the result remains robust to replacing IVSDn by other option-implied measures of risk (see Table A8).

3.5 Robustness

We first address the concern that ESG scores are available only for a small proportion of the firms in our sample at the beginning of the sample period. While all our regression specifications include year fixed effects, we alternatively consider a sub-sample restricted to observations from 2010 to 2022. We perform our baseline regression based on Equation (1) on that subsample. The results in panel A of Table A3 show that the relatively low number of firms with ESG scores at the beginning of the sample period does not appear to be driving our results. The subsample results remain consistent with those obtained over the entire period.

Another characteristic of the ESG dataset is the appearance of zero E scores for some firms in the sample, while the ESG, G and S scores for those firms have nonzero values at the same time. To alleviate concerns that zero pillar scores may be attributable to missing data, we also exclude firms with zero environmental scores. We perform our baseline regression based on the model in Equation (1). Panel B in Table A3 displays the results. Estimates for coefficients on ESG level and disparity remain consistent with those obtained without imposing the nonzero restriction on E scores in Table 6.

One major concern with the use of ESG scores is the low correlation of ESG data among ESG data providers (Berg et. al., 2024). To verify the robustness of our findings to the ESG data of other providers, we consider the MSCI ESG sustainability scores. Table A4 presents the results of the regressions of the monthly cost of protection against downside risk (IVSDn) on the MSCI sustainability performance and the ESG disparity based on the augmented model in Equation (2). The direction of the IVSDn—sustainability relationship remains consistent with our results based on Thomson Reuters ESG data.

We further examine the robustness of our results to using alternative option-implied risk measures. We consider three model-free measures of downside risk as captured by the implied volatility on the downside extracted from OTM puts: the *smfivd* measure of Martin (2011, 2017), the *mfivd bkm* measure of Bakshi et al. (2003), and the *mfivd bjn* measure of Britten-Jones and Neuberger (2000). Panel

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A of Table A5 presents the results of the regressions based on the model in Equation (1) using these alternative downside risk measures. We find strong evidence that the different downside risk measures have a negative and statistically significant relationship with firms' ESG, environmental and social performance. As with our IVSDn measure, the relationship between downside risk measures and the firm governance score remains inconclusive and statistically insignificant.

We also consider option-implied risk measures that do not focus exclusively on downside tail events. We compute the simple model-free implied volatility (*smfiv*) of Martin (2011, 2017), the model-free implied volatility (*mfiv bkm*) of Bakshi et al. (2003), the model-free implied volatility (*mfiv bjn*) of Britten-Jones and Neuberger (2000), the model-free implied skewness (*mfis*) and kurtosis (*mfik*) based on Bakshi et al. (2003), the corridor volatility index (*cvix*) of Andersen and Bondarenko (2007) and Andersen et al. (2015) measured on the relative deviation of 2 standard deviations from the at-the-money (ATM) moneyness of 1, and the rare disaster concern index (*rix*) of Gao et al. (2018). The findings in Panel B of Table A5 indicate that, except for *mfis*, all option-implied risk measures exhibit the relationship with ESG performance documented for our baseline measure, the implied volatility slope on the downside (IVSDn). For the model-free implied skewness that quantifies the asymmetry in the risk-neutral distribution, there is no significant relationship with the overall firm ESG performance. The relationship becomes positive and significant for the E and S scores.

All the risk measures that we have considered so far have been computed on the basis of options data. To examine the general validity of our results outside the option market, we alternatively consider credit default swaps (CDS). CDS provide insurance protection to the buyer against default of the reference entity. We therefore take the CDS spread as an alternative measure of the cost of protection against extreme downside events. We obtain daily CDS spreads based on 5-year senior bonds—which are the most liquid CDS contracts traded on the US market. Data is obtained from S&P Global and covers the period from January 2004 to December 2021. For each firm, we compute the monthly average CDS spread. We match firms with CDS data to the availability of Thomson Reuters ESG scores, resulting in a sample of 205 US firms. Table A6 presents the regressions of the monthly CDS on the sustainability performance and ESG disparity based on the model in Equation (2).

Our findings based on CDS spreads confirm the results obtained for the option-implied measure of the relative cost of protection against downside tail risk. Firms

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with higher ESG scores and lower ESG disparity have lower CDS spreads. The results are similar for the three pillar scores, although in some cases coefficient estimates lose significance. For the category scores, while the results for the level of each individual score are somewhat mixed, we document a consistent and significant relationship between the CDS spread and firms' ESG disparity. Overall, we find consistent support that firms with low ESG disparity have low cost of protection against downside tail risk, regardless on whether it is captured on the option market or implied from CDS spreads.

Finally, we consider different variants of the regression model in Equation (2) that include year of sector fixed effects and clustered standard errors. Table A7 shows the results. Different model specifications yield the same robust relationship between the overall ESG performance of a firm and the cost of option-implied protection against extreme downside events. Firms with low ESG scores and high disparity across the E, S and G dimensions of their score have consistently higher costs for downside risks protection.

4 Aggregate Downside Risk

We have established that better ESG performance or lower divergence across the E, S and G dimensions of a firm's sustainability score is associated with lower cost of protection against downside tail risk for that firm. In this section, we investigate whether investments built following ESG criteria can serve as a hedge against downside risk. We estimate the risk-neutral probability of downside events in the economy which we term 'aggregate downside risk'. It reflects the price of insurance against extreme future downside movements of the financial market (similar to the definition of Gao et al. (2018) for the rare disaster index (RIX)). It captures the ex-ante market expectations about future disasters or downside events.

We begin by constructing each firm's downside risk (FDR) measure following the procedure in Gao et al. (2018). Details on how we obtain the FDR measure are outlined in the Appendix. We extract our measure of aggregate downside risk (ADR) via principal component analysis following Siriwardane (2015):

$$FDR_{it}(\tau) = \Psi_i * ADR_t(\tau), \tag{3}$$

where Ψ_i is a firm-specific constant and $ADR_t(\tau)$ is the aggregate downside risk measure at time t which depends on the time to maturity τ. $ADR_t(\tau)$ is the risk-

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neutral probability of downside events from time t to $t+\tau$ and is common to all firms. All cross-sectional variation in $FDR_{it}(\tau)$ is driven by variation in Ψ_i and $ADR_t(\tau)$ is common to all firms. This implies that $FDR_{it}(\tau)$ is governed by a single factor.

We use daily data on OTM options of US firms from OptionMetrics covering the period from 2001 to 2021 to construct the firm downside risk (FDR) and aggregate downside risk (ADR). Our approach is similar to that in Gao et al. (2018) used to obtain a market-wide rare disaster index. We use out-of-the-money (OTM) put options with 30 days to expiration. We interpolate the implied volatilities across a range of observed moneyness levels and fill in the implied volatilities beyond the observed moneyness bounds with the volatilities on the bounds. We generate 1,001 implied volatility data points over the moneyness range from 1/3 to 3. We use the implied volatility curves to compute the Black Scholes (1973) OTM option prices and then apply Equation (A5) to obtain daily FDR for each US firm in our sample.

We proceed to obtain ADR through principal component analysis. We only consider firms with at least 18 daily estimates of FDR in a month. PCA is performed on the correlation matrix of the monthly FDR_i. In our subsequent analyses, we consider firms with at least 192 monthly FDR_i estimates. This leaves us with a total of 1,191 US firms for the computation of the ADR measure. Figure 2 shows the first 10 principal components from a PCA on the correlation matrix of the firm's downside risk measures FDR_i. We observe that the first principal component explains about 45% of the variation across the firm downside risk measures, while the variation explained by the remaining principal components is very low – ranging from 9% for the second component to 1% for the tenth component. This indicates that a single major factor drives the time series variation in FDR_i across firms. This single major factor represents the aggregate downside risk (ADR) that is common to all firms.

Figure 3 visualizes the time series of the ADR measure representing the aggregate risk-neutral probability of downside events. The evidence is in line with the results documented in Siriwardane (2015). Consistent with the interpretation of ADR as the risk-neutral probability of downside events common to all firms, we see that ADR experienced the highest spike during the Covid-19 pandemic followed by the spike during the global financial crisis.

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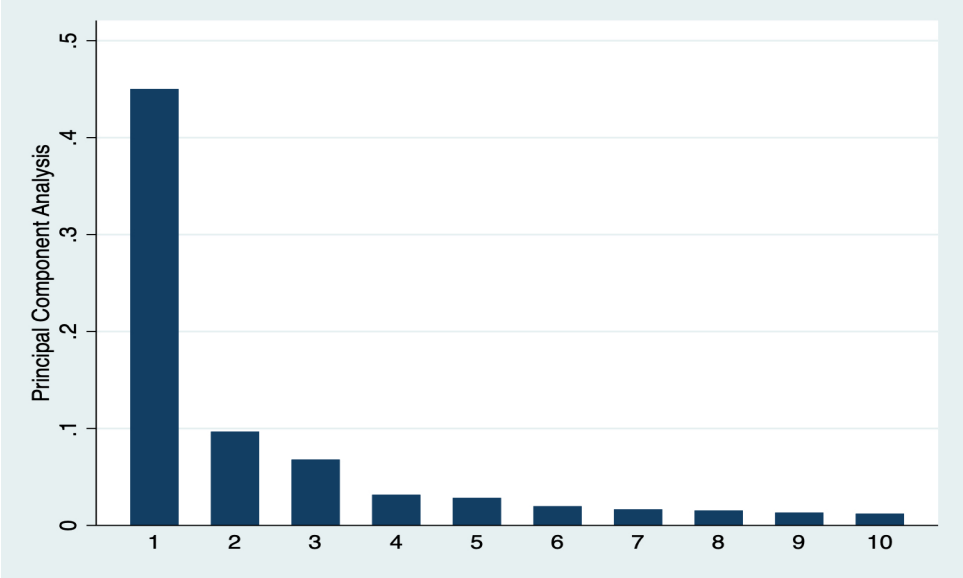


Figure 2: **Principal Component Analysis (PCA) on Firms' Downside Risk (FDR).** The figure reports the first 10 principal components based on the correlation matrix of the firm downside risk measure, FDR_i, extracted from option prices. For the computation of the principal components, a firm must have at least 18 daily observations per month to be included. This analysis applies to a set of firms with at least 192 monthly observations. The data range is from January 2001 to December 2021.

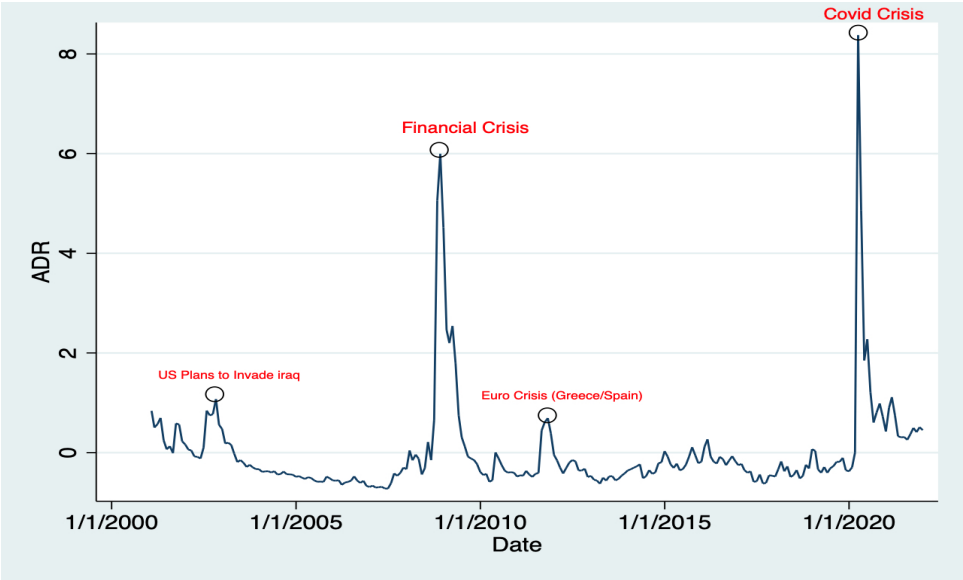


Figure 3: **Aggregate Downside Risk (ADR).** The figure plots a monthly time series of the risk-neutral probability of downside events, defined as the first principal component extracted from the panel of firm downside risk measures, FDR_i, and estimated from option prices. The risk-neutral probability of downside events is constructed following Siriwardane (2015). A firm must have at least 18 daily observations in a month to be included. PCA is conducted on the correlation matrix of the monthly FDR_i. We discard firms with less than 192 monthly observations. The data range is from January 2001 to December 2021.

4.1 Sustainability Scores and Aggregate Downside Risk

In the following, we focus on investigating whether ESG-based investments can serve as a hedge against downside market events. We verify whether investing in firms with high ESG ratings can protect investors against aggregate downside risk. We

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first determine each firm's exposure to ADR by running the following 12-month rolling regression for each time $t \in [m-12; m]$ and month m:

$$R_{i,t} = \alpha_{i,m} + \beta_{i,m} ADR_t + \epsilon_{i,t}, \tag{4}$$

where $R_{i,t}$ is the monthly return of firm i at time t, ADR_t is the aggregate downside risk for time t, and $\beta_{i,m}$ is the downside beta for firm i in month m. The monthly returns are filtered to exclude penny stocks which are defined as stocks with less than a share price of \$5. We also include firms with ESG scores but without individual options data. After obtaining 12-month rolling downside betas for each firm, we group the firms in high, medium and low sustainability performance terciles according to their ESG scores as observed at the end of the previous year and compute the average beta in each tercile across companies and over the sample period.

Table 8: **Sustainability Scores and Firms' Exposure to Aggregate Downside Risk (ADR)**

This table reports estimates of the sensitivity of firms' returns to aggregate downside risk (ADR). For each firm i at each time t, we perform a 12-month moving-window regression based on the regression model in Equation (4). Reported are the average parameter estimates $\beta_{i,m}$ across firms in high, medium and low terciles, formed according to the level of sustainability scores observed at the end of the previous year. Firms are grouped into terciles at the end of each year and average $\beta_{i,m}$ estimates are calculated for the months m of the current year. Then, the average $\beta_{i,m}$ between firms is obtained throughout the sample period from 2003 to 2021. Panel A reports time series and cross-sectional $\beta_{i,m}$ estimate averages for the following sustainability score terciles: the ESG score, and the Environmental, Social and Governance pillar scores. Panel B reports time series and cross-sectional $\beta_{i,m}$ estimate averages for terciles formed according to our ESG disparity measure.

Sustainability terciles	High	Medium	Low
		$\beta_{i,m}$	
Panel A: ESG performance			
ESG	$-0,026$	$-0,034$	$-0,052$
Environmental	$-0,022$	$-0,041$	$-0,047$
Social	$-0,028$	$-0,041$	$-0,042$
Governance	$-0,034$	$-0,037$	$-0,040$
Panel B: ESG disparity			
ESG disparity	$-0,045$	$-0,033$	$-0,033$

Panel A of Table 8 presents the average downside risk betas for firms with low, medium and high overall ESG, E, S and G scores. Since downside risk is decreasing in downside beta, the most negative downside risk betas connote the highest downside risk. We observe that irrespective of their ESG performance, firms are negatively exposed to ADR on average. However, firms with high ESG scores have lower exposure to ADR as compared to firms with low ESG performance. This implies that investing directly in high ESG firms does not provide an insurance against downside risk but an investment strategy of longing high ESG firms and shorting

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low ESG firms might protect investor portfolios against downside risk. The results remain similar in magnitude when we consider separately the E, S and G components of firms' sustainability scores. Panel B reports the ADR betas for firms sorted according to ESG disparity. Firms with low disparity across their E, S and G scores have the lowest exposure (in absolute terms) to ADR.

4.2 The Price of Aggregate Downside Risk

In the following, we determine the pricing of ADR conditioned on the ESG performance of firms. We categorize firms into low, medium and high ESG performance terciles at the end of each month m. For each sample of firms, the overall sample and the three ESG performance tercile samples, we perform Fama and MacBeth (1973) regressions of month $m+1$ excess stock returns on month m firms' downside betas and the risk factor loadings of standard asset pricing models.

The downside betas of individual firms and the factor loadings corresponding to the CAPM, the 3-factor Fama-French model and the 5-factor Fama-French model, are obtained by running 12-month rolling regressions of monthly excess stock returns on month m ADR and the set of standard risk factors. For each sample of firms and for each month m, we perform the following cross-sectional regression:

$$R_{i,m+1} = \alpha + \lambda_m^{ADR}\beta_{i,m}^{ADR} + \Omega_m^{riskfactors}X_{i,m}^{riskfactors} + \epsilon_{i,m}, \tag{5}$$

where $R_{i,m+1}$ is the month $m+1$ excess return of stock i, $\beta_{i,m}^{ADR}$ is the aggregate downside risk beta of stock i in month m, and $X_{i,m}^{riskfactors}$ is the vector of standard risk factor betas estimated in month m for firm i. Table 9 reports the time-series average of monthly λ^{ADR} estimates from the cross-sectional regression in Equation (5) for the entire sample of firms. We find that regardless of the risk specification, ADR is priced in the cross-section and commands a significant negative risk premium.

In a next step, we perform the cross-sectional regression in Equation (5) on three samples conditional on the ESG performance of firms. Table 10 presents the results for a model where ADR is the only risk factor (Panel A), a model where ADR is augmented by the market factor (Panel B), a model augmented with the 3-factor Fama-French model (Panel C), and a model augmented by the Fama-French 5-factor risk model (Panel D). We note that the expected return – β^{ADR} relationship is negative irrespective of the firms' ESG performance. However, it is statistically significant only in the cross-section of firms that belong to either the top or the

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Table 9: **The Price of Aggregate Downside Risk (ADR)**

This table presents the results of Fama and MacBeth (1973) regressions of month $m+1$ excess stock returns on month m ADR betas $\beta_{i,m}^{ADR}$ and risk factors betas for the CAPM, the Fama-French 3-factor model, and the Fama-French 5-factor model. The table reports the intercept of each regression (α) and the market prices of risk corresponding to aggregate downside risk (λ^{ADR}), and the three factor models: the CAPM (λ^{MKT}, for the market factor), the Fama-French 3-factor model (adding λ^{SMB} and λ^{HML}, corresponding to the size and value factors, respectively), and the Fama-French 5-factor model (adding λ^{RMW} and λ^{CMA} for the profitability and investment factors, respectively). Newey West t-stats are reported in parentheses.

Portfolio	α	λ^{ADR}	λ^{MKT}	λ^{SMB}	λ^{HML}	λ^{RMW}	λ^{CMA}
ADR	0.010	−0.116					
	(2.980)	(-2.121)					
CAPM + ADR	0.007	−0.087	0.004				
	(2.932)	(-2.059)	(2.059)				
3-Factor + ADR	0.007	−0.084	0.003	0.002	0.0006		
	(2.891)	(-2.284)	(2.079)	(0.355)	(0.400)		
5-Factor + ADR	0.008	−0.084	0.003	0.002	0.0007	−0.0005	−0.0006
	(3.091)	(-1.870)	(1.746)	(2.943)	(0.661)	(-0.975)	(-1.135)

bottom ESG score terciles. ADR does not appear to be priced in the cross-section of firms with medium ESG scores. That pattern is confirmed across the different risk specifications considered.

We further condition our sample on the observed disparity between the E, S and G scores of each firm. We consider three samples of firms according to their ESG disparity observed at the end of each month m: high, medium and low disparity firms. We repeat the cross-sectional regressions for the three samples of firms and report the results in Panel A of Table 11. We find that for the low ESG disparity sample, ADR remains significantly and consistently priced across all risk model specifications. The exposure to ADR maintains a strong relation with expected stock returns for firms with mostly aligned E, S and G metrics. However, when we consider the sample of firms for which the E, S and G metrics deviate the most (the high ESG disparity sample), λ^{ADR} declines in both absolute magnitude and significance. The relationship between expected stock returns and ADR betas is no longer significant for the high ESG disparity sample.

In order to understand the relative importance of the level of ESG scores and their disparity in pricing ADR, we further condition both terciles of poorly and best performing firms in terms of ESG scores on the degree of disparity between the E, S and G components of the score. Results from the cross-sectional regression in

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Table 10: **Pricing of Aggregate Downside Risk (ADR) Conditioned on Firms' ESG Performance.**

This table presents the results of Fama and MacBeth (1973) regressions of month $m+1$ excess stock returns on month m ADR betas $\beta_{i,m}^{ADR}$ and risk factor betas for the CAPM, the Fama-French 3-factor model, and the Fama-French 5-factor model. Estimates are reported for three samples of firms, formed conditional on their ESG performance observed at the end of month m. 'Low ESG Score', 'Medium ESG Score' and 'High ESG Score' refer to the estimates for firms in the low, medium or high ESG score tercile. The table reports the intercept of each regression (α) and the market prices of risk corresponding to aggregate downside risk (λ^{ADR}), and the three factor models: the CAPM (λ^{MKT}, for the market factor), the Fama-French 3-factor model (adding λ^{SMB} and λ^{HML}, corresponding to the size and value factors, respectively), and the Fama-French 5-factor model (adding λ^{RMW} and λ^{CMA} for the profitability and investment factors, respectively). Newey West t-stats are reported in parentheses.

Portfolio	α	λ^{ADR}	λ^{MKT}	λ^{SMB}	λ^{HML}	λ^{RMW}	λ^{CMA}
ADR:							
Low ESG Score	0.010	-0.124					
	(2.838)	(-2.220)					
Medium ESG Score	0.010	-0.090					
	(2.945)	(-1.589)					
High ESG Score	0.0092	-0.140					
	(3.119)	(-2.199)					
CAPM + ADR:							
Low ESG Score	0.0079	-0.0997	0.0031				
	(2.757)	(-2.176)	(1.443)				
Medium ESG Score	0.0064	-0.0743	0.0041				
	(2.361)	(-1.548)	(2.291)				
High ESG Score	0.0063	-0.0900	0.0045				
	(2.779)	(-2.200)	(2.066)				
3-Factor + ADR:							
Low ESG Score	0.0072	-0.09292	0.00272	0.0031	0.0009		
	(2.816)	(-2.186)	(1.313)	(4.494)	(0.759)		
Medium ESG Score	0.0071	-0.0734	0.0030	0.0022	0.0003		
	(2.546)	(-1.614)	(1.795)	(3.0247)	(0.269)		
High ESG Score	0.0066	-0.0875	0.0044	0.0003	0.0004		
	(2.891)	(-2.284)	(2.079)	(0.355)	(0.400)		
5-Factor + ADR:							
Low ESG Score	0.0077	-0.1002	0.0025	0.0035	0.0011	0.0003	-0.0009
	(2.923)	(-2.139)	(1.165)	(4.086)	(0.897)	(0.338)	(-1.888)
Medium ESG Score	0.0078	-0.0698	0.0021	0.0022	-0.00002	-0.0003	-0.0003
	(2.623)	(-1.55)	(1.104)	(2.495)	(-0.018)	(-0.607)	(-0.505)
High ESG Score	0.0066	-0.0785	0.0041	0.0002	0.0005	0.0002	-0.0009
	(2.926)	(-2.080)	(1.974)	(0.193)	(0.434)	(0.258)	(-1.390)

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Table 11: **Pricing of Aggregate Downside Risk (ADR) Conditioned on Firms' ESG Disparity.**

This table presents the results of Fama and MacBeth (1973) regressions of month $m+1$ excess stock returns on month m ADR betas $\beta_{i,m}^{ADR}$ and risk factors betas for the Fama-French 5-factor model. Firms are allocated to a low, medium or high ESG score tercile according to their ESG score at the end of month m. Within each one of these terciles, as well as for all firms, firms are further split in terciles according to their ESG disparity observed in month m. 'Low ESG Disparity', 'Medium ESG Disparity' and 'High ESG Disparity' refer to the estimates for firms in the low, medium or high ESG disparity tercile. The table reports the intercept of each regression (α) and the market prices of risk corresponding to aggregate downside risk (λ^{ADR}), the market risk factor (λ^{MKT}), the size (λ^{SMB}), value (λ^{HML}), profitability (λ^{RMW}), and investment (λ^{CMA}) factors. Panel A reports the regression results on all firms in our sample. Panel B reports the regression results conditioned on firms with low ESG performance. Panel C reports the regression results conditioned on firms with high ESG performance. Newey West t-stats are reported in parentheses.

Portfolio	α	λ^{ADR}	λ^{MKT}	λ^{SMB}	λ^{HML}	λ^{RMW}	λ^{CMA}
Panel A: All firms							
Low ESG Disparity	0.008	-0.123	0.002	0.003	0.001	0.0006	-0.0008
	(3.136)	(-2.068)	(1.105)	(3.470)	(1.254)	(0.783)	(-1.602)
Medium ESG Disparity	0.007	-0.078	0.003	0.002	0.0009	-0.0004	-0.0009
	(2.786)	(-1.944)	(1.662)	(2.313)	(0.978)	(-0.509)	(-1.603)
High ESG Disparity	0.008	-0.065	0.004	0.002	0.0002	-0.001	-0.0002
	(2.863)	(-1.440)	(2.034)	(2.255)	(0.205)	(-1.815)	(-0.338)
Panel B: Low ESG performance							
Low ESG Disparity	0.006	-0.178	0.008	0.004	0.002	0.004	-0.0001
	(1.710)	(-2.297)	(1.956)	(4.041)	(0.986)	(-1.359)	(-0.182)
Medium ESG Disparity	-0.029	0.220	0.023	0.006	0.016	-0.002	-0.002
	(0.785)	(-0.865)	(1.127)	(1.463)	(0.976)	(-2.007)	(-2.748)
High ESG Disparity	0.012	-0.050	-0.001	0.002	0.004	-0.0009	-0.0004
	(3.276)	(-1.208)	(-0.377)	(0.446)	(1.080)	(-1.565)	(-0.538)
Panel C: High ESG performance							
Low ESG Disparity	-0.016	-0.096	0.040	-0.012	-0.041	-0.024	-0.0003
	(-0.836)	(-2.374)	(1.150)	(-0.705)	(-0.929)	(-1.043)	(-0.462)
Medium ESG Disparity	0.005	-0.157	0.008	0.001	0.0003	0.0003	-0.0011
	(1.607)	(-2.353)	(1.736)	(0.770)	(0.103)	(0.380)	(-1.598)
High ESG Disparity	0.009	-0.053	0.005	-0.005	-0.005	0.0002	-0.0009
	(2.570)	(-0.053)	(2.186)	(-0.414)	(-0.620)	(0.297)	(-1.224)

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Equation (5) are reported in Panels B and C of Table 11 for firms belonging to the bottom tercile of ESG performance and those belonging to the top tercile of ESG performance, respectively. Interestingly, for both sets of firms, we confirm the pattern observed in Panel A of Table 11: ADR is priced only in the cross-section of stocks for which the three components of their ESG score are mostly aligned. Regardless of overall ESG scores, it is only for firms with low ESG disparity that we observe a consistent and strong negative relationship between expected returns and ADR exposure.

5 Conclusion

With the increasing abundance of ESG-related regulation, firms are faced with a growing uncertainty with respect to the adoption and scope of new regulation, as well as their ability to manage future regulatory developments. In this paper, we explore three main areas: (1) the ESG uncertainty emanating from the development of ESG regulations, (2) the firm's ability to manage regulatory development, and (3) the pricing of ESG exposure to aggregate downside risk.

First, we find that uncertainty related to environmental, social and governance (ESG) regulatory developments is reflected in asset prices. At the aggregate or at the economy level, the cost of protection against downside risk is higher when the ESG regulatory uncertainty is higher, and even more so when the economic conditions are worse. At the firm level, firms with high ESG scores have a lower cost of protection against downside tail risk compared to firms with low ESG performance. However, more granular scores show a nuanced pattern, as firms with higher governance ratings or better management scores are also associated with an increased cost of protection against downside tail events.

Second, we account for the possibility that a firm's ESG standing may include divergent ratings along the environmental, social and governance dimensions of its sustainability profile. We find that firms with high ESG disparity have a higher cost of protection against downside risk. This implies that firms with a low ability to manage ESG regulatory development command a higher cost of protection against downside risk.

Third, we find a negative price of aggregate downside risk for firms with either high or low ESG performance. Firms with high ESG performance command a lower negative price of aggregate downside risk. Both high and low ESG firms have negative exposure to downside risk. However, high ESG firms have lower exposure

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to downside risk compared to low ESG firms. Investing directly in high ESG firms does not provide insurance against downside risk as they have negative exposure to downside risk. However, an investment strategy of longing high ESG firms and shorting low ESG firms might provide insurance against downside risk.

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Appendix

Firm downside risk (FDR) is the firm's price of a downside insurance contract. To understand the foundation for the construction of the FDR, please refer to Gao et al. (2018). The computation to extract the FDR is as follows:

$$IV_{it} = \frac{2e^{r\tau}}{\tau}\{\int_{K>S_{it}} \frac{1}{K^2} C_{it}(S_{it}; K, T)dK + \int_{K<S_{it}} \frac{1}{K^2} P_{it}(S_{it}; K, T)dK\} \tag{A1}$$

$$\begin{aligned} V_{it} = \frac{2e^{r\tau}}{\tau}\{\int_{K>S_{it}} & \frac{1 - ln(K/S_{it})}{K^2} C_{it}(S_{it}; K, T)dK \\ & + \int_{K<S_{it}} \frac{1 - ln(K/S_{it})}{K^2} P_{it}(S_{it}; K, T)dK\}, \end{aligned} \tag{A2}$$

where r is the constant interest rate, τ is the time to maturity or time to expiration, and $C_{it}(S_{it}; K, T)$ is the price of firm's i call options with strike price T and $maturityK$. $P_{it}(S_{it}; K, T)$ is the price of firm's i put options with strike price T and maturity K. The difference between V_{it} and IV_{it} is $-ln(K/S_{it})$ in V_{it} which implies that larger (smaller) weights are assigned to more deeply OTM put(call) options. This allows us to extract extreme price deviation. The difference between the V_{it} and IV_{it} captures investors' expectations about the distribution of large price variation (Gao et al. (2018)).

Next, we obtain only the downside measures of the firm's IV and V which leaves us with only the OTM put options:

$$IV_{it}^{-} = \frac{2e^{r\tau}}{\tau} \int_{K<S_{it}} \frac{1}{K^2} P_{it}(S_{it}; K, T)dK. \tag{A3}$$

$$V_{it}^{-} = \frac{2e^{r\tau}}{\tau} \int_{K<S_{it}} \frac{1 - ln(K/S_{it})}{K^2} P_{it}(S_{it}; K, T)dK. \tag{A4}$$

$$FDR_{it} = V_{it}^{-} - IV_{it}^{-} = \frac{2e^{r\tau}}{\tau} \int_{K<S_{it}} \frac{ln(K/S_{it})}{K^2} P_{it}(S_{it}; K, T)dK. \tag{A5}$$

FDR_{it} is the difference between V_{it}^{-} and IV_{it}^{-} which captures investors' expectation of extreme downside price movement of firm's i. It can also be interpreted as the risk-neutral probability of firm's i extreme downside movement. FDR_{it} can also be seen as the value of a simple portfolio of put options on firm i and form at date t to extract extreme downside movement.

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Table A1: Variable definitions for risk measures, sustainability measures and controls.

Variable	Definitions
Panel A: Risk Measures	
smfiv	Simple model-free implied volatility from Martin (2011, 2017).
mfiv_bkm	Model-free implied volatility from Bakshi et al. (2003). This is equation A2 in our paper.
mfiv_bjn	Model-free implied volatility from Britten-Jones and Neuberger (2000). This is equation A1 in our paper.
smfivd	Simple model-free implied volatility for OTM puts (downside) from Martin (2011, 2017)
mfivd_bkm	Model-free implied volatility for OTM puts (downside) from Bakshi et al. (2003). This is equation A4 in our paper.
mfivd_bjn	Model-free implied volatility for OTM puts (downside) from Britten-Jones and Neuberger (2000). This is equation A3 in our paper.
mfis	Model-free implied skewness based on Bakshi et al. (2003).
mfik	Model-free implied kurtosis based on Bakshi et al. (2003).
cvix_sigma2	Corridor volatility index from Andersen and Bondarenko (2007), Andersen et al. (2015) measured on the relative deviation of 2 sigmas from the At-the-Money (ATM) moneyness of 1.
rix	Rare disaster concern index (rix) from Gao et al. (2018). This is the difference between mfivd_bjn and mfivd_bkm. This is equation A5 in our paper.
Panel B: Sustainability Measures	
Environmental, Social and Governance (ESG) score	The term ESG used in this study is the ESG combined (ESGC) score which takes into consideration the ESG controversies. ESGC overlays the ESG score with ESG controversies to provide a comprehensive evaluation of the company's sustainability impact and conduct over time. ESGC scores provide a rounded and comprehensive scoring of a company's ESG performance, based on the reported information pertaining to the ESG pillars, with the ESG controversies overlay captured from global media sources.
Environmental (E) score	Resource use score, Emissions reduction score, and Innovation score are aggregated to form the Environmental Score.
Social (S) score	Workforce score, Human rights score, Community score, and Product responsibility score are aggregated to form the Social score.
Governance (G) score	Management score, Shareholders score, and CSR strategy score are aggregated to form the Governance score.

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Table A1 – continued from previous page

Variable	Definitions
Resource use score	The resource use score reflects a company's performance and capacity to reduce the use of materials, energy or water, and to find more eco-efficient solutions by improving supply chain management.
Emissions reduction score	The emission reduction score measures a company's commitment and effectiveness towards reducing environmental emissions in its production and operational processes.
Innovation score	The innovation score reflects a company's capacity to reduce the environmental costs and burdens for its customers, thereby creating new market opportunities through new environmental technologies and processes, or eco-designed products.
Workforce score	The workforce score measures a company's effectiveness in terms of providing job satisfaction, a healthy and safe workplace, maintaining diversity and equal opportunities, and development opportunities for its workforce.
Human rights score	The human rights score measures a company's effectiveness in terms of respecting fundamental human rights conventions.
Community score	The community score measures the company's commitment to being a good citizen, protecting public health and respecting business ethics.
Product responsibility score	The product responsibility score reflects a company's capacity to produce quality goods and services, integrating the customer's health and safety, integrity and data privacy.
Management score	The management score measures a company's commitment and effectiveness towards following best practice corporate governance principles.
Shareholders score	The shareholders score measures a company's effectiveness towards equal treatment of shareholders and the use of anti-takeover devices.
CSR strategy score	The CSR strategy score reflects a company's practices to communicate that it integrates economic (financial), social and environmental dimensions into its day-to-day decision-making processes.
Panel C: Controls	
Return	Monthly return for the individual US firms
Volatility	12-month rolling window of the firm standard deviation based on the firm's return.
Beta	12-month rolling window of the firm beta based on the regression of the firm's return on S&P 500 return (market return).
Logassets	Natural logarithms of total assets
Divnetinc	Gross dividends-common stocks divided by net income after taxes

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Table A1 – continued from previous page

Variable	Definitions
Ebitassets	Normalized Earnings before interest and taxes (EBIT) divided by total assets
Capexassets	Capital expenditure (Capex) divided by total assets
Booktomar	Book value(computed as book value per share multiply by total common shares outstanding) divided by market capitalization
Debtassets	Total debt divided by total assets

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Table A2: **ESG Performance and Disparity Across Sectors.**

This table displays the results of the regressions of the monthly cost of protection against downside risk (IVSDn) on the sustainability performance and the ESG disparity based on Equation (2). This table reports only the coefficients on sustainability performance (β) and on ESG disparity (λ) for each sector. The control variables are beta, volatility, return, logassets, divnetinc, ebitaseets, capexaseets, debtassets and booktomar. It also controls for a fixed-year effect. We classify firms into sectors based on the Global Industry Classification Standard (GICS). The GICS classifies firms into 12 sectors: Energy, Material, Industrials, Consumer Discretionary, Consumer Staples, Health Care, Financials, Information Technology, Communication Services, Utilities, and Real Estate. We label firms that we could not match to any sector as 'No sector identified'. Standard errors are reported in parentheses. Conventional significance levels apply. *p<0.1; **p<0.05; ***p<0.01.

	ESG		Environmental		Social		Governance	
Coefficients	β_1	λ_1	β_1	λ_1	β_1	λ_1	β_1	λ_1
Industry:								
Energy	−0.001***	0.003***	−0.002***	0.002***	−0.001***	0.003***	−0.00001	0.003***
	(0.0003)	(0.0004)	(0.0002)	(0.0004)	(0.0002)	(0.0004)	(0.0002)	(0.0004)
Material	0.001***	0.001	0.001***	0.001**	0.001***	0.001*	0.0003*	0.0003
	(0.0002)	(0.0004)	(0.0002)	(0.0004)	(0.0002)	(0.0004)	(0.0002)	(0.0004)
Industrials	−0.001***	0.001**	−0.0004**	0.001*	−0.001***	0.001**	0.001***	0.001**
	(0.0002)	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0003)
Consumer	−0.001***	0.002***	−0.001***	0.001***	−0.001***	0.002***	−0.0004***	0.002***
Discretionary	(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)
Consumer	−0.0004*	0.002***	−0.0001	0.002***	−0.001***	0.002***	0.0003	0.002***
Staples	(0.0002)	(0.0004)	(0.0002)	(0.0004)	(0.0002)	(0.0004)	(0.0002)	(0.0004)
Health Care	−0.002***	0.001***	−0.001***	0.0003	−0.002***	0.001**	−0.0001	0.001***
	(0.0002)	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0003)
Financials	−0.0002	0.004***	−0.001**	0.004***	0.001**	0.005***	−0.00002	0.004***
	(0.001)	(0.001)	(0.0003)	(0.001)	(0.0005)	(0.001)	(0.0003)	(0.001)
Information	−0.001***	0.003***	−0.001***	0.002***	−0.001***	0.003***	0.0002	0.003***
Technology	(0.0002)	(0.0003)	(0.0001)	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0003)
Communication	0.004***	−0.001**	−0.001***	−0.001	−0.002***	−0.0003	0.002***	−0.001**
Services	(0.001)	(0.001)	(0.0004)	(0.001)	(0.0005)	(0.001)	(0.0003)	(0.001)
Utilities	0.0005	0.0001	0.002***	0.001	0.001**	0.0002	0.001**	−0.0003
	(0.0004)	(0.001)	(0.0003)	(0.001)	(0.0004)	(0.001)	(0.0003)	(0.001)
Real Estate	−0.001***	−0.001**	−0.001***	−0.002***	0.00001	−0.001**	−0.0004*	−0.001*
	(0.0003)	(0.0004)	(0.0002)	(0.0005)	(0.0003)	(0.0004)	(0.0002)	(0.0005)
No sector	0.006***	0.001	0.001**	0.003**	0.005***	0.002*	0.002***	0.001
identified	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)

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Table A3: **Sub-Sample Regressions**

This table presents the results of the sub-sample regressions of the monthly cost of protection against downside risk (IVS) on the sustainability performance and the ESG disparity based on Equation (2). Only the coefficients on sustainability performance and on ESG disparity are reported. The control variables are firms' CAPM beta and volatility, estimated over a 12-month period, return, *logassets* (measuring firm size and is computed as the natural logarithm of firm's assets), *divnetinc* (the ratio of the firm's gross dividend to net income), *ebitassets* (the ratio of the firm's earnings before interest and tax (EBIT) to assets), *capexassets* (the ratio of the firm's capital expenditure (capex) to assets), *debtassets* (the ratio of total debt to total assets), and *booktomar* (the ratio of the firm's equity book value to the market value). All specifications include year fixed effects. Panel A runs a regression of the sample from January 2010 to December 2021. Panel B reports results for a sample that covers the period from 2002 to 2022 and excludes firms with zero environmental scores. Standard errors are reported in parentheses. *p<0.1; **p<0.05; ***p<0.01.

	Dependent variable:			
	Cost of protection against downside risk			
	(1)	(2)	(3)	(4)
Panel A: Sample from 2010 to 2022				
ESG	−0.001***			
	(0.0001)			
E		−0.001***		
		(0.0001)		
S			−0.001***	
			(0.0001)	
G				0.0002***
				(0.0001)
ESG disparity	0.002***	0.001***	0.002***	0.002***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Fixed Effects	Yes	Yes	Yes	Yes
Constant and Controls	Yes	Yes	Yes	Yes
Observations	82,528	82,528	82,528	82,528
R^2	0.224	0.224	0.225	0.223
Adjusted R^2	0.224	0.224	0.225	0.223
Residual Std. Error (df = 82505)	0.401	0.401	0.401	0.401
F Statistic (df = 22; 82505)	1,081.669***	1,082.779***	1,091.286***	1,075.681***
Panel B: Excluding firms with zero E score				
ESG	−0.001***			
	(0.0001)			
E		−0.001***		
		(0.0001)		
S			−0.001***	
			(0.0001)	
G				0.00004
				(0.0001)
ESG disparity	0.001***	0.001***	0.001***	0.001***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Fixed Effects	Yes	Yes	Yes	Yes
Constant and Controls	Yes	Yes	Yes	Yes
Observations	80,395	80,395	80,395	80,395
R^2	0.275	0.275	0.275	0.274
Adjusted R^2	0.275	0.275	0.275	0.274
Residual Std. Error (df = 80366)	0.364	0.364	0.364	0.365
F Statistic (df = 28; 80366)	1,091.023***	1,089.241***	1,091.353***	1,082.686***

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Table A4: **MSCI ESG Scores**

This table presents the results of the regressions of the monthly cost of protection against downside risk (IVS) on the MSCI sustainability ESG, E, S, and G scores and ESG disparity based on Equation (2). This table reports only the coefficients on sustainability performance and on ESG disparity. All specifications include the control variables in Table 3. Standard errors are reported in parentheses. *p<0.1; **p<0.05; ***p<0.01.

	Dependent variable:			
	Cost of protection against downside risk			
	(1)	(2)	(3)	(4)
ESG	−0.021***			
	(0.002)			
E		−0.018***		
		(0.001)		
S			−0.004***	
			(0.001)	
G				0.005***
				(0.001)
ESG disparity	0.006***	0.008***	0.006***	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)
Year FE	Yes	Yes	Yes	Yes
Constant and Controls	Yes	Yes	Yes	Yes
Observations	79,167	79,167	79,167	79,167
R^2	0.185	0.187	0.184	0.184
Adjusted R^2	0.184	0.186	0.183	0.184
Residual Std. Error (df = 79146)	0.457	0.457	0.458	0.457
F Statistic (df = 20; 79146)	896.532***	907.718***	889.728***	891.151***

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Table A5: **Other Option-Implied Risk Measures**

This table displays the results of the regressions of the option-implied risk measures outlined in Panel A of Table A1 on the sustainability performance based on the model in Equation (1). Only the coefficients on sustainability performance are reported for brevity. All specifications include the control variables in Table 3, as well as year fixed effects. Panel A reports results for model-free implied volatility measures on the downside. Panel B has the results for other option-implied measures. Standard errors are reported in parentheses. *p<0.1; **p<0.05; ***p<0.01

Dimension	ESG	Environmental	Social	Governance
Panel A: Model-free implied volatility measures on the downside				
smfivd	−0.0002***	−0.0002***	−0.0001***	−0.00001
	(0.00002)	(0.00001)	(0.00001)	(0.00001)
mfivd_bkm	−0.0004***	−0.0003***	−0.0001***	0.00003
	(0.00003)	(0.00002)	(0.00003)	(0.00003)
mfivd_bjn	−0.0003***	−0.0002***	−0.0001***	0.00001
	(0.00003)	(0.00002)	(0.00002)	(0.00002)
Panel B: Other option-implied measures				
smfiv	−0.001***	−0.0003***	−0.0001	0.0001**
	(0.00005)	(0.00003)	(0.00004)	(0.00003)
mfiv_bkm	−0.001***	−0.0004***	−0.0001***	0.00004
	(0.00005)	(0.00003)	(0.00004)	(0.00003)
mfiv_bjn	−0.001***	−0.0004***	−0.0001***	0.00004
	(0.00004)	(0.00003)	(0.00004)	(0.00003)
mfis	0.00004	0.0003***	0.001***	−0.00004
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
mfik	−0.001***	−0.003***	−0.005***	0.002***
	(0.0003)	(0.0002)	(0.0003)	(0.0003)
cvix_sigma2	−0.001***	−0.0004***	−0.0001***	0.00004
	(0.00005)	(0.00003)	(0.00004)	(0.00003)
rix	−0.0001***	−0.0001***	−0.00001*	0.00002***
	(0.00001)	(0.00001)	(0.00001)	(0.00001)

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Table A6: **Credit Default Swap (CDS) Spreads**

The table reports the results of the regression of monthly credit default swap spreads on firms' ESG rating and ESG disparity based on the model in Equation (2). Only the coefficients on sustainability performance and ESG disparity are reported for brevity. All specifications include the control variables in Table 3, as well as year fixed effects. Panel A reports results for the overall ESG score. Panel B reports estimates for the Environmental, Social and Governance pillar scores. Panel C reports results for the category scores. Standard errors are reported in parentheses. *p<0.1; **p<0.05; ***p<0.01.

	Dependent variable : Credit Default Swap	
Coefficients	ESG rating - β_1	ESG disparity - λ_1
Panel A: Overall ESG Score		
ESG	−0.276***	0.179**
	(0.055)	(0.088)
Panel B: Pillar Scores		
Environmental	−0.145***	0.136
	(0.041)	(0.091)
Social	−0.032	0.217**
	(0.047)	(0.088)
Governance	−0.038	0.230***
	(0.042)	(0.088)
Panel C: Category Scores		
Environmental:		
Resource use	−0.001	0.222**
	(0.032)	(0.090)
Emissions reduction	−0.103***	0.158*
	(0.033)	(0.090)
Innovation	−0.047	0.206**
	(0.029)	(0.088)
Social:		
Workforce	−0.011	0.220**
	(0.038)	(0.088)
Human rights	0.251***	0.305***
	(0.029)	(0.088)
Community	−0.087*	0.216**
	(0.045)	(0.087)
Product responsibility	−0.143***	0.207**
	(0.030)	(0.087)
Governance:		
Management	−0.035	0.235***
	(0.033)	(0.088)
Shareholder	0.188***	0.190**
	(0.032)	(0.087)
CSR strategy	−0.171***	0.141
	(0.029)	(0.088)

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Table A7: **Alternative Regression Specifications**

This table presents the results of the different regression models of the monthly cost of protection against downside risk (IVS) on firm's ESG rating and ESG disparity based on the model in Equation (2). Only the coefficients on sustainability performance and ESG disparity are reported for brevity. All specifications include the control variables in Table 3. Column(1) provides regression results that incorporate year fixed effects but no clustered standard errors. Column(2) provides regression results that incorporate year-sector fixed effect but no clustered standard errors. Column(3) provides regression results that incorporate year-sector fixed effect and year-clustered standard errors. Column(4) provides regression results that incorporate year-sector fixed effect and year-sector clustered standard errors. Standard errors are reported in parentheses. *p<0.1; **p<0.05; ***p<0.01.

	Dependent variable:			
	IVS			
	(1)	(2)	(3)	(4)
Panel A : Thomson ESG Data				
ESG rating	−0.001***	−0.001***	−0.001***	−0.001***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
ESG disparity	0.001***	0.001***	0.001***	0.001***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Constant and controls	Yes	Yes	Yes	Yes
Fixed effect	Year	Year + Sector	Year + Sector	Year + Sector
Clustered SD error	No	No	Year	Year + Sector

Table A8: **Average Treatment Effect of ESG membership on Different Measures of Risk**

The table presents the result of the DiD estimates of the effect of the inclusion of a S&P 500 company in the S&P 500 ESG Index on the cost of protection against downside risk, proxied by the IVS, as well as alternative measures of risk: the simple model-free implied volatility (*smfiv*) and its version focusing on the downside (*smfivd*) of Martin (2011, 2017), the model-free implied volatility (*mfiv bkm*) of Bakshi et al. (2003), and the rare disaster concern index (*rix*) of Gao et al. (2018). *Treated* is a dummy variable that is equal to 1 if a firm is included in the S&P 500 ESG Index. *Post* is a dummy variable taking the value of 1 for the period after the launch of the S&P 500 ESG Index which in April 2019. Controls include firm's market beta, volatility, return, log assets, dividends standardized by net income, EBIT, CAPEX, and debt, all standardized by total assets, as well as its book-to-market ratio. The main variable of interest is the interaction term of *Treated* * *Post* which indicates the average treatment effect of ESG membership on the cost of protection against downside risk. *p<0.1; **p<0.05; ***p<0.01.

	Dependent variable:				
	IVS	smfiv	smfivd	mfiv_bkm	rix
	(1)	(2)	(3)	(4)	(5)
Treated	−0.064***	−0.020***	−0.011***	−0.024***	−0.002***
	(0.003)	(0.002)	(0.001)	(0.002)	(0.0003)
Post	0.103***	−0.034***	−0.012***	−0.036***	−0.006***
	(0.006)	(0.003)	(0.001)	(0.004)	(0.001)
Treated * Post	−0.145***	−0.113***	−0.036***	−0.114***	−0.018***
	(0.006)	(0.004)	(0.001)	(0.004)	(0.001)
Fixed Year Effect	Yes	Yes	Yes	Yes	Yes
Controls and constant	Yes	Yes	Yes	Yes	Yes
Observations	102,799	102,799	102,799	102,799	102,799
R^2	0.269	0.353	0.400	0.358	0.230
Adjusted R^2	0.268	0.352	0.399	0.358	0.230
Residual Std. Error (df = 102769)	0.366	0.221	0.077	0.225	0.038
F Statistic (df = 29; 102769)	1,301.243***	1,930.319***	2,358.373***	1,979.511***	1,057.269***

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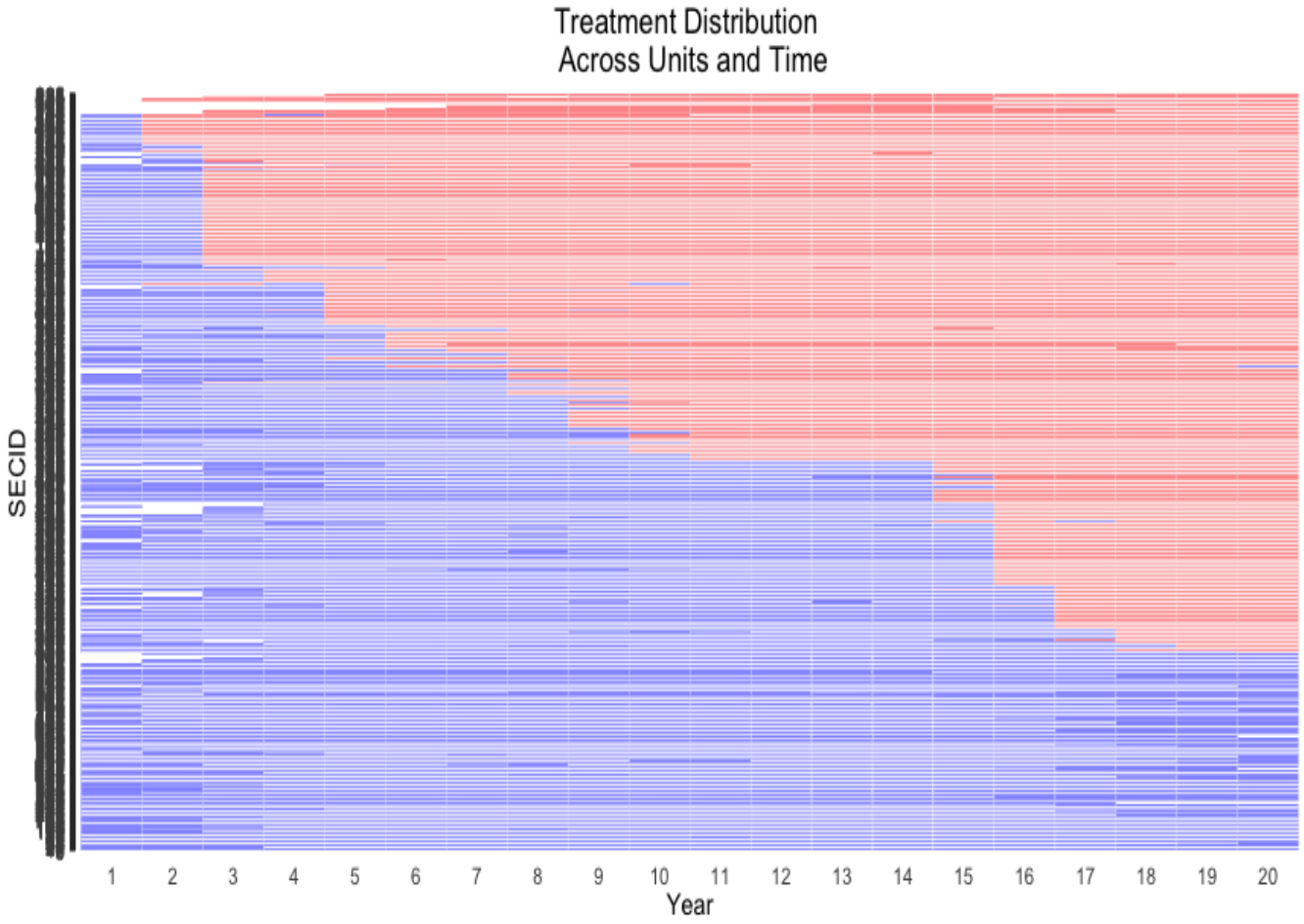
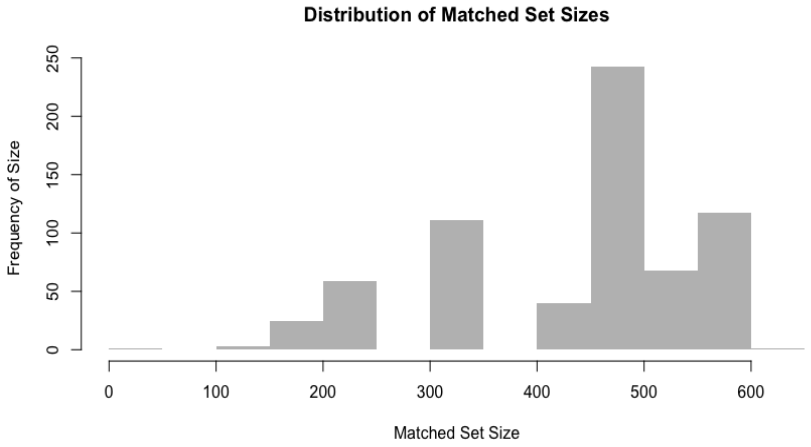


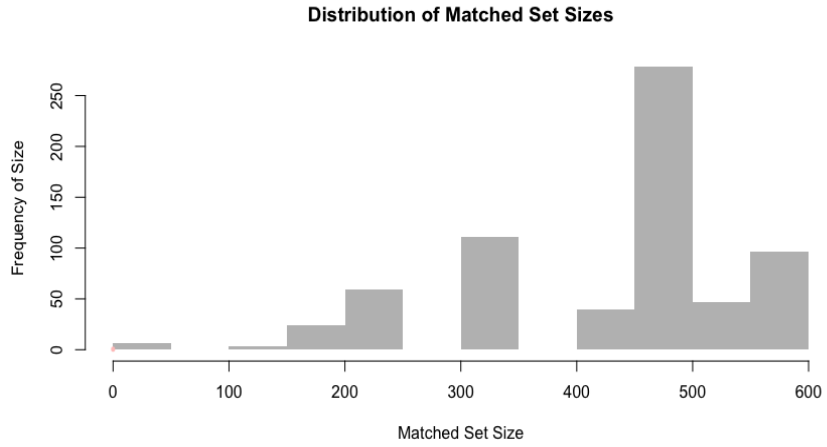
Figure A1: **Treatment Variation Plot for the Distribution of ESG Treatment Across Firms and Time.** Each bar corresponds to a firm (identified by its security ID, SECID, on the vertical axis). The red (blue) bars represent the ESG treatment (control) firm-year observations. Year 1 corresponds to 2001 and year 20 corresponds to 2020.

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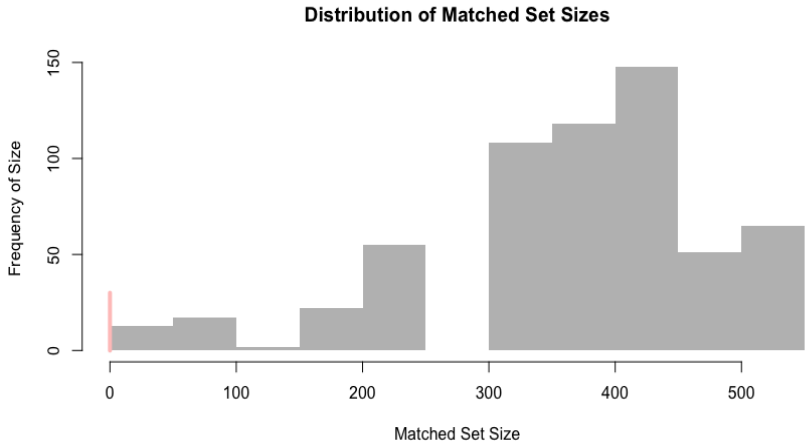
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(a) Up to 6 identical treatment periods



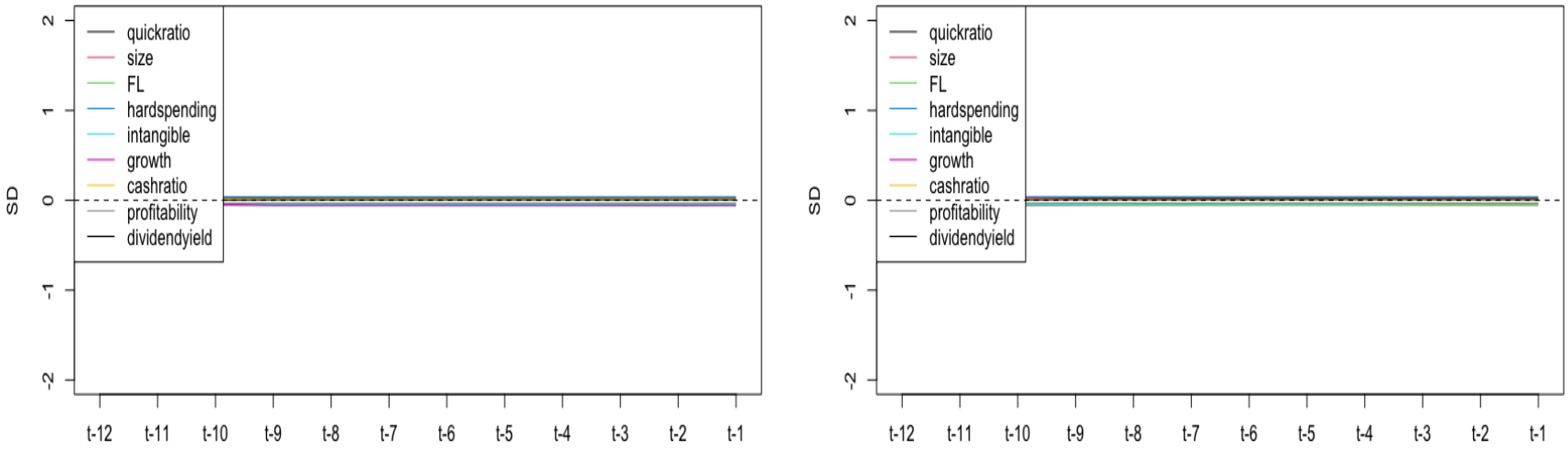
(b) Up to 12 identical treatment periods



(c) Up to 24 identical treatment periods

Figure A2: **Frequency Distribution of the Number of Matched Control Firms.** This figure plots the distribution of matched set sizes, i.e. the number of control matched firms that share the same treatment history as the treated firm prior to the treatment period. Panels (a) through (c) correspond to treatment periods of 6, 12 and 24 months. The thinner red vertical bars at zero represent the number of treated observations that have no matched control units.

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(a) CBPS Weighting

(b) PS Weighting

Figure A3: **Covariates Balance** The figure plots the standardized mean difference between treated and matched firms' covariates over the 12-month pre-treatment period for two different weighting methods. The covariates we consider are firms' quick ratio, size, financial leverage, hardspending, intangibles, growth, cash ratio, profitability and dividend yield. Panel (a) plots the covariates balance based on the covariates balance propensity score (CBPS) weighting method. Panel (b) plots the covariates balance based on propensity score (PS) weighting.