The Importance of Climate Risks for Institutional Investors

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According to our survey about climate risk perceptions, institutional investors believe climate risks have financial implications for their portfolio firms and that these risks, particularly regulatory risks, already have begun to materialize. Many of the investors, especially the long-term, larger, and ESG-oriented ones, consider risk management and engagement, rather than divestment, to be the better approach for addressing climate risks. Although surveyed investors believe that some equity valuations do not fully reflect climate risks, their perceived overvaluations are not large. (*JEL* G11, G2, G3, Q54)

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Climate risks have potentially large effects on investors' portfolio companies. Some companies face direct costs related to changes in the climate, originating from extreme weather events or a general rise in sea levels. Examples include insurance companies' exposures to higher losses from insured properties in coastal areas and food producers' exposures to sustained drought spells. Other companies can be negatively affected from policies and regulations implemented to combat climate change. Fossil fuel firms, for instance, can

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be adversely affected by carbon pricing or limits on carbon emissions. Technological innovations related to climate change also threaten the business models of some portfolio firms that operate in traditional industries. For example, electric or fuel-cell-powered vehicles could disrupt traditional car manufacturers. These risks to portfolio companies, which can broadly be categorized into physical, regulatory, and technological climate risks, have the potential to adversely affect the outcomes for many investment management clients, pension beneficiaries, and shareholders of institutional investors. At the same time, climate change also provides investment opportunities for the portfolio companies and their institutional investors, for instance, in the areas of renewable energy or energy storage.

A nascent literature in finance provides theoretical and empirical evidence that institutional investors should consider climate risks in their investment decisions. Notably, recent asset pricing models highlight the importance of climate risks as a long-run risk factor (Bansal, Kiku, and Ochoa 2017) and the importance of carbon risks and environmental pollution in the cross-section of stock returns (Bolton and Kacperczyk 2019; Hsu, Li, and Tsou 2019). Growing evidence indicates that climate risks may be mispriced in financial markets (Hong, Li, and Xu 2019; Daniel, Litterman, and Wagner 2017; Kumar, Xin, and Zhang 2019). At the firm level, Addoum, Ng, and Ortiz-Bobea (2019) show that extreme temperatures can adversely affect corporate earnings, Pankratz, Bauer, and Derwall (2019) provide evidence that increasing exposure to high temperatures reduces revenues and operating income, and Kruttli, Tran, and Watugala (2019) show that extreme weather is reflected in stock and option market prices. Moreover, evidence suggests significant changes for firms after the Paris Agreement. For example, greater climate risk leads to lower firm leverage with firms decreasing their demand for debt and lenders reducing their lending to firms with the greatest risk (Ginglinger and Moreau 2019); banks began to price carbon risk into their loans after the Paris Agreement (Delis, de Greiff, and Ongena 2019); and credit ratings and yield spreads changed for polluting firms (Seltzer, Starks, and Zhu 2019). In addition, studies conclude that firms can lower their cost of capital and increase value by improving their environmental policies (Sharfman and Fernando 2008; Chava 2014; El Ghoul et al. 2018). On the investor side, archival studies show that better environmental policies are related to lower downside and overall portfolio risk (Hoepner et al. 2019; Gibson Brandon and Krueger 2018). In a similar spirit, Jagannathan, Ravikumar, and Sammon (2019) argue that investors can reduce portfolio risk by incorporating climate criteria into their investment processes and Rameli et al. (2019) provide evidence that investors react to political events related to firms' climate strategies.

Despite the growing empirical evidence that investors should take climate considerations into account, integrating climate risks into the investment process can prove to be challenging, with investment tools and best practices not yet well established. For example, many market participants, including

institutional investors, find climate risks difficult to price and hedge, possibly because of their systematic nature, a lack of disclosure by portfolio firms, and challenges in finding suitable hedging instruments.[1]

In this study we use a survey instrument to better understand whether and how institutional investors consider climate risks in their investment decisions. As such, we examine the ways in which investors view and manage climate risks and whether systematic cross-sectional variation exists in their opinions about climate risks and their strategies to manage these risks. Through this analysis we contribute to the emerging archival research that suggests investors should consider climate risks. Our study also contributes to the knowledge on how institutional investors engage with their portfolio companies on climate risk matters, adding to the findings in Dimson, Karakaş, and Li (2015, 2018) and McCahery, Sautner, and Starks (2016). Understanding the specific role of institutional investors is important, as they are increasingly viewed as catalysts in driving firms to reduce their carbon emissions and to prepare for a low-carbon economy (Andersson, Bolton, and Samama 2016b; OECD 2017).

The 439 survey respondents should be knowledgeable about the role of climate risks for their institutions, as one-third hold executive-level positions in their institutions. Further, our sample includes 48 respondents from institutions with more than $100 billion in assets under management. This sizeable representation of very large investors is useful, because such institutions could have particularly strong influences on their portfolio firms' climate policies. The respondents' institutions are located throughout the world, which allows us to provide a global perspective on the role of climate risks. Our survey addresses four key areas: the role of climate risks in investment decisions; climate risk management; shareholder engagement related to climate risks; and the implications of climate risks for asset pricing.

With regard to the first set of questions focused on the importance of climate risks in comparison to other risks, we find that our respondents deem traditional financial risks to be the most important risks they face, followed by operating, governance, and social risks. Climate risks and environmental risks are ranked fifth and sixth, respectively. However, this low relative rank does not imply that climate risks are considered as financially immaterial. The investors believe that climate risks have significant financial implications for portfolio firms. This concern is also reflected in their climate expectations: the vast majority of investors expect a rise in global temperature by the end of this century, and four in ten even predict an increase that exceeds the Paris 2°C target. These expectations reflect the possibility of very negative effects on financial assets (Dietz et al. 2016).

A major challenge to investors can be the uncertainty of the time horizon (Barnett, Brock, and Hansen Forthcoming; Andersson, Bolton, and Samama

[1] See Barnett, Brock, and Hansen (Forthcoming) for the challenges to price uncertainty induced by climate change. Engle et al. (2019) and Andersson, Bolton, and Samama (2016a) discuss strategies to hedge climate risks.

2016a) over which climate risks will materialize. Consequently, we also evaluate the investors' views on the horizons over which they expect climate risks to materialize financially. Despite the potential horizon uncertainty, our respondents do not view climate risks as a theme of the distant future. Fewer than 10% believe that climate risks will materialize only in 10 years or more, whereas 50% state that climate risks related to regulation have already started to materialize.

Considerations of climate risks arise from both financial and nonfinancial motivations. Purely financial motivations include how climate risks can affect returns and risks. For example, Bénabou and Tirole (2010) posit that one view of being environmentally responsible would be that of "doing well by doing good," under which investors take a long-term view and maximize intertemporal profits. Some argue that climate change results in the stranding of assets, which will lower portfolio values (Litterman 2013). Others maintain that numerous investors consider climate risks primarily because of nonpecuniary motives. Examples include the preferences of their clients or those of their investment managers (Riedl and Smeets 2017; Hong and Kostovetsky 2012). Other suggested motivations include regulatory requirements (FIR 2016), peer pressure, or moral obligations.

Our survey demonstrates that no single motivation strongly commands investors' perspectives on the incorporation of climate risks into their portfolio decisions. Agreement is strongest for three motives: the protection of the investors' reputations, their moral/ethical considerations, and their legal/fiduciary duties, two of which (protection of reputation and legal/financial duties) have both financial and nonfinancial implications (e.g., Fombrun and Shanley 1990). The next highest-frequency motivations are more purely financial: the ideas that incorporating climate risks into the investment process improves investment returns and reduces portfolio risks.

The second and third areas of the survey focus on implementation aspects, in particular, risk management and shareholder engagement. A survey is a useful approach for studying these topics as implementation techniques are difficult to detect using archival methods, because they are generally unobservable to the researcher. For example, without asking investors, it is difficult, if not impossible, to understand their use of scenario analyses, hedging activities, and behind-the-scenes engagement practices. Our survey shows that investors take a wide variety of approaches to managing climate risks, with only a small percentage (7%) having chosen no approach to manage their climate risks during the 5 years preceding the survey.[2] Although large variation exists in their approaches, the two major approaches are to conduct analyses of portfolio firms' carbon footprints and stranded asset risks, which are employed by 38% and 35% of the respondents, respectively. Some of the respondents take these

[2] We note that respondents with more sophisticated tools would have been more likely to participate in the survey.

approaches one step further by attempting to reduce the carbon footprints (29%) or stranded asset risks (23%) of their portfolios. Investors also use other forms of climate risk management, such as incorporating climate risks into their valuation models (26%) or hedging against climate risks (25%). From the list of 12 possible approaches, the least frequently used tool is to divest problematic portfolio firms, which is employed by 20% of the investors. The large heterogeneity across investors suggests that the industry is still in the process of finding the most effective ways to manage climate risks.

Our cross-sectional analyses indicate that institutions more concerned about the financial costs of climate risks use a wider range of tools to manage risks associated with climate change. Additionally, investors with longer horizons, and institutions with a higher fraction of holdings subject to ESG analysis, also engage in more climate risk management.

Institutional investors can also mitigate climate risks by engaging with their portfolio firms.[3] Through survey questions we examine the investors' engagement strategies as well as their portfolio firms' responses. We find a generally high level of engagement by our respondent group as only 16% had taken no engagement actions over the previous 5 years. This percentage is comparable to the percentage in the McCahery, Sautner, and Starks (2016) survey on shareholder engagement, in which they find that only 19% of the respondents did not engage with their portfolio firms. The respondents typically use multiple channels to engage over climate risks. Having discussions with management is cited as the most frequently used channel (43% of respondents used this approach, with 32% proposing specific actions to management on climate risk issues). Close to 30% of the investors submitted shareholder proposals on climate risk issues, and a similar fraction voted against management on proposals because of climate risk concerns. These numbers are consistent with a recent trend of successful votes on climate shareholder proposals submitted to major oil and gas firms (Lemos Stein 2018).

Most firms responded to the investors' engagements, although a number of the firms simply acknowledged an issue rather than successfully resolving it. Successful engagements are reported by 25% of respondents. If portfolio firms did not respond to engagement or showed resistance, then the investors typically refrained from further actions rather than initiating more engagement, trying to hedge the climate risk issue or divesting from the firm. In fact, divestment was the least used course of action when investors were dissatisfied with firm responses to their engagement (only 17% exited under such circumstances). This observation, together with the low prevalence of divestment for risk management purposes, is interesting in light of the debate about whether

[3] To engage with portfolio firms, institutional investors are increasingly banding together over climate-focused initiatives, such as Climate Action 100, the Portfolio Decarbonization Project, the Global Investor Coalition on Climate Change, and CDP. For example, CDP—a nongovernmental organization that collects data on how publicly listed firms manage climate risks—has support from investors who represented over $87 trillion in assets under management in 2018.

divestment or engagement is more effective in combating climate change, particularly given that divestment is the approach recommended by a number of activists and followed by an increasing number of institutions (Mooney 2017).

We find that investors that are more concerned about the financial effects of climate risks engage firms along more dimensions. Larger investors also engage firms across a wider range of channels, possibly because they have more resources to engage and they have larger firm holdings. The latter reduces free-rider concerns and implies stronger engagement incentives (Dimson, Karakaş, and Li 2018).

The survey's fourth section addresses the implications of climate risks for asset pricing. Understanding institutional investors' perceptions of any potential mispricing is particularly relevant as they likely act as marginal investors, thereby affecting equity prices. We elicit investors' beliefs regarding whether equity markets over- or underprice climate risks. To achieve meaningful responses, we employ a sector-level approach including both directions of mispricing, as climate risks may cause some sectors to be overvalued and others to be undervalued.

Our respondents believe that equity valuations do not fully reflect the risks from climate change, although the overvaluations are not perceived as being very large. Not surprisingly, the oil sector is considered as the most overvalued sector overall, followed by traditional car manufacturers and electric utilities. Yet, the perceived misvaluation of these sectors relative to other sectors seems modest.[4] We find little evidence for a systematic link between investor characteristics and their beliefs about the mispricing of climate risks. That is, there exists little cross-sectional variation in the investor types with the exception of two characteristics. We observe that the investor types that view more underpricing of climate risks are those with a larger share of their portfolios oriented to ESG standards and those that engage portfolio firms along more dimensions (which may explain their engagement activities).

We also asked the investors for their opinions on whether climate change causes assets in certain sectors to become stranded (Litterman 2013). We find the largest percentages of respondents (25% and 21%) consider this stranded asset risk to be very high in the coal and unconventional oil producer sectors, respectively.

In terms of generalizability of our findings, we should note that our respondent group is likely biased toward investors with a relatively high awareness of climate risks, and possibly with higher credentials in climate risk management. The reason is that such investors are probably more disposed to participate in a climate risk survey. In addition, some of our responses were obtained at ESG conferences. Nevertheless, understanding the views and actions of such investors is particularly important, because they are more likely

[4] Nevertheless, even small adjustments can significantly affect asset values. A 5% market capitalization correction among the world's ten largest oil firms would imply a $65 billion value loss, based on data from May 2018.

to shape corporate climate policies and to guide future practices of integrating climate issues into investment management.

Our paper contributes to a better understanding of the treatment of climate risks in financial markets. By designing our survey in order to analyze conceptual and empirical questions that are not directly testable through archival research, we contribute to several literatures. We contribute to a better understanding of the uncertainties of pricing of climate risk (e.g., Hong, Li, and Xu 2019; Bansal, Kiku, and Ochoa 2017; Daniel, Litterman, and Wagner 2017) through documenting the importance institutional investors place on climate risks, their forecasts of the probability of temperature changes, their assessments of the relative mispricing in the industrial sectors most exposed to climate risks, and how these attributes are related to investor characteristics. Additionally, we contribute to the literature on risk management, particularly the management of climate risk exposure (e.g., Andersson, Bolton, and Samama 2016a; Engle et al. 2019) by showing the extent to which institutional investors use various risk management techniques and how investor characteristics can explain these behaviors. We contribute to the literature on shareholder engagements on environmental issues (e.g., Dimson, Karakaş, and Li 2015; Dimson, Karakaş, and Li 2018; Hoepner et al. 2019; Barko, Cremers, and Renneboog 2019) through our analyses of which investors engage, the engagement channels they use to combat climate risk, and by providing evidence on how firms typically respond to such engagements.

1. Methodology and Research Design

1.1 Survey development

Our survey focuses on questions that are difficult to answer based on archival data. Whenever possible, we generated our questions on the basis of theories that make predictions about different aspects of climate risks. Internet Appendix B provides the survey instrument.[5] We used an iterative process for developing the survey. As part of this process, we revised the survey based on the feedback from two referees, several academics, and practitioners. We then presented the survey instrument at a conference at Columbia University. After this event, we further revised the survey based on feedback by a discussant and conference participants. We also ran beta tests with practitioners to ensure the wording and questions would be clear. Finally, we had a professional survey designer review the wording, the ordering of the questions, and the length of the survey. We then programmed an online version with random orderings of response choices. An iterative process in designing a survey has been found to be

[5] The survey also contained questions on methods to evaluate the consequences of climate risks for the investors' portfolios, questions on the climate risk disclosure, and questions on the portfolio holdings relative to a low-carbon benchmark. These questions are not covered in this paper because of space considerations. However, they are discussed in Ilhan et al. (2019).

beneficial (Krosnick and Presser 2010). Surveys are increasingly used in the finance literature, enabling better understandings of such topics as managers' corporate-finance choices (Graham and Harvey 2001), institutional investor activism (McCahery, Sautner, and Starks 2016), investor relations (Karolyi and Liao 2017), ESG investing (Amel-Zadeh and Serafeim 2018), and barriers to cross-border investing (Harvey et al. 2014).

1.2 Survey delivery

We used both an online and a paper version of the survey that we distributed through four delivery channels. First, we personally distributed the paper version at four institutional investor conferences: the Sustainable Investment Conference in Frankfurt on November 9, 2017; the ICGN Paris Event on December 6 and 7, 2017; the Asset Management with Climate Risk Conference at Cass Business School in London on January 23, 2018; and the ICPM Conference in Toronto on June 10–12, 2018. We used the responses from Frankfurt and Paris as beta tests to further improve the design. As a result, some of the questions in the final survey were not included in these beta versions, and some beta questions were dropped eventually. We obtained a total of 72 responses from these four conferences.

Second, we distributed the survey to a list of investment professionals compiled by a survey service provider that manages a global panel of more than 5m registered participants. The panel contains detailed data on individuals' industries, job titles, and age to identify relevant panel subsamples. The service provider has several mechanisms in place to ensure the authenticity of the participants. Based on this panel we identified 1,018 individuals that work in senior functions at institutional investors. The provider then invited these panelists in March 2018 to participate in the online survey. To encourage participation, the panelists received a small gift when filling in the survey (a voucher or donation to charity). We obtained 410 initial responses from this channel. To mitigate concerns over careless responses, we excluded participants that took less than five minutes to complete the survey and participants for which basic checks yielded logical inconsistencies in the responses (Meade and Craig 2012). We eliminated 90 responses in this process leaving 320 responses of good quality. These respondents took on average 15 minutes to complete the survey.

Third, in April 2018, we emailed invitations to participate in the survey to a list of institutional investors that cooperate with a major asset owner on climate risk topics through CERES and IIGCC. The asset owner ranks among the world's largest investors and wrote a supporting letter on our behalf. We obtained 28 responses through this channel. The investor neither influenced the survey design nor the analysis of responses. The investor also did not ask for or receive access to the survey responses.

Fourth, we sent invitations to participate in the online survey to personal contacts of the authors who work at different institutional investors, yielding

19 additional responses. In total we received 439 responses across the four delivery channels.

1.3 Respondent characteristics

Table 1 provides an overview of the characteristics for our survey respondents. The largest numbers of respondents are fund/portfolio managers (21%), followed by executive/managing directors (18%). About one-third of the sample hold executive level positions in their institutions, such as CIO (11%), CEO (10%), or in related functions (10%). Remaining respondents include investment analysts/strategists (16%) and ESG/RI specialists (10%). Most respondents work for asset managers (23%) and banks (22%), followed by pension funds (17%), insurance companies (15%), and mutual funds (8%). The remaining 15% work for other institutions, including sovereign wealth funds, endowments or hedge funds. Our sample includes 19% of respondents that work for institutions with less than $1 billion in assets under management, 32% with assets between $1 billion and $20 billion, 23% with assets between $20 billion and $50 billion, and 16% with assets between $50 billion and $100 billion. A total of 48 respondents, or 11%, work for institutions with more than $100 billion in assets.

We asked the respondents to report the typical holdings periods for their investments. Respondents could classify holding periods into short (less than 6 months), medium (6 months to 2 years), long (2 years to 5 years), and very long (more than 5 years). Only 5% of respondents' institutions typically hold investments for less than 6 months, 38% have medium holding periods, 38% have long holding periods, and the remaining 18% typically hold investments for more than 5 years. The headquarters of the institutions for which our respondents work are located in different world regions: 32% are in the United States, 17% in the United Kingdom and Ireland, 12% in Canada, 11% in Germany, 7% in Italy, 5% in Spain, and the rest in other parts of the world. We also collected information on the institutions' investment structures. Across the institutions the average portfolio share that incorporates ESG aspects is 41%, they invest on average 47% in equities (43% in fixed income), and an average of 38% of their assets is passively invested. Finally, we asked which positions at their firms would be responsible for the implementation of climate risks in the investment process (they could indicate more than one). The results indicate that climate risks have become a topic with C-level responsibility at more than 50% of the investors: CIOs are responsible for implementing climate risks at 36%, and CEOs at 23%, of the institutions.

Because our respondents are anonymous, one question could be whether we have redundancy in responses. However, we are confident that in the vast majority of cases we have only one observation per institutional investor. The reason is that, for 87% of the observations, we have sufficient data to determine that none of the following identifying characteristics coincide: location, assets under management, institutional investor type, investor horizon,

Table 1
Survey and respondent characteristics

Distribution channels (N = 439)	Percentage	Investor horizon (N = 432)	Percentage
Panel	73	Short (less than 6 months)	5
Conferences	16	Medium (6 months to 2 years)	38
Asset owner	6	Long (2 to 5 years)	38
Personal	4	Very long (more than 5 years)	18
Respondent position (N = 428)	**Percentage**	**Region (N = 429)**	**Percentage**
Fund/portfolio manager	21	United States	32
Executive/managing director	18	United Kingdom	17
Investment analyst/strategist	16	Canada	12
CIO	11	Germany	11
CEO	10	Italy	7
CFO/COO/chairman/other executive	10	Spain	5
ESG/RI specialist	10	The Netherlands	4
Other	2	France	3
Institutional investor type (N = 439)	**Percentage**	Others (<3%)	9
Asset manager	23	**Investment structure of portfolio**	**Mean**
Bank	22	ESG share (N = 415)	40.6
Pension fund	17	Equity share (N = 400)	47.0
Insurance company	15	Fixed income share (N = 402)	43.1
Mutual fund	8	Passive share (N = 419)	38.2
Other institution	15	**Positions responsible for climate risk (N = 439)**	**Percentage**
Assets under management (N = 430)	**Percentage**	CIO	36
Less than $1 billion	19	Fund/portfolio manager	29
Between $1 billion and $20 billion	32	Investment analyst/strategist	26
Between $20 billion and $50 billion	23	CEO	23
Between $50 billion and $100 billion	16	ESG/RI specialist	23
More than $100 billion	11	CFO/COO/chairman/other	19
		Executive/managing director	18

This table provides summary statistics on the survey distribution channels and the characteristics of the 439 individuals that participated in our survey. As not all respondents provided information on all investor or investment characteristics, the number of observations used in the different parts of the table can fall below 439. We report data on the distribution channel, position of the responding individuals (Question G8), type of institution (Question G1), institution size (Question G6), investment horizon (Question G2), geographic distribution (Question G7), ESG shares (Question G5), equity and fixed income shares (Question G3), passive shares (Question G4), and institutional responsibility for climate risk policies (Question D3).

ESG share (±10% variation in the variable), equity share (±10%), and passive share (±10%). In 9% of the observations we cannot exclude the possibility that respondents work for the same institutional investors, as identifying observations coincide. However, the responses are sufficiently different among these respondents to discount that possibility with some degree of assurance. In the remaining observations we have insufficient information to determine whether characteristics coincide.

Internet Appendix Table 1 compares the respondents' characteristics across distribution channels. Most responses from our personal contacts were ESG specialists, while respondents linked to the asset owner were mostly executive/managing directors. The conference channel yielded mostly asset managers or asset owners (especially pension funds), partially because they

were the demographics targeted by the conferences. The panel respondents and those related to the asset owner work in smaller institutions; the panel institutions further have shorter horizons. ESG portfolio shares are largest among the asset owner's partners and smallest for the panel. We use distribution-type fixed effects in all of our subsequent regression analyses to account for systematic differences in the responses across the four distribution channels.

1.4 Response bias

Any survey faces the risk that respondents answer strategically or untruthfully. To mitigate this concern, we guaranteed anonymity, did not ask for names or employers, and collected only limited information on the respondents' institutions. The limitations of this approach are that we are unable to link the survey responses to the institutions' portfolio holdings and that some of the collected investor characteristics may be too coarse to allow us to obtain significant results in our cross-sectional tests.

We are unable to fully assess the potential response bias in our sample, such as how our responses would change if we had a random set of investors. However, we can provide some assessment of nonresponse bias by comparing characteristics of responding investors to those of the population at large, following, for example, Karolyi and Liao (2017). We compare the FactSet population of institutional investors to our sampled population and find that pension funds and banks are somewhat overrepresented in our sample (see Internet Appendix Figure 1). In contrast, mutual funds and asset managers are somewhat underrepresented. In terms of geographic distribution, our respondents are more likely to work for institutions in North America and Europe, compared to the universe of investors.

Overall, our respondent group is potentially biased toward investors with a relatively high awareness of ESG topics and relatively higher credentials in climate risk management. This outcome is a result of the fact that such investors can be expected to be more disposed to participate in a climate survey, and it is potentially also due to our delivery methods (especially the conference channel). This potential sampling bias is reflected in our respondents' high average ESG share of 41%, which exceeds the percentages reported in other studies. Amel-Zadeh and Serafeim (2018), for example, report an average ESG share of less than 15% in their sample of institutional investors.[6] We also have an oversampling of large investors. However, as pointed out earlier, understanding the views and actions of large investors with more sophisticated climate risk policies is instructive due to their role as leaders in guiding climate policies at portfolio companies, and other institutional investors.

[6] Some part of the difference in the ESG shares may be explained by the growing trend of considering ESG topics in investment mandates. Although our study captures investment characteristics survey as of 2018, the survey by Amel-Zadeh and Serafeim (2018) was executed in 2016.

In Internet Appendix Table 2, we evaluate the direction of the response bias between institutional investors with high and low ESG share, and between large and small institutions. We discuss these in Section 6.

2. Climate Risks in the Investment Process

2.1 Expectations about climate change

For climate risks to be important in the investment process requires that investors believe that climate change represents a risk. Thus, we first examine whether investors view climate change itself as being a significant possibility for the future. We ask their expectations regarding global temperature increases at the end of the century. We anchored expectations by referring to the 2°C target of the Paris Climate Accord and then requested the respondents' own expectations.

Figure 1A illustrates the respondents' climate expectations in total and by region. The figure shows a widespread belief in climate change. Across all respondents, only 3% do not expect any temperature increase, 16% expect an increase by up to one degree, and 30% by up to 2°C. Moreover, four in ten respondents expect a temperature rise that exceeds the Paris 2°C target, with 12% expecting an increase of more than 3°C. Illustrating the consequences of a temperature rise beyond 3°C , Thomas Buberl, CEO of insurer AXA has expressed the view that "we can clearly say that at a scenario between 3°C and 4°C, it's not insurable anymore" (Hirtenstein 2018). These expectations suggest that many of our respondents view very damaging climate scenarios to be likely, which implies that at least some of our respondents should have deep concerns about the effects of climate change on their portfolios. Examining the differences across regions, we find that similar proportions of respondents from North America and Europe expect temperature increases above 2°C. In addition, North American respondents have more pessimistic expectations when it comes to the most extreme scenario.

Because of the large uncertainty concerning climate change and its consequences (Barnett, Brock, and Hansen Forthcoming; Andersson, Bolton, and Samama 2016a), we asked the respondents to detail their confidence in the reported expectations. Figure 1B illustrates their responses to this question. Overall, there exists a large degree of confidence in expectations about global warming given that 45% reported that they are relatively confident in their expectations and another 34% are more or less confident. The figure also indicates some heterogeneity in confidence levels across world regions, as the percentage of relatively confident respondents varies between 36% and 51% with confidence levels being highest among North American respondents. Internet Appendix Table 3 shows that respondents that expect a stronger increase in temperatures also believe that climate change will have larger consequences for firms, which indicates internal validity across responses for some of the key climate variables we collected.

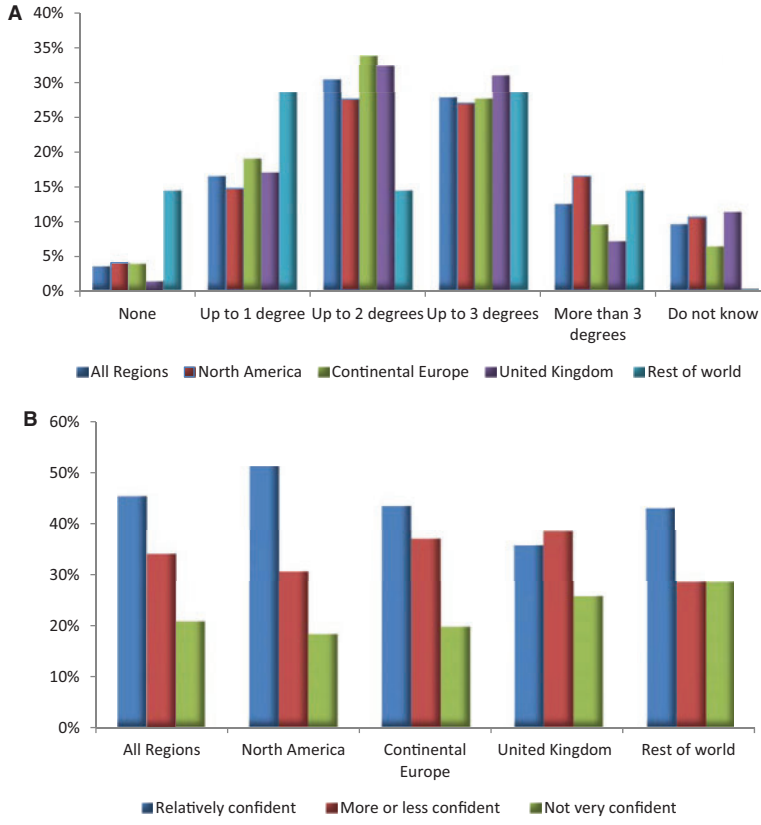

Figure 1
Institutional investor climate change expectations
Figure 1A provides respondents' expectations for the global temperature rise by the end of this century. We report results for the full sample and by region. Regions include North America (United States and Canada), Continental Europe, the United Kingdom and Ireland, and Rest of World. We anchored expectations by referring in our question to the 2°C target of the 2016 Paris Climate Accord. Respondents were asked to state their own climate expectations (Question D1) and to provide us with a confidence level for their assessment (Question D2). Figure 1B provides responses on the confidence level, again reported for the full sample and by region.

2.2 Importance of climate risks

Recent asset pricing models highlight the importance of climate risks as a long-run risk factor (Bansal, Kiku, and Ochoa 2017). However, it is unclear to what extent investors consider climate risks to be important in their investment decisions relative to other risks, and even whether they incorporate climate risks into those decisions at all. To establish a benchmark for the investors' risk considerations, we asked the survey participants to state the relative importance of six major risks when making investments in portfolio firms. Respondents were required to rank these investment decision risks from one (most important risk) to six (least important) (Question A1). Investors had to rank all six risks and tied ranks were not allowed. Table 2, panel A, shows the percentage of

respondents that rank a specific risk as most important as well as each risk's mean importance rank. As the table illustrates, investors consider standard financial risks (e.g., risks related to earnings or leverage), as most important, followed by operating risks (e.g., changes in demand), corporate governance risks (e.g., board structure), and social risks (e.g., labor standards). Climate risks are ranked fifth, with only other environmental risks, such as air pollution placing sixth. We find that 10% of the respondents consider climate risks as the most important risk. Overall, the ranking across risks appears in line with the focus on traditional investment risks in most of the finance literature. It also reflects that most investors currently concentrate resources in the investment process on risks other than climate risks (Blackrock 2016).

The low relative ranking of climate risks does not imply that the effects of climate change are perceived as financially irrelevant. To understand expectations of the financial effects of climate risks for portfolio firms, we asked our participants in Question A2 to rate the financial materiality of three sources of climate risks: physical risks (changes in the climate), regulatory risks (changes in regulation), and technological risks (climate-related technological disruption). Respondents were asked to rate each of these climate risks on a scale of one ("very important") to five ("not at all important"). Table 2, panel B, shows that the respondents on average rate the financial consequences of all three climate risks between 2.2 and 2.5, which means that the respondents regard the financial materiality of climate risks to be somewhere between "important" and "fairly important." The effects of regulatory and technological risks are seen as somewhat more important overall than those of physical risks (the

Table 2
Importance of climate risks and investor characteristics

A. Ranking of importance of investment risks (N = 406)

	Financial risk	Operating risk	Governance risk	Social risk	Climate risk	Other environ. risk
Percentage top risk	51	15	12	11	10	4
Mean ranking	2.2	2.9	3.3	3.7	4.0	4.6

B. Financial materiality and materialization of climate risks

Financial materiality	Regulatory climate risk (N = 393)	Physical climate risk (N = 393)	Technological climate risk (N = 393)
Mean ranking	2.2	2.5	2.2
Risk horizon	**Regulatory climate risk (N = 406)**	**Physical climate risk (N = 401)**	**Technological climate risk (N = 369)**
Already today	55%	34%	33%
< 2 years	19%	32%	19%
2 to 5 years	17%	15%	26%
5 to 10 years	5%	9%	11%
10 to 25 years	2%	7%	7%
> 25 years	0%	1%	3%
Never	1%	2%	1%

(*Continued*)

Table 2
(Continued)

C. Climate risks and investor characteristics

	Climate risk ranking	*Climate risk top 2*	*Climate risk relative to financial risk*	*Regulatory climate risk*	*Physical climate risk*	*Technological climate risk*
	(1)	(2)	(3)	(4)	(5)	(6)
Medium horizon	0.20	−0.36	−0.18	−0.18	−0.46	−0.60
	(0.35)	(−0.66)	(−0.40)	(−0.31)	(−0.89)	(−1.44)
Long horizon	0.39	−0.45	0.12	−0.68	−0.91**	−0.86**
	(0.66)	(−0.70)	(0.20)	(−1.31)	(−2.20)	(−2.28)
Assets under management	−0.16*	0.08	−0.15*	−0.08	−0.16*	−0.06
	(−1.93)	(1.03)	(−1.83)	(−0.71)	(−1.95)	(−0.46)
ESG share (x100)	−0.60	0.89	−1.46***	−0.39	−1.22***	−0.92***
	(−1.20)	(1.19)	(−3.83)	(−0.84)	(−3.02)	(−3.81)
Passive share (x100)	−0.30	0.39	−0.64	−0.10	−0.08	−0.08
	(−0.73)	(1.03)	(−1.21)	(−0.14)	(−0.27)	(−0.14)
Independent institution	0.17	−0.17	0.26*	−0.09	0.37*	−0.07
	(1.18)	(−0.52)	(1.83)	(−0.58)	(1.88)	(−0.58)
HQ country norms	−1.20	2.10	−1.73	2.17	3.03***	1.93
	(−0.78)	(0.94)	(−1.02)	(1.06)	(7.58)	(1.54)
Respondent position FE	Yes	Yes	Yes	Yes	Yes	Yes
Distribution channel FE	Yes	Yes	Yes	Yes	Yes	Yes
N	365	365	360	373	373	373
Pseudo *R*-sq.	.013	.048	.029	.025	.040	.023

Panel A reports the respondents' rankings of six major investment risks. We asked respondents to rank the six risks from one to six, where one is the most important risk and six the least important risk (Question A1). The panel reports the percentages of respondents that rank a risk as the most important risk. We also report the mean response, calculated as the average rank across respondents. Panel B reports the respondents' ratings of the financial materiality of different components of climate risk with respect to their portfolio firms (Question A2). The responses can vary between one (very important) and five (not at all important). The panel additionally reports the time horizons over which the respondents expect different climate risks to materialize financially (Question A3). Panel C reports ordered logit regressions (probit in Column 2) relating the perceived importance of climate risks to investor characteristics. We use five dependent variables: *Climate risk ranking* is the absolute ranking of the importance of climate risks (see panel A). The variable ranges from one (most important risk) to six (least important risk). *Climate risk top 2* equals one if climate risk is ranked as the most or second most important risk, and zero otherwise. *Climate risk relative to financial risk* is the difference in the ranking between climate risk and financial risk. The smaller the difference the closer climate risk is ranked relative to financial risk. *Regulatory, physical, and technological climate risk* measure the financial materiality of regulatory climate risk, physical climate risk and technological climate risk (Question A2). All three variables can range between one (very important) and five (not at all important). We use the following independent variables: *Medium horizon; Long horizon*; *Assets under management*; *ESG share; Passive share; Independent institution;* and *HQ Country Norms* (larger numbers reflect a stronger belief in the importance of environmental issues in an institutions' country). Table A1 defines all variables in detail. *t*-statistics (reported in parentheses) are based on standard errors that are clustered at the investor-country level. *$p < .1$; **$p < .05$; ***$p < .01$.

differences are statistically significant at the 1% level but relatively small in magnitude).

The perception that climate risks matter financially conforms with evidence from studies that use archival data to examine the financial effects of climate risks. Ilhan, Sautner, and Vilkov (2019), for example, document that regulatory climate risks increase tail risks in stock prices, and Addoum, Ng, and Ortiz-Bobea (2019) find that extreme temperatures affect firm performance. Baldauf, Garlappi, and Yannelis (2019) and Bernstein, Gustafson, and Lewis (2019)

show that expected sea level rises affect real asset values in coastal areas, although Murfin and Spiegel (2019) reach the opposite conclusion in their analysis. Akey and Appel (2018) and Bartram, Hou, and Kim (2019) show that pollution has real effects on firm decisions. Additional papers examine how fund managers (Kumar, Shashwat, and Wermers Forthcoming) and other investors (Choi, Gao, and Jiang Forthcoming) react to physical climate risk realizations. Similarly, Gibson Brandon and Krueger (2018) find that institutional investors' environmental policies change after extreme weather events and Painter (2019) shows that climate change considerations affect municipal bond prices. Further evidence regarding investor responses to climate risks lies in the fact that green bonds have become increasingly important (Baker et al. 2018; Flammer 2018; Tang and Zhang 2018; Zerbib 2019).

We expand this literature by evaluating investors' expectations regarding the horizons over which climate risks are expected to materialize. A challenge to investor decision-making is that the horizon by which climate risks materialize is highly uncertain (Barnett, Brock, and Hansen Forthcoming).[7] Although one usually assumes that physical risks mostly materialize over the longer term, regulatory risks can have a much shorter time frame. We elicit investors' views on the time period over which they consider the climate risks will materialize financially (Question A3).

Table 2, panel B, shows that the respondents overall believe that climate risks have already become important concerns. Very few respondents, less than 10%, believe that the three components of climate risk will have a delayed materialization of 10 years or more. In fact, a majority of the sample agrees that regulatory risks are already important concerns today. Fewer investors, but still more than 30%, believe that physical (and technological) risks are also relevant today, consistent with some of the evidence in the research cited earlier.

Overall, our numbers indicate that the respondents consider climate risks to matter for their institutions' short-term as well as their long-term assets. Moreover, their answers are consistent with the arguments of Weitzman (2012) and Barro (2013) that climate change corresponds to disaster risk. As Giglio et al. (2018) point out, climate change constitutes "a rare event with potentially devastating consequences for the economy."

The widespread perception that climate risks have begun to materialize raises the question of when, if at all, investors began to incorporate these risks into their investment processes. That is, how long have they been concerned about these risks? Internet Appendix Figure 2 shows that for most investors this is a relatively recent phenomenon. More than half of the respondents that incorporate climate risks started to do so within the past 5 years. On the other hand, a significant minority of investors have been long concerned about this

[7] Painter (2019) finds that investors seem to incorporate climate change into municipal bond pricing only for long-term bonds.

risk as 21% incorporated the risks into their investment process in some form more than 10 years *ago*.[8]

2.3 Investors' climate risk perceptions and investor characteristics

Next, we examine more closely the variation in perceptions of climate risks across investors. Temperature-augmented long-run risk models, such as that of Bansal, Kiku, and Ochoa (2017), imply that climate risks should be a bigger concern for long-term investors, who are more likely to bear the consequences of adverse climate risk realizations. In addition, recent research based on archival data suggests that long-term investors care more about ESG issues (Starks, Venkat, and Zhu 2018), and that environmental issues matter more for investment performance when institutions are long-term oriented (Gibson Brandon and Krueger 2018). These findings support the implication that long-term investors should be more concerned about climate risks than shorter-term investors. Related evidence comes from Shive and Forster (2019), who document a positive association between firm-level pollution and pressure from short-term investors.

The largest institutional investors often own a slice of the world economy through their sizeable holdings, and, thus, they are sometimes referred to as universal owners. Such investors become more exposed to externalities from climate change, causing them to be potentially more concerned about climate risks. Much like the universal owners, other institutional investors with highly diversified and more passively managed portfolios also should be more exposed to climate risks, as they have less scope to divest assets with large climate risk exposure. In addition, we expect investors who incorporate ESG factors also to be more concerned about climate risks, given that they explicitly consider environmental risks in their investment processes.

To test these cross-sectional predictions, we run regressions of the perceived importance of climate risks on several investor characteristics. The results, reported in Table 2, panel C, have several different proxies for investor perceptions of climate risk as dependent variables. The dependent variable in Column 1 is each respondents' absolute ranking of climate risk. In Column 2 the dependent variable is a dummy that equals one if climate risk is ranked as the most or second-most important risk. In Column 3, *Climate risk relative to financial risk* is the difference in the ranking between climate risk and financial risk, with smaller values of the variable indicating that a respondent has ranked climate risk closer to financial risk. In Columns 4 to 6 the dependent variables are the respondents' assessments of the materiality of regulatory, physical, and technological climate risks, respectively. These three variables range between one (very important) and five (not at all important).

We include a set of independent variables to evaluate the predicted relationships between perceptions of climate risks and investor characteristics.

[8] It should be noted that this number could reflect a high awareness for climate risks among our respondents.

Medium horizon (*Long horizon*) equals one if the typical holding period of an investor is between 6 months and 2 years (above 2 years). *Assets under management* equals one (less than $1bn); two (between $1 billion and $20 billion); three (between $20 billion and $50 billion); four (between $50 billion and $100 billion); or five (more than $100 billion). *ESG share* is the percentage of the investor's portfolio reported as incorporating ESG issues, and *Passive share* is the fraction of the portfolio that is passively invested. We additionally control for the institutional investor type (*Independent institution*) and for the environmental norms in an institution's home country (*HQ Country Norms*). *Independent institution* equals one if an investor is considered to be an independent institution and is zero otherwise.[9] We control for *HQ Country Norms* as the environmental norms in the country in which institutions are headquartered are important determinants for their CSR preferences (see Dyck et al. 2019). We also add fixed effects for the respondents' positions in the firm and for the survey distribution channel. These latter two aspects could affect the responses.

In Columns 1 to 3 we cannot detect that medium- or long-term investors differ from short-term investors in their perceptions of the importance of climate risk. We find as shown in Columns 1 and 3 that larger investors rank climate risks higher relative to other risks, possibly because such investors are more exposed to externalities from climate change. We do not find a systematic link between the importance of climate risk and the tendency of an institution to invest passively. However, we do find in Column 3 that investors with higher ESG shares rank climate risk closer to financial risk in terms of its overall importance (reflected in a smaller distance in the rank importance of climate risk relative to financial risk), which is consistent with the main investment thesis of ESG oriented investors.

In Columns 4 to 6, we further find that several differences exist across investors in terms of the perceived financial materiality of the three climate risk components. Long-term investors find climate risks, in particular physical and technological risks, to be substantially more financially material than do other investors. Given that the average rankings (as shown in Table 2, panel B) of these risks are either 2.2 or 2.5, the implied estimated differences in rankings of around one-half for physical and technological risks are economically sizeable. Large institutions consider physical risks in Column 5 as more financially material, which is consistent with the idea that such investors bear greater costs related to climate change. However, larger investors do not differ from other investors in their assessments of the importance of regulatory and technological risks. As would be expected, institutions with a greater proportion of ESG

[9] As argued in Ferreira and Matos (2008) and Dyck et al. (2019), independent institutions are more likely to collect information, have fewer potential business relationships with portfolio firms, and are therefore anticipated to be more involved in monitoring management. We classify mutual funds, asset managers, hedge funds, private equity funds, and public pension funds as independent institutions.

investments regard physical and technological climate risk as more financially relevant than do other investors.

2.4 Motives for incorporating climate risks

Investors' motivations for incorporating climate risks into their investment decisions can be financial, nonfinancial, or a combination of both. Financial motives include a quest for higher returns (possibly through mitigating the costs of climate change), or lower risks (e.g., lower portfolio and tail risk). Bénabou and Tirole (2010) propose several views on firm managements' motivations to engage in corporate social responsibility. One view is that institutional investors take a long-term view and seek to maximize inter-temporal profits. With regard to climate risks, this view implies that incorporating these risks into the investment process is beneficial, because of higher returns or lower risks. Gibson Brandon and Krueger (2018) and Hoepner et al. (2019) use archival data in support of this view, but our survey allows for a more decisive answer regarding investor motivations through a direct question about the financial merits of incorporating climate risks.

Climate risk considerations can also arise because of nonfinancial motivations. For example, considerations about climate risks may reflect the investment managers' personal preferences or their perceived moral or ethical obligations. Hong and Kostovetsky (2012), for instance, show that political preferences of investment managers predict their investments in socially responsible stocks. A related view posits that investment managers consider climate risks because it benefits them at the expense of their beneficiaries (Bénabou and Tirole 2010). Further rationales include a combination of financial and nonfinancial motivations, such as regulatory requirements, protecting their reputations, and peer pressure.

We evaluate the relative importance of these nonmutually exclusive motivations through Question A4 in which respondents could indicate their agreement with different possible motives on a scale of one ("strongly disagree") to five ("strongly agree"). Table 3 reports the percentage of respondents that "strongly agree" with each statement as well as the mean response score. We also report the results of t-tests of the null hypothesis that each mean score is equal to three (neither agree nor disagree) and that the mean score for a given reason is equal to the mean score for each of the other reasons.

The table shows that agreement is strongest for two motives: the protection of the investor's reputation (30% strongly agree), which can arise from both financial and nonfinancial motives, and moral/ethical reasons to consider climate risks (27.5%), which would be a purely nonpecuniary motive. Institutions also tend to agree with the motive of incorporating climate risks due to a legal obligation/fiduciary duty (27%). Purely financial motives also score relatively high, especially the idea that incorporating climate risks is beneficial to returns (25% strongly agree) and reducing portfolio risk (24%) or tail risk (21%).

Table 3
Motivation to incorporate climate risks

		% with 5 ("strongly agree") score	Mean score	N	H_0: Mean score = 3	Significant differences in mean score vs. rows
Motivation to incorporate climate risks into the investment process		(1)	(2)	(3)	(4)	(5)
(1)	Protects our reputation	29.7	4.03	417	***	2-11
(2)	Is a moral/ethical obligation	27.5	3.88	415	***	1, 8-11
(3)	Is a legal obligation/fiduciary duty	27.0	3.87	415	***	1, 8-11
(4)	Is beneficial to investment returns	25.2	3.85	417	***	1, 9-11
(5)	Reduces overall portfolio risk	23.5	3.85	417	***	1, 9-11
(6)	Reflects our asset owners' investment preferences	22.6	3.88	416	***	1, 8-11
(7)	Reduces tail risks	21.4	3.81	416	***	1, 9-11
(8)	Allows us to address negative spillovers	19.7	3.77	412	***	1-3, 6, 10-11
(9)	Helps attract fund flows	18.5	3.69	411	***	1-7
(10)	Is increasingly stressed by proxy voting advisors	18.2	3.68	390	***	1-8
(11)	Follows the concerns of other institutional investors	15.6	3.68	416	***	1-8

This table reports responses on the statements regarding possible motivations to incorporate climate risks into the investment process (Question A4). Respondents could indicate their agreement on a scale of one ("strongly disagree") through five ("strongly agree"). Column 1 presents the percentage of respondents indicating strong agreement to the statement. We rank results based on this measure. Column 2 reports the mean score, where higher values correspond to stronger agreement. Column 3 reports the number of respondents. Column 4 reports the results of a t-test of the null hypothesis that each mean score is equal to 3 (neither agree nor disagree). Column 5 reports the results of a t-test of the null hypothesis that the mean score for a given reason is equal to the mean score for each of the other reasons, where significant differences at the 10% level are reported. ***$p < .01$.

3. Climate risk management

3.1 Approaches to climate risk management

Managing climate risks poses challenges to institutional investors because of difficulties in pricing and hedging these risks. In addition, there are few generally agreed upon methodologies as to how climate risks could and should be managed. Through a survey we can develop a better understanding of how institutional investors are approaching these issues. We collect information on risk management tools currently employed by investors, which allows us to evaluate current practices and to identify dimensions along which impediments may exist. The academic literature on climate risk management at this point is still in early stages, but Andersson, Bolton, and Samama (2016a) and Engle et al. (2019) show that in principle investors can hedge climate risks, although others argue that they are difficult to hedge in practice (CISL 2015). Another form of risk management would be to avoid problematic firms as pointed out theoretically by Heinkel, Kraus, and Zechner (2001) and empirically tested by Fernando, Sharfman, and Uysal (2017). Focusing on a more established mechanism, Dimson, Karakaş, and Li (2015) show that engagement on climate risks can enhance shareholder value, and Dimson, Karakaş, and Li (2018) study coordination in shareholder engagement on ESG issues. Our survey is

Table 4
Climate risk management approaches

Climate risk management approaches taken in the past 5 years		Percentage that took this measure (1)	N (2)	Significant differences in mean response vs. rows (3)	Classification of approaches for Table 5 (4)
(1)	Analyzing carbon footprint of portfolio firms	38.0	410	4-14	Passive
(2)	Analyzing stranded asset risk	34.6	410	5-14	Passive
(3)	General portfolio diversification	33.9	410	6-14	Passive
(4)	ESG integration	31.7	410	6-14	Passive
(5)	Reducing carbon footprint of portfolio firms	29.3	410	1-2, 10-14	Active
(6)	Firm valuation models that incorporate climate risk	25.9	410	1-4, 12-14	Passive
(7)	Use of third-party ESG ratings	25.6	410	1-4, 12-14	Passive
(8)	Shareholder proposals	25.1	410	1-4, 12-14	Active
(9)	Hedging against climate risk	24.6	410	1-4, 13-14	Passive
(10)	Negative/exclusionary screening	23.7	410	1-5, 13-14	Active
(11)	Reducing stranded asset risk	22.9	410	1-5, 13-14	Active
(12)	Divestment	20.2	410	1-8, 12-14	Active
(13)	None	7.1	410	1-12, 14	n/a
(14)	Other	3.7	410	1-13	n/a

This table reports the percentage of respondents that in the previous 5 years took a given approach to incorporate climate risks into the investment process (Question B1). Responses were not mutually exclusive. We rank results based on their relative frequency. Column 1 presents the percentage of respondents that took a certain measure. Column 2 reports the number of respondents. Column 3 reports the results of a t-test of the null hypothesis that the percentage for a given approach is equal to the percentage for each of the other approaches, where only differences significant at the 10% level are reported. Column 4 classifies the motives into more active and more passive approaches for the analysis in Table 5.

additionally informative because it allows to evaluate which risk management techniques a broad spectrum of investors uses.

Question B1 is designed to determine which approaches the respondents' institutions had taken in the previous 5 years to incorporate climate risks into their investment processes. Table 4 reports the percentage of respondents that employed a particular approach. Strikingly, only a very small percentage (7%) of respondents had not taken any measures, which could be influenced to some extent by our sample selection. The responses also indicate that investors employ a wide spectrum of approaches without one approach being strongly dominant. The fact that there does not exist an overwhelming dominant approach could reflect the immaturity of the developed approaches to climate risks. That is, investors are still learning how to deal with these risks.

The most frequently used current techniques have been analyses of firms' carbon footprints and stranded asset risks, employed by 38% and 35% of the investors, respectively. Thirty-two percent of the respondents deal with climate risks by integrating ESG more generally into their investment processes. The flipside of these numbers is that they indicate about two-thirds of investors currently do not even use these basic approaches to manage climate risks. Some investors indicate that they incorporate climate risks prior to making investments, especially through screening (24%).

Regarding actions taken to manage climate risk after investments have been made, 29% (23%) of respondents strive to reduce the carbon footprint (stranded asset risk) of their portfolios, and 25% use some form of climate risk hedging. The low percentage of investors who hedge climate risks may be in part a result of the difficulty in differentiating among the uncertainty components of risk, ambiguity, and misspecification (Barnett, Brock, and Hansen Forthcoming) as well as further difficulties to hedging pointed out by Engle et al. (2019). Hedging against climate risks requires not only understanding the fundamentally long-lived risk of climate change, but also dealing with the difficulty of identifying shocks, the proper horizon, and identifying the assets that correlate with the outcomes, which overall results in the lack of existence of derivatives to engage in hedging for climate change.

The least frequently used approach is divestment, although there still exists a significant minority of investors (20%) who take this approach. The relatively small number of investors who choose divestment informs the debate regarding whether divestment or engagement is the more effective method for reducing climate risk. We show in further analysis below that our investors have a higher propensity to engage over climate risks than to avoid it by divesting. This is consistent with the stated views of the Harvard endowment: "we maintain a strong presumption against divesting investment assets" as the endowment is "a resource, not an instrument to impel social or political change."[10] The lack of use of divestment is consistent also with Bessembinder's (2017) analysis indicating significant costs to investors who divest fossil fuel companies. These costs include reduced diversification, ongoing compliance costs, and transaction costs.

3.2 Climate risk management and investor characteristics

To better understand institutions' climate risk management, we develop an index that reflects the spectrum of risk management techniques employed. *Climate risk management* counts the different approaches an investor has taken in the previous 5 years. In our survey we cover 13 possible techniques, implying that the index can vary between 0 and 13. The index is designed to capture the extent to which investors used different types of risk management tools, rather than the degree to which they used any one type. Thus, we are capturing the breadth of approaches rather than the depth or intensity. Conditional on performing some sort of climate risk management, the median investor in our sample uses three different approaches.

Additionally, we use two refinements of the index to explore which investors use more active or more passive risk management techniques. *Active approaches* counts the number of more active approaches used (shareholder proposals, negative/exclusionary screening, reducing carbon

[10] See Faust (2013). A related discussion is provided in Shancke et al. (2014).

footprint, divestment, reducing stranded asset risk), while *Passive approaches* counts the number of more passive approaches used (analyzing carbon footprint, general diversification, ESG integration, valuation models, analyzing stranded asset risk, hedging). We also explore which investor characteristics are related with ex ante screening, exit (divestment) and voice (shareholder proposals), three important but very different approaches to actively address climate risks.

Given the uncertainty regarding how to manage climate risks, we expect investors who are more concerned about the consequences of climate change to engage in more climate risk management by using a greater breadth of approaches. Similarly, investors who expect climate risks to materialize earlier should also engage in more risk management techniques. Traditionally, economists and others have assumed that climate risks are likely to be more severe over the long term, which implies a prediction that long-term investors would use a wider range of tools to manage these risks. In contrast, Giglio et al. (2018) argue that short-term cash flows are riskier because they bear the full brunt of a climate disaster, whereas long-term cash flows are less exposed because the economy can recover. Thus, whether the breadth of risk management approaches is higher among long-term or short-term investors poses an empirical question. Given their role as universal investors, it is likely that large investors employ more risk management, as they are more exposed to climate externalities. Additionally, such investors should have more resources to develop and use risk management tools. The role of the passive portfolio share is more ambiguous. Investors with high passive holdings may use more risk management as they cannot easily divest because of index tracking or tracking error considerations. However, the low-cost business model of passive investors may imply that they do not invest resources to actively manage climate risks.

The results in Table 5 partially support our hypotheses. As expected, we find in Column 1 that investors more concerned about the financial implications of climate risks use a more diverse set of risk management tools. (Note that smaller numbers for *Climate risk materiality* indicate that the investor perceives climate risk as being more financially important.) In Column 2 we find no difference in the number of tools used between investors who expect climate risks to materialize sooner versus those that expect them to materialize later. Column 3 shows that investors with longer horizons engage in a wider range of tools to manage climate risks. In fact, the estimates imply that investors with a medium (long) horizon use 0.8 (1) more approaches, a large number relative to the median of three approaches. Consistent with our hypothesis, we find in Column 4 that larger investors manage climate risks more broadly. Once we use a more complete specification in Column 5, we find that some of the effects weaken, but most of the conclusions remain valid. In particular, long-term investors still use about 30% more tools than the median investor. Columns 6 and 7 show that medium-term and long-term investors

Table 5
Climate risk management approaches and investor characteristics

	Climate risk management					Active approaches	Passive approaches	Screening	Divestment	Shareholder proposals
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Climate risk materiality	−0.49***				−0.45***	−0.30**	−0.41***	−0.15***	0.01	−0.13**
	(−7.77)				(−5.78)	(−2.50)	(−3.40)	(−2.64)	(0.12)	(−2.19)
Climate risk horizon		−0.12			−0.01	0.06	−0.10	0.04	0.12	−0.19**
		(−0.71)			(−0.03)	(0.30)	(−0.64)	(0.31)	(1.36)	(−1.97)
Medium horizon			0.66**		0.58	0.57	0.46	−0.09	0.45	0.59
			(2.24)		(1.52)	(1.47)	(1.31)	(−0.33)	(0.74)	(1.33)
Long horizon			0.93***		0.84**	0.42	0.78**	−0.25	0.77	0.41
			(3.07)		(2.07)	(1.05)	(2.02)	(−0.70)	(1.43)	(0.92)
Assets under management				0.14**	0.09	0.04	0.10	−0.10***	0.07	0.04
				(2.05)	(1.32)	(0.36)	(1.13)	(−3.02)	(1.08)	(0.90)
ESG share (x100)	1.23***	1.43***	1.25***	1.22***	1.18***	1.59***	0.45	0.84***	0.53**	0.83***
	(3.30)	(3.94)	(4.17)	(4.22)	(3.12)	(3.98)	(1.41)	(3.36)	(2.18)	(2.92)
Passive share (x100)	−0.18	−0.26	−0.32	−0.21	−0.25	−0.10	−0.37	0.03	0.38	−0.12
	(−0.51)	(−0.90)	(−1.20)	(−0.71)	(−0.61)	(−0.28)	(−1.00)	(0.09)	(1.39)	(−0.35)
Independent institution	0.44**	0.44*	0.49**	0.45**	0.50**	0.15	0.57***	−0.18	0.46	0.21
	(1.98)	(1.85)	(2.37)	(2.02)	(2.21)	(0.41)	(3.02)	(−1.63)	(1.45)	(1.35)
HQ country norms	0.09	−0.68	0.07	0.22	−0.24	0.30	−0.97	0.19	−1.71**	−1.68
	(0.05)	(−0.40)	(0.04)	(0.11)	(−0.15)	(0.18)	(−0.65)	(0.16)	(−2.53)	(−1.12)
Respondent position FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Distribution channel FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	374	393	398	399	370	370	370	367	367	367
Pseudo *R*-sq.	.050	.041	.036	.035	.051	.052	.051	.142	.080	.113

This table reports ordered logit and probit regressions relating climate risk management approaches to investor characteristics. *Climate risk management* counts the number of approaches used in the past 5 years to incorporate climate risks into the investment process (Question B1). The remaining dependent variables capture subsets of this index. *Active approaches* counts the number of active approaches used (shareholder proposals, negative/exclusionary screening, reducing carbon footprint, divestment, reducing stranded asset risk). *Passive approaches* counts the number of passive approaches used (analyzing carbon footprint, general portfolio diversification, ESG integration, valuation models, analyzing stranded asset risk, hedging). *Screening* equals one if an institutional investor used negative/exclusionary screening to manage climate risks, and zero otherwise. *Divestment* equals one if an institutional investor divested to manage climate risks, and zero otherwise. *Shareholder proposals* equals one if an institutional investor submitted shareholder proposals to manage climate risks, and zero otherwise. We use the following independent variables: *Climate risk materiality* (smaller numbers reflect greater perceived importance); *Climate risk horizon* (smaller numbers indicate that climate risks are expected to materialize sooner); *Medium horizon; Long horizon*; *Assets under management*; *ESG share; Passive share; Independent institution;* and *HQ country norms* (larger numbers reflect a stronger belief in the importance of environmental issues in an institutions' country). Table A1 defines all variables in detail. *t*-statistics (reported in parentheses) are based on standard errors that are clustered at the investor-country level. $^{*}p < .1$; $^{**}p < .05$; $^{***}p < .01$.

focus primarily on passive tools to address climate risks. The regressions in Columns 6 and 7 also show that investors who deem climate risk as being more important do not distinguish between active and more passive approaches but use both approaches more broadly. Across Columns 1 through 5 we find that investors with higher ESG shares use more climate risk management tools for their investments. Unsurprisingly, high-ESG-share investors focus primarily on active approaches to manage climate risks. In terms of our control variables, we find that independent institutions engage in a wider range of primarily passive tools to manage climate risks.

Turning to the specific tools used by the investors, Column 8 shows that screening is more frequently used by smaller investors and by investors with higher ESG shares, which seems intuitive because large investors are probably more constrained in terms of screening and screening is probably one of the most important forms of implementing ESG investing. The decision to divest is unrelated to investor characteristics, with the exception that investors with high ESG shares are more likely to exit due to climate concerns. Column 9 shows that more investors with higher ESG shares are also more likely to make shareholder proposals on climate topics, which is also the case for the investors who believe that climate risks are more important and will materialize earlier.

4. Shareholder Engagement on Climate Risks

4.1 Approaches to and success rates of climate risk engagements

Next, we assess how investors engage portfolio firms over climate risks, whether such engagements are considered effective by the investors, and what actions the investors take when their engagements are deemed unsuccessful. The benefit of a survey is that because many engagements take place behind the scenes, it is difficult to measure the effectiveness of engagement using archival data. We asked the participants in Question B2 which measures of direct engagement over climate risks they had taken with portfolio firms over the previous 5 years.

Table 6 presents evidence of a generally high level of engagement by our respondent group: only 16% had not taken any actions over the past 5 years. The respondents indicate that they used multiple channels to engage portfolio firms over climate risks. Discussions with management were most frequent, with 43% indicating that they had used the approach. The percentage compares with 63% of the respondents in the McCahery, Sautner, and Starks (2016) survey who used private discussions to engage management on governance issues. The widespread use of private investor intervention regarding climate topics supports the interpretation from their article that many investors first engage firms through negotiations and take public actions only once the private interventions fail. These results are also similar to the typical anatomy of the engagement sequences analyzed in Dimson, Karakaş, and Li (2015), in which engagements most often start with discussions between management and shareholders and then potentially escalate depending on how the initial

Table 6
Climate risk engagement

		Percentage that used this approach	N	Significant difference in mean response vs. rows
Direct engagement over climate risk issues in the past 5 years		(1)	(2)	(3)
(1)	Holding discussions with management regarding the financial implications of climate risks	43	406	2-10
(2)	Proposing specific actions to management on climate risk issues	32	406	1, 6-10
(3)	Voting against management on proposals over climate risk issues at the annual meeting	30	406	1, 6-10
(4)	Submitting shareholder proposals on climate risk issues	30	406	1, 6-10
(5)	Questioning management on a conference call about climate risk issues	30	406	1, 6-10
(6)	Publicly criticizing management on climate risk issues	20	406	1-5, 9
(7)	Voting against reelection of any board directors due to climate risk issues	19	406	1-5, 9
(8)	Legal action against management on climate risk issues	18	406	1-5, 9
(9)	Other	1	406	1-8, 10
(10)	None	16	406	1-9

This table reports the percentage of respondents that haven taken a particular approach of direct engagement over climate risk issues in the past 5 years (Question B2). We rank results based on their relative frequency. Responses were not mutually exclusive. Column 1 presents the percentage of respondents that took a certain approach. Column 2 reports the number of respondents. Column 3 reports the results of a t-test of the null hypothesis that the percentage for a given approach is equal to the percentage for each of the other approaches, where significant differences at the 10% level are reported.

discussions are received. Table 6 also indicates that a striking one-third of the investors used these discussions to propose specific actions to management about the firm's climate policies. This result implies that a number of institutional investors are actively involved with companies in combatting the problems from climate change.

Climate risks are increasingly a controversial topic at annual shareholder meetings. About one-third of the respondents have submitted shareholder proposals on climate risk issues, and a similar fraction voted against management proposals because of climate risk concerns. These numbers are consistent with a recent trend of successful shareholder proposals at oil companies. A proposal at Exxon Mobil, for example, asked management to examine and disclose how climate risks would affect the company in the future. The measure passed in 2017 with 62% of the vote.[11] More confrontational engagements are also taking place: 20% state that they publicly criticized the management of portfolio firms over climate risk issues, 19% voted against

[11] See Olson (2017) or Bauer, Moers, and Viehs (2015), who provide additional evidence on engagement success with their finding that environmental proposals are more likely to be withdrawn, particularly if the sponsoring shareholder is an institutional investor.

the reelection of directors because of their handling of climate risks, and 18% initiated legal measures over climate risks. Reflecting an increasing trend of climate litigation risk, BP's CEO recently refused to disclose climate targets and to answer questions from activist investors because of the fear of legal actions.[12] The median investor in our sample engaged through two channels only.

A benefit of a survey is that it allows the direct measurement of whether engagement—especially when private—is successful. Thus, we asked how portfolio firms typically responded to engagement over climate risks (Question B3). Targeted firms responded in most cases (71%) to the climate risk engagement by their investors (Figure 2A), although the typical response was acknowledging an issue rather than successfully resolving it (Figure 2B). A successful completion of a typical engagement is reported by 25% of respondents. Figure 2C further shows that if portfolio firms did not respond to an engagement or showed resistance, then investors usually gave up and did not take further actions (40%) (Question B4). Only 17% indicate that they divested when being dissatisfied with portfolio firms' responses. The remaining investors either initiated the next level of engagement (21%) or tried to hedge the risk (23%). These numbers corroborate our prior result that climate risks usually do not trigger divestment, at least among most investors in our sample. Most of our investors' actions appear consistent with the view that divestment would reduce investor influence to improve climate policies. As Marcel Jeucken, managing director of responsible investment at PGGM observed, "if we divest, other investors will buy the stock and nothing will change" (see Nicholls 2015).

4.2 Climate risk engagement and investor characteristics

Next, we study the determinants of investors' propensity to engage over climate policies. As with our risk management index, we create a variable that sums the different engagement channels used by an investor. Our survey covers nine intervention channels, implying that the index can vary between zero and nine. Larger numbers indicate a stronger tendency to engage along multiple channels. A caveat of our index is that it equally weights the different measures without accounting for the severity of the actions taken (e.g., initiating a lawsuit is probably a more severe action than holding discussions with management). The index also does not account for the investor effort or cost associated with using a specific engagement channel. To partially address these caveats, we also individually examine how investor characteristics relate to the three most frequent approaches as well as to the most hostile one (lawsuits).

Similar to our arguments for risk management, investors that are more concerned about climate risks, and those that expect the risks to materialize earlier, should engage along more dimensions. Investors with longer horizons

[12] See Hodges, Leatherby, and Mehrotra (2018). This article also documents that litigation against firms over climate change massively increased in the last few years.

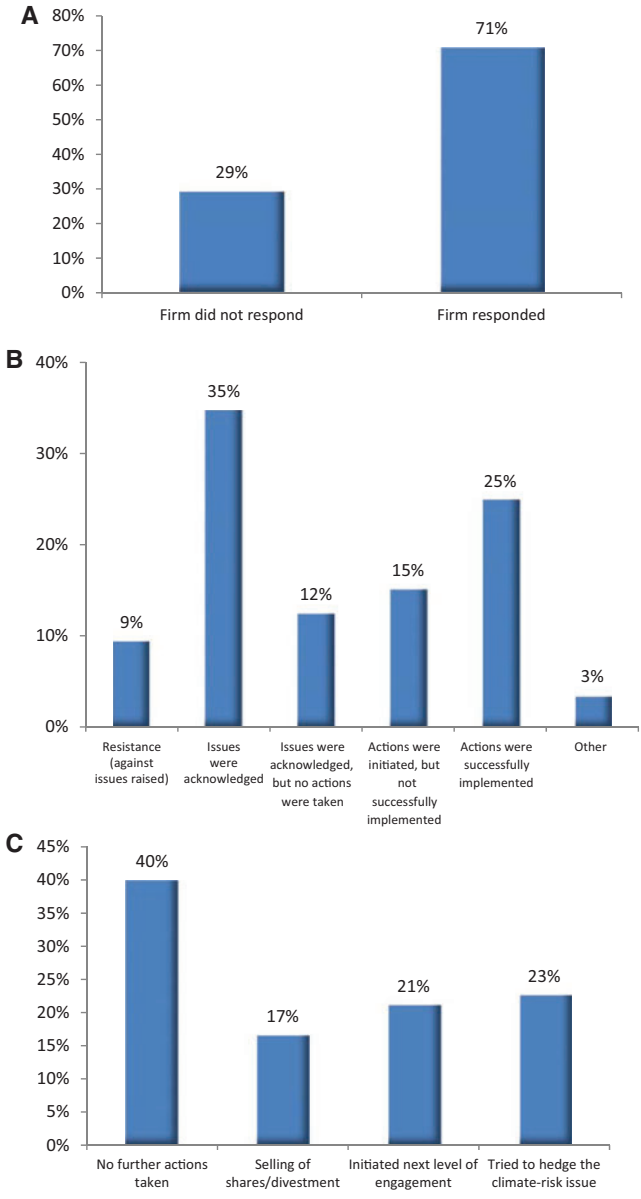

Figure 2
Responses to climate risk engagement
Figure 2A reports whether the management of portfolio companies typically responded to the investor's engagement over climate risk issues (Question B3). Figure 2B reports the portfolio companies' typical responses to such engagements (also Question B3). Figure 2C reports the investors' responses if the portfolio companies either did not respond to the engagement (see Figure 2A) or showed resistance (see Figure 2B) (Question B4).

should also have stronger engagement incentives, as they benefit more from improving climate policies. Larger investors have more resources and larger holdings in firms, reducing free-rider concerns and implying also stronger engagement incentives. For the reasons provided above, ESG investors should have stronger incentives to engage. The role of the passive portfolio share is again more ambiguous, for the same arguments provided in the previous section on the management of climate risks.

Table 7 reports our tests of these hypotheses. Consistent with our hypotheses, we find that the investors who consider the effects of climate change to be more financially material and use more engagement channels (see Column 1). Further, as predicted, larger investors also engage firms along more dimensions (see Columns 4 and 5), although we have no evidence that long-term investors use more engagement channels. Some evidence suggests, however, that investors with medium investment horizons engage using more channels (see Column 3). As expected, investors with a greater share of ESG-oriented investments use a wider variety of engagement channels. We find that investors with more passive holdings tend to use fewer engagement channels.

When we explore individual engagement channels, we find that more passive institutions have a lower propensity to engage in discussions with management (see Column 6). The institutions that expect climate to materialize earlier are more likely to propose specific actions to management (see Column 7). Moreover, the investors that are more concerned about the financial effects of climate risks, and those that expect them to materialize earlier, are more likely to vote against management. The same holds for larger institutions and institutions with larger ESG shares. The willingness to file a lawsuit because of climate issues is higher among larger institutions but otherwise unrelated to investor characteristics.

5. Pricing of Climate Risks across Industries

Recent research suggests that climate risks can significantly affect equity markets. In Bansal, Kiku, and Ochoa (2017) rising temperatures negatively affect the economy by increasing economic risk and reducing growth. Daniel, Litterman, and Wagner (2017) calibrate the price of climate risk and suggest that potentially large deadweight costs exist from delays in climate change mitigation. In a similar spirit, Litterman (2011) argues that carbon emissions should be priced at high levels immediately, primarily due to the risk of catastrophic damages. In line with these approaches, Andersson, Bolton, and Samama (2016a) assume that markets overvalue carbon-intensive assets to derive hedging strategies. Empirical evidence supporting the mispricing of climate risks exists as well. For example, Hong, Li, and Xu (2019) conclude that the exposure of food stocks to drought risks are incorrectly valued by markets. Similarly, Kumar, Xin, and Zhang (2019) present evidence that firms' exposures to climate risks predict returns, which implies that stock markets

Table 7
Climate risk engagement and investor characteristics

	Climate risk engagement					*Holding discussions*	*Proposing actions*	*Voting against management*	*Legal action*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Climate risk materiality	−0.56***				−0.53***	0.05	−0.09	−0.47***	−0.04
	(−5.30)				(−4.39)	(1.01)	(−1.29)	(−10.02)	(−0.38)
Climate risk horizon		−0.25			−0.15	0.01	−0.22**	0.21**	−0.09
		(−1.59)			(−1.02)	(0.10)	(−2.08)	(2.56)	(−0.57)
Medium horizon			0.97***		0.52	0.61*	−0.02	0.61*	0.06
			(3.50)		(1.44)	(1.85)	(−0.08)	(1.78)	(0.20)
Long horizon			0.57		0.09	0.39	0.24	0.17	−0.03
			(1.31)		(0.16)	(0.66)	(0.67)	(0.42)	(−0.05)
Assets under management				0.25**	0.15**	0.02	0.05	0.10***	0.19*
				(2.41)	(2.11)	(0.44)	(1.09)	(2.63)	(1.75)
ESG share (x100)	1.16***	1.43***	1.37***	1.24***	1.06***	0.36	−0.12	0.61**	0.55
	(3.87)	(4.36)	(4.24)	(4.64)	(3.03)	(1.05)	(−0.63)	(2.06)	(1.25)
Passive share (x100)	−1.04*	−1.00**	−0.97**	−0.92**	−1.04*	−0.88***	−0.23	−0.02	0.13
	(−1.77)	(−2.43)	(−2.52)	(−1.99)	(−1.71)	(−4.12)	(−0.65)	(−0.09)	(0.25)
Independent institution	0.37***	0.37***	0.35***	0.38***	0.36***	0.19	−0.11	0.31**	0.07
	(2.87)	(2.81)	(2.90)	(3.02)	(2.70)	(1.14)	(−1.19)	(2.27)	(0.33)
HQ country norms	0.47	−0.70	0.11	−0.01	0.44	−1.22	−1.69	−0.17	−0.19
	(0.37)	(−0.64)	(0.08)	(−0.01)	(0.32)	(−1.38)	(−1.20)	(−0.19)	(−0.10)
Respondent position FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Distribution channel FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	374	393	398	399	370	364	364	364	317
Pseudo *R*-sq.	.054	.042	.046	.048	.057	.069	.056	.158	.069

This table reports ordered logit and probit regressions relating climate risk engagement channels to investor characteristics. *Climate risk engagement* counts the number of different direct engagement channels that an investor has taken in the past 5 years (Question B2). The remaining dependent variables used in this table are individual components of this index. *Holding discussions* equals of one if an institutional investor held discussions with management regarding climate risks, and zero otherwise. *Proposing actions* equals one if an institutional investor proposed specific actions to management on climate risk issues, and zero otherwise. *Voting against management* equals one if an institutional investor voted against management on climate risk issues and zero otherwise. The variable *Legal actions* equals one if an institutional investor took legal actions against management on climate risk issues, and zero otherwise. We use the following independent variables: *Climate risk materiality* (smaller numbers reflect greater perceived importance); *Climate risk horizon* (smaller numbers indicate that climate risks are expected to materialize sooner); *Medium horizon; Long horizon*; *Assets under management*; *ESG share; Passive share; Independent institution;* and *HQ country norms* (larger numbers reflect a stronger belief in the importance of environmental issues in an institutions' country). Table A1 defines all variables in detail. *t*-statistics (reported in parentheses) are based on standard errors that are clustered at the investor-country level. $*p < .1$; $**p < .05$; $***p < .01$.

misprice climate risks. On the other hand, through their theoretical analysis, Bansal, Kiku, and Ochoa (2017) show that equity portfolios have negative exposures to long-run temperature fluctuations, which suggests that financial markets may be able to price climate risks at least to some extent.[13]

We are able to contribute additional findings to this limited, and somewhat mixed, evidence through questioning our investors directly in order to understand the extent to which they believe that stock markets price climate risks correctly. To examine investor beliefs on this issue, we asked the participants whether they believe that current equity valuations correctly reflect the risks and opportunities related to climate change (Question C1). As the exposure to climate risks likely varies across the economy, we asked for their beliefs across a range of industries. This sector approach, with both directions of mispricing, is critical because the direction of mispricing is not known. The degree to which climate risks are not recognized in valuations could vary by sector with some sectors expected to be overvalued (e.g., the oil or coal sectors) and other sectors expected to be undervalued (e.g., battery producers or water utilities). This approach is supported by the prior research that indicates climate risks are likely to vary across industries, depending on factors such as carbon emissions or stranded assets (see Krueger 2015). Because of space and time constraints for our participants, the survey does not cover all industries but only those for which prior analysis indicates that climate change is likely to have a large effect (Mercer 2015). As estimates about mispricing are uncertain, we take a Bayesian approach and allow respondents to specify the confidence in their estimates (Question C2). This enables us to evaluate how results change once we put more weight on the responses accompanied with higher confidence levels. That is, some respondents may provide more informed estimates given their level of information.

Responses for each industry, reported in Table 8, can range between plus two ("valuation much too high"; underpricing) and minus two ("valuations much too low"; overpricing). Column 1 reports the mean score per industry, and Column 2 reports the standard deviations of the means. Column 3 displays a measure of relative misvaluation, which we construct as the industry mean score relative to the mean score across all industries. We report in Columns 4 and 5 the percentages of respondents that indicate valuation levels that are "much too high" or "much too low." Column 6 reports the mean scores only for "relatively confident" respondents. Although we directly asked about misvaluations related to climate change, a caveat to our approach is that some respondents' opinions might reflect their views of general industry misvaluations at the time of the survey.

The table reveals two principal findings. First, a mean valuation score of zero would indicate a fair valuation. In contrast, we find the mean valuation scores to

[13] See Hjort (2016) for a review of earlier climate risk papers.

Table 8
Pricing of climate risks across industry sectors

Industry	Mean score	STD	Relative industry misvaluation	Percentage with score of +2 (much too high)	Percentage with score of -2 (much too low)	Mean score (Confident respondents)	N
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Oil	0.52	1.03	37%	17	3	0.59	352
Automotive (traditional)	0.48	0.94	25%	14	2	0.53	352
Electric utilities	0.47	0.91	25%	13	3	0.48	353
Information technology	0.47	0.98	23%	16	3	0.50	353
Insurance	0.46	0.91	21%	14	1	0.39	352
Natural gas	0.44	0.91	17%	11	2	0.51	352
Coastal real estate	0.43	0.96	13%	14	3	0.43	350
Gas utilities	0.40	0.94	6%	11	4	0.38	353
Transportation	0.40	0.92	4%	12	3	0.37	351
Construction	0.39	0.90	3%	10	3	0.44	351
Banking	0.38	0.96	0%	13	4	0.40	351
Telecommunications	0.38	0.88	−1%	11	2	0.40	353
Water utilities	0.37	0.96	−2%	13	3	0.46	353
Infrastructure	0.37	0.93	−3%	12	3	0.35	351
Nuclear energy	0.35	1.05	−7%	14	5	0.37	351
Chemicals	0.35	0.96	−8%	12	3	0.40	350
Coal mining	0.35	1.07	−9%	16	5	0.35	351
Automotive (electric)	0.33	0.92	−14%	11	2	0.36	352
Renewable energy	0.31	0.98	−17%	11	3	0.30	351
Raw materials (excluding coal)	0.27	0.90	−28%	7	3	0.34	350
Battery producers	0.27	0.97	−28%	11	4	0.30	349
Agriculture	0.27	1.02	−28%	13	5	0.39	349
Forestry and paper	0.27	0.97	−29%	9	4	0.36	351
Mean (across all industries)	0.38			12	3	0.41	

This table reports survey responses to a question that asked respondents to evaluate to what extent equity valuations of firms in different industries reflect the risk and opportunities related to climate change (Question C1). Responses for each industry can range between plus two (valuations much too high) and minus two (valuations much too low). The table reports in Column 1 the mean scores across all respondents and in Column 2 the corresponding standard deviations. Column 3 reports a measure of relative misvaluation across industries. It is constructed as the mean industry score divided by the mean score across all industries, minus 1. We also report in Columns 4 and 5 the percentage of respondents that indicate valuation levels that are "much too high" or "much too low." Column 6 reports the mean score only for those respondents that indicate that they are "relatively confident" about their valuation assessment (Question C2). We rank responses by the mean score in Column 1.

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exceed zero for every industry sector included in the survey. Thus, the average respondent believes that the equity valuations of the sectors a priori most exposed to climate risk do not fully reflect this risk. Rather the scores indicate that investors believe valuations are somewhat too high, which suggests an aggregate investor belief of climate risk underpricing.[14] However, the responses for most sectors are around 0.4, indicating that although investors believe in widespread overvaluations, they are only modest overvaluations. Those participants with more confidence in their assessments of relative valuation show a slightly higher belief in mispricing. That is, mispricing is slightly larger if we condition responses on participants with "relatively confident" assessments. Another important finding is that investors' answers do not reflect precise estimates as substantial uncertainty exists around the mean estimates (standard deviations range between 0.9 and 1.1).

The second principal finding is that relative sector mispricing is largest among oil firms, traditional car manufacturers, and electric utilities. Yet, the magnitude of sector-level mispricing is surprisingly low: the misvaluation of the three most overpriced sectors is around 0.5 only, while the mean across all sectors is 0.38. These numbers lead to a need for further research to better understand whether the numbers reflect the broad belief that markets have already started to account for the relative pricing of climate risks, or, instead, whether greater mispricing exists but our investors do not recognize it. (Alternatively, it also could be that our question simply did not capture relative mispricing well.) The first possibility is consistent with the conclusions of Griffin et al. (2015) regarding their findings of limited negative stock market reactions to concerns about a carbon bubble and stranded assets for the largest oil and gas firms.[15]

To understand the responses to our mispricing question better, we examine whether they vary systematically with certain investor characteristics. To conduct this test, we create two indexes designed to capture the aggregate mispricing. The first index, *Climate risk underpricing,* approximates an investor's aggregate view about overvaluation by averaging positive mispricing scores (negative scores are set to zero). The index ranges between plus two (strong average overvaluation) and zero (no average overvaluation). Our second index measure, *Climate risk mispricing*, is nondirectional and is designed to capture the general mispricing of climate risks by averaging the absolute values of all mispricing scores. We additionally report regressions that explain the underpricing of climate risks in the three industries that our investors believe are the most mispriced. We use the same independent variables as in previous tables and add the risk management and engagement indexes.

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[14] The mean misvaluation score across all sectors of the economy is likely to be lower, as the sectors we selected for our survey are probably more affected by climate change than the sectors that we did not include.

[15] The authors point out that investors could have not been as concerned, because they considered alternatives, such as carbon capture and sequestration, and other technological advances, changes in government energy policies, whether oil and gas demand could actually be scaled back "within an economically meaningful horizon," or the lack of investor information about firms' positions.

The regressions in Table 9 provide little evidence of a widespread systematic link between mispricing and investor characteristics. However, two characteristics emerge as being particularly relevant. First, investors with larger ESG shares generally view assets as being subject to more mispricing (especially underpricing), possibly a reason that such investors promote ESG factors to begin with. Second, investors that engage firms along more dimensions believe that climate risks are more underpriced, which may explain their engagement.

Assets are "stranded" if firms are unable to recover their investment cost, implying a loss of value for investors (Carbon Tracker 2015). Many of those concerned about climate risks consider stranded assets to be a particularly significant risk for investors. McGlade and Ekins (2015), for example, estimate that one-third of oil reserves, half of gas reserves, and over 80% of coal reserves must remain unused until 2050 if countries are to meet the targets stipulated in the Paris climate agreement. Thus, we question our investors on the risk that climate change causes specific assets to become stranded (Question C3). Table 10, panel A, reports how the investors consider this risk for six industry subsectors, which we selected based on prior research (McGlade and Ekins 2015). Respondents could indicate their views on stranded assets using a scale of one ("low") through four ("very high"); they could also indicate "Do not know." For each industry subsector we report the percentage of respondents that consider stranded asset risks to be "very high."

We find that stranded asset risks are largest among coal producers, followed by unconventional oil producers (tar sands or fracking). Yet, even for the coal producers, which have the highest percentage of respondents believing that they face stranded asset risks, only 25% believe this risk is very high. However, the average response is 2.73 (out of 4), which suggests that a tendency exists for investors to believe that stranded asset risk is present in the coal sector.

Somewhat different from the cross-sectional analysis on mispricing, we find in Table 10, panel B, evidence that the perception of stranded asset risks is related to investor characteristics. Notably, investors that are more concerned about the financial effects of climate risks believe that stranded asset risks are higher among oil and natural gas producers. As before, investors who engage firms more over climate topics, and those with larger ESG shares, perceive higher stranded asset risks across most of the selected assets. Further, investors with a higher share of passive investments perceive more stranded asset risk.

Thus far, our analysis has mostly focused on downside risks associated with climate change. However, climate change is likely to generate winners as well. Understanding the associated opportunities is important for investors allocating capital in the future. To identify how the institutional investor respondents consider the potential opportunities, we asked them through an open question to tell us which areas they see as providing the biggest opportunities from

Table 9
Climate risk pricing across industry sectors and investor characteristics

	Climate risk underpricing		*Climate risk mispricing*		*Climate risk underpricing*		
	Average across all sectors		Average across all sectors		Oil	Automotive (traditional)	Electric utilities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Climate risk materiality	0.00	−0.01	−0.03	−0.04	−0.06	0.03	0.08
	(0.08)	(−0.18)	(−1.10)	(−1.57)	(−0.37)	(0.25)	(0.43)
Climate risk horizon	−0.00	−0.01	0.05	0.04	0.05	−0.09	0.31*
	(−0.09)	(−0.29)	(0.87)	(0.75)	(0.45)	(−0.68)	(1.81)
Medium horizon	−0.07	−0.06	−0.01	0.00	0.08	−0.86	0.36
	(−0.50)	(−0.46)	(−0.05)	(0.03)	(0.17)	(−1.61)	(0.46)
Long horizon	−0.06	−0.05	−0.01	−0.00	−0.14	−1.07**	0.12
	(−0.43)	(−0.43)	(−0.09)	(−0.00)	(−0.28)	(−2.29)	(0.11)
Climate risk engagement	0.04**		0.03**		0.02	0.11	0.20***
	(2.18)		(2.87)		(0.21)	(1.61)	(3.54)
Climate risk management		0.01		0.00			
		(1.01)		(0.54)			
Assets under management	0.03	0.03	−0.00	−0.00	−0.06	0.25***	0.14
	(1.42)	(1.59)	(−0.24)	(−0.03)	(−0.67)	(3.14)	(1.54)
ESG share (x100)	0.28**	0.29***	0.19**	0.22**	0.67	0.91*	0.55
	(2.78)	(2.95)	(2.16)	(2.51)	(1.30)	(1.86)	(1.48)
Passive share (x100)	0.02	−0.00	−0.01	−0.03	1.23***	0.28	0.30
	(0.22)	(−0.00)	(−0.06)	(−0.27)	(2.67)	(0.51)	(0.42)
Independent institution	−0.05	−0.04	−0.04	−0.04	0.15	0.16	−0.12
	(−0.73)	(−0.60)	(−0.70)	(−0.53)	(0.61)	(0.53)	(−0.44)
HQ country norms	−0.18*	−0.19*	−0.29	−0.31*	0.50	−0.07	−0.25
	(−1.93)	(−1.88)	(−1.64)	(−1.85)	(0.47)	(−0.09)	(−0.16)
Respondent position FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Distribution channel FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	343	343	343	343	340	340	341
Pseudo *R*-sq.	.035	.023	.012	.000	.041	.055	.040

This table reports OLS and ordered logit regressions relating perceptions of climate risk pricing to investor characteristics. The dependent variables capture the respondents' views on mispricing of climate risks (Question C1). *Climate risk underpricing* averages positive mispricing scores (negative scores are set to zero). The variable ranges between plus two (strong average overvaluation) and zero (no average overvaluation). *Climate risk mispricing* averages the absolute values of all mispricing scores. We also report regressions that explain the underpricing of climate risks in the three industries perceived to be most mispriced (oil, utilities and traditional automotive). We use the following independent variables: *Climate risk materiality* (smaller numbers reflect greater perceived importance); *Climate risk horizon* (smaller numbers indicate that climate risks are expected to materialize sooner); *Medium horizon; Long horizon*; *Climate risk engagement; Climate risk management*; *Assets under management*; *ESG share; Passive share; Independent institution;* and *HQ country norms* (larger numbers reflect a stronger belief in the importance of environmental issues in an institutions' country). Table A1 defines all variables in detail. *t*-statistics (reported in parentheses) are based on standard errors that are clustered at the investor-country level. $*p < .1$; $**p < .05$; $***p < .01$.

Table 10
Stranded asset risk

A. Importance of stranded asset risks

	Stranded asset risk	% with 4 ("very high") score	Mean score	% with "do not know"	N	H_0: Mean score = 1	Significant differences in mean score vs. rows
		(1)	(2)	(3)	(4)	(5)	(6)
(1)	Coal producers	25.1	2.78	3	371	***	2-6
(2)	Unconventional oil producers	21.3	2.69	3	371	***	1, 4-6
(3)	Conventional oil producers	16.7	2.64	4	371	***	1, 4-6
(4)	Natural gas producers	11.9	2.46	3	370	***	1-3, 5
(5)	Iron and steel producers	11.7	2.40	5	369	***	1-4
(6)	Conventional electricity producers	10.5	2.42	4	371	***	1-3

B. Stranded asset risk and investor characteristics

	Stranded asset risk "very high"					
	Coal producers	Unconventional producers	Conventional producers	Natural gas producers	Iron and steel producers	Conventional electricity producers
	(1)	(2)	(3)	(4)	(5)	(6)
Climate risk materiality	−0.23	−0.60***	−0.66***	−0.57***	−0.18	−0.18
	(−1.26)	(−3.14)	(−2.87)	(−4.18)	(−1.11)	(−0.94)
Climate risk horizon	0.34**	0.03	−0.19	0.07	0.06	0.17
	(1.98)	(0.18)	(−1.02)	(0.37)	(0.38)	(0.72)
Medium horizon	−0.80	0.17	−0.42	−1.93***	−1.09	−0.64
	(−0.99)	(0.21)	(−0.53)	(−2.66)	(−1.36)	(−0.76)
Long horizon	−0.99	0.01	−1.26	−1.84**	−0.33	−1.08
	(−1.18)	(0.02)	(−1.53)	(−1.97)	(−0.44)	(−0.94)
Climate risk engagement	0.13	0.14*	0.18**	0.22*	0.22**	0.27***
	(1.07)	(1.86)	(2.15)	(1.92)	(2.22)	(3.90)
Assets under management	−0.05	−0.17**	−0.13	0.22***	−0.25	0.12
	(−0.33)	(−2.16)	(−1.61)	(3.27)	(−1.59)	(0.46)
ESG share (x100)	−0.30	1.38***	0.61	1.06	1.78***	1.57***
	(−0.80)	(4.13)	(0.97)	(1.45)	(2.73)	(2.79)
Passive share (x100)	2.10***	2.36***	1.79***	2.22***	0.86	1.39**
	(3.65)	(5.61)	(5.25)	(3.75)	(1.11)	(2.18)
Independent institution	−0.26	0.08	−0.88***	−0.28	0.71**	0.09
	(−1.49)	(0.26)	(−2.60)	(−0.65)	(2.44)	(0.25)
HQ country norms	−2.66	−5.09**	−0.44	2.86**	0.24	4.61***
	(−1.50)	(−2.42)	(−0.24)	(2.02)	(0.14)	(4.27)
Respondent position FE	Yes	Yes	Yes	Yes	Yes	Yes
Distribution channel FE	Yes	Yes	Yes	Yes	Yes	Yes
N	345	345	343	346	337	343
Pseudo R-sq.	.200	.175	.172	.177	.134	.143

Panel A reports the investors' responses to the question of how large they consider the risk that climate change causes some assets to become stranded, that is, unable to recover their investment cost, with a loss of value for investors (Question C3). We listed in the survey six industries for which we asked the respondents to evaluate this risk. Respondents could indicate their views on a scale of one ("low") through four ("very high"). They could also indicate "Do not know." In panel A, Column 1 presents the percentage of respondents indicating that stranded asset risk is "very high." We rank results based on this measure. Column 2 reports the mean score, where higher values correspond to higher stranded asset risk. Column 3 presents the percentage of respondents indicating "Do not know." Column 4 reports the number of respondents. Column 5 reports the results of a t-test of the null hypothesis that each mean score is equal to 1 (low stranded asset risk). Column 6 reports the results of a t-test of the null hypothesis that the mean score for a given reason is equal to the mean score for each of the other reasons, where significant differences at the 10% level are reported. Panel B in this table reports ordered logit regressions relating perceptions of stranded asset risks to investor characteristics. The dependent variables equal one if the respondent stated that stranded asset risks are "very high" and zero otherwise. We drop observations where respondents indicated "Do not know." We use the following independent variables: *Climate risk materiality* (smaller numbers reflect greater perceived importance); *Climate risk horizon* (smaller numbers indicate that climate risks are expected to materialize sooner); *Medium horizon; Long horizon*; *Climate risk engagement; Assets under management*; *ESG share; Passive share; Independent institution;* and *HQ country norms* (larger numbers reflect a stronger belief in the importance of environmental issues in an institutions' country). Table A1 defines all variables in detail. t-statistics (reported in parentheses) are based on standard errors that are clustered at the investor-country level. *$p < .1$; **$p < .05$; ***$p < .01$.

Figure 3
Investment opportunities from climate change
This figure displays in a word cloud the responses that were given to an open question that asked the respondents to indicate in which areas, if any, they see the biggest investment opportunities resulting from climate change (Question D4). The size of the words in the cloud corresponds to the frequency of their occurrence, with larger font sizes reflecting that an investment opportunity was more frequently stated. We only list the top-15 words. N=378.

climate change (Question D4). We classified the answers and report in Figure 15 the fifteen most frequent responses. The word cloud displays in larger font those responses that were more frequent. Our respondents identify opportunities mostly in renewable energy, but also in the areas of water (including water supplies and management), electric vehicles, and technology.

6. Direction of Response Bias

To evaluate the direction of potential response bias, we compare key survey responses across different cuts of the data. Internet Appendix Table 2 reports this comparison. We focus on contrasting the results between institutional investors with high and low ESG share and between large and small institutions. Additionally, we report a comparison of key results between the panel respondents and the other three distribution channels. In panel A we find only small differences across the subsamples in terms of the importance of climate risks (high-ESG institutions rank climate risks only slightly higher than low-ESG institutions). High-ESG-share and larger institutions generally also believe that the financial materiality of the different sources of climate risks is higher. In panel B we find high-ESG-share institutions, large institutions, and institutions that were not part of the panel more strongly agree that they incorporate climate risks because of financial and nonfinancial motives. Consistent with this finding, panels C and D show that high-ESG-share and large institutions have a higher propensity to conduct climate risk management and engagement. As we have an oversampling of larger institutions and institutions with more ESG funds, these differences support the possibility that our responses may be biased toward investors with more developed climate risk polices.

7. Conclusions

We survey institutional investors to gain a better understanding of whether, why, and how they consider climate risks in their investment decisions. We find that the survey respondents generally think that climate risks have important financial implications for their portfolio firms. Further, the majority believes that climate risks, especially those related to regulation, have already started to materialize. These beliefs are also reflected in the respondents' climate expectations: the vast majority expect a significant rise in global temperature by the end of this century. Such expectations indicate that at least a significant proportion of our respondents should have deep concerns about the effects of climate change on their portfolios. The opinion that climate risks matter financially conforms with evidence from studies that use archival data to examine the financial effects of climate risks.

No single motive dominates the investors' explanations for why they incorporate climate risks into their investment processes. The most common motives provided by the investors are to protect their reputations, moral/legal

considerations, and the belief that climate risks affect portfolio risk and returns. These findings imply that institutional investors consider climate risks both because of nonfinancial and financial reasons.

Most of the respondents have taken at least first steps toward managing climate risks, although the two most common approaches (analyses of carbon footprints and stranded asset risks) have been used by less than half of them. Divestment is the least frequently used approach overall. This finding is interesting in light of the current debate about whether divestment or engagement is more effective in combating climate change. Investors with longer horizons generally use a wider range of tools to manage risks associated with climate change. When investors engage portfolio firms over climate risks, they usually prefer private discussions with management. The widespread use of private intervention over climate topics implies that many investors first engage firms through negotiations and take public actions only once these private interventions failed. Larger investors generally engage firms along more dimensions.

The average respondent believes that equity valuations do not fully reflect the risks from climate change. Overvaluations are considered to be largest among oil firms, followed by traditional car manufacturers, and electric utilities, although the magnitudes of the overvaluations seem to be modest. Respondents with larger ESG shares, and those that engage portfolio firms along more dimensions, generally see more underpricing of climate risks.

Overall, our evidence indicates that investors consider climate risks as important investment risks. While investors have already started to integrate climate risks, the industry as a whole is still at early stages of incorporating these risks into their investment processes. For example, many investors still do not consider the basic approaches to identify and manage carbon and stranded asset risks. In general, the long-term and larger investors appear better prepared for the transition to a low-carbon economy.

Our analysis contributes to research that documents that investors *should* consider climate risks. We hope that our findings help to spur additional theoretical and empirical research in the area.

Appendix

Table A.1
Variable definitions

Variable	Definition	Survey question
Climate risk ranking	This variable is the absolute ranking of the importance of climate risks. The variable ranges from one (if climate risks are considered the most important risk) to six (if they are considered the least important risk).	Question A1
Climate risk top 2	This variable equals one if climate risk is ranked as the most or second-most important risk and zero otherwise.	Question A1
Climate risk relative to financial risk	This variable is calculated as the difference between the ranking of the importance of climate risk and the ranking of the importance of financial risk.	Question A1
Regulatory climate risk	This variable measures the financial materiality of regulatory climate risk. The variable can range between one (very important) and five (not at all important).	Question A2
Physical climate risk	This variable measures the financial materiality of physical climate risk. The variable can range between one (very important) and five (not at all important).	Question A2
Technological climate risk	This variable measures the financial materiality of technological climate risk. The variable can range between one (very important) and five (not at all important).	Question A2
Climate risk materiality	This variable averages the responses to three questions about the financial materiality of regulatory, physical, and technological climate risk. Each of these three variables can range between one (very important) and five (not at all important).	Question A2
Climate risk management	This variable counts the number of approaches used in the past 5 years to incorporate climate risks into the investment process.	Question B1
Active approaches	This variable counts the number of active approaches used (shareholder proposals, negative/exclusionary screening, reducing carbon footprint, divestment, reducing stranded asset risk, and/or hedging).	Question B1
Passive approaches	This variable counts the number of passive approaches used (analyzing carbon footprint, general portfolio diversification, ESG integration, valuation models, and/or analyzing stranded asset risk).	Question B1
Screening	This variable equals one if an institutional investor used negative/exclusionary screening to manage climate risks and zero otherwise.	Question B1
Divestment	This variable equals one if an institutional investor divested to manage climate risks and zero otherwise.	Question B1
Shareholder proposals	This variable equals one if an institutional investor made submitted shareholder proposals to manage climate risks and zero otherwise.	Question B1
Climate risk horizon	This variable averages the responses to three questions about when the risk related to climate change will materialize financially. Smaller numbers indicate that the risks will materialize sooner.	Question A3
Climate risk engagement	This variable counts the number of different direct engagement channels that an investor has taken in the past 5 years.	Question B2

(*Continued*)

Table A.1
(Continued)

Variable	Definition	Survey question
Holding discussions	This variable equals one if an institutional investor held discussions with management regarding climate risks and zero otherwise.	Question B2
Proposing actions	This variable equals one if an institutional investor proposed specific actions to management on climate risk issues and zero otherwise.	Question B2
Voting against management	This variable equals one if an institutional investor voted against management on climate risk issues, and zero otherwise.	Question B2
Legal actions	This variable equals one if an institutional investor took legal actions against management on climate risk issues and zero otherwise.	Question B2
Climate risk underpricing	This variable averages positive mispricing scores (negative scores are set to zero). The variable ranges between plus two (strong average overvaluation) and zero (no average overvaluation).	Question C1
Climate risk mispricing	This variable averages the absolute values of all mispricing scores.	Question C1
Medium horizon	This variable equals one if the indicated typical holding period of an institutional investor is between 6 months and 2 years and zero otherwise.	Question G2
Long horizon	This variable equals one if the indicated holding period of an institutional investor is above 2 years and zero otherwise.	Question G2
Assets under management	This variable indicates the size of an institutional investor and equals one (assets under management less than $1 billion); two (between $1 billion and $20 billion); three (between $20 billion and $50 billion); four (between $50 billion and $100 billion); and five (more than $100 billion).	Question G6
ESG share	This variable is the percentage of the institution's portfolio that incorporates ESG issues.	Question G5
Passive share	This variable is the percentage of the institution's portfolio that is passively managed.	Question G4
Independent institution	This variable equals one if an institutional investor is considered to be an independent institution, and zero otherwise. As in Ferreira and Matos (2008) and Dyck et al. (2019), independent institutions are more likely to collect information, have fewer potential business relationships with the corporations they invest in, and therefore are anticipated to be more involved in monitoring management. We classify mutual funds, asset managers, hedge funds, private equity funds, and public pension funds as independent institutions.	Question G1
HQ country norms	This variable captures the importance of environmental issues in the country in which an institutional investor is headquartered. The data are from Dyck et al. (2019), who construct the variable based on the Environmental Performance Index obtained from the Yale Center for Environmental Law (Yale University) and the Center for International Earth Science Information Network (Columbia University) for 2004. Larger numbers reflect a stronger common belief in the importance of environmental issues.	Question G7

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