Business sustainability behaviour and alignment with climate targets

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Business sustainability behaviour and alignment with climate targets

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Abstract

Climate actions by the private sector are crucial to cutting global emissions and meeting the climate targets set by the Paris Agreement. In recent years, an increasing number of companies have pledged to help achieve those targets. However, the emissions pathways of most firms are still not aligned with these goals. To explain the root causes of this discrepancy between effort and outcome, we developed a new methodology to track the actions implemented by major public corporations to reduce their emissions. Our analysis shows that firms with emissions pathways aligned with climate targets prioritise actions focused on creating growth opportunities, such as investing in research and development and new products as well as fostering cooperation with other ecosystem players. Overall, we provide a new systematic framework to track the effort of major corporations to align their emissions with climate targets. Our approach can be used by investors and policymakers to redirect capital towards its most sustainable use and to design behaviourally founded policy interventions to align business emissions with climate targets.

To limit global warming within the goals set by the Paris Agreement countries have put forward emission targets, but meeting these targets depends on the actions of a number of actors, most notably corporations[1,2]. Indeed, a significant component of global greenhouse gas (GHG) emissions can be directly associated with business activities, from industrial production to transportation and land use[3]. Therefore, changes in corporate behaviour are crucial to reducing the impact of human activities on long-term climate dynamics[1,4].

A large number of public corporations have pledged to lower their emissions, and a subset of these firms have put forward explicit targets to achieve the temperature goal of the Paris Agreement[5–7]. However, as of 2019, out of ~ 13000 large public corporations, only $\sim 18\%$ (~ 2300) have emissions pathways aligned with the temperature goals set by the Paris agreement (Figure S1). Therefore, despite a decade-long series of commitments[8], and the unprecedented flow of resources towards supposedly environmentally sustainable funds

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and firms[9], the private sector is failing in delivering the transition towards a sustainable economy.

Explaining the root causes of this failure requires monitoring what companies are doing to lower their emissions to a level compatible with Paris targets and understanding what type of climate actions are most effective in achieving this goal. Understanding the causes of businesses' inability to contribute to sustainable development is crucial for (1) business leaders to better understand how to change their firm's operations to achieve better outcomes, (2) market participants, to allocate capital towards its most sustainable use, and (3) policymakers to devise effective intervention strategies to curb emissions. Yet, finding an answer is challenging due to a lack of a systematic reporting framework of corporate climate actions and spending.

Most previous works that look at firms' contribution to the achievement of climate targets have mostly focused on the analysis of commitments (e.g., whether or not a firm has set emission targets and the type of target[5,10,11]) and high-level climate actions (e.g., disclosure of emissions and business costs, and the extent to which climate change responsibilities are delegated to the board or senior management[10]). Other works looked at the management practices in further details by analysing standardised datasets such as, for example, the climate actions self-reported to the Carbon Disclosure Project (CDP)[12]. Here we take a different approach. Specifically, we develop a systematic framework to identify and characterise the actions that companies are taking to reduce their emissions. Differently from previous works we focus on specific actions that are already implemented (not firm-level commitments), we look at a broad spectrum of actions (not only those reported to CDP), and we focus on a large number of firms (~ 4000), countries (48) and years (10).

To collect information about firms' climate actions, we use information disclosed in sustainability reports: annual reports that describe the activities a corporation has undertaken during a given fiscal year to address societal problems, from lowering emissions to reducing inequality in their management, workforce and local communities. Several studies have looked at the information content of sustainability reports (see Ref.[13] for a recent analysis and Ref[14] for a comprehensive review). However, the lack of clear reporting standards and the resulting lack of comparability and quantifiability of the information content of sustainability reports is a major limiting factor for their analysis[15]. Indeed, to

the best of our knowledge, no database currently exists that systematically maps the unstructured information contained in the text of the reports into objective, quantitative and material information about corporate behaviour[†]. Here we address this gap. Specifically, we build a machine learning process that searches, identifies and classifies climate actions for the major publicly listed companies around the globe.

In our dataset, we classify each climate action, or climate-related sustainability initiative (we use the terms interchangeably), based on the type of activity implemented by the firm, e.g., development of new products, donation and funding for climate change causes, changes in operating processes, renovation of plant and equipment. Then, we further classify each activity based on the particular climate-related Sustainable Development Goal (SDG) that it is meant to address. The choice of focusing on SDGs is motivated by the observation that, as governments and international institutions face growing pressure to realise the SDGs, companies will be forced to align their behaviours with these targets to limit negative environmental externalities[16,17], and to report their initiatives within this framework[18]. In the following, we will refer to a particular combination of climate-related sustainability initiatives - categorised as activity/SDG - as a *climate-related sustainability behaviour*, or simply *sustainability behaviour*.

Using our dataset, we provide an in-depth, large-scale, analysis of the distribution and the temporal evolution of sustainability behaviour. Moreover, we assess the relationship between companies' sustainability behaviour, as they emerge from the reports, their GHG emissions, and the alignment with the targets set by the Paris Agreement. Overall, our dataset contributes to the ongoing effort[19] of monitoring companies' actions to align with the United Nations 2030 Agenda.

Results

In the following sections we present our dataset and an overview of the sustainability behaviour of a large population of publicly listed firms. Then we compare the sustainability

[†]ESG analysts also use information from sustainability reports, but only as input for their scoring models. Also, the output of their models are risk exposure measures which are not objective assessments of corporate behaviour.

behaviour of companies that succeed in limiting their emissions to the behaviour of high-emitting firms.

A systematic categorisation of sustainability initiatives

Our population comprises ~ 3900 publicly traded firms listed in major exchanges worldwide with a homogeneous distribution across both sectors and geographies (see Figure S2 panels **a,b** in the Supplementary Information). The inclusion criteria include availability of accounting and emission data and whether or not a firm has published a sustainability reports during the observation period 2010-2019. We exclude 2020 from the observation period because the COVID-19 lockdown had a negative impact on emissions which confound the effects of the initiatives. Importantly, our sample is a good representation of the total population as it covers ∼75% of global (public) market capitalisation and invested capital, ∼80% of the direct and first-tier indirect emissions available for public corporations, and $\sim 50\%$ of global emissions (see Figure S2 panels **c** in the Supplementary Information and Methods). The reports included in our sample (1) tend to follow GRI standard ($\sim 95 - 100\%$), (2) are almost exclusively consolidated reports ($\sim 90 - 95\%$), and (3) are often assured by external audit firms, ($\sim 60 - 70\%$), see Figure S2 panels **d** in the Supplementary Information.

In the Methods section and the Supplementary Information we provide a detailed description of our data-collection process. Briefly, for each company in our sample and for each year from 2010 to 2019 we download or purchase a sustainability report (when available). Then, we train a neural network to (1) identify sustainability initiatives and (2) categorise an initiatives based on the type of action, or activity, undertaken by the firm (e.g., a research and development investment, the deployment of new products, training of employees) and the SDG that the activity is meant to target. In the Supplementary Information section B we provide a full description of our taxonomy of activities. In section C we provide some examples of the initiatives and their categorisation.

Each environmental SDG comprises multiple targets, but most of these targets are not related to reducing GHG emissions. For example, SDG 12 includes target related to reducing

food waste (target 3), general waste (target 5) and increasing transparency in reporting (target 6). Because here we are interested in the initiatives implemented in order to reduce GHG emissions, we extract from the total number of initiatives only those related to this particular issue (see Methods). Figure 1 panel **a** shows how the activities are distributed across SDGs in our sample. The figure shows the Sankey diagram of a matrix where each row is an activity and each column an SDG. Each cell in the matrix is therefore the total number of initiatives detected in the report. We refer to this matrix as our *behavioural matrix* (see figure S5 in the Supplementary Information). In our framework, a sustainability behaviour is a specific allocation of sustainability effort, i.e., a specific configuration of the behavioural matrix.

Figure 1 panel **a** shows a large degree of heterogeneity in both activities and SDG targets. Specifically, we have found that most of the activities are asset modifications and modification of procedures intended to meet goals 12 (responsible consumption and production) and 7 (affordable and clean energy). Examples of these initiatives can be found in table ST1 in the Supplementary Information. SDG 13 (climate action) is poorly represented in our population. At first, this result could be surprising as SDG 13 is the most relevant goal for tackling climate change. However, it is important to notice that the targets of SDG 13 are related mostly to country-level initiatives (e.g., "Integrate climate change measures into national policies, strategies and planning", "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries").

When interpreting the Sankey diagram of the behavioural matrix in figure 1 it is important to bear in mind two important limitations. First, all the initiatives reported in the panel are accounted for independently of their complexity. Therefore, it is not surprising that activities such as donation & funding (which are easily implemented) are significantly more common than, for example, development of new products (which require a significant managerial effort). Second, the *real* total number of initiatives in the population is likely significantly larger than the one reported here. This is because we impose a strict definition of what an initiative is in order to only include in the analysis initiatives that require a significant effort (see Methods and Supplementary Information section A for a more in depth discussion).

Figure 1 panel **b** and **c** show the distribution of the SDGs and activities, respectively, across sectors. The y-axis in the panels shows the number of occurrence of a particular activity divided by the total number of activities in the sector. Overall, we have found a strong homogeneity in the SDG behaviour and a significant heterogeneity in the activity behaviour. For example, firms in the Financial sector implement a large number of donation & funding initiatives and only a limited number of research & development (R&D) initiatives. On the other hand, firms in the Energy and Material sectors are those with the largest effort in R&D. It is important to notice that some of the differences in the number and relative frequency of activities across sectors are likely due to the nature of the assets of the firms (the proportion of tangible versus intangible assets and the energy needs for production).

The sustainability behaviour of high emissions sectors

In order to fairly compare the sustainability behaviour of different firms it is important to focus on firms with comparable business needs. Therefore, in the following we restrict our analysis to four sectors: Energy, Material, Industrial and Utilities. Firms in these sectors account for $\sim 90\%$ of the emissions in our population (see figure S6). Moreover, in contrast to sectors such as Financial and ICT where revenue strongly depend on the value of intangibles (e.g., patents), the business models of firms within these sectors are comparable in that production and revenue strongly depends on tangible assets[‡] as well as fossil fuel price. In this section we provide an overview of the sustainability behaviour within these sectors.

In these sectors our sample consists of ~ 1800 firms and ~ 20000 initiatives (see figure S7). The average number of initiatives per report as well as the total number of initiatives (red) and reports (blue) per year is shown in figure 2 panel **a**. The panel shows that, on average, we observe a very limited number of GHG reductions related initiatives per report (from 2 to 10, depending on the sector and year). Importantly, the figure also show that the total number of initiatives dropped significantly in 2015 and 2016. This trend is particularly evident in the Energy and Utility sector and we do not observe it in the sectors excluded from this analysis (see Figure S8 in the Supplementary Information). We believe that the

[‡] $\sim 40\%$ of total assets in these four sectors are tangible assets, e.g. plant, versus $\sim 20\%$ in the other sectors. The differences are statistically significant

likely cause for this drastic reduction of number of initiatives in 2015 and 2016 is due to a revenue loss that followed the crash of oil prices in 2015.

Interestingly, figure 2 panel **b** shows that while the average number of initiatives per report is small, there are firms in the sample with a large number of initiatives. Specifically, the y-axis is the fraction of firms with less than n% of the total number of initiatives in the sector mentioned across all company reports (x-axis). The diagonal line represent an hypothetical uniform distribution. The larger the deviation from the diagonal the more skewed the distribution. For example, in the Industrial sector (blue line) $\sim 85\%$ of firms do less than 20% of the total number of initiatives. Overall the panels show that the distributions of the number of initiatives are (1) significantly skewed and (2) significantly different across sectors. Figure S9 in the Supplementary Information shows that the skewness of the distributions is also a function of size, with the top 0.1% largest firms taking as many as 18 times the median number of initiatives.

Linking sustainability behaviour and GHG emissions

We now focus on understanding what is the relationship between companies' sustainability behaviour and their emissions.

Figure 3 panel **a** shows that there is a positive correlation between the number of initiatives (x-axis, in quartiles) and the total GHG emissions in the two years following the initiatives (y-axis). The positive correlation is likely due to larger companies needing to take on more initiatives to reduce their impact, as well as having more capacity to both undertake and advertise sustainability initiatives. To test this hypothesis panel **b** show a three stage model that attempt to describe how the number of initiatives a company takes influence its future emissions. Briefly, we assume that the number of initiatives depends mainly on: the available capital to finance the initiatives, which can in turn be divided in invested capital and revenue, and the nature of the assets of the firm (whether revenue is generated from tangible or intangible assets). In the Methods section we describe the model and the estimation procedure in further details. The model implies that if the number of initiatives has an impact on future emissions, the effect (red link in the graph) should persist after

controlling for these three factors. Panel **c** shows that this is not the case, after controlling for revenue, the positive (and strongly statistically significant) correlation between the number of initiatives and the future emissions vanishes. The figure suggests that doing more does not necessary imply emitting less.

In this section we have shown that the number of sustainability initiatives that a firm undertake during a given fiscal year is unrelated to its future emissions. In the next section we show that the relevant explanatory variable for future emissions is the particular sustainability behaviour that a firm implements, i.e. the particular combination of activities and SDGs. In other words, we show that what companies do is more important than how much they do. To illustrate this point we run two analysis. First, we build portfolios of firms with the lowest and largest year-to-year change in emissions and we compare the sustainability behaviours of the firms in the two populations. Second, we compare the behaviours of firms that, as of 2019, have emission pathways aligned with the climate targets set by the Paris Agreement versus those that have emission pathways misaligned with these targets.

The importance of sustainability behaviours

In order to infer what type of sustainability behaviour is associated with better outcomes (lower future emissions) we perform an ex-post analysis by looking at the differences in the behaviour of portfolios of firms that have increased or decreased their emissions on a year-to-year basis during the observation period (see Methods). Specifically, we construct portfolios of ratios of future emissions over current emissions. The portfolio are built as yearly quartile of the ratio. The year-to-year change in emissions is independent of the number of initiatives (figure 4 panel **a**), and the portfolios are shown in figure 4 panel **b**. Importantly, Size and number of initiatives are approximatively the same across portfolios (figure S10 top panel in the Supplementary Information). Therefore, the behaviour of the portfolios is directly comparable.

Figure 4 panel **c** shows the excess effort of the companies in the bottom quartile portfolios versus the top quartile portfolios. Excess effort is defined as the difference between

the proportion of activities and SDGs in the two portfolios, i.e. the difference between the normalised behavioural matrices. Portfolios of decreasing emissions are characterised by more r&d investments, associations, donations and incentives, incentives, pricing and new products, as well as more effort in targeting SDG 7. The panel provides only a summary view of the full difference in sustainability behaviour. The full difference matrix is shown in figure S10 bottom panel in the Supplementary Information. Overall, this result suggests that companies successful at lowering their emissions have behaviours that focus more on activity and SDG related to creating value and growth opportunities, rather than implementing changes in asset already in place.

To assess the statistical significance of our finding we re-evaluate the model in figure 3 panel **b** twice. Once by only focusing on the activities and SDGs with a positive excess effort and once by using the activities and SDGs with negative excess efforts (see Methods). Results are shown in table S11 in the Supplementary Information. We have found a consistently negative and statistically significant coefficient in the first regression (-0.04, p-value < 0.05) and a positive but not statistically significant coefficient in the second regression (0.03, p-value > 0.1). Overall, these results suggest that sustainability behaviours tilted towards r&d investments and associations aimed at meeting the targets set in SDG 7 are associated with lower future emissions.

Alignment with climate targets

In the previous section we analysed the behaviour of hypothetical portfolios. Here instead we focus on the difference in behaviour between companies that, as of 2019, are aligned or misaligned with climate targets. First, we consider a firm to be aligned with a climate target if the projected emission pathway as of 2019 is below the required pathway to limit global warming below 2°C. Later we test the robustness of our results with the well below 2°C target set by the Paris Agreement. Emission pathways are computed by TruCost using the Sectoral Decarbonization Approach (SDA) and the Greenhouse gas emissions per unit of value added (GEVA) approach, see Methods. For comparison purposes we first focus on the largest firms in the sample (later in the section we extend our analysis to the full population). In this group there are 399 firms, 128 of which are aligned with the goal

of limiting global warming below 2°C, and 271 are not. These firms together account for approximatively 70-90% of the total emissions of the sectors (65-81% of total emissions), see figure 5 panel **a**.

The gap in the contribution to the total sectors' emission in the two groups (aligned and misaligned firms) shown in figure 5 panel **a** is due mainly to the different number of firms in the two populations. Indeed, figure 5 panel **b** shows that firms in the two groups have approximatively the same level of emissions. However, firms aligned with the 2°C target have, on average, decreased their emissions (the effect is stronger starting from 2015), while the emissions of misaligned firms are approximatively the same across the observation period. Notice that panel **a** and **b** report statistics in our sample. The full emission statistics for the largest firms aligned and misaligned with the target, including those for which we have no behavioural data, are shown in figure S12. The pattern is qualitatively the same.

The average number of initiatives in the misaligned and aligned groups are 3.9 and 4.5, respectively, and the difference is not statistically significant (p-value > 0.1). On the other hand, the type of initiatives that the two groups undertake are significantly different. Figure 5 panel **c** shows the excess effort of companies aligned with the 2°C target. Companies aligned with the target focus more on r&d investments, association and new products, and on realising SDG 7 (the effect is significantly stronger at the SDG level than at the activities level). Similarly to the results shown in figure 4 panel **c**, asset modifications to realise SDG 12 are significantly underrepresented in the population of firms aligned with the target.

It is important to notice that the values shown in panel **c** are the sum of the rows and columns in the behavioural matrix. The full behavioural matrix of the differential behaviour is shown in figure S13 in the Supplementary Information. The matrix highlights important details that are masked in the summary view shown in figure 5 panel **c**. For example, the strong negative value of asset modifications is driven by SDG 12, while excess effort for asset modifications aimed at SDG 7 is positive. Similarly, firms exhibit a positive excess effort in the development of new product in SDG 7 and a negative excess effort in the development of new product in SDG 12. Overall, the matrix illustrates that the behaviours of the two populations differ in a few key activities.

Similarly to the previous analysis, we re-evaluate our initiatives-emissions model taking into account the behavioural differences observed in figure 5. The positive excess activities/SDGs (blue bars in figure 5 panel **c**) have a negative and statistically significant coefficient (-0.06, p-value < 0.05, i.e., doing more of these initiatives is associated with lower future emissions), while the negative excess activities/SDGs (red bars) have no effect on future emissions (0.01, p-value >0.1). Results are shown in Figure S14 in the Supplementary Information.

To further confirm the robustness of our results, we repeat the same analysis on the population of firms aligned and misaligned with a well below 2°C target (see Methods). In this population, out of the total 399 firms, 82 are aligned with the target and 317 are not aligned. Results are shown in figure S15 and figure S16 in the Supplementary Information and are qualitatively similar to the results shown in the main text. Overall, figure 4 panel **c**, figure 5 panel **c**, and figure S15 panel **c** all show a similar pattern: firms aligned with climate targets exhibit a sustainability behaviour which is significantly different from that of less virtuous firms.

Finally, as a further robustness check, we repeat the analysis for all the other size quartiles. Results are shown in table ST3. As we focus on smaller firms the number of initiatives diminish significantly. However, results are consistent with those presented in the main text: the behaviours associated with firms aligned with the 2°C and well below 2°C Paris agreement targets are negatively (and statistically significantly) associated with future emissions, i.e. doing more of these activities tend to be associated with lower future emissions.

Discussion

Business leaders of the majority of large public corporations have pledged to align the emissions of their firms with the target set by the Paris agreement of limiting global warming well below 2°C. Yet, emissions from many public corporations continue to rise (see Supplementary Information figure S17) and so do average annual temperature anoma-

lies[20,21]. What are companies doing to lower their emissions? What differentiates companies that are successful in meeting climate targets from those that fail? Answering these questions requires a detailed knowledge of corporate sustainability behaviour and investment plans. Unfortunately, contrary to the disclosure of financial information which is a strictly enforced and regulated process, disclosure of nonfinancial information is largely voluntary and unregulated. Significant progress have been made in recent years to standardise climate related disclosure (e.g., through for example the Task Force on Climate-Related Disclosure, TCFD), but the proportion of firms following these standard is still limited (~ 2600 firms follow TCFD guidelines). Therefore information on corporate sustainability behaviour is scarce and difficult to quantify. To address this issue, in this work we have presented a new sustainability dataset that maps unstructured information contained in sustainability reports into a quantitative and systematic framework that can be used to study corporate sustainability behaviour.

Our analysis shows a large degree of heterogeneity in sustainability behaviour across firms in our sample, which include some of the largest corporations in public markets. Most sustainability initiatives focus on SDG 7 and 12 and involve implementing changes in existing assets and procedures. Importantly, the low incidences of SDG 13 ("Climate Action") in our dataset is due to (1) the policy nature of SDG 13 targets and (2) the overlap in scope with other SDGs, most notably SDG 7 and 12. Looking at the link between sustainability behaviour and future emissions, we have shown that, after accounting for scale factors, the total number of initiatives undertaken to lower emissions is unrelated to the emission-reduction capacity of a firm (figure 3 panel **c**). However, while the total number of initiatives cannot explain future emissions, the differential managerial effort placed on different activities/SDGs (i.e., the particular sustainability behaviour adopted by a firm) is an important explanatory variable. Specifically, we have shown that sustainability behaviours that prioritise changes that create growth opportunities (e.g., r&d investments, incentives, new products) and cooperation (association, communication) are associated with lower future emissions. On the other hand, behaviours that priorities changes of asset already in place (e.g., asset modification, modification of procedures, assessment and measurements) are associated with higher future emissions. Our main findings are shown in figure 4 panel **c**, figure 5 panel **c**, and figure S15 panel **c**.

It is important to notice that results from this work are not *causal*. Our evidence points towards a statistically significant associations, i.e., firms that tend to employ a particular behaviour also tend to have lower emissions. These associations do not imply that the initiatives themselves lower the emissions, although we expect that at least some of the initiatives do. For example, we expect that developing new products and investing in research and development for improving energy efficiency (e.g., SDG 7 target 3) results in lower future emissions. However, the positive association between donation & funding and lower future emissions can only be explained as a spurious associations that masks a latent causal structure. Further research is needed to shed light on the causal mechanisms underlying these associations, and to systematically distinguish causative initiatives from non-causative initiatives (as a preliminary analysis, figure S18 shows that results are robust after removing non-causative activities from the study). Additionally, in the context of establishing causality, our dataset can provide a starting point to design interventions that sustainability teams can implement to assess the impact of various behaviours on the sustainability of their firms. A proper causal analysis of the impact of different sustainability behaviours on future emissions could also be relevant to understand what type of climate actions can facilitate large scale decarbonisation solutions.

We believe our analysis and dataset can be relevant for three societal actors. Firstly, *business leaders* can benefit from a detailed understanding of the sustainability behaviours of peers and competitors to improve their climate strategies. Our analysis already illustrates some results relevant for sustainability strategists, namely, the importance of focusing more on activities that create external value over those that involve changes in assets already in place. Second, *investors* can use our datasets for allocating capital to its most sustainable use. Indeed, sustainable capital allocation requires market participants to have access to transparent information on nonfinancial activities of public corporations. However, as discussed in the Introduction, to the best of our knowledge, no dataset currently exists that systematically map the unstructured information of sustainability reports into objective, quantitative and actionable information. Currently, investors mostly rely on Environmental ratings to assess the sustainability of public firms. However, Environmental ratings are subjective assessment of companies' exposure to climate risks, and are not necessarily

predictive of future emissions reduction[§22]. On the other hand, our behavioural dataset focuses on the actions that companies are now taking to lower their environmental impact. Therefore it can be used to build predictive models grounded on transparent and objective information. Finally, our dataset offers *policymakers* the opportunity for assessing the status of sustainability reporting at large and for developing new regulations to improve transparency and reliability of nonfinancial reporting.

There are several limitations to our analysis. We discuss these limitations in the Supplementary Information section A.5. Here we provide a summary discussion. First, there is a degree of subjectivity in our definition of sustainability initiatives which is then coded in the training set and might induce biases in the analysis. When studying the population at large, this bias should be consistent across all firms, therefore firm-to-firm comparison should not be affected by it. However, this is an important limitation to bear in mind when focusing on the analysis of a single entity. Second, we do not differentiate between initiatives based on their complexity. Further research is needed to systematically categorise initiatives based also on the effort required to accomplish them. Finally, sustainability reports are self-reported documents and therefore our dataset is biased by self-selection of reported initiatives. Further work is needed to integrate non-sustainable initiatives into our dataset by, for example, analysing news media and legal databases.

Overall, our analysis opens up new opportunities for studying sustainability behaviour within a systematic and quantitative framework. We believe this is a crucial step to foster the transition towards a more inclusive and just economy.

[§]For example, Environmental rating cannot distinguish between firms with emission pathways aligned and misaligned with the climate target of the Paris Agreement (figure S19 panel **a**). Also, they are uncorrelated with total emissions (figure S19 panel **b**)

Methods

Behavioural dataset

Here we provide a brief summary of the process we follow to collect the behavioural dataset. In the Supplementary Information section A we provide a more technical presentation. Our main unit of analysis is a *sustainability initiative*: a concrete action or set of related actions that a firm is pursuing outside of its normal core business operations with the intent to directly address one of the 17 sustainable development goals (SDGs). Importantly, to be classified as an initiative an action need to refer to something that a company has done, or is actively pursuing. Investment plans and future projects are not regarded as initiatives.

Our study is centred around the analysis of annual corporate sustainability reports. Depending on availability, the sustainability reports are either standalone reports (i.e., reports that only present non-financial information), integrated reports (i.e., reports that present financial and non-financial information within a integrated framework), or annual reports with a significant section on sustainability. The links to the PDFs are from REFINITIV. Sustainability reports not available at the url's provided by REFINITIV were bought from Corporate Register (https://www.corporateregister.com/). Overall, we analyse 25293 reports for ~ 6000 companies. Of these 6000 companies we have complete information about emissions and accounting data for ~ 3900 (~ 16000 reports). figure S2 and table ST2 show the summary statistics of our population while figure S3 shows the summary statistics of the full population.

In order to extract sustainability initiatives from the texts of the reports we use neural machine learning models trained on a training set developed by the GOLDEN Foundation (http://foundationgolden.org/blog/golden-is-golden-for-impact/). The training set was created by manually annotating 507 sustainability reports (~ 55088 initiatives). To test the reliability of the training set the annotators cross-validated their classification and computed their average agreement as the Cohen's Kappa. Values range from 49% to 76%.

To extract the initiative from the text, the documents are converted from pdf formats to

json, making them machine-readable. Textual fields from the pdfs are extracted and converted to plain text. The full text is separated into individual sentences for further analysis. Metadata from the pdf is also extracted, such as the creation time and any optional comments that were added by the authors. The system analyses each sentence in every report in order to determine whether they refer to sustainability initiatives. Detected sentences are then further combined, as a single initiative is often described with multiple sentences or whole paragraphs. We use two separate machine learning systems for this task and combine their predictions together for an ensemble model in order to achieve the best accuracy (see Supplementary Information section A). After the algorithm identifies an initiative the text goes through a separate system that classifies them based on (1) The type of the action or activity (e.g., adoption of standards and rules, communication, donation & funding, etc.) and (2) The Sustainable Development Goal (SDG). In section B we provide a detailed definition of the activities. The classification scheme is generated by reading sustainability reports and identify common activities described by the corporations. While there could be alternative taxonomies to classify the activities, we believe that those reported in the main text are the most common mutually exclusive and collectively exhaustive activities pursued by the firms in our sample.

While our dataset cover the full spectrum of sustainability initiatives, in the main text we focus solely on those initiatives that address the problem of reducing GHG emissions. To isolate these initiatives from the rest we analyse the text extracted from the reports and we only keep those initiative that mention: climate change, emissions, global warming, greenhouse gases (or ghg), green technologies, renewable, energy efficiency, environmentally efficient, natural energy, fuel efficient, electric power consumption, energy use, energy saving, carbon reduction, energy consumption. To identify the words in the dictionary we first start with a few keywords (climate change, emissions, global warming). Then we isolate initiatives containing those words and we look extensively to all the other initiatives. From these other initiatives we select a second subsample and we repeat the process until the discarded initiatives do not contain a significant number of actions aimed at reducing emissions (see section C for example of initiatives).

Fundamental and emission data

Additionally to our behavioural dataset, in this work we use data from third parties. Specifically, we use COMPUSTAT for firms' fundamental. We define Size as the log of sales (SALE, in USD) adjusted for inflation (https://fred.stlouisfed.org/series/CPIAUCSL); Invested Capital is long plus short-term debt (DLTT+ DLC), plus book equity (CEQ) plus cash and short-term investments (CHE); Tangibility is property plant and equipment (PPENT, in USD) divided by book assets (AT, in USD). Exchange rates are from REFINITIV. Information on the nature of the sustainability reports (whether they are standalone or integrated, or if they follow GRI guidelines and are assured by external audit firms) and the links to the pdfs are from REFINITIV. Equity data used to calculate total market capitalisation are from REFINITIV. Finally, data for global GHG emissions are from the climate watch portal (https://www.climatewatchdata.org/).

Emissions data are from TruCost. In particular we measure total GHG emissions as Direct plus first-tier indirect emissions which are defined as GHG protocol scope 1 emissions, plus any other emissions derived from a wider range of GHGs relevant to a company's operations, plus GHG protocol scope 2 emissions, plus the company's first-tier upstream supply chain—their direct suppliers. This is the TruCost's default measure of emissions (see https://www.spglobal.com/spdji/en/documents/additional-material/faq-trucost.pdf). Emission data from TruCost are a combination of self-reported and estimated data. In our sample, approximatively 65% of the Scope 1 and Scope 2 emissions values are self-reported. On the other hand, approximatively 55% of the the Scope 3 emissions data are self-reported.

A model for the sustainability initiatives

Figure 3 panel **b** shows our hypothesis concerning the role of sustainability behaviour in reducing company's total emissions. Our model is divided in three time period. At t_0 a firm has book assets and capital to invest. The book assets generate revenue at t_1 while the invested capital can be used to finance tangible and intangible assets. The gray nodes in the graph represent variables (intangible) that are not relevant for this analysis. The sustainability behaviour, here represented by the total number of initiatives at t_1 depends

on the amount of tangible assets (as intuitively tangible assets require more expenses for maintainance and improvement); The initiatives are financed with the capital raised for investment and revenue. Revenue and tangible asset generate emissions which we measure here as the cumulative sum of the GHG emissions in year t_2 and t_3. The hypothesis we want to test is if the link from the total number of initiatives and the total emissions (red link in the graph) exists after controlling for the possible confounders. Unobserved (and unaccounted for) confounders are shown as gray node in the graph. Additional controls include sectors and geographies dummies (as well as time fixed effects).

Because firms that issue sustainability reports might different systematically from non-publishing firms, but we only observed the reports for the firms that have one, we estimate the model with the Heckman correction[23]. That is, first we run a Probit model where the independent variable is one if a firm issue a report in year Y and zero otherwise (data on issuance are from REFINITIV). In the Probit model we also control for the probability of a firm in sector S to publish a report in year Y and for whether or not a firm has an ESG rating in year Y. Rating data are from MSCI. If the firm does not have a MSCI ESG rating we check if either REFINITIV or S&P Capital have rated the firm. Then we use the inverse Mills ratio from the Probit as additional covariate in the Robust Linear Model estimation step. Standard errors are adjusted for heteroskedasticity and firm-level clustering. To illustrate the reliability of the confidence intervals of the coefficients we show the Q-Q plot of the residuals

Emission portfolios

We build yearly emissions portfolios as follow. Firstly we create an year-to-year change in emission measure by scaling next year emissions by current emissions, i.e. $\frac{E_{t+1}}{E_t}$. This value is independent on the number of initiatives as shown in figure 4 panel **a**. Then for each year, from 2010 to 2018, we take the quartile of this measure. Firms that fall within the quartile are part of the same portfolios. The last year of observation is 2018 because of the lag in the numerator of the emission intensity measure (2020 is excluded from the analysis because of exogenous factors driving emissions). Observations in the quartile portfolios have approximatively the same size and number of initiatives (figure S10 top panels).

The excess effort in the bottom versus top quartile portfolio is measured as the average difference between the normalised behavioural matrices $\mathcal{B}$. We normalise the behavioural matrix by dividing it for the total number of initiative, i.e. Normalised Effort $= \frac{\mathcal{B}_{ij}}{\sum_{i,j}\mathcal{B}_{ij}}$. To evaluate the statistical significance of our results we estimate the model presented in A model for the sustainability initiatives as follow: first we build an independent variable which is the sum of the initiatives with positive excess effort (i.e., over-represented in the bottom quartile portfolios), then we build an independent variable with all the other initiatives. Then, we run two models one for each independent variable and we compare the sign and significance of the results.

Climate targets

Data on alignment with climate targets are from TruCost. Specifically, we use the difference between the projected emission pathway of a firm as of 2019 and the required pathway to limit global warming below 2°C. The horizon of the pathway (i.e. the final year of forward-looking data assessed) is set at 2025, and the base year is 2012. Negative values indicate that the transition pathway of a company is aligned with the 2°C outcome. TruCost estimate the transition pathway using the methodologies highlighted by the Science Based Targets Initiative (SBTI). Specifically, they use the Sectoral Decarbonization Approach (SDA) for high-emitting companies with an homogeneous business activity and the The Greenhouse Gas Emissions per Unit of Value Added (GEVA) approach for low-emitting companies with heterogeneous business activities. Additionally, TruCost also provide data on alignment with a "well below" 2°C outcome (which is the official target of the Paris Agreement). The aligned population is significantly smaller when focusing on this target therefore statistics are less robust. However, in the Supplementary Information we use these data to confirm the validity of our results.

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Data Availability. In the analysis we use data from COMPUSTAT, REFINITIV, MSCI, and

TruCost. Because these data are proprietary, they cannot be shared by us. The behavioural dataset is available upon reasonable requests to the authors.

Code availability. The code used for the analysis will be available upon acceptance of the manuscript.

Authors contribution. SC and MB designed the study, SC performed the analysis and wrote the first draft of the paper. MR developed the algorithm to generate the data. MZ developed the theoretical framework for the generation of the dataset. MB supported the development of the dataset. SC, MB, MR, MZ wrote the final version of the paper.

Competing interests. The authors declare no competing interests

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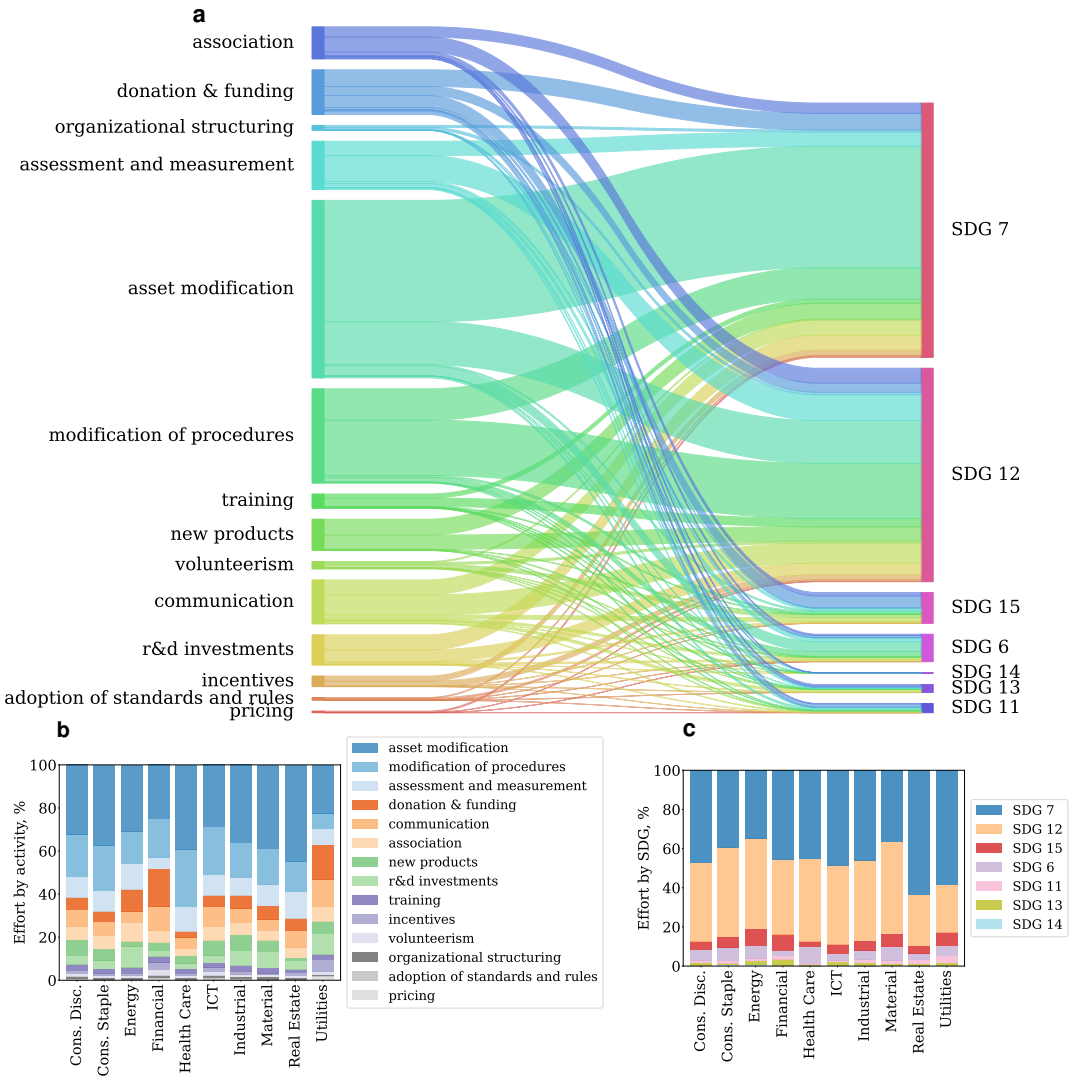


Fig. 1 | Sustainability behaviour. Panel **a** provides a summary view of the distribution of the sustainability initiatives. This is a Sankey diagram of the behavioural matrix shown in figure S5. Each line in the diagram represents an activity implemented to meet one of the climate-related SDGs. The thickness of each activity is proportional to the relative representation of the activity in the population. The panel illustrates that most of the activities are changes of assets in place and modification of procedures implemented to align the firm with SDG 7 and 12. Panel **b** and **c** show the sustainability effort by sector, i.e., the number of occurrence of a particular activity (or SDG) divided by total number of activities (or SDGs) in the sector. Overall, the figure provides an overview of the climate actions that companies implement to lower their emissions.

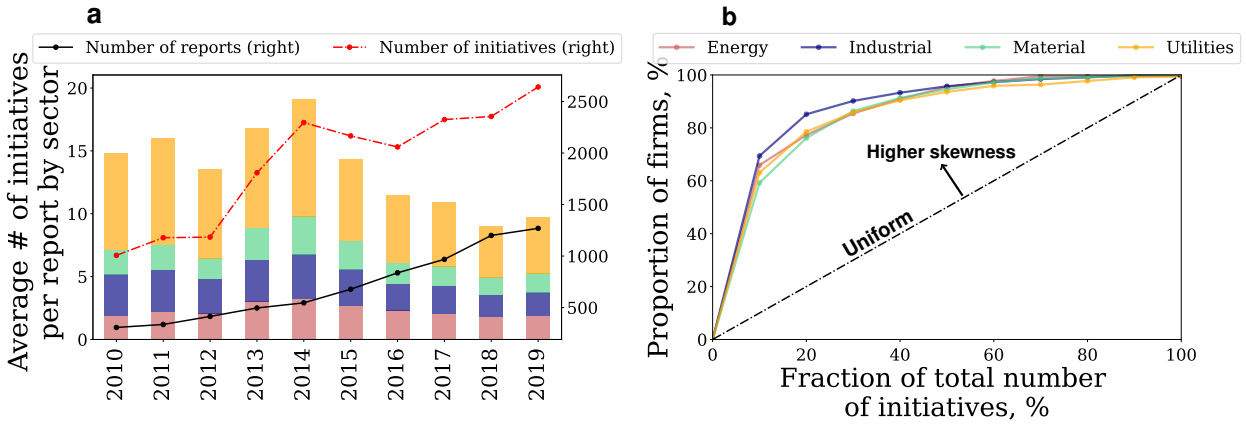
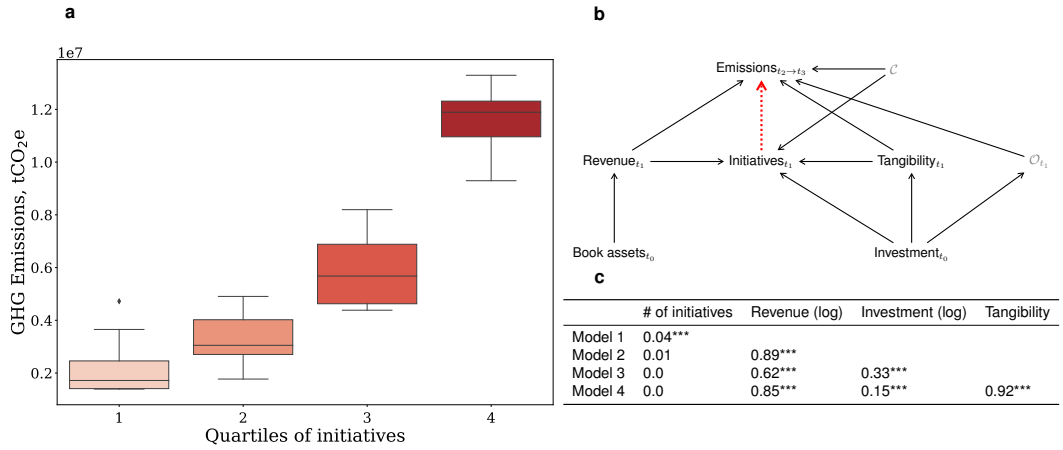


Fig. 2 | Sustainability initiatives in the high-emissions sectors. Panel **a** show the average number of initiatives per report (bar plot, left axis and colour legend on top of panel), the total number of report (black line, right axis) and the total number of initiatives (red line, right axis). Panel **b** shows the skewness of the distribution of the initiatives compared to a uniform distribution (black diagonal line). Overall, the figure shows a significant heterogeneity in the sustainability behaviour of firms in our sample both longitudinally and cross-sectionally.



c

	# of initiatives	Revenue (log)	Investment (log)	Tangibility
Model 1	0.04***			
Model 2	0.01	0.89***		
Model 3	0.0	0.62***	0.33***	
Model 4	0.0	0.85***	0.15***	0.92***

Fig. 3 | Total emissions do not depend on the number of initiatives. Panel **a** shows the relation between the number of sustainability initiatives a firm undertake (x-axis, in quartiles) and the emission in the two years ahead (y-axis). Panel **b** shows our hypothesis concerning the relationship between number of initiatives and total emissions. The nodes in the graph represent variables and arrows represent direct effects. The gray nodes, C and O, represent unobserved confounders. The red arrow shows the effect we want to estimate. See Methods for a detail presentation of the model. Panel **c** shows the coefficient from the evaluation of the model shown in panel **b**. Each row in the table shows the coefficient estimated including the factors shows in panel **b**. For example, the first model (first row) shows the unconditional association of the number of initiatives and future emissions. The last model (last row) shows the coefficient estimated after controlling for all factors. *, **, *** denote statistical significance at 10%,5%, and 1%, respectively. Overall, the figure shows that the positive relation between number of initiatives and emission is likely due to a size effect. After accounting for Size we found no relationship between the two quantities.

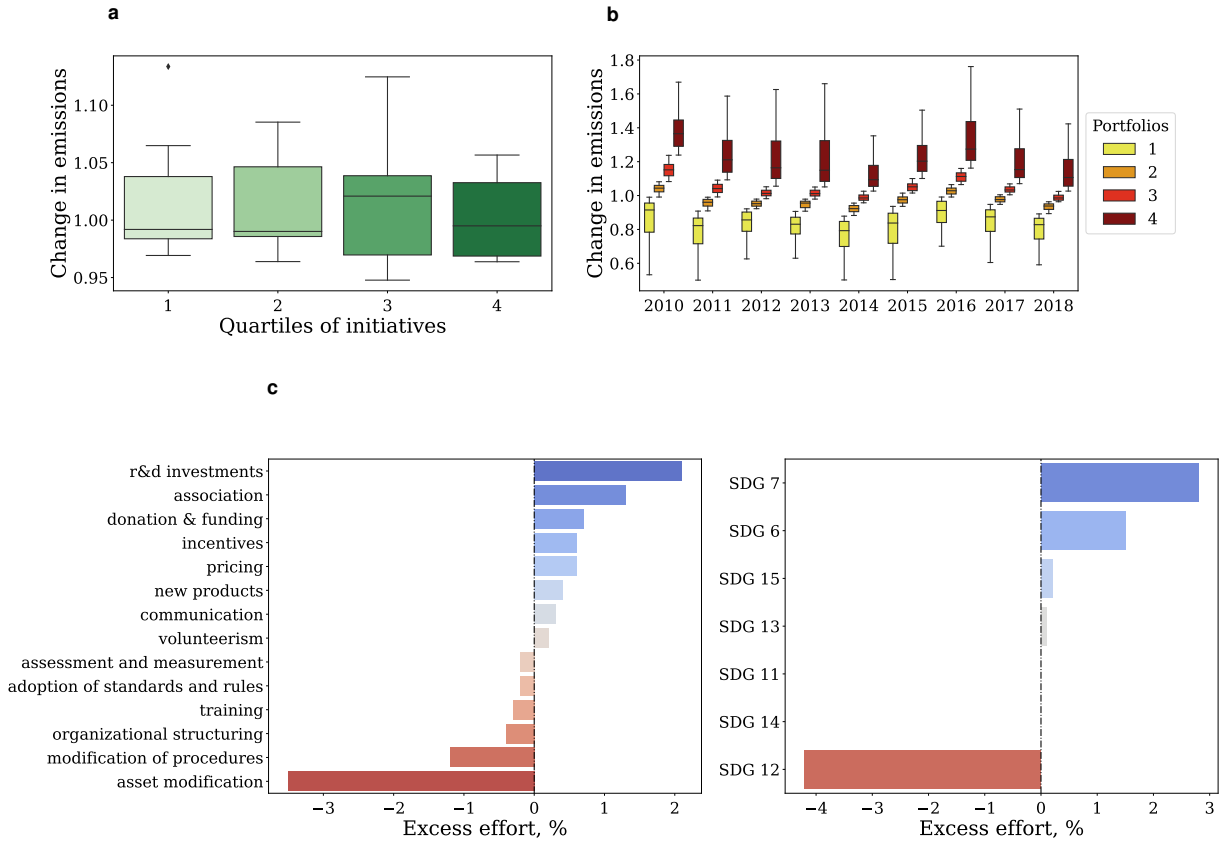


Fig. 4 | Effective sustainability behaviours in high-emissions sectors. Panel **a** shows that the average year-to-year change in emissions is independent on the number of initiatives. Panel **b** shows the evolution of the emissions quartile portfolios. Panel **c** shows the excess sustainability effort of firms in the bottom quartile portfolios versus those in the top quartile portfolios. Excess effort is defined as difference in relative incidence of an activity or SDG in the two portfolios. Overall the figure suggests that firms effective in lower their emissions focus on behaviours that prioritise research & development and associations to realise SDG 7. Figure S11 shows that the results are statistically significant.

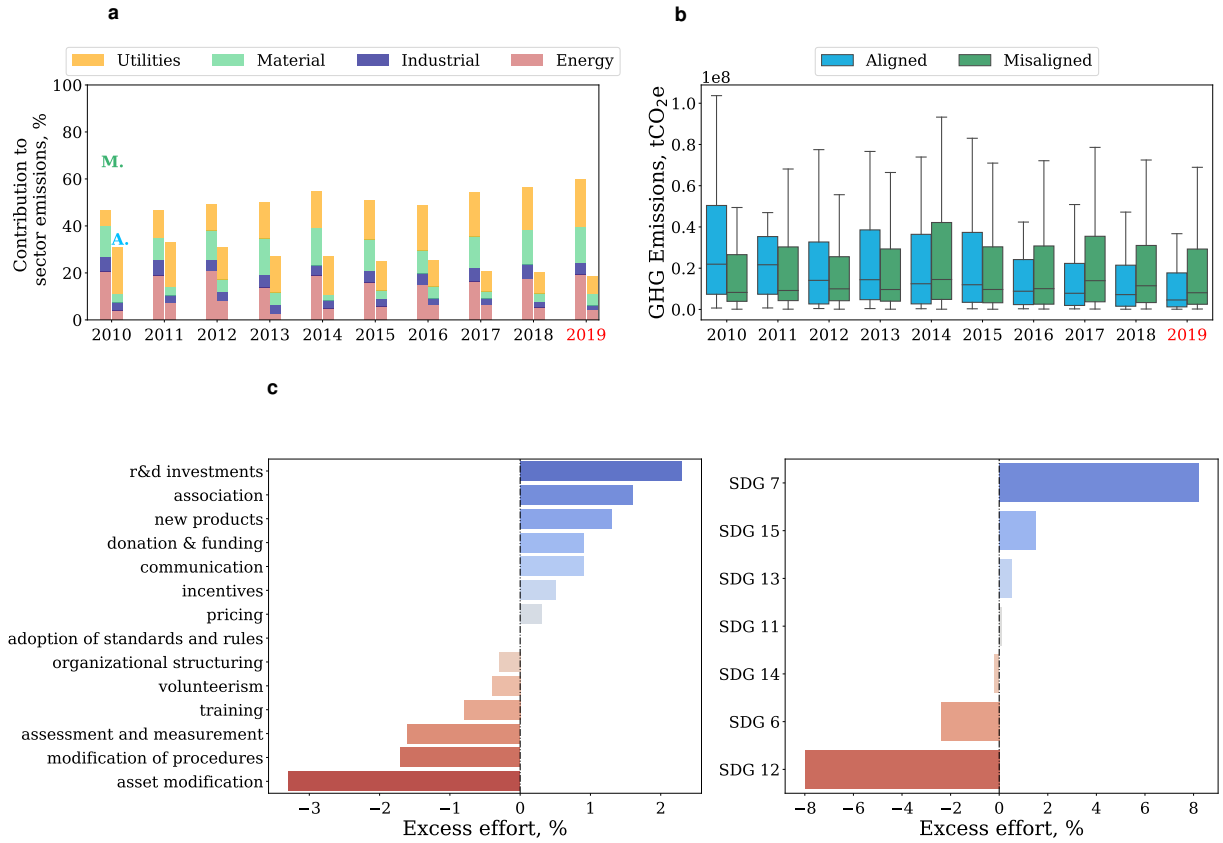


Fig. 5 | The sustainability behaviour of firms aligned with climate targets. Panel **a** shows the contribution to the sector emissions of the firms analysed in this section. Panel **b** shows that firms aligned with the target of limiting global warming below 2°C as of 2019 have, on average, managed to reduce their emissions. The effect is more evident starting from 2015. Panel **c** shows the excess sustainability effort of firms aligned with the target. Excess effort is defined as difference in relative incidence of an activity or SDG in the two portfolios. Overall, similarly to figure 4, the figure shows that firms with emissions pathways aligned with climate goals focus on behaviours that priorities activities that create growth opportunities to realise SDG 7. Figure S14 shows that results are statistically significant.

Supplementary Information: Business sustainability behaviour and alignment with climate targets

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A Details of the machine learning system for initiative detection

The company reports are analysed using automated systems which process the text and extract information about the initiatives described in each report. The system works in three stages: preprocessing, initiative detection and initiative classification. Below we provide a description of the system. Further details can be found in Ref[24]

A.1 Preprocessing

The company reports are in pdf format and the first step is to convert them to plain text. This is done using the Unix *pdftotext* tool.[¶] The text is then broken into individual sentences using the spaCy[**] toolkit and saved as a json file for further processing. Various metadata about the pdf, such as the creation time and an *md5* fingerprint, are also retained.

A.2 Initiative detection

Next, the reports are processed in order to detect the sustainability initiatives they describe. We trained supervised machine learning models to classify individual sentences as either belonging to an initiative description or not. We use two neural transformer models for initiative detection, then combine their output probabilities in order to create an ensemble prediction with increased reliability. The models are trained on manually annotated company reports, with 507 reports in the training set and 81 reports in the development set.

The first model is based on *BERT-base*[25] and takes three sentences as input when making a prediction: the target sentence, the preceding sentence and the following sentence. This contextual information allows the model to better understand the meaning of the target sentence and make more accurate decisions. The second model is based on *RoBERTa-base*[26] and takes two sentences as input: the target sentence and the preceding sentence. As the RoBERTa model is larger by itself, we found it was sufficient to only give it one sentence of context as input.

Both models were trained for 5 epochs on the annotated training data, using batch size 32 and learning rate $1e-05$. Early stopping of the training process was performed based on the sentence-level $F_{0.5}$ metric on the development set. The models were implemented using PyTorch[27] and Hugging Face[28].

We apply length filters, classifying any sentences shorter than 10 tokens or longer than 100 tokens as non-initiative. Most of such sentences are either numerical values extracted from tables or difficult cases for sentence separation. We found that only a small fraction of real initiatives have sentences

[¶]https://linuxappfinder.com/package/poppler-utils

[**]https://spacy.io/

with such extreme lengths, therefore the filtering is able to decrease processing time for the models with minimal decreases in accuracy. All the other sentences are passed through both machine learning models, the two predictions are averaged and any sentence with a score higher than 0.66 is classified as belonging to an initiative. This threshold was chosen based on evaluation on the development set. Any consecutive sentences that have been classified as belonging to an initiative are then combined into the same multi-sentence intiative.

A.3 Initiative classification

The output of the previous step provides spans of sentences that refer to initiatives described in a particular report. As the next step, we classify the initiatives based on three attrubutes: the SDG corresponding to that initiative, the type of the initiative and the stakeholder of the initiative.

For detecting each of these attributes we trained separate multi-class class classifiers based on *RoBERTa-base*. These models were given three sentences of input: the target, the preceding and the following sentence. Training was performed in batches of 32 for 20 epochs using learning rate $1e-05$. Early stopping was performed based on the multi-class accuracy metric on the development set. The models predict a probability distribution showing the likelihood of each sentence belonging to a particular class. For multi-sentence initiatives, these distributions were averaged in order to produce a single probability distribution for the whole initiative. The classes with the highest average scores were then chosen as the final predictions for the SDG, initiative type and stakeholder of each initiative.

A.4 Performance on a test set

There are two important statistics to assess the performance of the algorithm in the test set: (1) the capacity to identify an initiative (recall), and (2) the quality of the classification (precision). In the validation set we found a recall of $\sim 40\%$, i.e. that is we identify $\sim 40\%$ of the initiatives in the reports. The value is set so to maximise precision, which is $\sim 96\%$, i.e. 96% of the time we identify an initiative we were correct to classify the sentence as such. To assess the recall on the test set we manually read 20 reports and we calculate the ratio of initiatives identified manually and by the algorithm. We have found that the algorithm has a recall of approximatively 24% in the test set. However, the recall is consistent across reports since the training set was chosen as to reduce sector biases. Therefore, while the recall is low it is the same across firms. Some firm-specific bias is possible due to the format of the pdfs. To evaluate the capacity of the algorithm to classify initiatives into activities and SDGs we perform a manual check on a random sample of reports on the test set. Specifically we randomly sample 300 initiatives and we assess the precision in the classification of the SDG, the activity and the joint activity/SDG precision. The results are shown in the table below. For illustrative purposes, in section C we report a sample of initiatives alongside their classification into activities and SDGs. Before showing the examples, in the next section, we present the definition of activities used in the analysis.

	Activity	SDG	Joint
Precision	89.2%	88.1%	77.6%

A.5 Limitations of our approach

As discussed in the Discussion, there are a number of limitations to our analysis. Three of these limitations are important to discuss in further depth. One issue concerns the definition of sustainability initiative. In our analysis, an initiative is a specific action or project that an organisation has launched and it is actually working on. Importantly, we do not include projects not yet started or intentions. There is a degree of subjectivity to this definition which is then coded into the training set that we use to train the neural network. When study the population at large this bias should be consistent across all firms, therefore firm-to-firm comparison should not be affected by it. However, this is an important limitation to bear in mind when focusing on the analysis of a single entity.

Another important limitation is that, at this stage, we do not differentiate between initiatives that require different level of managerial effort or funding. In our analysis, a low-cost and superficial initiative matters as much as a costly and complex project. Differentiating among initiatives would introduce an additional level of subjectivity. This problem could be alleviated by using data on spending in sustainability-related projects. Unfortunately, this data are rarely available. However, our dataset comprises also the text of the raw initiatives therefore further research can address this important issue.

Finally, sustainability reports are self-reported documents. While a significant proportion of these reports ($\sim 75\%$) are assured by external audit firms, they unlikely include information that that would be damaging for a corporation (e.g., ongoing lawsuits). Therefore our dataset is biased by a self-selection of reported initiatives. Further work is needed to integrate non-sustainable initiatives into our dataset by for example analysing news media and legal database

B Definition of sustainability activitys

Here we provide the definition of the sustainability activities used in the main text.

- **Communications**: Activities that bring specific information or knowledge from the firm to a certain interlocutor, to generate awareness, engage stakeholders, communicate policies, meetings and conferences, marketing campaigns and information about products, even through web communication.
- **Association**: Activities through which companies join, collaborate or promote cooperation with other firms, organisations, institutions or communities, including multilateral agreements and collaboration initiatives.
- **Donations & Funding**: Philanthropic activities through which companies donate money, goods or services as gifts. Includes supporting or sponsoring external sustainability-related organisations, initiatives or programs. In addition, it includes employee benefits, such as healthcare plans. (The donation comes from the corporate itself, not from its stakeholders.)
- **Volunteerism**: Activities that stimulate and promote volunteerism, fundraising and personal donations from individuals within or outside the firm (i.e. employees, costumers, community volunteerism). Notably, employees donations of goods are encapsulated within Donation, unless the initiative's description specifies otherwise.
- **Adoption of Standards & Rules**: Activities involving the underwriting, adoption or compliance with externally sourced policies, guidelines, procedures, or standards.

- **Modification of Procedures**: Activities that modify the procedures adopted by the firm in order to perform a specific activity (e.g. HR selection processes and supply chain activities).
- **Assessment and measurement**: Activities with which the firm collect information from inside or outside. Including retrieval, research, survey, data collection, studies and measurement.
- **Organisational Structuring**: Activities that involve a structural change in the organisational structure of the firm. Including the modification or establishment of new divisions, functions, roles (e.g. management positions), committees, teams or bodies.
- **Training**: Teaching activities aimed at improving knowledge, skills, and competencies.
- **Pricing**: Marketplace activities by which the firm sets up or modifies pricing structures and tariffs.
- **Incentives**: Activities that typically involve the development of benefits, privileges, or rewards toward a particular stakeholder in order to gratify or stimulate an action. They might conversely take the form of active disincentives and punishments in order to discourage a detrimental action.
- **R&D Investments**: Activities that encompass an investment aimed at introducing a technological novelty in a product, service or process. They include structural investments in prototyping, trial and researching.
- **New product**: Launch of a new product or service (made available to the market). It includes new product's technical specification, the inclusion of new components or features into an existing product or service, as well as packaging.
- **Assets Modification**: Activities that build, expand or modify the physical assets owned and used by the Company to run their activities. This may include production assets, commercial assets and distribution assets (e.g. machines, devices, vehicles, buildings or facilities).

C Examples of sustainability initiatives

Here we provide a few examples of extracts from the texts of the sustainability initiatives. Importantly, we only show an extract of the text. The classification to the particular SDG take into consideration a broader context.

Activity	SDG	Text
assessment & measurements	6	Our Tommy Hilfiger business conducted a pilot project to explore different finishing techniques for its denim products , helping suppliers to adopt practices that significantly reduce water and energy consumption and require less chemical use per garment
r&d investments	7	In this experiment , hydrogen is produced by the electrolysis of water with clean electricity generated from photovoltaic cells , which is then used to run three 5kW pure hydrogen fuel cell batteries ..The aim of this experiment is to verify reliability and efficient operational control under variable power demands ..Through this demonstration experiment , we aim to improve the pure hydrogen fuel cell functions , contributing to the creation of a society where people can live safely with clean energy.
association	11	Additionally , ENDESA carries out various projects with third sector entities to provide training on efficiency and optimising the electricity bill , also reinforcing security measures and risk prevention for vulnerable families .
new products	12	Norfolk Southern is helping communities enhance air quality with Eco locomotives , a new class of low - emission yard locomotives .Branded " Eco " for their operating efficiencies in reducing emissions and fuel use , the locomotives were funded in part by federal Congestion Mitigation and Air Quality Improvement Program grants .
r&d investments	13	NEGEM Project : Quantifying and Deploying Responsible Negative Emissions in Climate Resilient Pathways , a European Horizon 2020 Programme , to assess the realistic potential of Negative Emission Technologies and Practices (NETPs) and their contribution to climate neutrality , as a supplementary strategy to emissions mitigation.
asset modification	14	Hydroelectric power stations generate environment-friendly electricity , but can prevent migratory fish swimming upstream. When building new weirs such as that at Albbruck-Dogern on the Upper Rhine in Germany or modernising such river power plant,RWE always installs fish ladders to ensure that the rivers remain passable for indigenous fish populations ..Two more hydroelectric power stations were retrofitted with such ladders in 2010.
association	15	Our collaboration is supporting their Reduced - Impact Logging for Carbon (RIL - C) initiative in Gabon and Indonesia , where they are developing a set of scientific practices that balance the economic needs of forest - based communities with environmental goals .

Activity	SDG	Text
Asset modification	12	Since 2016 , we have replaced more than 14% of our fleet with more environmentally efficient vehicles , liquidating almost 1,000 vehicles and purchasing nearly 550 new vehicles .
Asset modification	7	This year , by using biogas as an emission - friendly renewable energy source , we have optimized the biogas plant to produce 1,5 megawatts of electricity .
Asset modification	7	In addition , at the commercial facility Tokyu Plaza Omotesando Harajuku , two wind turbines have been installed on the rooftop to foster the use of natural energy .
Asset modification	12	Reductions have been achieved by the use of more fuelefficient vehicles through the introduction of hybrid gasoline - electric cars , increased use of diesel engines fitted with particle filters , and other emission reduction options such as liquid natural gas or bio - fuels .
Asset modification	7	On the one hand , The Group completed the upgrading of energy - saving heating pipes technology , LED lighting , solar power water heater and insulation materials to eliminate and replace equipment of high consumption and low energy efficiency by applying new energy - saving technologies and devices on production equipment and public facilities .
Modification of procedures	12	Arcadis stimulates employees to use skype for internal meetings , which reduced the inter office transport .
Modification of procedures	7	The Group introduced the Green Touch Program to promote low - carbon practices that minimize carbon dioxide emissions by reducing power consumption when computers are not in use .
Modification of procedures	12	In fiscal 2014 this system produced an amount of recycled paper equivalent to 496 trees , and in calendar 2014 contributed to a reduction in greenhouse gas emissions of approximately 52.2 metric tons .
Modification of procedures	7	In fiscal year 2015 , DIC once again promoted efforts in line with Japan 's Cool Biz and Warm Biz campaigns , official efforts to reduce electric power consumption by limiting the use of air conditioning in summer and winter through measures such as the introduction of more relaxed office dress codes .

Table ST1: **Example of common initiatives** The table shows a few examples of the most common initiatives in our sample. Activity classified into SDG 7 and 12 are similar in scope. However, the algorithm seem to assign SDG 7 to activities that are more closely related to renewable energy and SDG 12 to activities that are more closely related to efficient use of resources.

Below we provide examples of initiatives excluded from our analysis because they are not directly related to GHG emissions

Activity	SDG	Text
modification of procedures	6	In 2017 , in addition to daily activities such as raising employees' awareness of saving water and conducting patrols to check water leakage , efforts were made to raise the ratio of utilization of recycled water at the sites where the wastewater recycling system has been introduced .
asset modification	7	Much of that build – including vastly improved wireless coverage in the Sea to Sky corridor between Vancouver and Whistler – will provide benefits to British Columbians for generations to come ..For instance , for the first time in Western Canada , Bell installed a solar - powered cell site as part of its Olympic - grade wireless network ..This site will continue to provide cellular service to thousands of residents in Porteau Cove , a growing community north of Vancouver ..For each of the 42 new cell sites we built , we consulted with local governments and First Nations groups , conducting environmental impact studies that included frog mating and migratory bird studies , as well as locating First Nations burial grounds ..One of the advantages of an IP network is that it does n't need as much cabling and other infrastructure as older technologies do ..As a result , we reduced the amount of materiel we used
communications	11	To foster a positive corporate image and increase exchanges with local communities , the company has promoted plant tours , and the number of people annually participating in such tours has surpassed 30,000 ..In addition , the company organized cleanup campaigns with respect to sidewalks and roads near its production plant
new products	12	CorrChoice also developed an EE - flute corrugated sheet strong enough to replace the non - recyclable polystyrene core in foam board display sheets .
association	13	Kellogg partnered with the World Business Council for Sustainable Development , Kukua , and our supplier , Olam , to provide needed climate information by piloting the installation of weather stations that provide more accurate forecasts via SMS messages to 500 cocoa smallholder farmers .
r&d investments	14	In 2014 we supported a stakeholder engagement and research initiative involving commercial fishers , government regulators , research organizations and other operators as part of our Caldita - Barossa field development .In addition to building strong stakeholder relationships , the group aims to contribute to the broader scientific understanding of fish distributions and stock structures which will assist long - term sustainable fisheries management as well as help our ongoing efforts to understand and mitigate the risks of our activities .
donation & funding	15	In North Carolina , we 're protecting more than 3600 acres of pine and hardwood forest in Brunswick County , along the southern coast of North Carolina .

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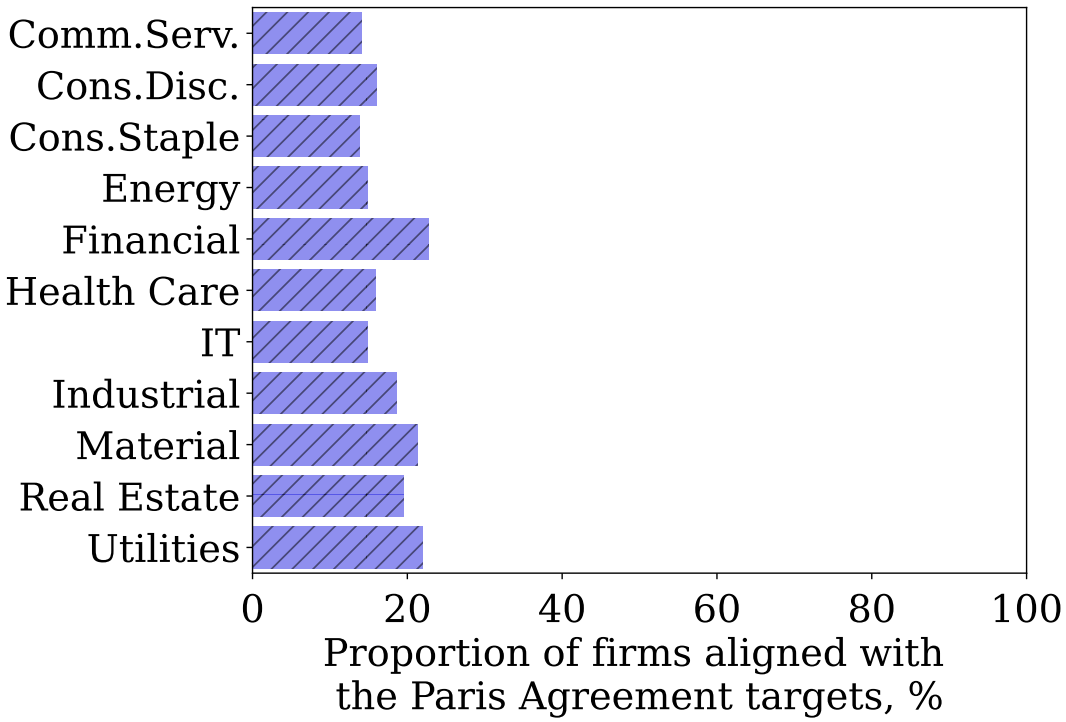


Fig. S1 | Alignment with Paris agreement targets. The figure shows the fraction of firms in the TruCost database, by sectors, with emissions pathways aligned with the target set by the Paris agreement of limit temperature increase well below 2°C. Data are from TruCost which estimates emissions pathways using the SDA (GEVA) approach, for high (low)-emitting companies with homogeneous (heterogeneous) business activities.

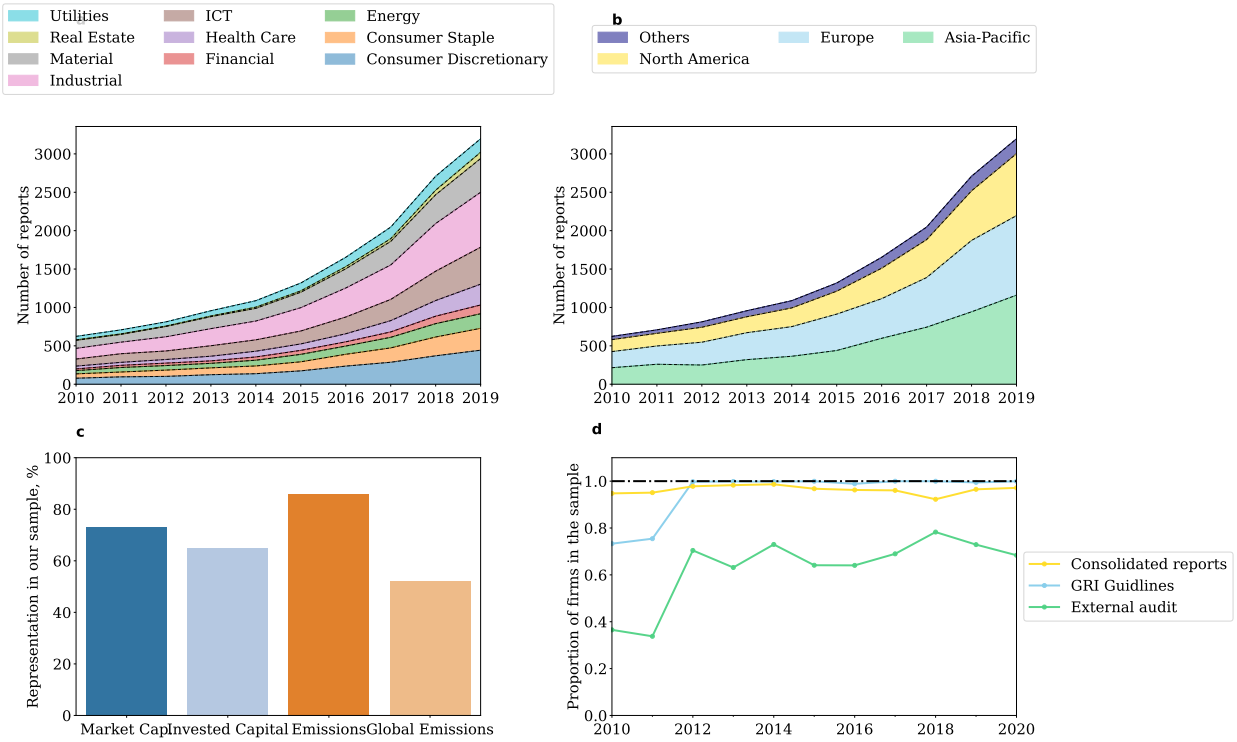


Fig. S2 | Overview of of our sample. Panel **a** shows the total number of reports per year and sector in our sample. Panel **b** shows the total number of reports by macro region. Panel **c** shows that firms in our sample cover $\sim 75\%$ of global market capitalisation; $\sim 60\%$ of total invested capital; $\sim 90\%$ of the direct control and first tier emissions covered by TruCost, and $\sim 50\%$ of global emissions (both business and non-business emissions). Panel **d** shows some characteristics of the reports.

rfyear	Size	Invested capital	Tangibility	Emissions (tCO_2e)	Emissions (cumulative)	# of firms	# of countries
2010	8.96	26669	0.31	8324363	5.427484e+09	621	38
2011	8.86	24619	0.32	8265768	1.160201e+10	706	39
2012	8.78	25301	0.31	8238692	1.860490e+10	811	39
2013	8.64	23547	0.31	8035970	2.663283e+10	955	39
2014	8.48	23794	0.30	7235494	3.488130e+10	1085	43
2015	8.25	20034	0.30	6599500	4.410740e+10	1316	44
2016	8.04	17811	0.30	5889574	5.443771e+10	1653	43
2017	7.94	17942	0.30	5831351	6.692263e+10	2044	46
2018	7.74	15674	0.28	5076982	8.140727e+10	2708	48
2019	7.52	14270	0.30	4411197	9.652002e+10	3198	46

Table ST2: **Summary statistics of the population**. The table shows the summary statistics of the firms in our sample. The first four columns are average values across the sample. The decrease in the average emissions is due to the inclusion of a large number of smaller firms in the TruCost database on a year-to-year basis. Indeed, average size and invested capital have also declined

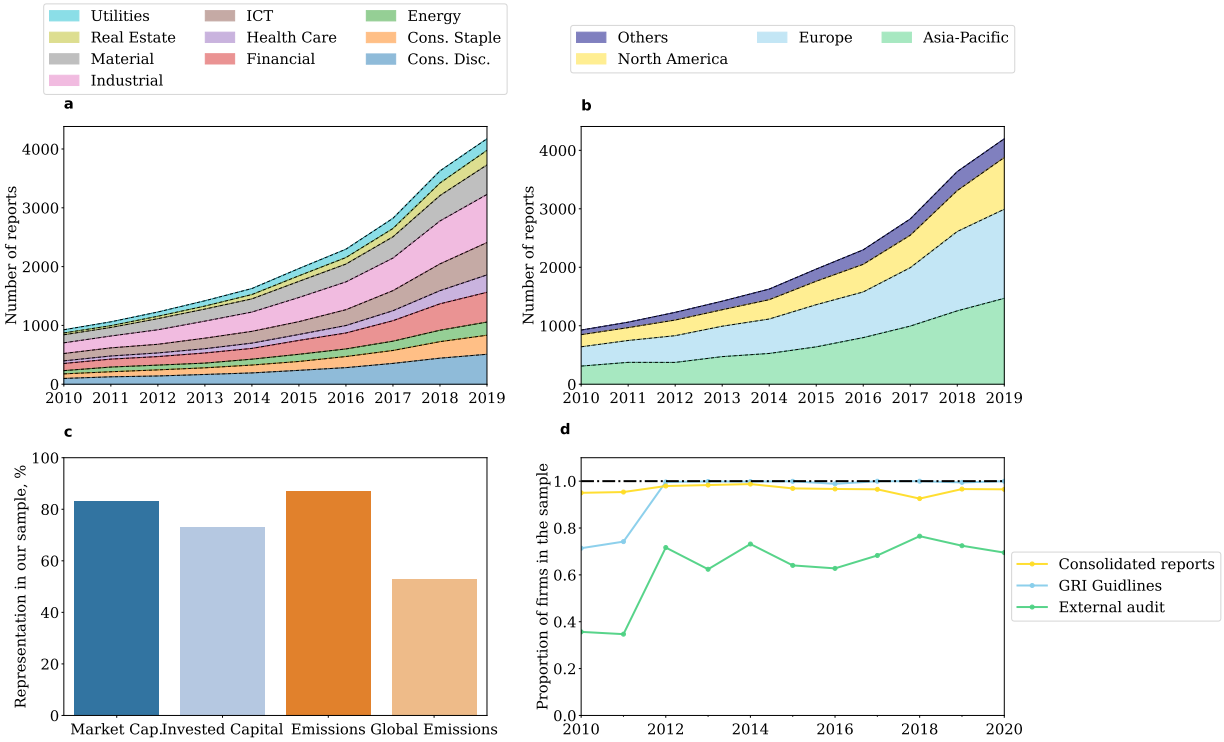


Fig. S3 | Overview of the full population. Panel **a** shows the total number of reports per year and sector. Panel **b** shows the total number of reports by macro region. Note, the total number of firms analysed in the main text is lower than the total number firms in our behavioural dataset as not all firms have the emission and accounting information used in the analysis. Panel **c** shows that firms in the full population cover $\sim 80\%$ of global market capitalisation; $\sim 70\%$ of total invested capital; $\sim 80\%$ of the direct control and first tier emissions covered by TruCost, and $\sim 50\%$ of global emissions (both business and non-business emissions). Panel **d** shows some characteristics of the reports.

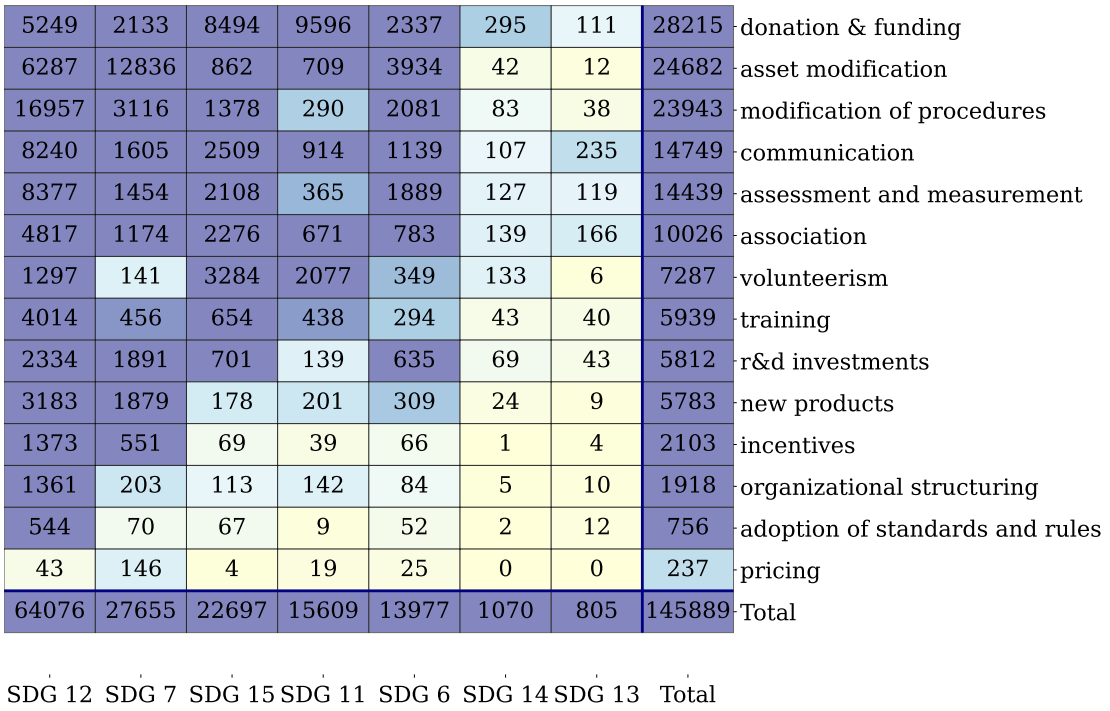


Fig. S4 | Behavioural matrix. The figure shows the full behavioural matrix of the firms in our population.

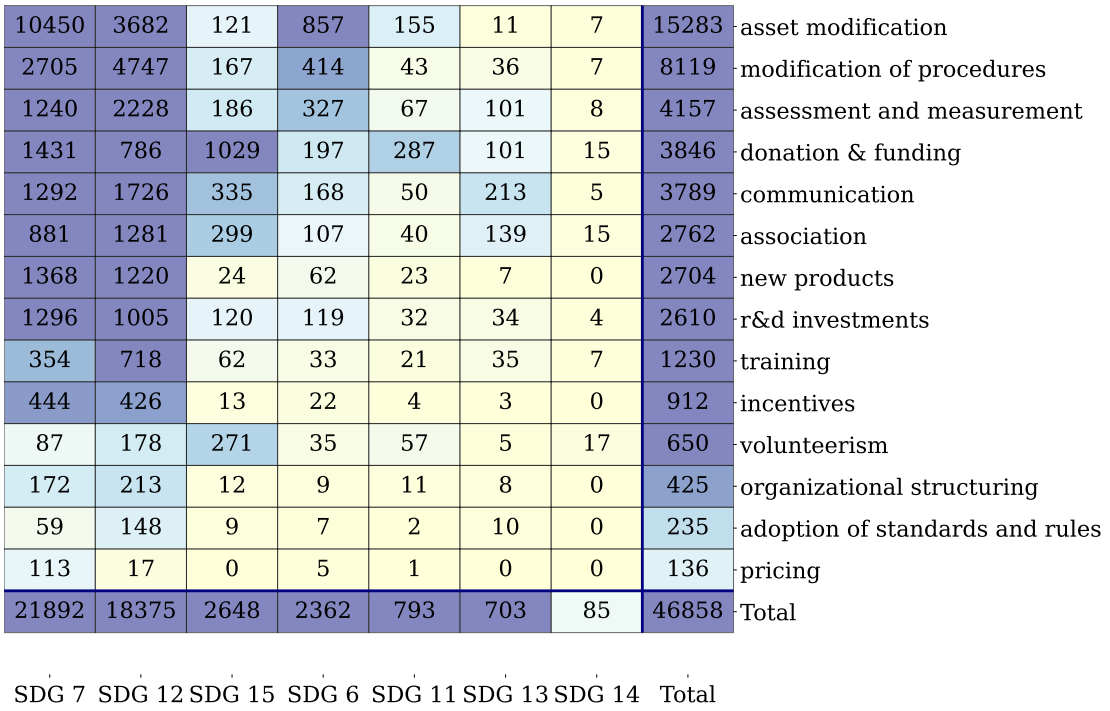


Fig. S5 | GHG initiatives in the behavioural matrix. The figure shows the full behavioural matrix of the firms in our population. Differently from figure S4, here we show only the initiatives that refer directly to an activity that is intended to reduce GHG emissions. Initiatives related to other environmental issues have been excluded from this analysis

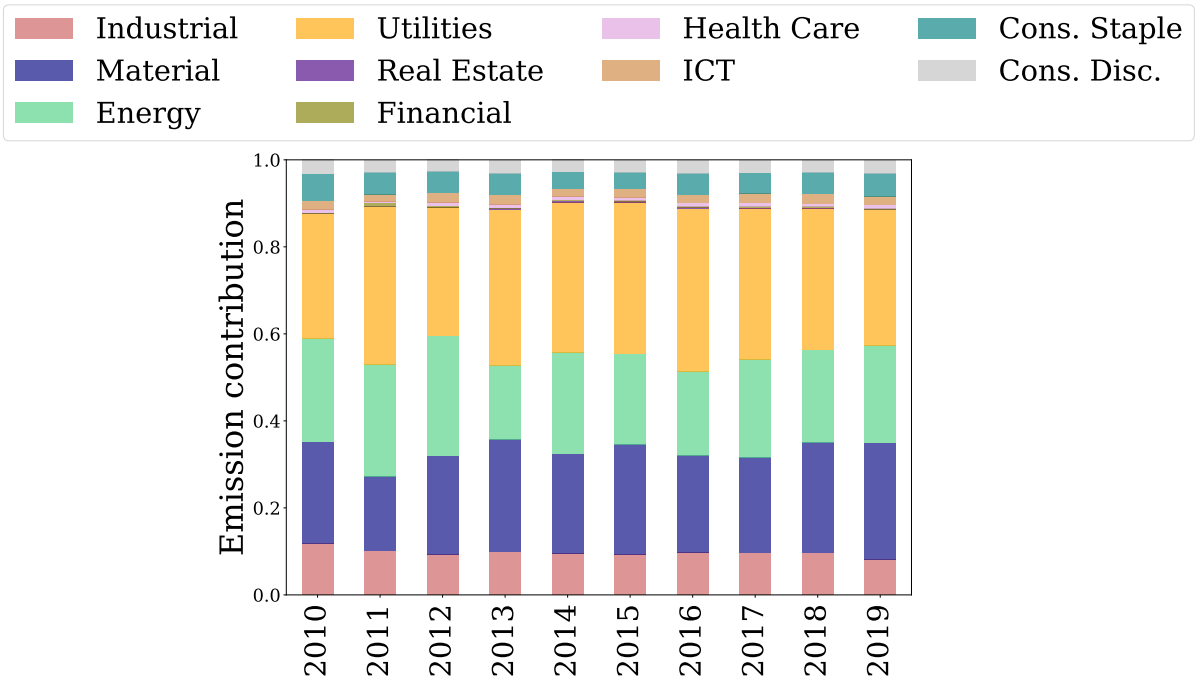


Fig. S6 | Contribution to total emissions by sectors. The figure shows that the Material, Industrial, Utilities and Energy sectors account for $\sim 90\%$ of the emissions in our sample

SDG 7	SDG 12	SDG 15	SDG 6	SDG 11	SDG 13	SDG 14	Total	
3664	1886	69	354	88	3	6	6070	asset modification
834	1448	79	183	23	14	2	2583	modification of procedures
822	266	456	83	151	34	10	1822	donation & funding
431	894	94	109	36	42	5	1611	assessment and measurement
781	610	72	78	22	13	3	1579	r&d investments
673	570	126	73	22	66	1	1531	communication
648	475	11	30	11	1	0	1176	new products
399	498	122	47	24	55	7	1152	association
182	264	29	16	14	20	5	530	training
260	126	6	12	1	2	0	407	incentives
47	58	95	12	27	0	2	241	volunteerism
45	74	6	3	6	3	0	137	organizational structuring
93	3	0	5	1	0	0	102	pricing
17	50	4	4	0	3	0	78	adoption of standards and rules
8896	7222	1169	1009	426	256	41	19019	Total

Fig. S7 | Behavioural matrix in the Material, Industrial, Utilities and Energy sectors. The figure shows the full behavioural matrix of the firms in the sectors (including only GHG related initiatives).

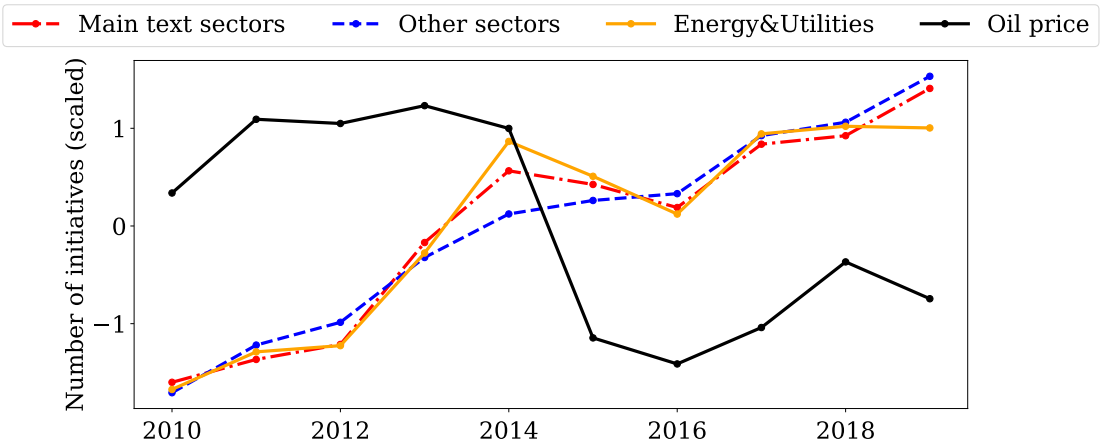


Fig. S8 | Number of initiatives and oil price. The figure shows the total number of initiatives (scaled to zero mean and unitary variance) in the four most polluting sectors (red), the other sectors (blue), and Energy and Utilities (orange). The black line shows the oil price during the observation period (scaled). Overall, the figure shows that the drop in number of initiatives in 2014-2016 is only observed in the sectors analysed in the main text and coincided with a drastic drop in oil prices.

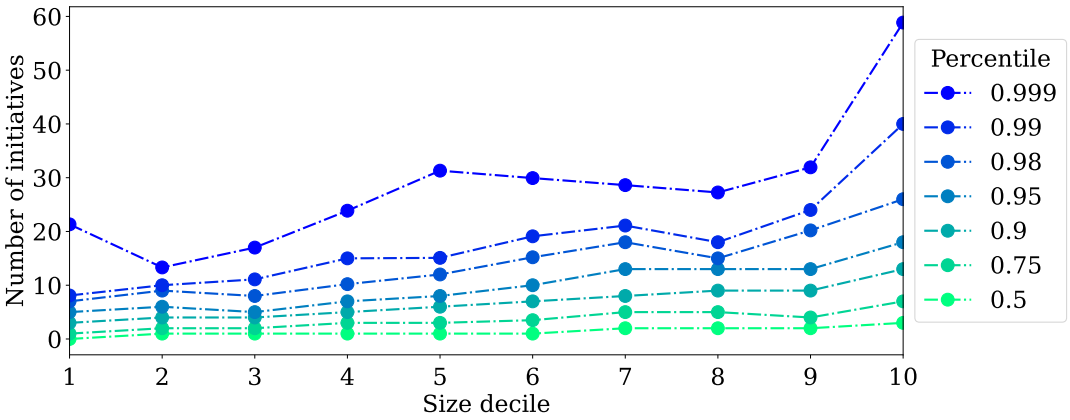
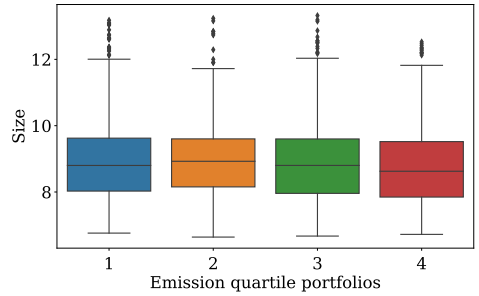


Fig. S9 | Number of initiatives and firm size. The x-axis is the size decile. The y-axis is the number of initiatives in the percentile coded by the colour map. The figure shows that there is a significant heterogeneity in the number of initiatives that different corporations undertake, and that this heterogeneity is more evident for larger firms.

a



b

Pair	Emission intensity	# of initiatives
Quartile 1 - 2	0.25	0.14
Quartile 1 - 3	0.36	0.06
Quartile 1 - 4	0.33	0.04
Quartile 2 - 3	0.21	0.75
Quartile 2 - 4	0.22	0.61
Quartile 3 - 4	0.98	0.88

c

Behavioral differences

SDG 7	SDG 6	SDG 15	SDG 13	SDG 11	SDG 14	SDG 12	Total	
1.5	0.3	-0.1	0	0.1	0	0.3	2.1	r&d investments
1.2	0.1	0	0.4	0	-0.1	-0.3	1.3	association
0.7	0.4	-0.4	0.1	0	0	-0.1	0.7	donation & funding
0.7	0	0	0	0	0	-0.1	0.6	incentives
0.5	0.1	0	0	0	0	0	0.6	pricing
-0.4	-0.1	0	0	0.1	0	0.8	0.4	new products
1.3	0.1	0.4	-0.1	0.1	0	-1.5	0.3	communication
0	0.1	0	0	0	0	0.1	0.2	volunteerism
0.3	0.2	-0.1	-0.1	0.1	0	-0.6	-0.2	assessment and measurement
0	0	0	0	0	0	-0.2	-0.2	adoption of standards and rules
0.1	0.1	0	0	-0.1	0	-0.4	-0.3	training
0	0.1	0	-0.1	-0.1	0	-0.3	-0.4	organizational structuring
0.1	-0.1	0.2	-0.1	-0.1	0	-1.2	-1.2	modification of procedures
-3.2	0.2	0.2	0	-0.1	0.1	-0.7	-3.5	asset modification
2.8	1.5	0.2	0.1	0	0	-4.2	0	Total

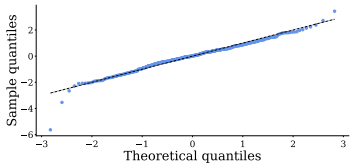
Fig. S10 | Emissions portfolios . Panel **a** shows that firms in the quartile portfolios have approximatively the same size. Panel **b** shows a series of pair t-test: the first column shows that the average emission intensity is independent on the number of initiatives; the second columns shows that the number of initiatives are approximatively the same across the quartile portfolios. Panel **c** shows the full difference-behavioural matrix. The matrix is the difference of two matrices that both sum up to 100%. Therefore, the bottom right cell is zero. Overall, the figure shows that observations in the different portfolios are comparable (top panels) and that there is a large degree of heterogeneity in the behaviour in the bottom and top quartile portfolios (bottom panel)

Positive Excess effort

	# of initiatives	Revenue (log)	Investment (log)	Tangibility
Model 1	0.03			
Model 2	-0.04*	1.01***		
Model 3	-0.04**	0.74***	0.31***	
Model 4	-0.04**	0.79***	0.28***	0.85***

Negative Excess effort

	# of initiatives	Revenue (log)	Investment (log)	Tangibility
Model 1	0.11**			
Model 2	0.12***	1.02***		
Model 3	0.11***	0.74***	0.35***	
Model 4	0.03	0.81***	0.29***	1.12***



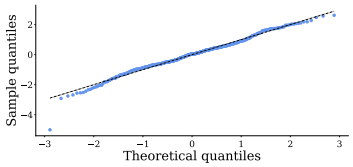


Fig. S11 | Sustainability behaviour and future emissions. The figure shows that initiatives over represented in the bottom quartile portfolios are associated with lower emissions (negative and statistically significant coefficient in the left table). On the other hand, under-represented initiatives in the bottom quartile portfolio are associated with higher emissions, but the coefficient is not statistically significant.

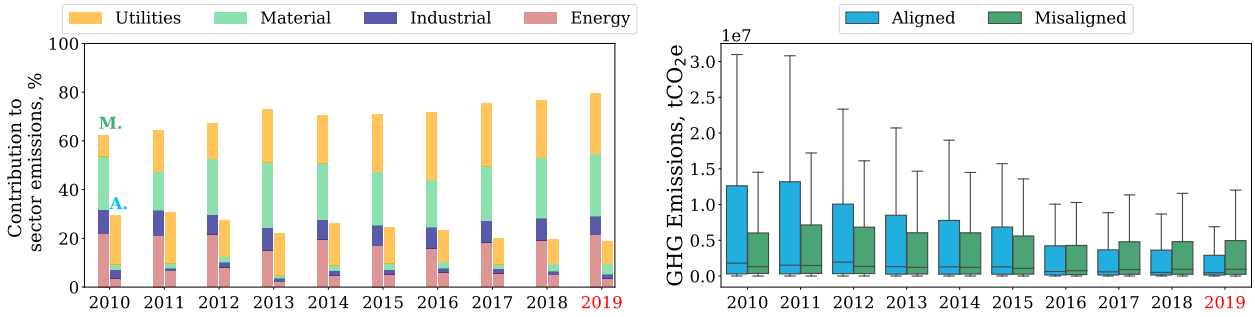


Fig. S12 | Emissions in the full sample (Climate targets). The figure shows the emissions contribution of the largest firms including also those excluded from our sample because of data availability.

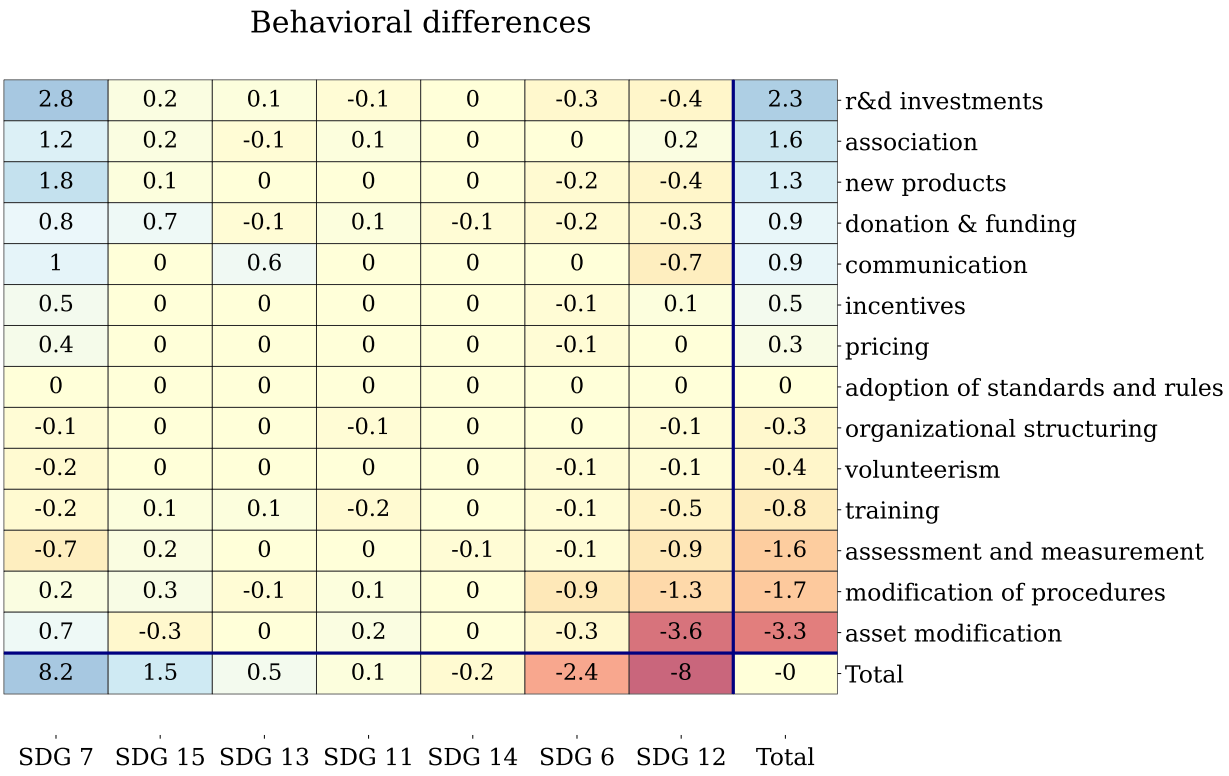


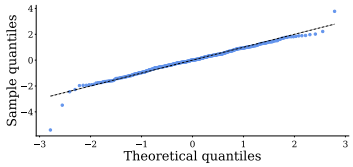
Fig. S13 | Difference behavioural matrix in the climate targets analysis. The figure shows the difference behavioural matrix in the aligned firms and misaligned firms.

Positive Excess effort

	# of initiatives	Revenue (log)	Investment (log)	Tangibility
Model 1	0.02			
Model 2	-0.05**	1.02***		
Model 3	-0.06**	0.77***	0.29***	
Model 4	-0.06**	0.86***	0.22**	0.82***

Negative Excess effort

	# of initiatives	Revenue (log)	Investment (log)	Tangibility
Model 1	0.1**			
Model 2	0.07*	1.02***		
Model 3	0.07*	0.68***	0.42***	
Model 4	0.01	0.8***	0.31***	1.12***



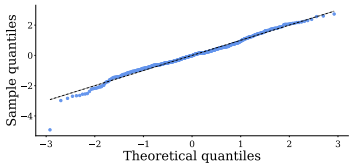


Fig. S14 | Sustainability behaviours and future emissions (climate target) . The figure shows that initiatives over represented in the firms aligned with the 2°C target are associated with lower emissions (negative and statistically significant coefficient in the left table). On the other hand, under-represented initiatives in the firms aligned with the target are uncorrelated with future emissions.

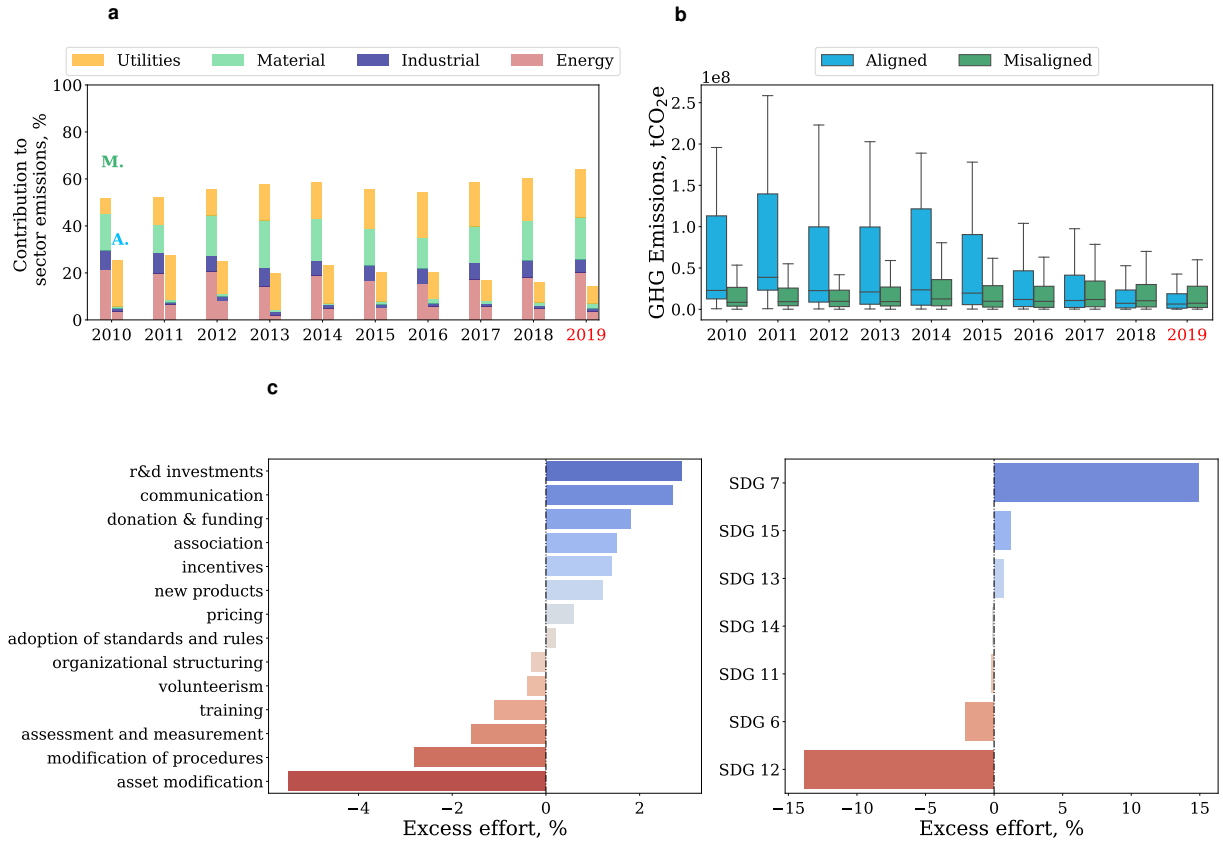


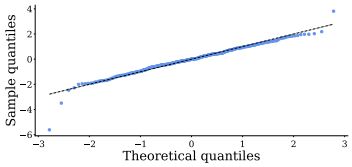
Fig. S15 | The sustainability behaviour of firms aligned with the Paris agreement ("well below" 2° target). Panel **a** shows the contribution to the sector emissions of the firms analysed in this section. Panel **b** shows that, on average, firms aligned with the target set in the Paris agreement have been reducing their emissions since 2015. Panel **c** shows the excess sustainability effort of firms aligned with the targets. Overall, the figure shows that firm aligned and misaligned with the target exhibit a different sustainability behaviour. The figure paints a similar picture as of figure 5

Positive Excess effort

	# of initiatives	Revenue (log)	Investment (log)	Tangibility
Model 1	0.02			
Model 2	-0.06***	1.04***		
Model 3	-0.06***	0.76***	0.32***	
Model 4	-0.07***	0.84***	0.27***	0.81***

Negative Excess effort

	# of initiatives	Revenue (log)	Investment (log)	Tangibility
Model 1	0.07			
Model 2	0.04	1.01***		
Model 3	0.03	0.65***	0.46***	
Model 4	-0.01	0.8***	0.31***	1.12***



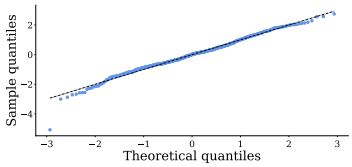


Fig. S16 | Sustainability behaviours and future emissions (Alignment wit the "well below" 2°C target) . The figure shows that initiatives over represented in the firms aligned with the targets set by the Paris agreement are associated with lower future emissions (negative and statistically significant coefficient in the left table). On the other hand, under-represented initiatives in the firms aligned with the targets set by the Paris agreement are uncorrelated with future emissions. The figure paints a similar picture as of figure S14

Well below 2°C Size quartile	Positive excess	Negative Excess	Fraction of initiatives
1	-0.05*	-0.0	0.13
2	-0.07**	0.01	0.21
3	-0.05	-0.03	0.26
4	-0.07***	-0.01	0.37

Below 2°C Size quartile	Positive excess	Negative Excess	Fraction of initiatives
1	-0.19***	-0.0	0.13
2	-0.07***	0.0	0.21
3	-0.05*	-0.02	0.26
4	-0.06**	0.01	0.37

Table ST3: **Model evaluation in different size quartiles.** The tables show the coefficients of the models for positive and negative excess effort evaluated for different size quartiles. The top table shows the results for the populations aligned and misaligned with the well below 2°C target. The bottom table shows the result for the below 2°C target. In the lower size quartiles there are only a limited number of initiatives therefore the accuracy of the statistical estimation diminish significantly. The last columns does not sum up to one because of rounding errors. Overall, the table shows that the results shown in the main text and in figures S15 and S16 are robust to the choice of the population.

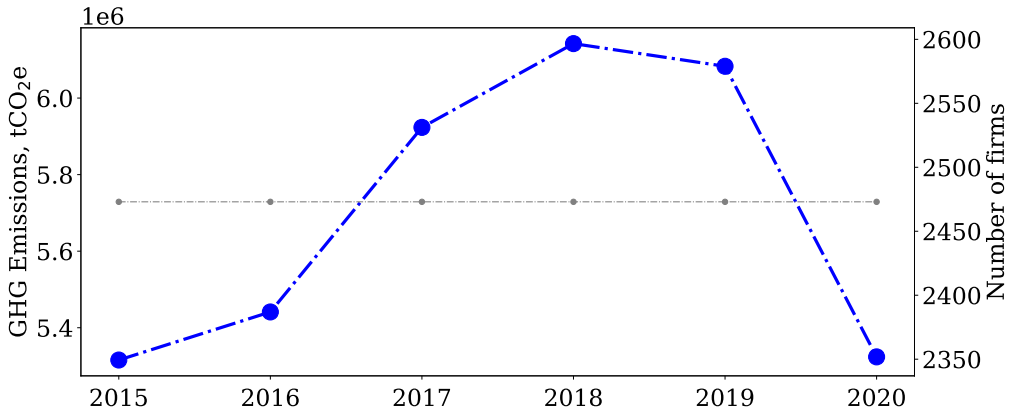
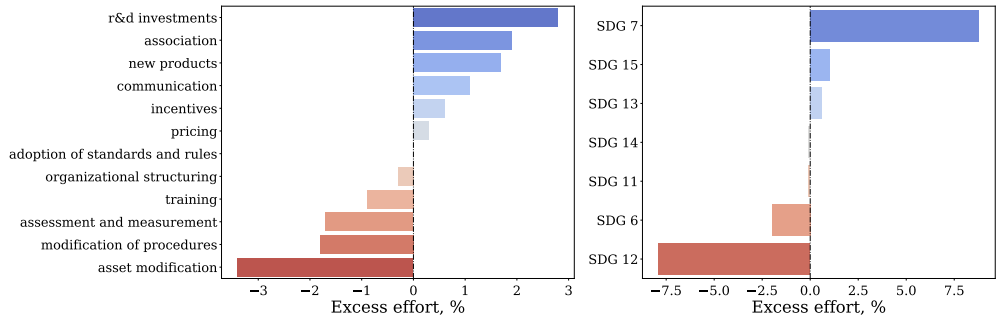


Fig. S17 | Emissions have continued to rise since 2015. The figure shows the average emissions of firms (blue line) for which emissions were available every year since 2015 (gray line). The figure shows that total GHG emissions have been steadily rising, except for 2020. The drop of 2020 emissions is likely due to lockdown measure introduced to curb the spreading of COVID-19. Indeed, in our sample we observe a drop of $\sim 9\%$ to be compared with an estimated drop of $\sim 6.4\%$ globally as reported in Tollefson, J. *COVID curbed carbon emissions in 2020 — but not by much*, Nature 589, 343 (2021). The figure illustrates the importance of removing 2020 from our sample in order to reduce the impact of confounding effects in our analysis.



Positive Excess effort

	# of initiatives	Revenue (log)	Investment (log)	Tangibility
Model 1	0.06			
Model 2	-0.05*	0.98***		
Model 3	-0.06*	0.71***	0.3**	
Model 4	-0.06**	0.8***	0.27**	0.87***

Negative Excess effort

	# of initiatives	Revenue (log)	Investment (log)	Tangibility
Model 1	0.06			
Model 2	0.04	1.01***		
Model 3	0.03	0.67***	0.43***	
Model 4	-0.01	0.81***	0.29***	1.11***

Fig. S18 | Analysis of alignment with climate targets without non-causal activities. The figure shows that results are robust when we remove activities with no causal relations to emissions (i.e., volunteering and donation&funding). The results should be compared with table S14

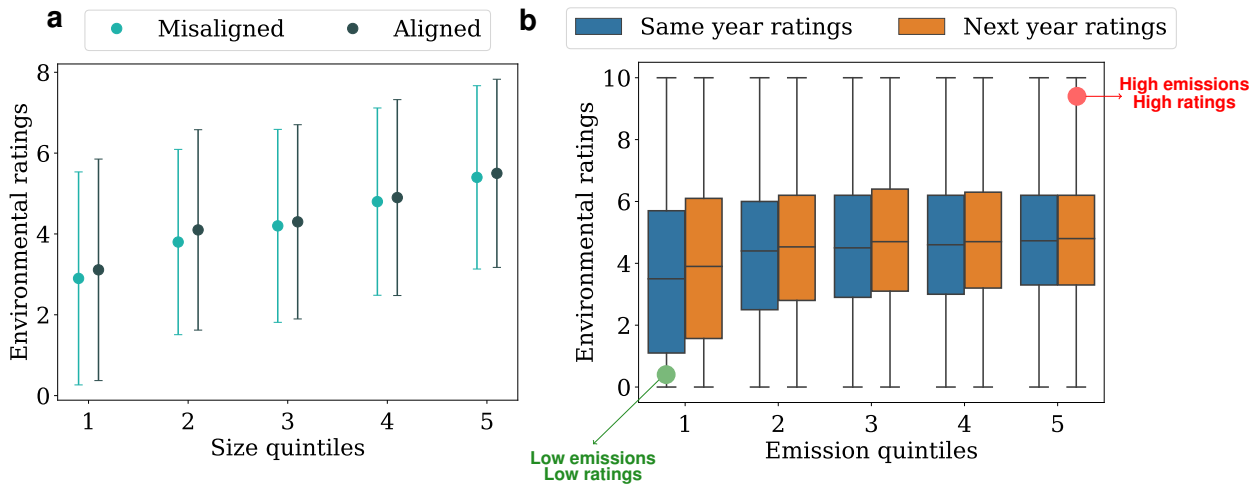


Fig. S19 | Flaw of ESG ratings. Panel **a** shows the average ESG ratings of firms with emission pathways aligned and misaligned with the target set by the Paris agreement (error bars show standard deviations). Panel **b** shows the distributions of ESG ratings of a large sample of public firms (~ 10000) as function of the absolute value of the emissions (in quintiles). Overall the figure shows that ESG ratings fail in capturing the alignment with climate targets (**a**) and the absolute value of environmental impact of most public firms (**b**).