The conundrum of scope 3 emissions for corporate reporting

Paul A. Griffin and Estelle Y. Sun

Unlike the vast amount of financial performance and risk disclosures in periodic regulatory filings, investors and creditors access virtually all their information on scope 3 emissions from outside data providers. Whether these estimates accurately reflect the array of emissions generated by the upstream and downstream value chain of a firm with sufficient precision for market pricing and financial stability remains an open question. Because of the sheer size of scope 3 emissions compared to scope 1 and 2 emissions, accuracy on scope 3 emissions is essential for meeting net-zero climate goals. An analysis of the accounting and finance literature on the market pricing effects of scope 3 emissions suggests more research is required. Additional evidence on scope 3 emissions can help shape policy on the mandatory disclosure of climate-related measures of firm performance and risk currently under consideration by the Securities and Exchange Commission and other prudential regulators.

1. Introduction

The case for mandatory firm-level scope 3 emissions disclosure in financial reports often hinges on "if you can measure it, you can manage it?", a belief dating back to Scottish scientist Lord Kelvin (Kelvin 1883), and also a conceptual underpinning of Kaplan and Norton's well-established balanced scorecard approach to management (Kaplan 2009). Today, in keeping with this belief, accounting regulators and disclosure advocates demand that firms measure and disclose scope 3 emissions, namely, the embodied and latent greenhouse gas emissions in a firm's value chain (discussed further in Section 2). Outside data providers offer a range of services for firms and investors to satisfy this demand. What if scope 3 emissions cannot be measured accurately without substantial cost to the firm? What if a measure to set scope 3 emission targets requires sharing information with suppliers that could gain from that information sharing? What if an alternative measure supplied by an outside data provider has little commensurability with other data providers' measures? When it comes to scope 3 emissions at this time, one can probably answer "Yes" to each one of these questions. Herein lies a conundrum and a challenge. In a nutshell, because scope 3 emissions are many multiples of scope 1 and 2 emissions for most industries and have been growing faster (Hertwich and Wood 2018), their reduction by corporate managers is critical to the success of global net-zero emissions goals. Moreover, given their magnitude, scope 3 emissions are doubtless essential for financial markets' efficient pricing of climate-related financial risk and thus for financial stability. Yet, as our investigation suggests, scope 3 emission disclosure in corporate financial reports so far is sparse at best, and global regulators have only just begun to discuss whether to mandate timely disclosure of scope 3 emissions in financial reports. Meanwhile, the planet warms, sea levels rise, and the social cost of carbon emissions increases.

In this essay, we examine the implicit promise of prudential regulators that the measurement and mandatory disclosure of scope 3 emissions will help firms and countries meet their emissions reduction commitments. Section 2 defines scope 3 emissions and discusses the issues of measurement and management at the firm level and disclosure for corporate reporting. Section 3 describes an analysis of trends in the disclosure of scope 3 emissions by firms in Securities and Exchange Commission (SEC) filings and the current efforts

of outside data providers to measure scope 3 emissions to fill the gap. Section 4 reviews the research in accounting and finance on whether financial markets price scope 3 emissions. Section 5 concludes by offering ideas for research in accounting.

Our findings are three-fold. First, company managers face significant challenges to measure and manage scope 3 emissions consistent with acting in the interests of the stakeholders to maximize firm value. Particularly vexing for understanding the extent of scope 3 emissions in a firm's value chain is the need for information sharing, which can be costly. Second, given the scarcity of scope 3 data directly from the firms, outside data providers have stepped in. But they offer only estimates of scope 3 emissions for investors. Evidence indicates that outside estimates reflect substantial estimation error and low commensurability across the different data providers, exclude important elements of scope 3 emissions, and lack adequate transparency in describing the methods and models used. Third, based on a review of the literature, we find mixed support for the view that firm-level scope 3 emissions indicate a risk premium and, thus, matter for financial markets. Our third finding relates to one of the justifications for enhanced disclosure–that firm-level scope 3 disclosures are value relevant.

2. Measurement challenges

The nomenclature of scope 1, 2, and 3 greenhouse gas emissions dates back to the GHG Protocol Corporate Standard Revised (Protocol 2004), the result of a multi-organization effort to define and measure the totality of emissions within the orbit of a corporation. Briefly, scope 1 emissions are the direct emissions generated by a firm from owned or controlled sources; scope 2 emissions relate to the emissions generated from purchased energy consumed within the boundary of the firm; and scope 3 emissions cover the indirect emissions elsewhere in the firm's value chain, that is, outside the firm's boundary. Scope 3 emissions, thus, mostly relate to (i) the emissions embodied in the goods and services in a firm's supply chain but outside of the boundary of the firm and (ii) the latent emissions in goods and services and assets owned by the firm that are released when assets are used and the goods and services are consumed over their life cycle. The six main components of scope 1, 2, and 3 greenhouse gas emissions (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) are usually defined in terms of equivalent tons of carbon dioxide per period (CO_2e per period) or carbon dioxide intensity per period, such as CO_2e per kilowatt-hour, CO_2e per kilowatt-hour per employee, or CO_2e per revenue or gross profit dollars per year. Because scope 3 emissions relate to a firm's value chain, the emissions of one firm from its upstream activities can be counted as another firm's emissions from its downstream activities. While national-level data may adjust for this double counting, firm-level scope 3 emissions may not, although there are ways to address this given sufficient resources and inter-firm cooperation, for example, using a Shapley allocation (Shrimali 2021)[1] or by adopting an accounting system that identifies emissions at each tier of the cycle of production and consumption (Kaplan and Ramanna 2021).

In proposing the measurement and disclosure of scope 3 emissions in financial statements, the SEC release (SEC 2022) builds on the concepts and standards for scope 3 emissions in the GHG Protocol Corporate Standard Revised (Protocol 2004), hereafter PS3. The TCFD framework (TCFD 2021, 2017) for scope 3 emissions and the 2022 ISSB climate disclosure proposal (ISSB 2022) also build upon PS3. Specifically, the SEC proposes that registrants measure and disclose scope 3 emissions conditional on whether the emissions are

[1] A Shapley allocation is a solution from game theory, where total scope 3 emissions are allocated to all supply chain members such that no member is allocated more than its fair share and all members are encouraged to reduce their emissions.

material or part of a target or goal that includes scope 3 emissions. To support its proposal, SEC (2022) contends that scope 3 emissions measurement and disclosure should be beneficial for investors. These benefits include a reduction in the ability of firms to "obscure for investors the full magnitude of the climate-related risks associated with their GHG emissions" (p. 176), the ability of the firm to "achieve emission targets" (p. 177), to "enable investors to better compare firms", and to fill an information gap because "disclosure of just scopes 1 and 2 emissions could convey an incomplete, and potentially, misleading picture." (p. 182). In addition, but without attribution to supporting evidence, SEC (2022) suggests that scope 3 emissions measurement and disclosure has already generated actual benefits, stating that "capital markets have begun to assign financial value to this type of metric, such that it can be material information for investors about financial risks facing an industry." SEC (2022), nonetheless, does recognize that because scope 3 emissions present measurement challenges, a period of safe harbor from certain forms of liability from good faith estimates, an exemption for smaller reporting firms, and delayed compliance may be required (p. 220).

What are these measurement challenges and why might they present difficulties for SEC reporting firms and investors? While the SEC mentions several issues, such as establishing the boundary of the firm, obtaining accurate emissions data from firms in the focal firm's supply chain, making assumptions about how consumers use the focal firm's sold products, and claims that measurement challenges may recede over time, several others receive only passing mention, if at all. Yet, if firms are to adopt the GHG Protocol of PS3, these and other issues could become major stumbling blocks to an industry's willingness to accept the proposal. For instance, PS3 requires a full value chain mapping of a firm's upstream and downstream activities, including a life-cycle analysis of the latent emissions in products sold and firm assets on and off the balance sheet. Three critical issues stand out in particular.

First, the cost of a full value chain mapping of emissions could be prohibitive when all costs are considered. S&P Global estimates first-time direct costs per firm of $245,000-$355,000[2]; South Pole estimates direct costs of between $10,000 and $100,000 based on one to three-months work[3]; Persefoni estimates an initial direct cost of $50,000–$125,000.[4] For Exxon Mobil in the energy sector, the costs would be much higher, estimated initially by the firm at $50 million.[5] But understanding the emissions in a firm's supply chain is not just about the direct out-of-pocket costs of mapping the supply chain. A mapping exercise is also likely to reveal significant proprietary information about the supplier and the focal firm. While the SEC proposal raises the issue of proprietary costs (SEC 2022, pp. 307, 406), it does not quantify that cost, such as the impact of scope 3 disclosure on innovation and more generally the ability of firms to protect their plans and strategies from rivals and future competitors. Understanding emissions in the supply chain could also lead to operational inefficiencies from the opportunistic behavior of the suppliers or the focal firm in a supply chain resulting in an unnecessary business risk from the agency costs of this behavior, also not quantified in the SEC proposal. This view of the high cost of scope 3 measurement and disclosure is supported by a wide range of research. For example, based on a review of the supply chain literature on the cost factors that may inhibit PS3's goal for firms to measure and manage scope 3 emissions, Patchell (2018, p. 941) concludes that the expectations for adoption by firms of PS3 are optimistic and aspirational at best, concluding that the "weight

[2] https://www.sec.gov/comments/s7-10-22/s71022-sp.pdf
[3] https://www.sec.gov/comments/s7-10-22/s71022-spole.pdf
[4] https://www.sec.gov/comments/s7-10-22/s71022-persefoni.pdf
[5] See supra note 4.

of these factors casts doubt on scope 3's ambition to compel firms to report a full audit of their scope 3 emissions."[6]

Second, the outsourcing of supply chain mapping to outside organizations could result in excessive imprecision resulting in compliance with an eventual rule based on the standard in form only. Firms may map only a fraction of their supply chain, focusing on a few level 1 suppliers only. The role of some countries in supply chain mapping could also present difficulties. For example, based on U.S. Census Bureau data, the dominant exporter to the United States is China. Yet, if the Chinese shipping firm (and not the local manufacturer) is viewed as the level 1 firm in a supply chain mapping, this could account for only a small fraction of the supply chain emissions associated with the shipped product, most of which would originate earlier with level 1+N suppliers in the same country.

Firms and financial markets are not well served when investors use low quality information (Lambert et al. 2007). Moreover, if firms resort to outside services to lower the cost of value chain mapping, this could exacerbate the imprecision. For example, to date, one method used by outside data providers estimates scope 3 emissions based on the EIO-LCA approach[7] applied to sectors (Blanco et al. 2016; Weber et al. 2010). Another is based on emission factors associated with industry or sector levels of activity (e.g., kilowatt-hours, employees, sales revenue) (e.g., Refinitiv 2022). Both methods bypass firm specific analyses of the emissions associated with supplied services or products at the different levels of the supply chain (Preudhomme et al. 2022; Shrimali 2021). However, some firm-level data is available through the EPA's GHGRP program, which provides scope 3 emission factors for some of the PS3 categories (EPA 2022). But this is at the facilities level of a firm. Facilities-level data must still be aggregated to the level of the firm. This can be difficult for a researcher because facilities level data is country specific whereas large firms tend to be global in scale. As a third example, financial institutions may also use second-best methods to measure their scope 3 emissions. For example, to calculate its scope 3 emissions, a bank may multiply borrowers' emissions (an estimate) times the fraction of the debt and equity of each borrower financed by the bank (an arbitrary fraction). These methods based on secondary data have been considered the least reliable for the measurement of scope 3 emissions (PACF 2020).

Third, given the leeway for firms in the SEC proposal to use different methods for scope 3 emissions, there may also be little chance that the measures would be comparable across firms and, thus, create a benefit for investors. For example, we can expect variation across firms in the boundary conditions (financial control, operational control, consolidation of 100 percent of majority-controlled subsidiaries), the inclusion of one or multiple levels of firm connections in the supply chain, and the formula to allocate double-counted emissions to different parties. Also, despite the claim in SEC (2022) that scope 3 emissions should enable comparisons across firms, the GHG Protocol notes that PS3 "is not designed to support comparisons between companies based on their scope 3 emissions" (Protocol 2004, p. 6). Supporting this view, Klaaßen and Stoll (2021) conclude, based on an analysis of technology

[6] Research on the 1998 change in segment reporting (SFAS 131, now ASC Topic 280), which required more detail on firms' operations, shows a similar unwillingness for expanded disclosure due to concerns over proprietary and agency costs (Berger and Hann 2007).

[7] Based on the pioneering work of Nobel prize winner Wassily Leontief, the EIO-LCA (Economic Input-Output Life Cycle Assessment) approach estimates environmental emissions in an economy based on macro and average sector-level relations.

firms, that the measurement and disclosure practices for scope 3 emissions in line with PS3 remain unsystematic and incomparable.

3. Disclosure in regulatory filings

While an increasing number of firms voluntarily share their scope 3 emissions with outside data providers such as the CDP (Eaglesham and Kiernan 2022), many do not, especially smaller and unlisted firms (Kolk et al. 2008). That said, it should also be recognized that the SEC's earlier guidance on climate-related information in financial statements (SEC 2010) already calls for the disclosure of material information on the impacts and risks of climate change in financial statements. So, it is possible that even without the new SEC proposal, some firms would have already disclosed information on scope 3 emissions on grounds of the materiality guidelines in SEC (2010).

To investigate this question, we searched all SEC filings from 2001 to 2022 (through March 17, 2022) for the word groupings of "scope 3", "scope three", "supply chain emission(s)", "transportation emission(s)", "upstream emission(s)", and "downstream emission(s)". Specifically, if an SEC filing of any kind included one or more of these word groups, we denoted it as a scope 3 discloser. This designation occurred regardless of whether a firm quantified its scope 3 emissions. If more than one SEC filing per firm per year included one or more of these words, only one firm-year mention was included. We counted 1,123 firm-year-mentions over the study period, a surprisingly small number of mentions given our relatively broad definition of inclusion (of just two words).[8] Of the different word groupings, 78.9 percent relate to "scope 3" (76.8%) and "scope three" (2.1%) emissions.[9]

Figure 1 shows the distribution of SEC scope 3 disclosers by year (Fig. 1a) and country of incorporation (Fig. 1b). First, Fig. 1a shows that while scope 3 emissions disclosure is extremely sparse, the numbers increase exponentially in recent years. The number of mentions so far in 2022 suggests that this trend will continue. The data for 2022 is a linear extrapolation based on the actual number of 165 mentions through March 17, 2022.[10] As a point of reference, Fig. 1a shows that global CO_2e emissions, which have been high for some time, do not follow the same pattern. Second, Fig. 1b shows that slightly more than a majority of SEC filers that mention scope 3 emissions are U.S. firms. Specifically, 50.2 (564÷1123) percent of the scope 3 mentions in SEC filings are in U.S. firm filings. The number of U.K.-incorporated firms with scope 3 mentions possibly relates to the government's Streamlined Energy and Carbon Reporting Scheme (SECR), which encouraged voluntary scope 3 disclosure starting in April 2019. In addition, while the totals differ across the countries, an untabulated analysis of the discloser firms indicates that each country reflects a similar acceleration of scope 3 mentions starting in 2020.

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[8] For example, one of our sample companies, Etsy, Inc., discloses detailed emissions information as an Item 1 (Business) disclosure in its 2021 10-K in line with the SASB emissions reporting protocol. Consistent with the dominance of scope 3 emissions over scope 1 and 2, Etsy reports 2021 scope 3 emissions as 548,900 tCO_2e versus scope 1 and 2 emissions as 350 tCO_2e and 420 tCO_2e, respectively (https://investors.etsy.com/home/default.aspx). Etsy's scope 3 emissions mostly relate to downstream activities such as transportation and packaging.

[9] Of 102 firm-year mentions of "transportation emissions", only two related to firms in the transportation industry, such that they could have been scope 1 or 2 emissions.

[10] A linear extrapolation is an approximation, however, as the likelihood of disclosure is not the same for every month of a year.

We then collected financial characteristic data for fiscal 2021 from Compustat based on SEC filers' CIK identifier. We choose fiscal year 2021 (and not an average of all years) because fiscal 2021 reflects the greatest number of scope 3 mentions in SEC filings. First, we compared S&P 500 disclosers with a matched sample of S&P 500 non-disclosers.[11] Second, we compared U.S. disclosers with non-U.S. disclosers (all other scope 3 disclosers including international SEC filers). The first comparison explores whether S&P 500 scope 3 disclosers differ from S&P 500 scope 3 non-disclosers based on their financial characteristics. While not matched one-to-one to the discloser sample, the second comparison allows us to explore differences between U.S. scope 3 disclosers and non-U.S. scope 3 disclosers.

Table 1 summarizes the results based on the financial characteristics of asset efficiency (sales-to-total assets), margin (net profit-to-sales), leverage (liabilities-to-common equity), growth prospects (PE ratio), absence of stranded asset risk (intangibles to total assets), firm size (market capitalization), and stock price. Panel A summarizes S&P 500 scope 3 disclosers. Panel B summarizes the matched sample of S&P 500 non-scope 3 disclosers. Panel C summarizes non-U.S. scope 3 disclosers. Panel D shows the t-statistics and significance levels of the difference between S&P 500 disclosers and matched S&P 500 non-disclosers (Panel A - Panel B) and S&P 500 disclosers less non-U.S. disclosers (Panel A - Panel C). These panels highlight two main findings. First, based on financial characteristics alone, S&P 500 disclosers are no different from S&P 500 non-disclosers. In addition, whereas Table 1 reports tests of mean differences, Figure 2 compares S&P 500 disclosers versus S&P 500 non-disclosers graphically over the entire distribution of each financial characteristic (based on fiscal 2021 data). The plots are remarkably similar. This suggests that S&P 500 firms' decision to mention scope 3 emissions in an SEC filing relates to factors other than their financial characteristics holding constant the sector designation of the firm. Second, possibly reflecting more energy and materials (e.g., mining) firms, Panel A - Panel C shows that non-U.S. disclosers compared to S&P 500 disclosers have lower growth prospects (PE ratio), higher stranded asset risk (i.e., lower intangibles to total assets), and smaller size. Together, these findings indicate that industry characteristics rather than financial statement differences are potentially more relevant as determinants of firms' scope 3 disclosure decision.

We performed a second analysis of scope 3 mentions in SEC filings by exploring differences between SEC scope 3 disclosure and firms' support for the TCFD framework. We deem the TCFD framework as relevant because it includes a recommendation for scope 3 disclosure similar to PS3 and the SEC proposal. We obtained data on S&P 500 firms' support for the TCFD framework from a September 21, 2021, analysis in a November 30, 2021, submission to the SEC before the release of the new proposal.[12] Our analysis reveals two findings. First, except for the financial sector and two large firms in communication services (Alphabet and Verizon), the number (Fig. 3a) and percentage of S&P 500 firms by market capitalization (Fig. 3b) in a sector indicating support for the TCFD framework is small. For the highly valuable information technology sector (worth $10.25 trillion) (Fig. 3c), the number and percentage of firms supporting the TCFD framework are among the smallest. Second, while one might predict TCFD supporters to have more scope 3 mentions in their filings than non-TCFD supporters, there is no significant relation in the proportion of S&P 500 disclosers versus S&P 500 non-disclosers and the proportion of S&P 500 TCFD supporters versus S&P 500 TCFD non-supporters in the SEC discloser sample. The sample of scope 3 mentions

[11] For each S&P 500 discloser, we identify all S&P 500 non-disclosers in the same sector and then select the firm with the closest value of total assets. Matching is done without replacement.
[12] https://www.sec.gov/comments/s7-10-22/s71022.htm.

included only one TCFD supporter and zero non-TCFD supporters. The chi-square statistic for a positive relation of 1.983 was not significant at $p<0.10$.

In summary, despite calls for additional disclosure and increasingly higher levels of data sharing with outside data providers, there is only sparse mention of scope 3 emissions in SEC regulatory filings. The SEC data, however, reveal a glimmer of interest in scope 3 emissions in the most recent years (2020–2021), which continues into 2022. Whether it relates to the materiality guidance of SEC (2010), is in anticipation of SEC (2022), or is prompted by other factors (e.g., investor demands, regulations in other countries) remains unclear.

4. Pricing in financial markets

To assess the market pricing or value relevance of scope 3 emissions by investors, we used Google Scholar and Semantic Scholar to identify studies on the impact of "emissions" on "firm value." We used a range of descriptors of "firm value" using words or word pairings such as stock price, stock returns, market or investor impact, market value or valuation, pricing, and carbon risk. This search located 18 studies comprising 13 published in finance and accounting journals and five unpublished studies as postings on SSRN. Table 2 and Figure 4 summarize the results. This analysis reveals that four studies single out scope 3 emissions (Aswani et al. 2022; Bolton and Kacperczyk 2021; Bolton and Kacperczyk 2022; Dai et al. 2022) (Fig. 4a), all dependent on Trucost data (Fig. 4b), and all published in 2021–2022 (Fig. 4c). Thus, the reality is that majority of the prior literature on the pricing effects of carbon emissions examines only scope 1 and 2 emissions. For most firms and sectors, scope 1 and 2 emissions comprise a much smaller share of total emissions than scope 3 emissions.

Unlike the earlier studies that regress share price or firm value on scope 1 and/or 2 emissions and control variables, the four recent studies that examine scope 3 emissions regress monthly realized stock returns on the different emissions scopes and control variables. In three studies, the data provider is Trucost (an arm of S&P Global). A fourth study uses Trucost, EU-ETS, and company-reported data. The papers theorize that if scope 3 emissions reflect an additional (and presumably unexpected) risk factor for assessing stock returns, then the coefficient on scope 3 emissions in a regression of realized returns on emissions should be positive. That is, conditional on receiving new scope 3 information, investors act to raise their estimates of future returns because of higher scope 3 emissions risk.

Three of the studies find a significantly positive coefficient, concluding that scope 3 emissions represent an additional risk factor for pricing securities. For example, Bolton and Kacperczyk (2021, p. 519) state that "we designate higher returns associated with higher emissions as a carbon premium" and that "there is also a significant carbon premium associated with year-to-year growth in emissions." Similarly, Dai et al. (2022, p. 32) find a significantly positive coefficient for scope 3 emissions and imported emissions, suggesting that investors expect higher returns on the stocks of carbon outsourcers that reflect higher emissions risk. Focusing on emissions intensity (emissions divided by sales revenue) as the potential driver of stock returns, a fourth study (Aswani et al. 2022) finds no significant relation between emissions and stock returns, claiming that the positive carbon risk factor documented in Bolton and Kacperczyk (2021) and Bolton and Kacperczyk (2022) occurs because Trucost uses estimates of emissions from a model that over-weights financial fundamentals in estimating carbon emissions.

To understand the link between high emissions (or growth in scope 3 emissions) and positive realized stock returns, we take a closer look. We first note that asset pricing theory in

accounting and finance (Campbell 1991) posits that realized stock returns stem from expected returns and news of unexpectedly higher or lower future cash flows (in the valuation numerator) and unexpectedly higher or lower risk (in the valuation denominator). Thus, positive realized stock returns are more likely to associate with unexpectedly higher cash flows (e.g., a positive earnings surprise) and/or an unexpected drop in financial risk (e.g., a lower cost of capital). Hence, in theory, if investors demand more future expected return for the higher expected risk they face, the current stock price should fall to adjust to the higher expected risk. In this scenario, firms with unexpectedly higher (or growing) emissions) will drop in price and generate negative realized returns. The negative emission news could also lead to higher expected risk. So, what might account for the positive relation documented in all three studies? Not good news about climate change, since that has been mostly negative for at least a decade (Ardia et al. 2021). Not the positive returns from holding green stocks (Pastor et al. 2022), since these would unlikely be high emissions firms. One possible explanation is to assume that observed positive realized returns associate with future positive expected returns.[13]

Second, we note that the Trucost emissions measures used to establish evidence of a scope 3 risk premium would have unlikely been contemporaneously available to investors in assessing returns conditional on emissions risk. In such an absence, investors would have to have used an expectation of scope 3 emissions. However, as discussed earlier, estimating actual and/or *future* scope 3 emissions is difficult, and when there is an error in the regression variables the coefficients can be biased. While, more realistically, the studies also examine models that regress monthly stock returns in year t+1 on Trucost emission measures as of year t, it is still uncertain whether investors would have had the emissions measures for all months in year t+1. Although it is unclear when Trucost releases scope 3 data on past emissions, CDP, for example, publishes its emissions survey data late in the following year (usually around August-September). Given that CDP is perhaps the only source of shared company-calculated scope 3 emissions, the same timing issue could apply to the actual scope 3 data used by Trucost. We also note that none of the three studies recognizes the Trucost disclosure flag to indicate the source of the data, such as estimated (TC), derived from a previous year (PRE), or based on financial report disclosure (AR*) (Trucost 2019, p. 10), which can be important if the statistical analysis is to recognize the variation in the quality of the emissions data and potentially adjust for a selection bias.[14]

Third, regardless of the timing of their availability and the prediction model used in the marketplace, Trucost's measures of past scope 3 emissions may not be reliable proxies for firms' scope 3 emissions if they are largely based on sector indexes and cover only upstream activities (Trucost 2019, p. 13). In addition, Busch et al. (2022) document low correlations between Trucost and CDP scope 3 measures from the companies (e.g., in a firm's survey response to the CDP), of 0.21 (Pearson correlation) and 0.59 (Spearman rank correlation). While the CDP data, much of which comes from the company itself, should be more accurate, when scope 3 emissions are estimated by the outside data provider, the correlations are even lower. For example, the correlation between Trucost and the scope 3 measures from ISS

[13] However, in a test of whether observed positive realized returns in response to earnings news associate with future positive expected returns or future negative expected returns, Choi et al. (2013) find evidence more consistent with a negative association.

[14] All three studies may also reflect bias from backfilling by Trucost, namely the inclusion in the dataset of historical estimates of scope 3 emissions (dating back to 2005) that may not have been contemporaneously available with investor decision-making in the earlier years.

(another outside data provider) is 0.16 (Pearson correlation) and 0.14 (Spearman rank correlation) (Busch et al. 2022). These low correlations across different data providers' measures of scope 3 emissions do not offer high confidence that Trucost is measuring scope 3 emissions with sufficient precision to form a reliable estimate of future emissions risk.

Fourth, in three of the four studies (Aswani et al. 2022; Bolton and Kacperczyk 2021; Bolton and Kacperczyk 2022), the regressions supporting the conclusion of the market relevance of scope 3 emissions do not include scope 1 *and* scope 2 emissions in the regressions as controls. This is important because the same non-emission variables (e.g., firm size, book-to-market ratio, return on equity) used in the papers to predict emissions are equally significant in predicting scope 1, 2, and 3 emissions (Bolton and Kacperczyk 2021, Table 7). This means that the different scopes are positively correlated.[15] When different variables in a regression are correlated, regression theory states that the coefficients for each can be unreliable and that other procedures for coefficient estimation (e.g., simultaneous equations regressions) may be more appropriate.[16]

By contrast, Dai et al. (2022) include scope 1 and 3 (but not scope 2) emissions in the same regression and find a significantly positive coefficient for scope 3 emissions but not for scope 1 emissions. While this may be evidence that scope 3 emissions have relevance for assessing returns incremental to scope 1 emissions, the setting of this paper focuses on firms that reduce their scope 1 emissions while increasing their scope 3 emissions from outsourcing at the same time, deemed an opportunistic behavior. Notwithstanding the distinction between realized and expected returns (Pastor et al. 2022), the positive coefficient for scope 3 emissions in Dai et al. (2022) could well reflect the risk of the opportunistic behavior of shifting emissions from scope 1 to scope 3 by outsourcing rather than the unpriced climate risk in scope 3 emissions more generally. The investor response would also have to relate to unexpected opportunistic behavior, as the expected behavior would already be impounded in the current share price and prior expected returns. It is also unclear how much of the variable "Import CO_2" emissions, which appears to be a narrower measure of scope 3 emissions, is included in the variable "Scope 3" emissions, which is a broader definition of scope 3 emissions. In other words, the Scope 3 and Import CO_2 emissions variables could involve some double counting.

Some other studies use emissions measures collected by a government agency (e.g., GHGRP in the United States and the EU-ETS in the European Union). Fig. 4b shows that six of the 16 studies use one of these data sets, either exclusively or in combination with data from another outside data provider. While these measures mostly capture scope 1 emissions at the

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[15] While not directed at scope 3 emissions, Aswani et al. (2022) make a similar point to explain why their results differ from Bolton and Kacperczyk (2021) and Bolton and Kacperczyk (2022). This is because the Trucost emissions data are mainly *estimates* of emissions based on fundamental financial variables (e.g., 80% of Trucost's 2018 emissions are estimated). Hence, Aswani et al. (2022) conclude that the positive relation between carbon emissions and realized stock returns most likely reflects the positive relation between firm fundamentals (e.g., firm size, book-to-market ratio, return on equity) and realized stock returns.

[16] Despite this discussion, Bolton et al. (2022) rigorously defend the conclusions of Bolton and Kacperczyk (2021) and Bolton and Kacperczyk (2022), concluding that those studies provide "evidence of a carbon return premium in the 2010s and provide more support for the hypothesis that investors increasingly perceive carbon emissions to be a relevant risk and require compensation for exposure to this risk." Bolton et al. (2022, p. 28).

level of a facility or installation, some may also capture scope 2 and 3 emissions. However, facility- or installation-based measures aggregated to the firm level, whether based on GHGRP or EU-ETS measures, apparently reflect less than 50 percent of the equivalent measures provided by outside data providers (Busch et al. 2022, Table 4), although the correlations between the two different measures are in the 60–80 percent range (Busch et al. 2022, Table 5). Thus, if the response of market prices or stock returns incorporates all emission scopes, then the coefficient of response to GHGRP or EU-ETS measures could be overstated.[17] So far, however, research has yet to identify whether financial markets distinguish between the different emission scopes and the timing and speed of the market adjustments.[18]

5. Conclusion

In this essay, we call attention to the urgent need of regulators to address scope 3 emissions measurement and disclosure in financial statements. With greenhouse gas emissions reaching record levels (IEA 2022), the obligation of firms to stakeholders and society to map their scope 3 emissions is more pressing than ever. Paradoxically, although they are the largest of all types of emissions generated by firms, scope 3 emissions thus far have received the least attention from firms, regulators, and researchers. While the presumed adoption of the SEC's recent proposal for standardized disclosure should help alleviate investors' and creditors' concerns for increased transparency and consistency of information on firms' emissions, the SEC's adoption of the GHG Protocol for scope 3 emissions measurement raises several serious issues, some of which could impose significant costs on U.S. public companies without demonstrated benefits. It can be expected that firms will voice these concerns loudly as the proposed disclosure rule moves toward adoption. However, despite the likely cost concerns of preparers, the alternative of relying on outside data providers' estimates of scope 3 emissions to satisfy investors' demands may not be the solution either. Mounting evidence suggests that those estimates lack reliability, completeness, and commensurability. As regulators seek to require emissions disclosure, academics can play a vital role in this struggle of how to satisfy investors' needs. Two key avenues of future research are required. The first should show clear and convincing evidence that scope 3 emissions as distinct from scope 1 and 2 emissions are relevant for assessing expected returns and/or the value of a firm. This also speaks to the issue of financial materiality. Second, in the absence of accurate information from the firm, there is a need for additional research to evaluate models for the measurement, analysis, and sharing of scope 3 emissions that incorporate the different degrees of precision and bias in the data to ensure the robustness of the models for estimation and prediction. Our preliminary analysis suggests that sector analysis will be an important element of this model development. Both avenues of research, we believe, are in their very early stages of development and would benefit immeasurably from academic participation.

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[17] This assumes that market prices efficiently reflect all emission scopes. It is unclear, though, whether this is a well-supported assumption. The regression coefficients in a valuation model are based on the data in the regression, that is, reported emissions. These can be smaller than the actual emissions, and investors may only be efficiently responsive to reported emissions.

[18] In reacting to emissions disclosures, market prices could also be responding to firms' use of allowances, offsets, and special subsidies issued to emission-emitting sectors by governments, assuming they are positively correlated with firm-level emissions disclosures.

LORIE TO FIX FORMATTING, ADD SENTENCE ABOUT LINKING TO VIDEO AND SUPPLEMENTAL MATERIAL

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(https://gsm.ucdavis.edu/profile/paul-griffin)

Estelle Y. Sun, Questrom School of Business, Boston University
(https://www.bu.edu/questrom/profile/estelle-yuan-sun/)

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Figure 1. Distribution of SEC scope 3 discloser firms by year and country

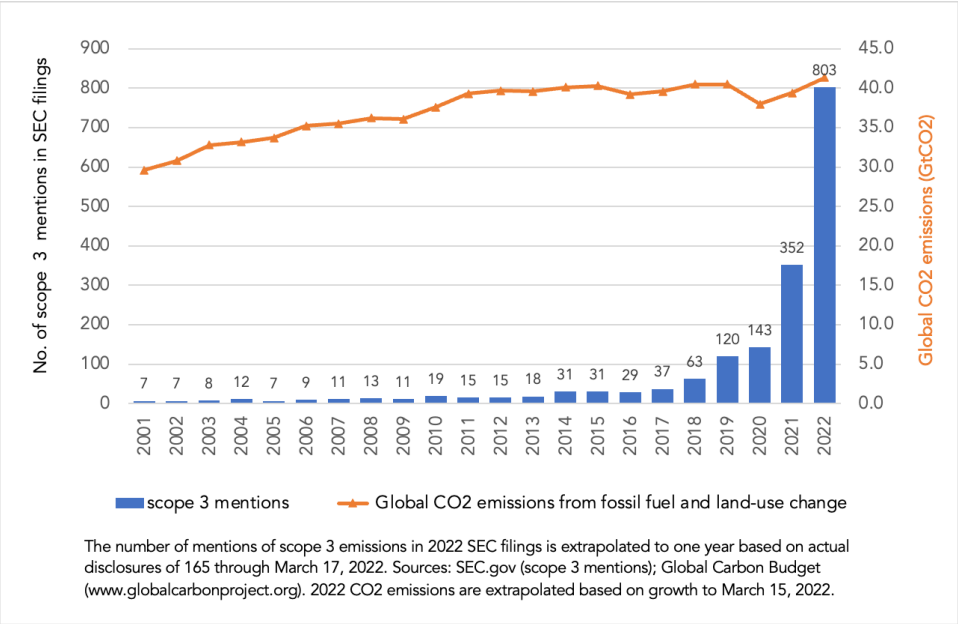


Fig. 1a Scope 3 disclosure over 2001–2022 compared to global CO_2e emissions

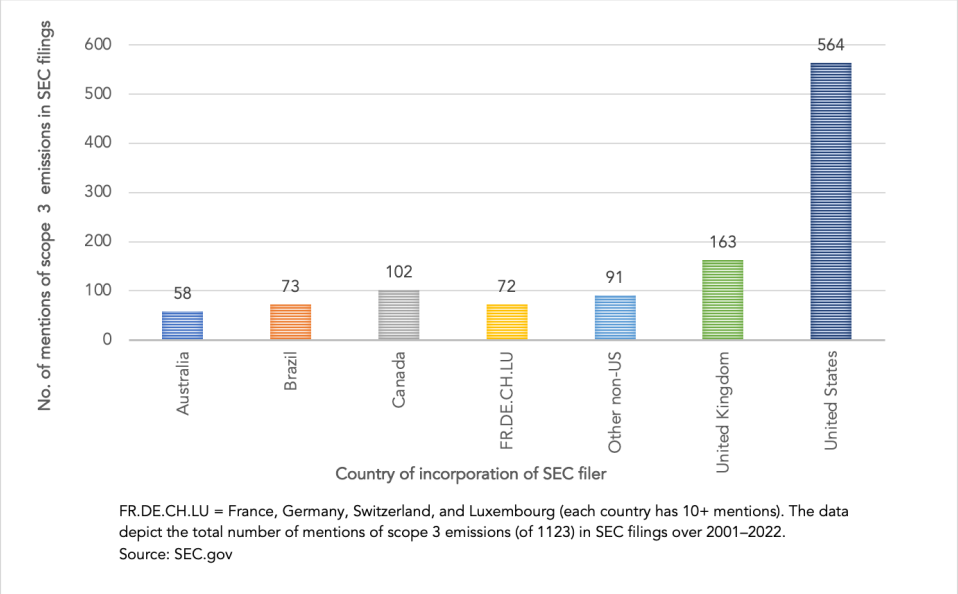
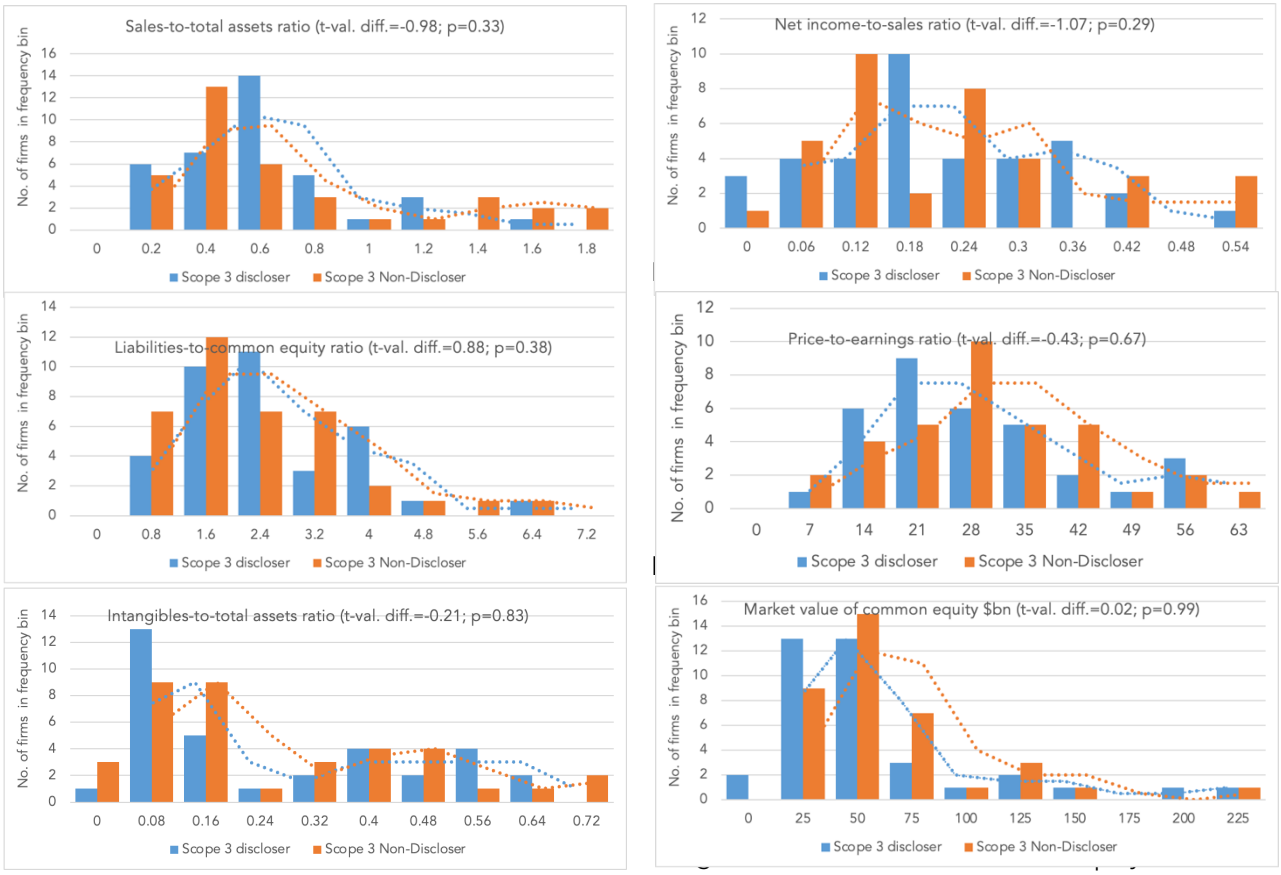


Fig. 1b. Scope 3 emissions disclosure over 2001–2022 by country of incorporation

The distribution relates to all SEC filers regardless of the country of incorporation. While most SEC filers are U.S. firms, firms incorporated in other countries also mention scope 3 emissions. Enlarge: https://drive.google.com/file/d/1_lQGFqx3I6pA32Al0JtLngDPx3LY7uZ-/view?usp=sharing

Figure 2. Financial characteristics of S&P 500 scope 3 discloser firms



These plots of the number of firms in a frequency bin compare the key financial characteristics of S&P 500 scope 3 disclosers with a size- and GICS-sector-matched sample of S&P 500 scope 3 non-disclosers. Each graph indicates the t-stat. and p-value of a t-test of the difference in the sample mean of scope 3 disclosers versus scope 3 non-disclosers. The dotted lines represent a moving average of the number of firms in the frequency bin of each distribution. Enlarge: https://drive.google.com/file/d/1yqiQ0Ut4oRNKFr7FsFN67Un4-n-8w-d8/view?usp=sharing.

Figure 3. S&P 500 support for the TCFD framework*

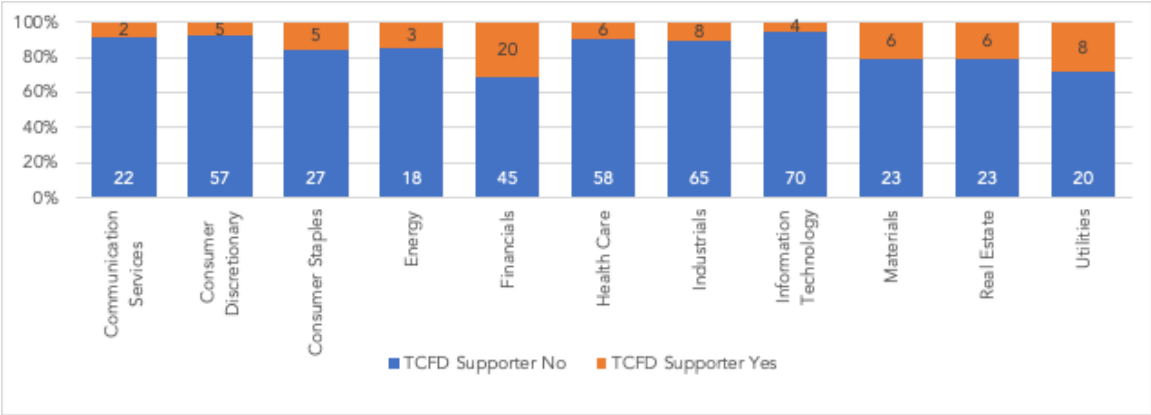


Fig. 3a. Number of S&P 500 firms supporting the TCFD framework

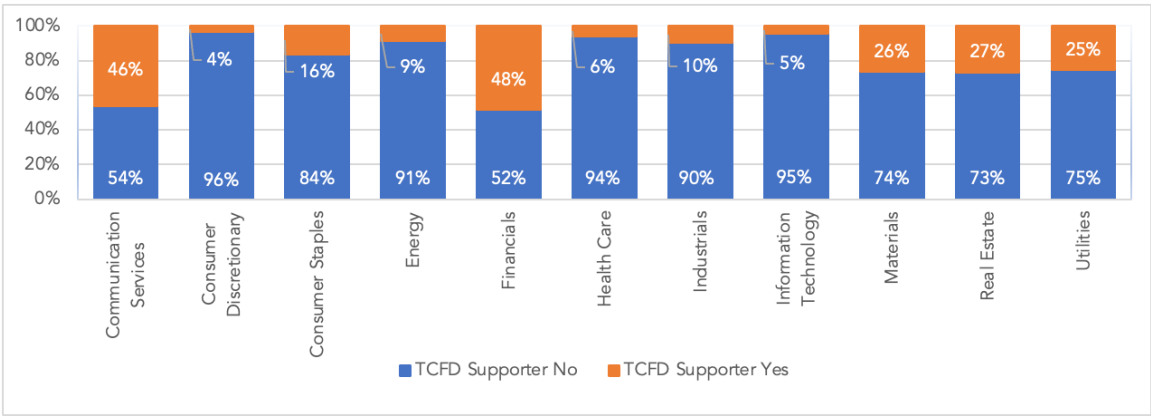


Fig. 3b. Percentage of 2021 sector market capitalization supporting the TCFD framework

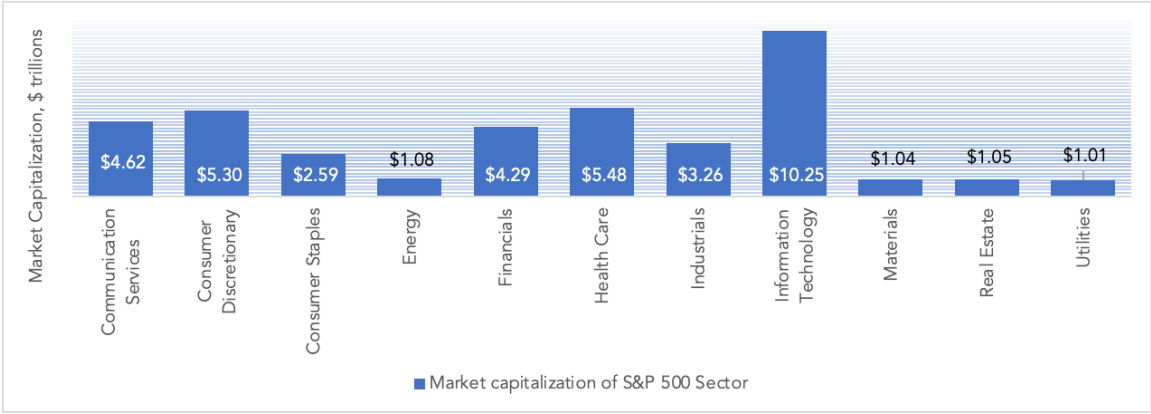


Fig. 3c. Total 2021market capitalization of equity ($ trillions) of S&P 500 firms

*Source. https://www.sec.gov/comments/s7-10-22/s71022-persefoni.pdf

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Figure 4. Analysis of scope 3 emissions

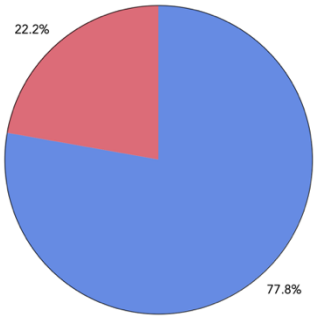
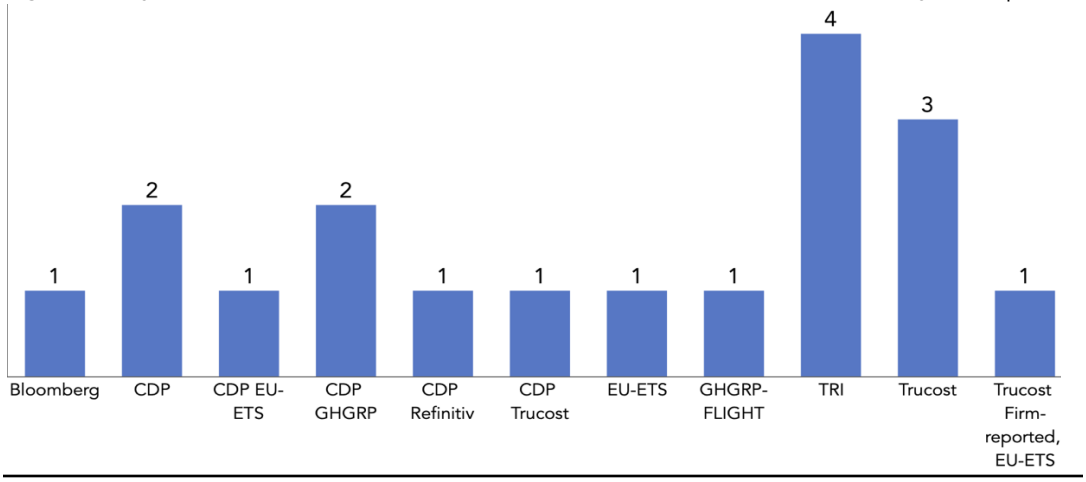


Fig. 4a. Only four (22.2%) of the 18 studies on the valuation of emissions analyze scope 3 emissions.



Outside providers of emissions data	
scopes 1 and 2	scope 3

Fig. 4b. Four studies analyze scope 3 emissions using data from Trucost.

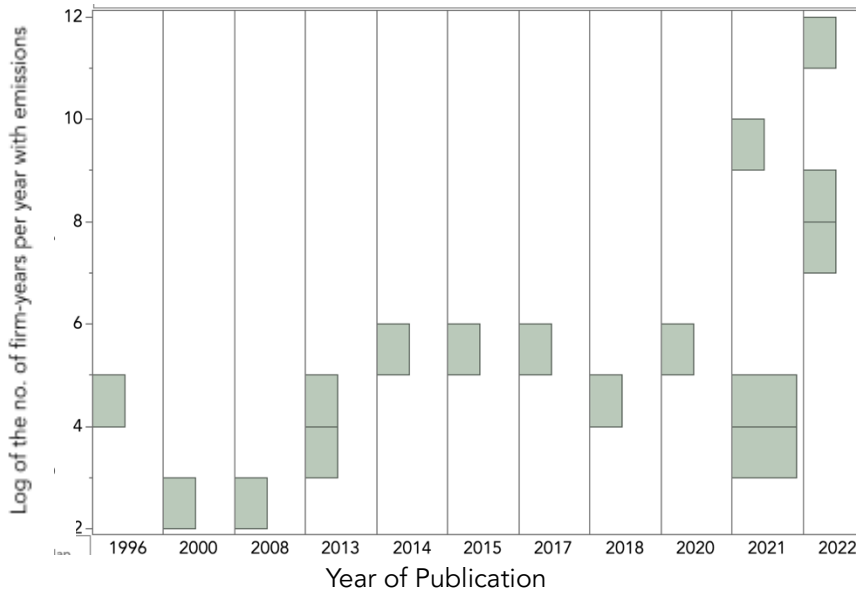


Fig. 4c. The number of emission firm-years per year studied has changed little since 1996 other than with four recent studies in 2021 and 2022.

Enlarge: https://drive.google.com/file/d/15hqgxy5jm5cKxV72W4FQ3I9OHjcIqwUZ/view?usp=sharing

Table 1. Financial characteristics of scope 3 discloser firms

Financial characteristic		Sales-to-assets		Net profit-to sales		Liabs.-to-comm. equity		Price-to-earnings		Intangibles-to-assets		Market capitalization		Price Per share	
	N	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Panel A. S&P 500 2021 scope 3 disclosers															
Communication Services	3	0.43	0.43	0.21	0.19	3.42	3.90	11.83	10.32	0.49	0.40	10,574	12,845	26	22
Consumer Discretionary	4	0.57	0.54	-0.14	0.10	2.38	2.28	18.95	18.95	0.15	0.13	18,315	12,153	48	41
Consumer Staples	4	0.96	0.93	0.20	0.14	5.45	3.17	26.65	24.57	0.41	0.45	28,486	25,517	109	66
Energy	7	0.84	0.65	0.12	0.13	1.24	1.00	27.70	14.66	0.10	0.04	94,101	42,031	72	78
Financials	2	0.17	0.17	0.16	0.16	5.77	5.77	21.40	21.40	0.29	0.29	32,370	32,370	130	130
Health Care	1	0.46	0.46	0.34	0.34	1.77	1.77	18.81	18.81	0.42	0.42	193,716	193,716	91	91
Industrials	6	0.88	0.56	0.27	0.29	1.77	1.45	28.40	22.24	0.26	0.21	40,127	30,946	198	181
Information Technology	2	0.45	0.45	0.26	0.26	3.37	3.37	21.71	21.71	0.36	0.36	164,820	164,820	111	111
Materials	3	0.39	0.38	0.17	0.16	1.19	0.94	35.34	35.95	0.04	0.05	55,541	56,702	150	75
Real Estate	3	0.27	0.13	0.26	0.24	4.87	1.99	53.91	53.66	0.25	0.25	57,371	30,774	132	51
Utilities	4	0.22	0.21	0.04	0.02	3.11	3.07	31.76	31.76	0.06	0.05	32,965	28,867	42	43
All	39	0.59	0.48	0.16	0.17	2.86	1.77	28.02	21.08	0.24	0.12	57,575	31,756	102	68
Panel B. S&P 500 2021 scope 3 non-disclosers															
Communication Services	3	0.46	0.49	0.11	0.08	1.84	1.59	32.89	33.49	0.49	0.41	12,076	14,943	52	28
Consumer Discretionary	4	1.50	1.47	0.42	0.44	2.70	3.04	19.56	21.34	0.10	0.08	45,836	37,473	204	240
Consumer Staples	4	1.74	1.47	0.19	0.19	1.50	1.69	28.61	31.84	0.27	0.29	81,203	47,377	175	91
Energy	7	0.71	0.41	0.15	0.21	1.76	1.25	21.90	21.04	0.07	0.02	26,752	30,735	53	36
Financials	2	0.20	0.20	0.10	0.10	3.60	3.60	31.91	31.91	0.27	0.27	48,420	48,420	134	134
Health Care	1	0.42	0.42	0.19	0.19	2.04	2.04	22.36	22.36	0.58	0.58	135,674	135,674	70	70
Industrials	6	0.68	0.62	0.29	0.25	2.30	2.03	33.16	30.01	0.42	0.38	55,440	56,192	269	239
Information Technology	2	0.39	0.39	0.14	0.14	1.00	1.00	22.26	22.26	0.47	0.47	231,202	231,202	184	184
Materials	3	0.65	0.29	0.19	0.08	0.76	0.80	56.87	22.25	0.31	0.15	34,418	33,807	104	129
Real Estate	3	0.17	0.12	0.24	0.09	5.75	0.82	37.61	35.41	0.14	0.02	58,340	35,300	159	170
Utilities	4	0.18	0.19	0.10	0.10	2.76	2.66	26.66	25.80	0.07	0.08	49,570	47,484	86	87
All	39	0.72	0.42	0.21	0.20	2.31	1.76	30.23	25.11	0.25	0.15	57,327	36,975	141	93
Panel C. Non-US scope 3 disclosers															
Communication Services	2	0.29	0.29	0.31	0.31	1.47	1.47	12.96	12.96	0.38	0.38	27,786	27,786	30	30
Consumer Discretionary	3	0.61	0.61	0.79	0.79	5.10	5.10	90.51	90.51	0.52	0.52	27,810	27,810	308	308
Consumer Staples	5	1.10	0.54	0.25	0.25	2.20	2.05	23.08	23.08	0.21	0.19	3,578	3,298	129	187
Energy	19	0.67	0.55	0.01	0.12	3.26	2.10	11.19	9.90	0.06	0.05	16,174	3,170	52	51
Financials	9	0.06	0.08	0.13	0.12	12.35	12.46	20.50	13.80	0.01	0.01	30,651	28,660	24	18
Health Care	3	0.34	0.36	-0.01	0.00	1.92	1.68	na	na	0.40	0.59	4,297	4,297	64	64
Industrials	6	0.68	0.86	0.13	0.09	2.13	1.61	32.95	35.55	0.23	0.28	19,327	8,477	97	72

Information Technology	5	0.58	0.62	0.41	0.58	1.50	1.98	42.03	54.93	0.30	0.18	9,454	9,454	584	896
Materials	19	0.62	0.63	0.28	0.30	1.87	0.90	12.83	7.41	0.06	0.03	11,061	4,871	67	82
Real Estate	1	0.07	0.07	-0.10	-0.10	1.99	1.99	na	na	0.00	0.00	1,672	1,672	20	20
Utilities	2	0.29	0.29	-0.84	-0.84	10.36	10.36	na	na	0.08	0.08	3,808	3,808	15	15
All	74	0.56	0.55	0.17	0.14	3.91	1.98	22.64	13.66	0.14	0.05	16,138	4,415	96	53
Panel D. Differences (t-stat., signif.)															
S&P 500 disclosers vs. S&P 500 non-disclosers (A-B)		-0.98		-1.07		0.88		-0.43		-0.21		0.02		-1.55	
S&P 500 disclosers vs. non-U.S. disclosers (A-C)		0.45		-0.30		-1.54		2.86***		2.13**		3.39***		0.20	

This table summarizes key 2021 financial characteristics of firms that mention scope 3 emissions in their SEC filings in 2021. Panel A summarizes S&P 500 scope 3 disclosers. Panel C summarizes a matched sample of S&P 500 non-scope 3 disclosers. Panel C summarizes non-U.S. scope 3 non-disclosers. Panel D shows the t-stat. and significance levels of the difference of S&P 500 disclosers less a matched sample of S&P 500 non-disclosers (Panel A – Panel B) and S&P 500 disclosers less non-U.S. disclosers (Panel A – Panel C). ***, **, and * denote two-tail significance at the 1%, 5%, and 10% level, respectively.

Table 2. Studies on the financial market effects of carbon emissions

Study	Year of study	Google Citations 7/19/2022	Citations per year	Scope 3 mentioned Yes=1, No=0	Scope 3 analyzed Yes=1, No=0	Study period years	Firm-years	Nat. log of firm-years per year
Hart and Ahuja (1996)	1996	2,614	97	0	0	2	127	4.15
Hughes (2000)	2000	422	18	0	0	8	90	2.42
Johnston et al. (2008)	2008	172	11	0	0	6	71	2.47
Chapple et al. (2013)	2013	278	28	0	0	1	58	4.06
Clarkson et al. (2013)	2013	584	58	0	0	4	195	3.89
Matsumura et al. (2014)	2014	815	91	0	0	3	584	5.27
Clarkson et al. (2015)	2015	223	28	0	0	4	843	5.35
Griffin et al. (2017)	2017	278	46	0	0	7	1677	5.48
Broadstock et al. (2018)	2018	96	19	1	0	16	2147	4.90
Ilhan et al. (2020)	2020	247	82	1	0	8	1963	5.50
Bolton and Kacperczyk (2021)	2021	462	231	1	1	13	189187	9.59
Downar et al. (2021)	2021	36	18	0	0	10	1257	4.83
Griffin et al. (2021)	2021	6	3	0	0	13	673	3.95
Jouvenot and Krueger (2021)*	2021	26	13	1	0	8	552	4.23
Yang et al. (2021)*	2021	5	3	0	0	15	744	3.90
Bolton and Kacperczyk (2022)*	2022	67	67	1	1	14	887429	11.06
Dai et al. (2022)*	2022	13	13	1	1	13	76356	8.68
Aswani et al. (2022)*	2022	14	14	1	1	15	17,852	7.08
Percentage "Yes"				39%	22%			

* Unpublished as of 7/19/2022

This table summarizes 18 studies that examine the relation between carbon emissions and their pricing effects in financial markets. Of the 18 studies that examine emission pricing effects, seven (39%) mention scope 3 emissions and four (22%) analyze firm-level scope 3 emissions.