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# Technological peer pressure and corporate sustainability

Shuangshi Wang [a], Cheng Yan [a,*], Yuqian Zhao [b]

[a] University of Essex, Colchester, CO4 3SQ, United Kingdom
[b] University of Sussex, Brighton, BN1 9RH, United Kingdom

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ABSTRACT

In this paper, we investigate the relationship between technological peer pressure (TPP) and corporate sustainability performance. Studying 1536 firms in the United States for the period 2002 to 2021, we provide strong and robust evidence that corporates' environmental and social performance have a negative effect on technological peer pressure. Our empirical findings support the view that resource constraints and agency problems serve as channels in this relationship. Additional analyses reveal industry heterogeneity of this relation that the negative impacts are stronger in the firm with high research and development (R&D) intensity, in high-tech industries, non-customer-facing sectors and "green" industries. In summary, our results highlight the importance of technological competition in the product market in the knowledge-based economy and firms' sustainability strategies in competitive industries.

## 1. Introduction

The famous argument by Friedman (1970) is that the primary goal of a firm is to maximize returns to its shareholders. Corporate sustainability is usually considered unnecessary and inconsistent with the goal of profit maximization, potentially harming shareholders' interests. Nonetheless, an increasing number of companies are actively involved in ESG (Environmental, Social and Governance)-related activities. For example, as documented by KPMG in 2020, 96% of the world's largest 250 firms report their engagements and commitments to corporate sustainability, which has increased substantially from 35% in 1999.[1] Many countries and associations also set rules about ESG information disclosure. The motivations and consequences for firms' engagement in ESG have been discussed in recent research (e.g., Bénabou and Tirole, 2010; Aguinis and Glavas, 2012), although no consensus has been reached. In general, the motivations and consequences of striving for ESG performance can be categorized into three main groups: the first category is commonly referred to as "doing well by doing good", suggesting that if a firm acts as a responsible corporate citizen, its firm value, profitability and competitiveness can be enhanced (Deng et al., 2013; Flammer, 2015). The second perspective considers ESG as a response to stakeholders' demands for corporations to deal with market failures and offers public goods, especially for state-owned enterprises (Hsu et al., 2021). The third category regards ESG as a sign of agency problem that raises corporate governance issues, such as insiders enhancing their reputation with charities (Barnea and Rubin, 2010) or political causes (Di Giuli and Kostovetsky, 2014) by investing in ESG. Meanwhile, innovation competition has drawn increasing attention in the knowledge-based economy. Both investments in R&D and corporate sustainability are crucial for satisfying a diverse range of stakeholders. Therefore, firms usually need to strike a balance between investing in R&D and corporate sustainability, given the limited resources (Hull and Rothenberg, 2008; Mithani, 2017). For example, in the pharmaceutical industry, some firms prioritize R&D to compete with their rivals, often at the expense of reducing investments in sustainability activities (IFPMA, 0000; Upton, 2017). In this paper, we focus on the aforementioned two fields and aim to answer the question of whether and how technological competition shapes corporate sustainability strategy.

Specifically, the relationship between the technological dimension of product market competition and firm-level sustainable practice is investigated. We focus on technological competition instead of other dimensions of competition, such as price, customer service, and distribution, amongst others, for two reasons. First, it is vital for firms to maintain profitability or even survive in today's knowledge-based economy, especially for firms in the U.S., where technology has been the primary driver of economic growth (Solow, 1956; Zingales, 2000; Eisdorfer and Hsu, 2011). Second, both investments in R&D and sustainability engagement are time-consuming processes. Innovation activities require accumulative investment, and engaging in sustainability, such as investing in workforce health and safety to build loyalty, may pay

* Corresponding author.
*E-mail addresses:* sw19662@essex.ac.uk (S. Wang), cheng.yan@essex.ac.uk (C. Yan), yuqian.zhao@sussex.ac.uk (Y. Zhao).

[1] See details on: https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2020/11/the-time-has-come.pdf.

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off in the long term. Thus, under intense technological peer pressure, firms should balance the prioritization of investing in R&D and social responsibility due to internal competition for scarce resources.

We use the panel data of publicly traded firms in the U.S. from 2002 to 2021 for our study. Following Cao et al. (2018), we construct the technological peer pressure (TPP) to measure technological competition. TPP captures the firm-level technological threats by comparing the R&D stocks of all competitors in an industry to the focal firm's R&D stock. The R&D stock is calculated by the focal firm's cumulative R&D expenditure in most recent years with a 15% decay rate. In other words, TPP measures rivals' technological advances relative to the firm's technological preparedness. Concerning the fact that TPP only measures the competition from an input perspective, we also construct the patent-based TPP for the robustness to capture the competitive dynamics on the output side. To measure corporate social responsibility, we mainly use two pillar scores, Environmental and social (E&S), provided by the Thomson Reuters ESG database. We expand our analysis on the heterogeneity across different sustainability dimensions. In additional robustness checks, we use an alternative ESG ranking score as the dependent variable collected from the MSCI ESG KLD database to ensure that our findings are not driven by a particular ESG rating methodology.

Controlling for firm-level determinants of social responsibility identified in the existing literature, we uncover robust evidence that technological peer pressure is negatively associated with firms' environmental and social engagement. Our main finding is unaffected when conducting a battery of robustness tests. To be specific, we use (1) the MSCI ESG KLD database to ensure our finding is not biased from the disparity of ESG rating methodology, (2) additional controls for other aspects of competition and fixed effects (such as state fixed effect) to account for omitted variables, (3) different model specification, (4) control the effect of corporate social responsibility reports disclosure, and (5) a regulatory event—the introduction of state-level R&D tax credits as an instrumental variable to address potential endogeneity concerns.

To shed light on plausible underlying mechanisms that may explain the revealed negative relationship, we attribute the inferior E&S performance under technological threats to the resource constraints and agency problems. First, our results indicate that the impact of intensifying technological competition on E&S performance is smaller for firms with more financial slack. This is consistent with the findings of Xu and Kim (2022) that financial constraints are negatively associated with corporate social responsibility engagement. Besides, we investigate firms' strategies of becoming either E&S specialists, who invest in a narrow scope of E&S activities, or generalists, who equally invest in all E&S categories. We find that firms tend to be E&S specialists rather than generalists under technological peer pressure. This aligns with the idea that undertaking a wide range of sustainability activities introduces barriers for firms by requiring multidimensional knowledge (Fu et al., 2020). Under intense competition, firms prefer to be involved in a narrow range of E&S activities due to limited resources. Finally, we investigate the resource constraint channel by examining whether innovation efficiency alters our main results. We find a weaker impact on high innovation efficiency firms, indicating these firms can achieve innovation success using limited resources. Our findings also support the view that managers engage in E&S policies for their private interests (e.g. Ho et al., 2023). Using proxies from the CEO perspective and board perspective, we observe that the negative relationship is more pronounced in firms with potential agency problems, which is in line with the notion of the disciplinary role of product market competition (e.g., Chen et al., 2023).

We further explore the cross-sectional heterogeneity from different perspectives. First, we investigate whether there is variation in our results based on R&D investment intensity. We divide our sample into R&D intensive industries and non-R&D intensive industries by firm's R&D expenditures over its total assets and the classification, proposed by Loughran and Ritter (2004). We find that the negative effects of TPP on E&S performance are stronger among the firms operating in the R&D-intensive industries. The possible explanation is that, given the cumulative and path-dependent nature of innovation activities, firms in R&D-intensive industries may prioritize R&D and pronouncedly response to technological threats. Second, we document that this negative relationship is less pronounced for firms in the business-to-consumer (B2C) sector where customers are more sensitive to firms' sustainability engagement. Third, we demonstrate a weaker relation between TPP on E&S performance for firms in heavily polluting industries because of their larger fixed inputs compared with firms operating in "green" industries.

Our paper contributes to the existing literature in three-fold. First, we make a contribution to the limited but growing strand of literature on corporate consequences from technological peer pressure. We provide robust evidences of a causal relationship between technological peer pressure and corporate sustainability, which is new to the literature. Previous literature in related fields document the effects of technological peer pressure on product disclosure (Cao et al., 2018), job postings (Cao et al., 2023), auditors' decision-making (Xu et al., 2022) and corporate financial policies (Qiu and Wan, 2015). In this paper, we complement this strand of literature, and our findings shed new light on how technological peer pressure affects corporate social responsibility initiatives and commitments.

Second, by proposing a new determinant of technological peer pressure, we contribute to the large literature on the determinants of corporate sustainability (e.g., Flammer, 2015; Lins et al., 2017). Several studies have documented how the general product market competition influences the corporate social responsibility engagement (e.g., Dupire and M'Zali, 2018; Flammer, 2015; Ding et al., 2022). However, there is no evidence showing whether and how the technology dimension of competition affects firms' social responsibility performance. Our paper complements this strand of literature by empirically evidencing the negative relationship between technological competition and sustainability practice.

Third, to the best of our knowledge, we are the first to explore the unexpected corporate consequence from the peers' R&D. It is not uncommon to conjecture that the peers' R&D will increase the R&D investment of the focal firm, but the potential cost of this R&D herding phenomenon is unclear. Our findings show that technological threats lead to a decrease in sustainability performance, and this relation can be explained by the resource constraints inside the firm and potential agency concerns.

The remainder of this paper proceeds as follows. Section 2 reviews related literature and proposes our hypothesis. Section 3 presents our variable construction, data and sample. Section 4 reports our baseline results as well as results from a series of robustness tests. Section 5 discusses the cross-sectional heterogeneity and we conclude in Section 6.

## 2. Literature review and hypothesis development

### 2.1. Literature review

There is a growing body of research focusing on corporate social responsibility issues, particularly in investigating the determinants of corporate sustainability at both the macro and micro levels. Some of these studies explore how social norms, characteristics of the economies and regulations affect firms' social responsible engagements (Di Giuli and Kostovetsky, 2014; Liang and Renneboog, 2017; Ding et al., 2022; Peng et al., 2023). There is a stream of literature focusing on whether and how a firm's financial status, such as profitability, credit constraints and ownership, influences corporate sustainability (Hong et al., 2012; Dyck et al., 2019; Xu and Kim, 2022; Hsu et al., 2021). From an insider horizon, the characteristics of firms' leadership and corporate governance structures also play crucial roles in firms' engagement in socially responsible activities (Ferrell et al., 2016; O'Sullivan et al., 2021; Benlemlih et al., 2022). Additionally, some research works document that the peer effect plays an important role in firms' corporate sustainability decisions (Li and Wang, 2022).

The existing research on corporate sustainability determinants presents diverse perspectives on the impact of competition on corporate sustainability. Some researchers suggest that the firms would look for a product differentiation strategy to enhance market power or establish a stronger connection with their customers by prompting better social performance (Flammer, 2015; Dupire and M'Zali, 2018; Leong and Yang, 2020; Fernández-Kranz and Santaló, 2010; Du et al., 2011; Ding et al., 2022). The product differentiation strategy can help them keep profitability or at least survive in the intense competition environment. For instance, employing a difference-in-differences methodology, Flammer (2015) finds that importing tariff reductions (exogenous increase in competition) increases firms' corporate social responsibility performance. Besides, engaging in socially responsible practices can be regarded as a strategy to compete, as good social responsibility performance leads to lower cost of capital (El Ghoul et al., 2011; Cheng et al., 2014). To sum up, the existing studies indicate the strategic nature of social initiatives.

Another vein of literature demonstrates competitive product market environment can reduce investment in corporate sustainability. These studies are in line with the resource constraints view (Hong et al., 2012; Xu and Kim, 2022), and agency concerns view (Ferrell et al., 2016; Krüger, 2015; Hsu et al., 2021) on corporate sustainability. Hong et al. (2012) consider corporate sustainability as a luxurious good so only well-performed firms can afford it, which also refers to "doing good by doing well". In the context of competition, with the squeezed profit margin, firms are forced to focus on survival, leading to an abandon of long-term investment, such as corporate sustainability. What is more, prior literature shows the disciplinary role of the product market competition in curbing insiders' behaviour to pursue private interests, such as political career, positive image to the public or just personal preference (Di Giuli and Kostovetsky, 2014; Masulis and Reza, 2015). Hence, firms tend to reduce their sustainability investment under intensifying competition.

Nonetheless, the existing studies mainly use the Hirschman–Herfindahl Index (HHI) or 10-K-based Product Market Fluidity (introduced by Hoberg et al., 2014) as proxies of product market competition. There are few works of literature that directly discuss the relationship between technological competition and corporate sustainability. Therefore, further empirical analyses and discussions on this specific relationship are needed. Our paper aims to fill this research gap.

### 2.2. Hypothesis development

To explore the relationship between technological competition and corporate sustainability, we draw upon arguments related to resource constraints and agency problem. First, intensifying product market competition can diminish corporate sustainability activities due to resource constraints. Firms facing resource constraints tend to forgo long-term investment, such as corporate sustainability, which has been well documented in previous studies (e.g., Hong et al., 2012). In the context of technological competition, firms concern to lose market power and growth opportunities, and may even face survival challenges if they cannot maintain a competitive advantage in the innovation competition (Cao et al., 2018). In a knowledge-based economy, succeeding firms in technological competition gain market power by reducing production costs, developing new products or product lines, and adding new features to their product. Thus, innovation capability is critical to firms. At the same time, R&D activities require significantly fixed assets investing, while corporate sustainability demands lower investments in fixed assets, making it comparatively easier to reverse. Hence, when facing threats from rivals' technological advances, a firm may cut its expenditure on corporate social responsibility practices with constrained resources.

Second, according to the agency model, product market competition can reduce corporate sustainability by restraining firm insiders' pursuits of personal interests through socially responsible activities. Jensen (1986) and Jensen and Meckling (1976) point out that managers have the incentives to overinvest for their own interests. Insiders may pursue their personal interests due to the severe information asymmetry problem in a less competitive market. Besides, because the majority of corporate sustainability activities require long-term investment and only yield results over the long term, their actions might not be immediately recognized. By investing in socially responsible activities, insiders may benefit from obtaining positive reputations, establishing social visibility after retiring from the company, and satisfying personal altruistic preferences. Furthermore, shareholders are willing to sacrifice for corporate sustainability when they are satisfied with the firm's profitability (Fernández-Kranz and Santaló, 2010). Thus, in an intensifying market competition industry, the squeezed profit margin compels insiders to focus on the firm survival, and as a result, firms can behave worse in social responsibility performance. Consequently, a firm's corporate sustainability efforts may be caused by the agency concern. Based on the aforementioned literature and discussion, we propose the following:

**Hypothesis.** Technological peer pressure has a negative effect on firms' corporate sustainability performance.

## 3. Measures, data and sample

In this section, we introduce the data sources and discuss the construction of the main variables that will be used in the empirical analyses. We also present the distribution and descriptive statistics of our sample.

### 3.1. Measures

#### 3.1.1. Corporate sustainability performance

To evaluate the firm-level social responsibility performance, we obtain data from the Refinitiv ESG database (also known as Thomson Reuters ASSET 4), which has been extensively adopted by researchers in corporate social responsibility related studies (e.g., Amiraslani et al., 2023; Asimakopoulos et al., 2023). Based on verifiable reported data in the public domain, such as annual reports, company websites, NGO websites, stock exchange filings, media outlets and sustainability or ESG reports in the public domain, Refinitiv ESG ratings consist of over 450 ESG measures (including both ESG compliance and ESG initiatives) with a history dating back to 2002. We focus on the Environmental and Social pillar scores as the primary proxies of firms' social responsibility performance.[2]

Refinitiv rates firms' environmental performance in three categories: product innovation, resource reduction and emission reduction. Social performance is evaluated in four categories: product responsibility, community, human rights and workforce. Each subcategory contains several E&S performance themes. For example, the emission reduction category contains four themes: carbon dioxide emission, waste, biodiversity and environmental management systems. The product responsibility category covers themes of responsible marketing, product quality and data privacy. The environmental and social scores are the relative sum of the category weights, which can vary across

[2] The Governance pillar score is excluded in our analysis because we are interested in the effect of technological peer pressure on environmental and social activities. It is common in the literature on corporate social responsibility that researchers always focus on the environmental and social performance and exclude the financial and governance factor in the analysis (e.g., Dyck et al., 2019; Albuquerque et al., 2020; Naughton et al., 2019). However, when we investigate firms' engagement in governance issues by using the corporate governance pillar score, the explored negative relationship still holds.

industries. The pillar weights are normalized to percentages ranging between 0 and 100 (also in letter grades from D− to A+) and provided annually.

In our paper, we consider firms with at least two years of historical data available, and most of the firms (approximately 95.3% of observations) are covered from 2005 onward.[3] For robustness checks in Section 4.2 we also obtain E&S performance data from the MSCI ESG KLD database (KLD), which is another major ESG data provider, to avoid potential bias with respect to the choice of data vendors.

#### 3.1.2. Technological peer pressure

One important part of this paper is to calculate the technological competition in the product market, which will be the key independent variable in our analysis. Although there are some technological competition measures proposed in recent studies, those measures mainly capture the technological competition in the technology space (Qiu and Wan, 2015; Bloom et al., 2013; Glaeser and Landsman, 2021). The measure of technological peer pressure (TPP) is inspired by the product market rivalry variable proposed in Bloom et al. (2013). Cao et al. (2018) modify it and construct the $TPP$ variable, which gauges a firm's technological threat that comes from its peers' technological advances proxied by R&D investments. The logic behind is that a sample firm $i$'s technological threat comes from a peer firm $j$'s R&D stock $G_{j,t}$ at the end of year $t$ weighted by the closeness $\omega_{ij}$ between these two firms in the product market. Considering the R&D investment benefits a firm in an extended period, Bloom et al. (2013) apply a depreciation rate of 15% when calculating $G_{j,t}$, Following Jaffe (1986): $G_{j,t} = R\&D_{j,t} + (1\% - 15\%) * G_{j,t-1}$, where $R\&D_{j,t}$ is the R&D expenditure in year $t$.

The closeness between two firms, $\omega_{ij}$, is calculated in the product market space using firm $i$'s and $j$'s sales in every four-digit Standard Industrial Classification (SIC) industries according to the Compustat Historical Segment database.[4] We denote $V_i$ a $K$-dimensional vector for firm $i$'s share of sales in every four-digit industry $k$. In our sample, each firm reports sales in 2.66 different four-digit industries on average, spanning 224 industries. Then, $\omega_{ij}$ can be defined as the cosine of vectors $V_i$ and $V_j$ in the product market space:

$$\omega_{ij} \equiv cos(\theta_{ij}) = \left\langle \frac{V_i}{\|V_i\|} \cdot \frac{V_j}{\|V_j\|} \right\rangle = \frac{\sum_{k=1}^{K} v_{ik} v_{jk}}{\sqrt{\sum_{k=1}^{K} v_{ik}^2}\sqrt{\sum_{k=1}^{K} v_{jk}^2}}. \quad (1)$$

Cao et al. (2018) formally calculate $TPP_{i,t}$ in Eq. (2).[5]

$$TPPi,t = ln\left[1 + \frac{1}{Gi,t}\sum^{i\neq j} \omega_{ij\times Gj,t}\right]. \quad (2)$$

The ratio inside the square bracket is the threats of rivals' technological advances relative to the firm $i$'s own technological preparedness. A higher value of TPP represents firms are under great technological competition from both the preparedness and outputs of R&D spending.[6] The mean of $TPP$ in our sample is 4.41, which means that, on average, peers invest \$81.27 ($e^{4.41} - 1$) in R&D for every dollar of R&D investment by the sample firm.

[3] We also conduct a subsample analysis by dropping the firms with observations of less than 5 consecutive years. The coefficients of $TPP$ are still significant at the 1% level.

[4] Following Bloom et al. (2013) we use sales from the entire sample span to calculate the proportions of each firm's segment sales crossing our analyses. Our results still hold when using the sales from the previous two years to calculate the proportions of each firm's segment sales Following Cao et al. (2018).

[5] The advantages of using TPP are discussed in Cao et al. (2018).

[6] To alleviate the concern that TPP is correlated with other omitted variables, in the untabulated results, we further control whether focal firm lacks R&D investment relative to its rivals. Our main findings are not affected when we conduct the same specification as the baseline regression.

#### 3.1.3. Control variables

Following the literature on other explanatory of E&S performance (Chen et al., 2020; Dyck et al., 2019), we control for a series of firm-level covariates commonly used in most corporate finance research. Based on the accounting data from Compustat, we include the following control variables: firm size (*Size*), *Tobin's Q*, *Leverage* and *Tangibility*. In particular, *Tobin's Q* and *Tangibility* are assumed positively related to firms' E&S performance. *Leverage* is positively related to firms' E&S performance. In this paper, firm size (*Size*) is measured by the natural log of firms' total assets plus one; *Tobin's Q* is calculated by the total assets minus the book value of equity plus the market value of equity over total assets; *Leverage* is measured as the sum of long-term and current debt deflated over total assets; *Tangibility* is defined as the net property, plants and equipment deflated by total assets. All control variables have been winsorized at the 1% level in each tail, and all price-related variables have been adjusted by CPI. The details about the definitions of all variables used in this study are provided in Table A.1.

### 3.2. Data and sample

Our sample covers active public companies traded in the NYSE and NASDAQ. The accounting data are obtained from the Compustat and are used to construct control variables and calculate the $TPP$. To calculate the closeness of any two firms in the product market, we use the Compustat Historical Segment Dataset on each firm's sales, which is broken down into four-digit SIC codes. The E&S performance data is from the Refinitiv ESG database. The full sample period ranges from 2002 to 2021 fiscal year. The sample starts in 2002 since it is the first year of firm-level ESG ranks available from Refinitive. We start with a total of 118,973 firm-year observations, and we then exclude 12,074 observations from the finance industry (SIC 6000-6999) and utility industry (SIC 4900-4999) because these industries have different competition landscapes and unique nature of their business operations (Li and Zhan, 2019). Second, we drop 71,914 firm-year observations that do not have R&D stock information and sales information in the sample year following Cao et al. (2018). Third, we exclude 131 observations without sustainability data. Finally, we eliminate 22,792 observations without the control variables and singleton observations. After these data clean processes, we get an unbalanced panel dataset of 12,062 observations in 1,536 unique firms from 2002 to 2021.[7] Table 1 reports our sample by two-digit industry and year. We find that most of firms from our sample are operating in R&D-intensive industries, and the Refinitive ESG database covers more firms in recent years. Table 2 shows descriptive statistics for all variables used for primary results. One can refer to Table A.1 in the Appendix for the definition of the variables.

We use the lagged $TPP$ as our key independent variable. The mean and standard deviation of $TPP_{t-1}$ are 4.41 and 2.33, respectively, consistent with Cao et al. (2018). The maximum value and mean values of $TPP_{t-1}$ at the enterprise level are 14.23 and 4.41, respectively, and the standard deviation is greater than 1, indicating that there are large gaps between the firms included in the study. The dependent variables in our paper are *Environmental* and *Social* pillar scores. A larger value of these variables indicates better E&S performance. The standard deviation of *Environmental* and *Social* are 31.76 and 23.75, respectively. This shows that there exist big divergences between firms, which is in line with previous studies that firms' social responsibility

[7] According to the methodology of the Refinitiv ESG database, the ESG scores will be marked as "definitive" for all historical years excluding the five most recent. Specifically, in our sample, the years before 2017 are unchanged even if there are changes to the underlying data due to company restatements or data corrections. To alleviate the concern that the changed ESG score may affect our results, we repeat our baseline model using the subsample from 2002 to 2016. The results are quantitatively similar to our baseline results.

**Table 1**
Distribution of sample firm-year observations by industry and year.

Panel A Distribution of sample firm-year observations by industry

| 2-Digit SIC | Industry description | Frequency | Percentage (%) |
|---|---|---|---|
| 28 | Chemicals and allied products | 2737 | 22.69 |
| 73 | Business services | 1584 | 13.13 |
| 36 | Electronic and other electrical equipment | 1549 | 12.84 |
| 38 | Instruments and related products | 1220 | 10.11 |
| 35 | Industrial and commercial machinery and computer equipment | 1214 | 10.06 |
| Others | – | 3758 | 31.16 |
| Total | | 12,062 | 100.00 |

Panel B Distribution of sample firm-year observations by year

| Year | Frequency | Percentage (%) |
|---|---|---|
| 2002 | 152 | 1.26 |
| 2003 | 179 | 1.48 |
| 2004 | 232 | 1.92 |
| 2005 | 262 | 2.17 |
| 2006 | 269 | 2.23 |
| 2007 | 285 | 2.36 |
| 2008 | 333 | 2.76 |
| 2009 | 373 | 3.09 |
| 2010 | 390 | 3.23 |
| 2011 | 399 | 3.31 |
| 2012 | 410 | 3.40 |
| 2013 | 422 | 3.50 |
| 2014 | 457 | 3.79 |
| 2015 | 636 | 5.27 |
| 2016 | 849 | 7.04 |
| 2017 | 1070 | 8.87 |
| 2018 | 1189 | 9.86 |
| 2019 | 1337 | 11.08 |
| 2020 | 1459 | 12.10 |
| 2021 | 1359 | 11.27 |
| Total | 12,062 | 100.00 |

*Note*: This table reports the two-digit Standard Industrial Classification (SIC) codes industry (Panel A) and annual (Panel B) distribution of the sample. The sample is comprised of 12062 firm-year observations over the period 2002–2021.

**Table 2**
Summary statistics.

| Variables | N | Mean | sd | q1 | Median | q3 |
|---|---|---|---|---|---|---|
| $TPP$ | 12,062 | 4.41 | 2.33 | 2.56 | 4.20 | 6.20 |
| $Environmental$ | 12,062 | 33.57 | 31.76 | 0.00 | 27.41 | 62.52 |
| $Social$ | 12,062 | 48.99 | 23.75 | 29.89 | 46.31 | 67.84 |
| $Size$ | 12,062 | 7.73 | 2.20 | 6.16 | 7.85 | 9.38 |
| $Tobin's\ Q$ | 12,062 | 2.19 | 1.64 | 1.20 | 1.65 | 2.51 |
| $Leverage$ | 12,062 | 0.23 | 0.19 | 0.07 | 0.21 | 0.34 |
| $Tangibility$ | 12,062 | 0.40 | 0.35 | 0.15 | 0.30 | 0.56 |
| $TNIC-HHI$ | 8700 | 0.31 | 0.26 | 0.11 | 0.21 | 0.42 |
| $HHI$ | 12,062 | 0.09 | 0.11 | 0.04 | 0.06 | 0.08 |
| $Fluidity$ | 9024 | 6.54 | 3.87 | 3.67 | 5.52 | 8.38 |
| $Environmental\ specialization$ | 11,555 | 0.43 | 0.51 | 0.00 | 0.25 | 0.69 |
| $Social\ specialization$ | 12,022 | 0.56 | 0.36 | 0.27 | 0.55 | 0.76 |
| $Environmental\ KLD$ | 9242 | 0.03 | 0.11 | 0.00 | 0.00 | 0.00 |
| $Environmental\ strength$ | 9242 | 0.05 | 0.12 | 0.00 | 0.00 | 0.00 |
| $Environmental\ concern$ | 9242 | 0.02 | 0.07 | 0.00 | 0.00 | 0.00 |
| $Social\ KLD$ | 9242 | 0.13 | 0.46 | 0.00 | 0.00 | 0.22 |
| $Social\ strength$ | 9242 | 0.27 | 0.47 | 0.00 | 0.00 | 0.50 |
| $Social\ concern$ | 9242 | 0.14 | 0.30 | 0.00 | 0.00 | 0.17 |
| $TPP\ patents\ filling$ | 5654 | 3.59 | 2.01 | 2.01 | 3.47 | 5.04 |
| $TPP\ patents\ issue$ | 5905 | 3.68 | 2.05 | 2.06 | 3.63 | 5.18 |
| $CSR\ reports\ disclosure$ | 11,997 | 0.56 | 2.02 | 0.00 | 0.00 | 1.00 |
| $Tax\ credit$ | 8823 | 10.55 | 2.09 | 9.49 | 10.90 | 12.08 |

*Note*: This table presents the summary statistics (number of observations, mean, standard deviation, first quartile, median and third quartile) for the key variables used in our regressions, including the technological peer pressure, corporate environmental and social performance, and other firm-level control variables. $TPP$ is the measure of technological peer pressure on firms following Cao et al. (2018). The $Environmental$ and $Social$ are corporate sustainability performance collected from the Refinitive ESG database. *Size* is measured by the natural log of firms' total assets plus one. *Tobin's Q* is calculated by the total assets minus the book value of equity plus the market value of equity over total assets. *Leverage* is measured as the sum of long-term and current debt deflated over total assets. *Tangibility* is defined as the net property, plants and equipment deflated by total assets. The sample consists of 12,062 firm-year observations from 2002 to 2021. Firm size (*Size*), *Tobin's Q*, *Leverage* and *Tangibility* are winsorized at the 1% and 99% levels. The Table A.1 provides the definition for the variables.

engagement and compliance are influenced by many factors such as the ownership structure, regions, laws, social forms and industries (Hsu et al., 2021; Cohen et al., 2020; Di Giuli and Kostovetsky, 2014; Liang and Renneboog, 2017; Ding et al., 2022).

Table 3 lists the Pearson correlation coefficients for the key variables. Consistent with our conjectures, we observe a significant negative correlation between E&S performance and 1-year lagged $TPP$, with coefficients of approximately −0.551 and −0.411, respectively.

None of the control variables exhibits considerable correlations with the dependent variable *Environmental* and *Social*, or the explanatory variable $TPP$ to mitigate concern of multicollinearity. Note that the correlations between Refinitive E&S performance scores and KLD E&S performance scores are lower than 0.4, which is in line with the previous studies about the disparities of E&S performance scores for the same firm crossing different rating agencies (Berg et al., 2022; Chatterji et al., 2016).

## 4. Empirical results

In this section, we empirically verify our main hypothesis by examining whether the technological competition in the product market affects firm-level E&S performance. We subsequently discuss the empirical results. In Section 4.1, we introduce the baseline model and report the baseline empirical results. Section 4.2 conducts a set of robustness checks by using alternative measures of E&S performance, different fixed effect combinations, and subsample analysis, adding additional control for product market competition. Lastly, to alleviate the endogeneity concerns, we adopt the instrumental variables approach in Section 4.3.

### 4.1. Baseline

Let us first concentrate on the following baseline model,

$$Sustainability\ performance_{i,t} = \alpha + \beta TPP_{i,t-1} + \gamma \mathbf{X}_{i,t-1} + FEs + \varepsilon_{i,t}. \quad (3)$$

where $i$ denotes a firm, and $t$ denotes a year. The dependent variable $Sustainability\ performance_{i,t}$ can be chosen as either the *Environmental* or *Social* rating score for firm $i$ in year $t$, and the key independent variable $TPP_{i,t-1}$ is the technological peer pressure for firm $i$ in year $t-1$.[8] The coefficient $\beta$ is what we are interested in, which represents the effect of technological competition on firms' sustainability performance.

$\mathbf{X}_{i,t-1}$ is a vector of the firm-level control variables described in Section 3 including *Size*, *Tobin's Q*, *Leverage* and*Tangibility*. $FEs$ are fixed effects. Given the variability of E&S performance across industries and its evolution over time, we add the industry and year fixed effects to further control the time-invariant industry-level characteristics and the variation across years to avoid omitted variables.[9] Throughout empirical analysis, standard errors are clustered at the firm level to correct for cross-section correlation.

As shown in Table 4 Column (1) and (4), we first estimate the baseline model without any controls. The coefficients of $TPP$ on *Environmental* and *Social* pillars are, −7.518 and −4.188, respectively, and they both are significant at the 1% significance level. After taking account for the firm-level controls, as well as year- and industry-fixed effects, we find the negative relation between the technological competition in the product market and firm-level E&S performance remains significant both statistically and economically. Specifically, in Column (3), the coefficient of the key dependent variable $TPP$ is −1.883, which implies that a one-standard-deviation increase in $TPP$ is associated with approximately a 4.39 (−1.883*2.33) units decrease in the firm's environmental performance. It accounts for 13.1% (4.39/33.57) of the sample mean of *Environmental*. The magnitude for *Social*, in Column (6), is about 7.3% (−1.528*2.33/48.99).

Moreover, the coefficients of firm-level controls echo the findings in previous research on the determinants of E&S performance. The coefficient of *Size* and *Tobin's Q* are significantly positive, which indicates bigger firms and better performance firms also do well in E&S activities, which is in line with the view "doing good by doing well" (Hong et al., 2012). The negative association between *Leverage* and E&S performance is consistent with the findings that financial slack also predicts E&S engagement (Xu and Kim, 2022). Firms with a higher proportion of tangible assets tend to perform better in E&S aspects.

The cost and materiality of corporate sustainability engagement vary among firms (e.g., Khan et al., 2016). To further explore the heterogeneity across different sustainability dimensions, we substitute the dependent variables *Environmental* and *Social* with their subcategory scores. This allows us to investigate whether or not our results on the negative relationship are driven by any specific factor. According to the Refinitive ESG rating methodology, each pillar score is calculated based on the weighted value of its subcategory scores. The Environmental pillar includes subcategory scores of environmental innovation, resource reduction and emission reduction. Social performance is rated in four categories: product responsibility, community, human rights and workforce.[10] As shown in Appendix Table 5, the coefficients of TPP still remain negative significantly across all Environmental and Social subcategory scores. In terms of economic significance, on average, a one-standard-deviation increase in $TPP$ is associated with a decrease of 15.5% in the environmental innovation score and 13.2% in the resource reduction score. Notably, we find that $TPP$ has a big influence on a firm's emission category score. A one-standard-deviation increase in $TPP$ is associated with approximately 5.63 (−2.415*2.33) units decrease in the firm's emission reduction, which accounts for 16.0% of the sample mean of emission reduction score. Consistent with the baseline findings, the economic significance on social category scores, while appearing smaller, still indicates a 3.4% and 6.6% decrease in the community and product responsibility categories, respectively. A potential explanation is that the cost of investment in environment-related activities is relatively higher than those associated with social issues. Thus, firms might be less inclined to engage in these costly activities in conditions of intense technology competition. These findings suggest that TPP remains robust to worsen firms' sustainability, but the magnitude of the impact can vary across subcategories.

### 4.2. Robustness tests

#### 4.2.1. Alternative measures of ESG

In the baseline regression, we use the Refinitive ESG rating to proxy firms' sustainability performance. However, some studies find that different methodologies and data sources provided by various ESG rating vendors may result in different ESG scores for the same firm (Berg et al., 2022; Chatterji et al., 2016). Chatterji et al. (2016) suggest cross-validation of the results with alternative ESG data providers. To tackle with this issue, we reperform the baseline model using ESG scores from another ESG rating vendor: MSCI ESG KLD database, which has been widely used in previous research (e.g., Cheng et al., 2022; Albuquerque et al., 2019). The KLD provides comprehensive data on firm-level social ratings across a number of criteria, including community, workforce diversity, employee relations, human rights, environment impact, product quality, corporate governance, and whether a firm's operations are related to tobacco, alcohol, gaming, firearms, military contracting, nuclear power. A firm receives one "Strengths" (or "Concerns") point for each socially positive (or poor) act it performs in each dimension. In this study, we only consider the KLD rating scores for environmental and social dimensions (including community, diversity, employee relations and product).[11]

[8] Our main results are unaffected when we use the log scores of E&S performance instead of raw scores. Besides, we replicate our baseline estimation by using $TPP_t$ as the main independent variable. The coefficients are −1.809 and −1.469 respectively, and they are significant at the 1% significance level.

[9] We use the three-digit SIC code to define industries. Our main results are robust to the Fama–French 48-industry classification for industries.

[10] The definitions of each category score are shown in Table A.2.

[11] We exclude the dimension of human rights because this category is only applied to a few companies so the variation of human rights is negligible (Chen et al., 2020).

**Table 3**
Correlation coefficients.

| Variables | *TPP* | *Environmental* | *Social* | *Size* | *Tobin's Q* | *Leverage* | *Tangibility* | *TNIC − HHI* | *HHI* | *Fluidity* | *Environmental specialization* | *Social specialization* | *Environmental KLD* | *Environmental strength* | *Environmental concern* | *Social KLD* | *Social strength* | *Social concern* | *Tax credit* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *TPP* | 1.000 | | | | | | | | | | | | | | | | | | |
| *Environmental* | −0.551 *** | 1.000 | | | | | | | | | | | | | | | | | |
| *Social* | −0.411 *** | 0.748 *** | 1.000 | | | | | | | | | | | | | | | | |
| *Size* | −0.681 *** | 0.713 *** | 0.567 *** | 1.000 | | | | | | | | | | | | | | | |
| *Tobin's Q* | 0.244 *** | −0.258 *** | −0.124 *** | −0.345 *** | 1.000 | | | | | | | | | | | | | | |
| *Leverage* | −0.142 *** | 0.164 *** | 0.127 *** | 0.224 *** | −0.102 *** | 1.000 | | | | | | | | | | | | | |
| *Tangibility* | −0.287 *** | 0.356 *** | 0.178 *** | 0.333 *** | −0.263 *** | 0.160 *** | 1.000 | | | | | | | | | | | | |
| *TNIC − HHI* | −0.134 *** | 0.063 *** | −0.038 *** | 0.033 *** | −0.122 *** | 0.065 *** | 0.189 *** | 1.000 | | | | | | | | | | | |
| *HHI* | −0.230 *** | 0.089 *** | 0.021 ** | 0.165 *** | −0.108 *** | 0.043 *** | 0.164 *** | 0.159 *** | 1.000 | | | | | | | | | | |
| *Fluidity* | 0.256 *** | −0.316 *** | −0.086 *** | −0.330 *** | 0.231 *** | −0.165 *** | −0.343 *** | −0.504 *** | −0.196 *** | 1.000 | | | | | | | | | |
| *Environmental specialization* | 0.000 | −0.116 *** | −0.090 *** | 0.036 *** | −0.048 *** | 0.025 *** | 0.049 *** | 0.109 *** | 0.075 *** | −0.247 *** | 1.000 | | | | | | | | |
| *Social specialization* | 0.289 *** | −0.612 *** | −0.821 *** | −0.412 *** | 0.101 *** | −0.131 *** | −0.112 *** | 0.011 | −0.002 | 0.127 *** | 0.057 *** | 1.000 | | | | | | | |
| *Environmental KLD* | −0.168 *** | 0.247 *** | 0.224 *** | 0.152 *** | −0.018 * | 0.034 *** | −0.018 * | −0.003 | −0.042 *** | −0.056 *** | −0.022 ** | −0.196 *** | 1.000 | | | | | | |
| *Environmental strength* | −0.271 *** | 0.306 *** | 0.251 *** | 0.265 *** | −0.065 *** | 0.077 *** | 0.038 *** | 0.022 * | −0.006 | −0.101 *** | −0.018 * | −0.183 *** | 0.820 *** | 1.000 | | | | | |
| *Environmental concern* | −0.192 *** | 0.125 *** | 0.067 *** | 0.207 *** | −0.082 *** | 0.077 *** | 0.093 *** | 0.042 *** | 0.057 *** | −0.079 *** | 0.004 | 0.003 | −0.212 *** | 0.386 *** | 1.000 | | | | |
| *Social KLD* | −0.091 *** | 0.274 *** | 0.344 *** | 0.144 *** | 0.113 *** | −0.000 | −0.100 *** | −0.090 *** | −0.125 *** | 0.095 *** | −0.086 *** | −0.285 *** | 0.312 *** | 0.229 *** | −0.120 *** | 1.000 | | | |
| *Social strength* | −0.171 *** | 0.198 *** | 0.264 *** | 0.195 *** | 0.094 *** | 0.030 *** | −0.092 *** | −0.080 *** | −0.033 *** | 0.038 *** | −0.033 *** | −0.202 *** | 0.432 *** | 0.557 *** | 0.255 *** | 0.786 *** | 1.000 | | |
| *Social concern* | −0.184 *** | 0.077 *** | 0.054 *** | 0.196 *** | −0.024 ** | 0.042 *** | 0.036 *** | 0.001 | 0.080 *** | −0.057 *** | 0.044 *** | 0.011 | 0.163 *** | 0.451 *** | 0.508 *** | −0.292 *** | 0.362 *** | 1.000 | |
| *Tax credit* | 0.621 *** | −0.113 *** | 0.040 *** | −0.093 *** | 0.176 *** | −0.067 *** | −0.257 *** | −0.397 *** | −0.191 *** | 0.236 *** | −0.051 *** | −0.041 *** | 0.000 | −0.083 *** | −0.138 *** | 0.158 *** | 0.097 *** | −0.096 *** | 1.000 |

***Note***: This table shows the pairwise correlation coefficients of key variables used in our analysis. The sample used in the main regression comprises 12,062 firm-year observations covering the period 2002–2021. *TPP* is the measure of technological peer pressure on firms following Cao et al. (2018). The *Environmental* and *Social* are corporate sustainability performance collected from the Refinitive ESG database. *Size* is measured by the natural log of firms' total assets plus one. *Tobin's Q* is calculated by the total assets minus the book value of equity plus the market value of equity over total assets. *Leverage* is measured as the sum of long-term and current debt deflated over total assets. *Tangibility* is defined as the net property, plants and equipment deflated by total assets. The Table A.1 provides the definition of variables. The symbols ***, **, and * indicate significance at the 1%, 5%, and 10% confidence levels, respectively.

**Table 4**
Baseline regression: TPP and corporate sustainability performance.

| Variables | Environmental | | | Social | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $TPP_{t-1}$ | −7.518*** | −1.470*** | −1.883*** | −4.188*** | −0.480** | −1.528*** |
| | (0.261) | (0.266) | (0.264) | (0.204) | (0.230) | (0.246) |
| | (0.261) | (0.266) | (0.265) | (0.204) | (0.231) | (0.248) |
| $Size_{t-1}$ | | 8.670*** | 9.865*** | | 6.073*** | 7.452*** |
| | | (0.295) | (0.315) | | (0.262) | (0.269) |
| $Tobin's\ Q_{t-1}$ | | 0.181 | 0.974*** | | 1.181*** | 0.976*** |
| | | (0.226) | (0.219) | | (0.201) | (0.182) |
| $Leverage_{t-1}$ | | −0.932 | −7.823*** | | 0.345 | −4.463** |
| | | (2.382) | (2.068) | | (2.095) | (1.863) |
| $Tangibility_{t-1}$ | | 11.637*** | 13.270*** | | −0.137 | 7.299*** |
| | | (1.772) | (2.113) | | (1.619) | (1.765) |
| N of Obs. | 12,062 | 12,062 | 12,062 | 12,062 | 12,062 | 12,062 |
| Adj. $R^2$ | 0.304 | 0.531 | 0.653 | 0.169 | 0.328 | 0.521 |
| Industry FE | NO | NO | YES | NO | NO | YES |
| Year FE | NO | NO | YES | NO | NO | YES |

***Note***: This table reports the baseline results from examining the effects of *TPP* on firms' environmental and social performance using OLS regression. The sample is comprised of 12062 firm-year observations over the 2002–2021 period. The dependent variables are *Environmental* and *Social*, which are collected from the Refinitive ESG database. The main variable of interest is $TPP_{t-1}$, technological peer pressure, which indicates the technological threats from rivals in the product market space. Column (1) and (4) include no control variables, and fixed effects; Column (2) and (5) include firm-level controls; Column (3) and (6) include firm-level controls and industry and year fixed effects. Industries are defined based on the three-digit Standard Industrial Classification (SIC) codes. The Table A.1 provides the definition of variables. *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively. Robust standard errors are reported in parentheses with standard errors robust to heteroskedasticity and clustered by firm.

**Table 5**
Relationship between TPP and different corporate sustainability subcategories.

| Variables | Environmental | | | Social | | | |
|---|---|---|---|---|---|---|---|
| | Innovation | Resource use | Emission | Product responsibility | Community | Human rights | Workforce |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| $TPP_{t-1}$ | −1.665*** | −2.185*** | −2.415*** | −1.350*** | −0.909*** | −1.145*** | −2.175*** |
| | (0.309) | (0.309) | (0.301) | (0.368) | (0.293) | (0.322) | (0.311) |
| N of Obs. | 12,060 | 11,557 | 12,062 | 12,062 | 12,062 | 12,022 | 12,062 |
| Adj. $R^2$ | 0.478 | 0.614 | 0.602 | 0.300 | 0.359 | 0.497 | 0.483 |
| Controls | YES | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES |

***Note***: This table presents results of OLS regressions of *TPP* on firms' *Environmental* and *Social* subcategories using the control variables and fixed effects from the baseline model. The definitions of these category scores are shown in the Table A.2. Industries are defined based on the three-digit Standard Industrial Classification (SIC) codes. The Table A.1 provides the definition of variables. *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively. Robust standard errors are reported in parentheses with standard errors robust to heteroskedasticity.

Following previous studies (Deng et al., 2013), we first exclude the controversial business involvement rating, i.e., whether a firm's operations are related to "sin" sectors such as tobacco, and alcohol, because firms cannot change their primary business operations, and these dimensions are mainly industry level and only score "Concerns". We calculate the annual Strength (Concern) score by summing up the total number of strengths (concerns) divided by the maximum number of strengths (concerns) for each dimension. Then, we subtract the concerns from the strengths to obtain the total corporate sustainability score: $Environmental\ KLD$ and $Social\ KLD$.

We re-analyse the baseline model using these two sustainability measures as the dependent variables.[12] As shown in Table 6 Column (1) and (4), the negative relationship between $TPP$ and firm-level E&S performance remains unchanged. Thus, the association between firms' sustainability performance and $TPP$ is not likely driven by the peculiarity of the Refinitive data.

As discussed in Section 2, a firm that engages in ESG may result from agency problems. Due to the unique rating methodology of the KLD ESG score, i.e., the corporate social responsibility performance equals strengths minus concerns, we can further divide the $Environmental\ KLD$ and $Social\ KLD$ into two parts: Environmental (Social) strength and concern, and then we test if the negative relation between $TPP$ and E&S performance results from agency problems. Indicated by the findings of Krüger (2015) that investors are sensitive to negative ESG events but not to positive ESG events, firms without agency concerns may spare no effort on mitigating the ESG concerns. On the contrary, if the goal of firm insiders is to pursue their own desires, engaging in philanthropy and personal interests, e.g., building a positive socially friendly image, rather than creating value for shareholders, they are more likely to invest more in strengths. Hence, we expect that, when facing intense competition in the product market, the negative relation will be more significant or only exist between $TPP$ and the Strength. We rerun the regression with the dependent variables replaced by Strength and Concern of environmental and social score. Table 6 Column (2) and (5) show the negative relations are still significant. In contrast, Column (3) and (6) indicate there is no significant association between $TPP$ and concerns. These results support the view that E&S engagement stems from agency problems. We will further test the agency view in Section 5.2.

[12] The latest version of the KLD database has been updated to 2019. Thus, after merging with our main sample, there are fewer observations compared with the baseline regression.

**Table 6**
Robustness tests: Alternative corporate sustainability and TPP measures.

Panel A: Alternative corporate sustainability measures

| Variables | Environment KLD | Environmental strength | Environmental concern | Social KLD | Social strength | Social concern |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $TPP_{t-1}$ | −0.007*** | −0.007*** | −0.000 | −0.021*** | −0.023*** | −0.002 |
| | (0.001) | (0.002) | (0.001) | (0.006) | (0.006) | (0.004) |
| N of Obs. | 9242 | 9242 | 9242 | 9242 | 9242 | 9242 |
| Adj. $R^2$ | 0.202 | 0.251 | 0.200 | 0.211 | 0.223 | 0.212 |
| Controls | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES |

Panel B: Patent-based TPP measures

| Variables | Environmental | | Social | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $TPP\ patents\ filling_{t-1}$ | −1.590*** | | −1.412*** | |
| | (0.464) | | (0.397) | |
| $TPP\ patents\ issue_{t-1}$ | | −1.854*** | | −1.465*** |
| | | (0.451) | | (0.373) |
| N of Obs. | 5651 | 5900 | 5651 | 5900 |
| Adj. $R^2$ | 0.636 | 0.639 | 0.555 | 0.550 |
| Controls | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES |

*Note*: This table presents the relationship between $TPP$ and corporate sustainability performance with alternative dependent sustainability measure and patent-based TPP measures. The ESG data comes from the MSCI ESG KLD database. In the Panel A, the dependent variables $Environmental\ KLD$ and $Social\ KLD$ are defined as the adjusted sum of strengths scores minus the adjusted sum of concerns scores for each firm year. $Social\ KLD$ includes community, diversity, employee relations and product attributes. The $Strength$ and $Concern$ are defined as the adjusted sum of strengths scores and the adjusted sum of concerns scores, respectively. The main variable of interest is $TPP_{t-1}$, technological peer pressure, which indicates the technological threats from rivals in the product market space. Panel B shows the results using an alternative patent-based TPP measure, which is constructed by replacing the proxies of R&D stock with the number of yearly patents filled and issued. Industries are defined based on the three-digit Standard Industrial Classification (SIC) codes. The Table A.1 provides the definition of variables. *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively. Robust standard errors are reported in parentheses with standard errors robust to heteroskedasticity.

#### 4.2.2. Patents-based TPP measure

In our baseline regressions, we construct the $TPP$ based on the firms' R&D investment, which captures the innovation competition on the input side. However, innovation competition is multidimensional as well, such as the race on patenting (e.g., Cappelli et al., 2023; Xu et al., 2023). Consequently, there is a concern that the negative relationship between technological peer pressure and corporate sustainability could be affected by a specific measure of technological peer pressure. To ensure our primary results are robust to alternative measures of TPP, we modify Eq. (2) discussed in Section 3.1.2 by replacing R&D stock $G_{j,t}$ with the number of patents filled and issued in a given year $t$.[13] The new patent-based TPP captures the level of technology competition from the output perspective. The correlation between the patent-based TPP and our original R&D investment-based TPP is approximately 0.8, indicating a strong connection across different dimensions of technological competition. As presented in Appendix Table 6 Panel B, the coefficients of TPP are significant statistically and economically. For instance, a one-standard-deviation increase in $TPP\ patent\ filling$ is associated with a decrease of 8.3% and 5.4% to Environmental and Social performance, respectively. The negative relationship between technological peer pressure and firms' E&S performance remains unchanged by investigating the output-side competition of innovation.

#### 4.2.3. Other robustness checks

We conduct a series of robustness tests to mitigate concerns that the negative relation between $TPP$ and E&S performance is driven by omitted variables and sample selection.

**Control other dimensions of competition.** Our $TPP$ captures the technological competition from one of the dimensions of the product market. There is a concern that this negative relationship between $TPP$ and E&S performance is mainly driven by general product market competition instead of technological competition. Therefore, we add three different firm-specific competition measures in our baseline model separately in order to capture the product market competition in general terms. They are product market concentration measure Herfindahl–Hirschman Index ($HHI$), the 10-K Text-based Network Industry concentration ($TNIC-HHI$) and the 10-K based Product Market Fluidity ($Fluidity$). The $HHI$, calculated as the sum of the squared market share of all members in the focal firm's two-digit SIC industry, is widely used in previous research as the measure of product market competition (e.g., Cao et al., 2023). The $TNIC-HHI$, introduced by Hoberg et al. (2014) and Hoberg and Phillips (2016), are based on the Text-based Network Industry Classifications (TNIC), identifying competitors to each firm using business descriptions disclosed in their 10-Ks.[14] $Fluidity$ measures the similarity between a firm's products and the moves made by its competitors in the firm's product market. The more a firm's product lines overlap with its rivals' product lines, the greater the competitive threat the firm faces. Both of these text-based measures of product market competition have been

[13] The number of observations are fewer than that used in the benchmark regressions due to the absence of patenting information for certain firms in the United States Patent and Trademark Office (USPTO) database. We conduct the baseline regression using the sample of firms with patent information. The primary findings still hold.

[14] The data are available on the authors' website: https://hobergphillips.tuck.dartmouth.edu/.

employed in previous studies, e.g., see, Chen et al. (2023), Li and Zhan (2019) and Alimov (2014). In Table 3, we show the correlation between $TPP$ and these three competition measures. The correlations between $TPP$ and $HHI$, $TNIC-HHI$ and $Fluidity$ are −0.230, −0.134 and 0.256, respectively, which are all significant at the 1% significance level. The low absolute values of the correlations suggest that these measures capture different dimensions of product market competition. Table 7 Panel A reports the results after controlling the different product market competition measures. The coefficients of $TPP$ are all significantly negative, and the magnitude is compatible to our baseline results.

**Alternative sets of fixed effects.** In the baseline regression, we use industry and year level fixed effects to control the industry-level time-invariant factors and year-specific effects. In order to mitigate the concern that our findings are sensitive to the choices of fixed effects combinations, we rerun our baseline regression with other fixed effects. The results are documented in Table 7 Panel B. We first control the firm- and year-fixed effects as shown in Column (1) and (4). Then, we add the state fixed effect, in Column (2) and (5), since the previous study shows that the headquarter location of firms can influence their ESG engagements due to the political leaning (Di Giuli and Kostovetsky, 2014). Besides, according to Gormley and Matsa (2014)'s findings, it is vital to control industry-year fixed effects as the Refinitive ESG score is industry-demeaned. We reanalyze the baseline regression with extra industry-year fixed effect to capture the variation from specific years in industries. The results are reported in Table 7 Panel B Column (3) and (6). We find that the negative relationship between $TPP$ and firms' E&S performance is robust to different fixed effects combinations.

**Changes instead of levels.** The environmental and social strategies may be stable for several years (Benlemlih et al., 2022). The $TPP$ may influence the E&S strategies differently from these firms to the firms with flexible E&S strategies. To address this concern, we conduct a change model: estimating the association between changes in $TPP$ and changes in E&S performance. As reported in Table 7 Panel C, the coefficients of $\Delta TPP$s are still negatively significant at the 10% significance level, indicating that changes in $TPP$ contribute to changes in E&S performance. This is in concordance with our main findings.

**Control corporate social responsibility (CSR) reports disclosure.** The CSR reporting is one of the main sources for the ESG rating agency to assess firm sustainability engagement. One may argue that the worsened sustainability performance may not driven by the TPP but by the stand-alone CSR reports disclosure. Ryou et al. (2022) find that the heightened product market competition from the reduction in import tariffs decreases the propensity and quality of voluntary corporate social responsibility reporting. To enhance the reliability of our baseline findings, we additionally control the impact of CSR report disclosure. The $CSR\ reports\ disclosure$ indicates whether a firm discloses a separate CSR report or a section on sustainability engagement in its annual report. Panel D in Table 6 presents the results with the same specification as the baseline model, and the coefficients on $TPP$ remain significantly negative. The economic significance of $TPP$ to $Environmental$ and $Social$ is 13.2% and 7.4%, respectively, which is close to the results obtained from the baseline regressions.

### 4.3. Endogeneity concerns

The potential endogeneity problem can bias the OLS coefficients. The main concern is the omitted variable issues: some unobservable factors not included in the baseline regression model may affect firms' E&S performance. Furthermore, there is a reverse-causality concern: firms with poor E&S performance often face higher financing costs, which in turn hinders their ability to invest in R&D. Firms would get more technological peer pressure at this time. To address these problems, we adopt an instrumental variable (IV) approach to mitigate the endogeneity concerns.

We employ the introduction of state-level R&D tax credit to calculate the instrumental variable $Tax\ credit$. This event can lower the cost of R&D activities by firms headquartered in the affected states, which introduces exogenous increases to R&D (Wilson, 2009). Thus, $Tax\ credit$ satisfies the relevance requirement for an IV. Besides, the introduction of the state-level R&D tax credit is legislature support that can promote the overall R&D in an economy (Byun et al., 2023; Wilson, 2009), so it is unlikely related to firms' sustainability strategies. We, thereby, deem the state-level R&D tax credit can be regarded as exogenous to firms' E&S performance.

To better understand our IV, we decompose $TPP$ into two components, see Eq. (2). $TPP$ can be divided by whether the state in which the peer firm is headquartered is the same state as the focal firm.

$$TPPi,t = ln\left\{1+\frac{1}{Gi,t}\left[\sum^{i\neq j}\omega_{ij}\times G_{j,t}\times I(S_{i,t}\neq S_{j,t}) + \sum^{i\neq j}\omega_{ij}\times G_{j,t}\times I(S_{i,t}=S_{j,t})\right]\right\}, \quad (4)$$

where $I(\cdot)$ is an indicator function that represents if the focal firm and its peer firm are headquartered in the same state. $S_{i,t}$ is the state in which firm $i$ headquarter located in year $t$.

Then, we can construct our instrumental variable $Tax\ credit$ as follows:

$$Tax\ credit_{i,t} = \sum^{i\neq j}\omega_{ij}\times I(Tax\ credit(S_{j,t}))\times I(S_{i,t}\neq S_{j,t}), \quad (5)$$

where $I(Tax\ credit(S_{j,t}))$ denotes if peer firm $j$ is headquartered in the state that has introduced tax credit at year $t$. The $Tax\ credit$ captures the increases of R&D stocks for the peer firms as the consequence of exogenous regulatory changes. $Tax\ credit$ is not highly correlated with $TPP$ but it is unlikely to affect the focal firm's E&S performance.

In Table 8, we present the IV estimation results by using $Tax\ credit$ as the instrument variable.[15] We find that, in the first stage, the IV are significantly positively associated with the $TPP$, as we expected. In the second stage, the fitted values of $TPP$ are negatively related to the $Environmental$ and $Social$ scores, which corroborate our primary findings in Section 4.1. The Kleibergen–Paap F statistic is extremely high, which indicates that the instrument is very strong. Thus, the negative relationship between technological peer pressure and firm-level E&S performance remains statistically significant after accounting for the potential endogeneity.

## 5. Cross-sectional analysis

Having identified the negative relationship between technological peer pressure and firm-level E&S performance, we subsequently investigate the cross-sectional heterogeneity of our main results. In this section, we employ multiple tests to explore the potential mechanisms between technological peer pressure and firm-level E&S performance.

### 5.1. Resource constraints

Previous studies have documented that more profitable firms perform better in social responsibility activities, implying that investing in corporate sustainability is luxurious, e.g., see, Hong et al. (2012). This is in line with the view of corporate sustainability that only well-performing firms can afford to invest in corporate sustainability activities, which is commonly referred to as "doing good by doing well". In this sub-section, we aim to investigate whether the uncovered negative relationship between TPP and E&S performance is driven by limited resources. We conduct several tests to check if this relation can be explained by the resource constraint assumption.

[15] We use a reduced sample because the introduction of state-level R&D tax credit only applied to firms headquartered in the U.S. So the firms located outside the U.S. are excluded. We also repeat the OLS regression using this subsample. The findings in the 4.1 are unaffected.

**Table 7**
Robust tests: additional controls, different fixed effects, changes instead of levels.

Panel A: Additional product market controls

| Variables | Environmental | | | Social | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $TPP_{t-1}$ | −1.885*** | −2.776*** | −1.891*** | −1.527*** | −2.497*** | −1.537*** |
| | (0.264) | (0.465) | (0.265) | (0.246) | (0.382) | (0.254) |
| $HHI_{t-1}$ | −5.312 | | | 2.371 | | |
| | (5.958) | | | (4.908) | | |
| $TNIC-HHI_{t-1}$ | | 0.821 | | | −0.312 | |
| | | (1.889) | | | (1.622) | |
| $Fluidity_{t-1}$ | | | −0.290* | | | 0.203 |
| | | | (0.172) | | | (0.150) |
| N of Obs. | 12,062 | 8700 | 9024 | 12,062 | 8700 | 9024 |
| Adj. $R^2$ | 0.653 | 0.601 | 0.602 | 0.521 | 0.506 | 0.496 |
| Controls | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES |

Panel B: Different level fixed effects

| Variables | Environmental | | | Social | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $TPP_{t-1}$ | −4.422*** | −1.616*** | −1.931*** | −3.327*** | −1.385*** | −1.435*** |
| | (1.027) | (0.259) | (0.272) | (0.922) | (0.254) | (0.258) |
| N of Obs. | 12,062 | 8827 | 11,315 | 12,062 | 8827 | 11,315 |
| Adj. $R^2$ | 0.864 | 0.609 | 0.644 | 0.815 | 0.507 | 0.497 |
| Controls | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | NO | YES | YES | NO |
| Industry | NO | YES | NO | NO | YES | NO |
| Firm FE | YES | NO | NO | YES | NO | NO |
| State FE | NO | YES | NO | NO | YES | NO |
| Industry*Year FE | NO | NO | YES | NO | NO | YES |

Panel C: Changes instead of levels

| Variables | Δ Environmental | | Δ Social | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $\Delta TPP$ | −0.971 | −1.569** | −1.464* | −1.460* |
| | (0.610) | (0.656) | (0.783) | (0.861) |
| N of Obs. | 10,486 | 9790 | 10,486 | 9790 |
| Adj. $R^2$ | 0.034 | 0.096 | 0.012 | 0.054 |
| Controls | YES | YES | YES | YES |
| Year FE | YES | NO | YES | NO |
| Industry FE | YES | NO | YES | NO |
| Industry*Year FE | NO | YES | NO | YES |

Panel D: Control CSR reports disclosure

| Variables | Environmental | | Social | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $TPP_{t-1}$ | −1.900*** | −1.940*** | −1.547*** | −1.448*** |
| | (0.264) | (0.272) | (0.247) | (0.259) |
| $CSR\ reports\ disclosure$ | 0.776 | 0.676 | 0.660** | 0.589* |
| | (0.505) | (0.481) | (0.319) | (0.303) |
| N of Obs. | 11,990 | 11,244 | 11,990 | 11,244 |
| Adj. $R^2$ | 0.655 | 0.646 | 0.522 | 0.499 |
| Controls | YES | YES | YES | YES |
| Year FE | YES | NO | YES | NO |
| Industry FE | YES | NO | YES | NO |
| Industry*Year FE | NO | YES | NO | YES |

***Note***: This table report four robustness tests. Panel A presents the results with extra product market competition measures: $HHI_{t-1}$, $HHI_{t-1}$ and $Fluidity_{t-1}$. Panel B repeat the baseline model with different fixed effect combinations: state fixed effect, firm fixed effect and industry*year fixed effect. Panel C reports the results of analysing the impact of changes in $TPP$ on changes in $Environmental$ and $Social$ performance using the control variables from the baseline model. Panel D presents the results with extra control of Corporate Social Responsibility (CSR) report disclosure. Industries are defined based on the three-digit Standard Industrial Classification (SIC) codes. The Table A.1 provides the definition of variables. *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively. Robust standard errors are reported in parentheses with standard errors robust to heteroskedasticity.

 

**Table 8**
Robustness tests: instrumental variable.

| Variables | First stage | Second stage | |
|---|---|---|---|
| | $TPP_{t-1}$ | Environmental | Social |
| | (1) | (2) | (3) |
| $Tax\ credit_{t-1}$ | 0.647*** | | |
| | (0.011) | | |
| $\widehat{TPP_{t-1}}$ | | −0.495* | −0.094 |
| | | (0.254) | (0.290) |
| N of Obs. | 8823 | 8823 | 8823 |
| Adj. $R^2$ | 0.838 | 0.444 | 0.395 |
| Controls | YES | YES | YES |
| Industry FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| Kleibergen–Paap F statistic | 3260 | | |

***Note***: This table presents the results of instrumental variable analysis while controlling for endogeneity. Column (1) shows the first-stage regression of the $Tax\ credit$ on $TPP$. Column (2) and (3) show the results of using the predicted $TPP$ from first-stage regression to estimate the relationship between $TPP$ and $Environmental$ and $Social$ performance. Industries are defined based on the three-digit Standard Industrial Classification (SIC) codes. The Table A.1 provides the definition of variables. *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively. Robust standard errors are reported in parentheses with standard errors robust to heteroskedasticity.

### 5.1.1. Financial constraints

We first examine if the negative relation between technological peer pressure and firm-level performance arises from financial constraints. Corporate sustainability requires a long-term investment and the benefits of engaging in corporate responsibility are likely to manifest over an extended time horizon (Ding et al., 2022). Several studies have shown that financial constraints are negatively associated with firm-level E&S performance (Di Giuli and Kostovetsky, 2014; Ding et al., 2022; Ma et al., 2023). Investment in E&S-related activities is costly, and only the profitable firms or those with good financial situation can afford such endeavours (Xu and Kim, 2022; Hong et al., 2012). When firms face constraints on financial resources, they are more likely to allocate these limited resources to what they consider as vital for their survival. Therefore, under technological peer pressure, we anticipate that firms are inclined to cut costs on E&S activities. Consequently, the negative relationship between TPP and E&S performance exists.

To test our hypothesis discussed in Section 2, we construct two financial constraint proxies to test it. The first is the financial slack, which is computed as the ratio of current assets to current liabilities, and it has been widely used in the literature, e.g., see, Fu et al. (2020). The second is the cash ratio, calculated as the ratio of cash holdings plus short-term investments over total assets. Firms with lower financial slack and cash holdings experience a weaker financial situation.

We divide our sample into high-constrained and low-constrained groups based on the median of the financial slack and cash ratio. We then rerun the baseline model with these subsamples. The results are presented in Table 9 Panel A. Consistent with our prediction and previous research (e.g., Xu and Kim, 2022), we find the negative association is more pronounced if the firms are financially constrained, such as shown in Columns (2) and (6). These results support the view that (a) technological peer pressure motivates firms to reallocate scarce resources between R&D and sustainability (Hull and Rothenberg, 2008; Mithani, 2017), and (b) financially constrained firms are more likely to reduce their ESG investment under intense product market competition (Ding et al., 2022).

### 5.1.2. ESG specialization

In addition to the financial constraints discussed above, we further investigate whether firms alter their corporate sustainability engagement strategy in response to increased technological competition. Fu et al. (2020) find that firms may specialize in one particular ESG dimension while neglecting others. Engaging in broader dimensions of corporate sustainability activities requires the integration of diverse fields of knowledge, which can be more expensive. Thus, firms may face a tradeoff between engaging in a broad range of corporate sustainability dimensions or concentrating on specific areas, conditioning on the limited resources. Given our finding of a negative relation between technological peer pressure and E&S performance, we anticipate that firms may opt to specialize in specific aspects rather than corporate sustainability generalists.

$$Corporate\ sustainability\ specialization = \frac{\left\{\left[\sum_{i=1}^{n}(Category\ score_i - Pillar\ score)^2\right]/n\right\}^{1/2}}{Pillar\ score}, \tag{6}$$

where $Pillar\ score$ is the environmental or social pillar scores; $Category\ score$ is the subdimension scores of each pillar score. To be specific, the environmental pillar comprises three categories: environmental innovation, resource reduction and emission reduction. Social performance is evaluated in four categories: product responsibility, community, human rights and workforce. The term $n$ represents the number of categories for each pillar (three for the environmental pillar and four for the social pillar). An increasing corporate sustainability specialization reflects higher levels of firm specialization in corporate sustainability activities.

We report the results of the relation between $Environmental\ specialization$, $Social\ specialization$ and $TPP$ in Table 9 Panel B. The coefficient of $TPP$ is significantly positive, which indicates firms would focus on specific E&S categories rather than stick to broader, generalized commitments to E&S. This finding supports the view that the relationship may be a result of resource constraints.

### 5.1.3. R&D efficiency

Next, we further investigate the resource constraint channel by investigating whether innovation efficiency influences our main results. As previously discussed, we find observe the firms decrease their engagement in the E&S activities due to resource constraints. Firms prefer to allocate limited resources on R&D-related activities under intense technology competition. However, if firms are more efficient in innovation, they might not be eager to withdraw the effort on the corporate sustainability issues as they have the ability to achieve innovation success with limited resources. Therefore, we expect that firms with high innovation efficiency would decrease less in E&S performance. We measure the innovation efficiency by comparing the innovation output and input, the annual patents applied or granted over the R&D expenditure. After categorizing the sample based on innovation efficiency, we re-estimate the baseline model. The results are presented in Table 9 Panel C. As anticipated, we find a weaker impact on firms with high innovation efficiency.

**Table 9**
Cross-sectional analysis: resource constraints.

Panel A: Financial constraints

| Variables | Environmental | | | | Social | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $TPP_{t-1}$ | −1.474*** | −2.516*** | −1.625*** | −1.726*** | −1.306*** | −1.818*** | −1.270*** | −1.448*** |
| | (0.243) | (0.527) | (0.250) | (0.463) | (0.259) | (0.439) | (0.264) | (0.411) |
| N of Obs. | 5953 | 5967 | 5918 | 5912 | 5953 | 5967 | 5918 | 5912 |
| Adj. $R^2$ | 0.565 | 0.656 | 0.618 | 0.645 | 0.413 | 0.551 | 0.460 | 0.553 |
| Controls | YES | YES | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES |
| Financial constraints proxies | Slack-high | Slack-low | Cash-high | Cash-low | Slack-high | Slack-low | Cash-high | Cash-low |
| Empirical $p$-value | 0.000 | | 0.160 | | 0.010 | | 0.060 | |

Panel B: Corporate sustainability specialization

| Variables | Environmental specialization | | Social specialization | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $TPP_{t-1}$ | 0.039*** | 0.038*** | 0.018*** | 0.017*** |
| | (0.007) | (0.007) | (0.004) | (0.004) |
| N of Obs. | 11,555 | 10,819 | 12,016 | 11,269 |
| Adj. $R^2$ | 0.097 | 0.074 | 0.426 | 0.407 |
| Controls | YES | YES | YES | YES |
| Industry FE | YES | NO | YES | NO |
| Year FE | YES | YES | YES | YES |
| Industry*Year FE | NO | YES | NO | YES |

Panel C: Innovation efficiency

| Variables | Environmental | | | | Social | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $TPP_{t-1}$ | −1.795*** | −2.441*** | −1.737*** | −2.368*** | −1.300*** | −2.479*** | −1.314*** | −2.064*** |
| | (0.247) | (0.751) | (0.246) | (0.799) | (0.248) | (0.562) | (0.246) | (0.581) |
| N of Obs. | 9180 | 2877 | 9023 | 3036 | 9180 | 2877 | 9023 | 3036 |
| Adj. $R^2$ | 0.673 | 0.620 | 0.673 | 0.621 | 0.545 | 0.481 | 0.542 | 0.499 |
| Controls | YES | YES | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES |
| Innovation efficiency | High | Low | High | Low | High | Low | High | Low |
| Proxies | Patents filing | Patents filing | Patents issue | Patents issue | Patents filing | Patents filing | Patents issue | Patents issue |
| Empirical $p$-value | 0.010 | | 0.000 | | 0.000 | | 0.000 | |

*Note*: This table presents the relationship between $TPP_{t-1}$ and firms E&S performance differentiated by the firm's finance constraints, the effect on the corporate sustainability specification, and the innovation efficiency. Panel A, we measure the degree of the financial constraint of a firm either by the financial slack and cash holding across the sample period. Following (Cleary, 1999), we perform Fisher's permutation test of differences in coefficient estimates between two groups. Panel B reports the relationship between $TPP$ and $Environmental\ specification$ and $Social\ specification$, respectively. Panel C shows subsample regression results by innovation efficiency which is measured by the yearly patents filled or issued over the R&D expenditure. The Table A.1 provides the definition of variables. Industries are defined based on the three-digit Standard Industrial Classification (SIC) codes. *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively. Robust standard errors are reported in parentheses with standard errors robust to heteroskedasticity.

### 5.2. Agency problems

Corporate sustainability engagement can be considered as an agency problem (Masulis and Reza, 2015; Cai et al., 2021; Cheng et al., 2023). Firms investing in socially responsible issues may, in part, be driven by managers' pursuit of personal interests at the expense of shareholders' benefits. Jensen (1986) and Jensen and Meckling (1976) argue that managers have the incentive to overinvest because of their personal benefits. Bénabou and Tirole (2010) document that E&S investment is motivated by management's own desire to engage in philanthropy, i.e., "delegated philanthropy". Cheng et al. (2023) refer to this as "do good with other people's money".

In the context of product market competition, intense competition makes firms to decide whether they should prioritize short-term survival or long-term profit-maximizing investment. Some studies have shown that a competitive environment can lead to a poorer E&S performance by alleviating the inside agency concerns (Krüger, 2015; Masulis and Reza, 2015). In other words, product market competition can be viewed as playing a disciplinary role. In low-competitive industries, the agency problem becomes more pronounced. Managerial overinvestment in E&S activities to pursue personal interests is less likely to be detected. Besides, investing in E&S activities may not be identified as an overinvestment, given that E&S investment often involves long-term commitments. Therefore, managers are more inclined to invest E&S in a low-competitive environment. However, in highly competitive industries, the primary focus for firms is survival and gaining a competitive edge. The investment in E&S is less essential for the shareholders.

In this regard, we would like to examine whether the negative relationship between TPP and E&S performance is attributable to agency concern. To assess agency problems from an insider perspective, we utilize two proxies: (1) whether the CEO is close to retirement age; and (2) the tenure of the CEO in the firm.[16] First, if a CEO seeks personal interests, such as building a positive image to the public, and getting good political career prospects, they may invest more in ESG activities, revealing greater agency problems. Second, the longer the tenure of a

[16] CEO retirement age is identified as if the CEO of the firm is above 60 years old (Hsu et al., 2021).

**Table 10**
Cross-sectional analysis: agency problem.

| Panel C: CEO perspective | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Variables | Environmental | | | | Social | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $TPP_{t-1}$ | −3.439*** | −2.984*** | −3.044*** | −2.963*** | −2.903*** | −2.697*** | −3.355*** | −2.064*** |
| | (1.077) | (0.665) | (0.701) | (0.781) | (0.817) | (0.542) | (0.571) | (0.612) |
| N of Obs. | 1517 | 4806 | 3346 | 2887 | 1517 | 4806 | 3346 | 2887 |
| Adj. $R^2$ | 0.618 | 0.585 | 0.583 | 0.601 | 0.552 | 0.509 | 0.509 | 0.534 |
| Controls | YES | YES | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES |
| Agency proxy | CEO retirement age | | CEO tenure | | CEO retirement age | | CEO tenure | |
| Group | Yes | No | High | Low | Yes | No | High | Low |
| Empirical $p$-value | 0.000 | | 0.400 | | 0.040 | | 0.000 | |
| **Panel B: Board perspective** | | | | | | | | |
| Variables | Environmental | | | | Social | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $TPP_{t-1}$ | −2.423*** | −1.460*** | −1.553*** | −2.053*** | −1.940*** | −0.999*** | −1.198*** | −1.624*** |
| | (0.375) | (0.307) | (0.283) | (0.329) | (0.345) | (0.296) | (0.274) | (0.353) |
| N of Obs. | 6364 | 5649 | 4361 | 4332 | 6364 | 5649 | 4361 | 4332 |
| Adj. $R^2$ | 0.636 | 0.698 | 0.669 | 0.601 | 0.541 | 0.539 | 0.529 | 0.491 |
| Controls | YES | YES | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES |
| Agency proxy | CEO duality | | Board independence | | CEO duality | | Board independence | |
| Group | Yes | No | High | Low | Yes | No | High | Low |
| Empirical $p$-value | 0.000 | | 0.050 | | 0.000 | | 0.060 | |

***Note***: This table presents the relationship between $TPP_{t-1}$ and corporate sustainability performance differentiated by the degree of the firm's agency problems. In Panel A, from the CEO perspective, we measure the agency concern by whether CEOs are at retirement age and the CEOs' tenure. In Panel B, we use the proxies of CEO duality and board independence to indicating the agency concerns. Following (Cleary, 1999), we perform Fisher's permutation test of differences in coefficient estimates between two groups. Industries are defined based on the three-digit Standard Industrial Classification (SIC) codes. The Table A.1 provides the definition of variables. *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively. Robust standard errors are reported in parentheses with standard errors robust to heteroskedasticity.

CEO, the more likely are CEOs to be entrenched in the firm, indicating greater agency problems.

Table 10 Panel A presents the results. We find this negative relationship is particularly pronounced in the group where the effects are stronger when the CEO is close to retirement age, as shown in Column (1) and (5). Furthermore, as presented in Column (3) and (7), the effects are stronger in firms with longer-tenure CEOs. Our findings support the view that E&S engagement results from agency problems and the disciplinary role of product market competition.

Moreover, we text the agency problem from the board perspective. The independence of the board denotes firm contexts with potential severity of agency problems (Aktas et al., 2019). The negative effect of TPP on corporate sustainability performance is more substantial for firms with low board independence. Following prior studies (e.g., Gu et al., 2021; Li et al., 2022), we use two common proxies for board independence. The first proxy *CEO duality* is a binary variable that equals one if a sole individual acts as both CEO and chair of the board of a firm. The second proxy *Board independence* is measured as the percentage of strictly independent board members on the board. Firms with CEO duality or lower board independence are more likely to suffer from agency problems. We perform the subsample tests with the same specification as the baseline model. As shown in Table 10 Panel B, the negative relationship between TPP and E&S performance is stronger for firms with severe agency concerns. The results offer empirical support for the perspective that engaging corporate sustainability is indicative of agency problems. Firms are prone to cut their investments on corporate sustainability when faced with intense technological competition.

### 5.3. Industry heterogeneity

The materiality varies from industry due to ESG referring to multiple dimensions (Khan et al., 2016). Thus, a question arises if the negative *TPP-E&S* relationship also depends on the type of industry. In this section, we further perform industry-wise analyses in three-fold. First, we consider the heterogeneity between R&D-intensive industries and non-R&D-intensive industries, as our paper focuses on the technological competition in the product market. The high-tech and low-tech industries in terms of the R&D intensity can be calculated by using a firm's R&D expenditures over its total sales (Fu et al., 2020). In addition, we also use the classification defined by Loughran and Ritter (2004) to divide the sample into high-tech and low-tech groups.

As shown in Table 11 Panel A Column (1) and (2), we find that the negative relation is more pronounced for the firms with high R&D intensity. The potential explanations are as follows: on one hand, innovation activities are highly path dependent and accumulative in nature (Nelson and Winter, 1985), so firms may set R&D activities as the primary task to ensure the success of R&D. Other activities, such as E&S, can be adjusted subject to R&D activities in firms with high R&D intensity or in R&D-intensive industries. On the other hand, in response to technological peer pressure, firms in R&D-intensive industries may be more sensitive and reactive. The results in Panel B, which show the heterogeneity between firms operating in high- and low-tech industries, also support our analysis above.

Second, we explore the consumer- and nonconsumer-facing industries. Previous study shows that firms increase their sustainability as a strategy to differentiate them from their rivals in the product market (Flammer, 2015). In addition, Lev et al. (2010) show that individual customers are more sensitive to firms' social responsibility engagement

**Table 11**
Cross-sectional analysis: industry heterogeneity.

| Panel A: R&D intensity | | | | |
|---|---|---|---|---|
| Variables | Environmental | | Social | |
| | (1) | (2) | (3) | (4) |
| $TPP_{t-1}$ | −1.616*** | −1.341** | −1.215*** | −1.259*** |
| | (0.271) | (0.526) | (0.297) | (0.439) |
| N of Obs. | 6018 | 6036 | 6018 | 6036 |
| Adj. $R^2$ | 0.666 | 0.623 | 0.517 | 0.536 |
| R&D intensity | High | Low | High | Low |
| Empirical $p$-value | 0.010 | | 0.340 | |
| **Panel B: High-tech industry** | | | | |
| Variables | Environmental | | Social | |
| | (1) | (2) | (3) | (4) |
| $TPP_{t-1}$ | −2.721*** | −1.462*** | −1.808** | −0.829*** |
| | (0.933) | (0.268) | (0.716) | (0.255) |
| N of Obs. | 3246 | 8816 | 3246 | 8816 |
| Adj. $R^2$ | 0.555 | 0.652 | 0.514 | 0.478 |
| High-tech industry | Yes | No | Yes | No |
| Empirical $p$-value | 0.000 | | 0.000 | |
| **Panel C: B2C industry** | | | | |
| Variables | Environmental | | Social | |
| | (1) | (2) | (3) | (4) |
| $TPP_{t-1}$ | −1.677*** | −2.475*** | −1.422*** | −1.606*** |
| | (0.258) | (0.568) | (0.285) | (0.464) |
| N of Obs. | 5159 | 6903 | 5159 | 6903 |
| Adj. $R^2$ | 0.723 | 0.589 | 0.532 | 0.513 |
| B2C industry | Yes | No | Yes | No |
| Empirical $p$-value | 0.000 | | 0.030 | |
| **Panel D: Dirty industry** | | | | |
| Variables | Environmental | | Social | |
| | (1) | (2) | (3) | (4) |
| $TPP_{t-1}$ | −1.623*** | −3.152*** | −1.403*** | −2.055*** |
| | (0.275) | (0.698) | (0.270) | (0.568) |
| N of Obs. | 8139 | 3923 | 8139 | 3923 |
| Adj. $R^2$ | 0.681 | 0.582 | 0.536 | 0.490 |
| Dirty industry | Yes | No | Yes | No |
| Empirical $p$-value | 0.000 | | 0.000 | |

***Note***: This table report the heterogeneity between $TPP_{t-1}$ and firm-level sustainability performance. Panel A and B show the heterogeneity between high-tech firms and low-tech firms. We use R&D intensity (Panel A) and R&D-intensive industry classification (Panel B) to divide our sample. Panel C reports the heterogeneity between firms in the B2C sector and the non-B2C sector. Panel D displays the difference between the firms operating in the "dirty" industries and the "green" industries. Following (Cleary, 1999), we perform Fisher's permutation test of differences in coefficient estimates between two groups. Each regression in this table includes the same set of control variables and industry and year fixed effects as in our baseline regressions. Industries are defined based on the three-digit Standard Industrial Classification (SIC) codes. The Table A.1 provides the definition of variables. *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively. Robust standard errors are reported in parentheses with standard errors robust to heteroskedasticity.

compared to industrial buyers. Thus, firms in consumer-facing industries invest more in E&S-related activities to maintain customer loyalty or build positive images to the public. Consequently, we observe that the negative relationship between TPP and E&S performance can be weaker in the consumer-facing industries than in the nonconsumer-facing industries. In order to examine this assumption, we divide the firms into two categories: operating in the B2C sector and non-B2C sectors, Following Lev et al. (2010).[17] Then we rerun the baseline regression using these two subsamples. As is shown in Table 11 Panel C Column (1) and (3), the negative effect is significantly weaker for firms operating in the B2C industries, consistent with the differentiation view of firms' E&S engagement.

Third, we consider the "dirty" industries. Firms in pollution-intensive industries, such as chemicals, are always under great pressure from environmental regulations and get relatively low sustainability ranking (Liu and Zhang, 2023). It is harder for firms with bad performance on corporate social responsibility to get access to external financing (Cheng et al., 2014). To maintain their competitiveness, firms in pollution-intensive industries would have a greater motivation in E&S investment. Furthermore, heavily polluting firms may be less flexible in adjusting their E&S engagement due to their larger fixed inputs compared with firms operating in "green" industries (Liu et al., 2019). Thus, we expect that the negative relationship between TPP and E&S performance would be weaker for firms in "dirty" industries.

To this end, we divide our sample into two groups based on whether the firms are operating in the "dirty" industries. We obtain the "dirty" industries from Berrone et al. (2013) and classify the "dirty" industries

[17] The firms are assigned in the B2C sector by their four-digit SIC codes: 0000–0999, 2000–2399, 2500–2599, 2700–2799, 2830–2869, 3000–3219, 3420–3429, 3523, 3600–3669, 3700–3719, 3751, 3850–3879, 3880–3999, 4813, 4830–4899, 5000–5079, 5090–5099, 5130–5159, 5220–5999, 7000–7299, 7400–9999.

**Table A.1**
Variable definitions.

| Variables | Definition |
|---|---|
| *TPP* | Technological peer pressure for firm $i$ at the end of fiscal year $t$. $TPPi,t = ln\left[1 + \frac{1}{Gi,t}\sum^{i\neq j}\omega_{ij\times Gj,t}\right]$. Firm $i$'s technological threat comes from a peer firm $j$'s R&D stock $G_{j,t}$ at the end of year $t$ weighted by the closeness $\omega_{ij}$ between these two firms, where $\omega_{ij} = \left\langle \frac{V_i}{\lVert V_i \rVert} \cdot \frac{V_j}{\lVert V_j \rVert} \right\rangle$. $V_i$ is the vector of firm $i$'s sales with the $k$th element being the share of firm $i$'s total sales in the preceding two years made in industry (four-digit SIC) $k$. |
| *Environment* | Environmental pillar score of Refinitiv ESG Score. |
| *Social* | Social pillar score of Refinitiv ESG Score. |
| *Size* | Natural log of firms' total assets. |
| *Tobin's Q* | Total assets minus the book value of equity plus the market value of equity, all divided by total assets. |
| *Leverage* | The sum of long-term debt and current debt deflated by total assets. |
| *Tangibility* | Net property, plant and equipment divided by total assets. |
| *Environmental KLD* | The adjusted sum of environment strengths scores minus the adjusted sum of environment concerns scores across in environmental dimension from MSCI KLD ESG database. |
| *Environmental strength* | The adjusted sum of environment strengths scores. |
| *Environmental concern* | The adjusted sum of environment concerns scores. |
| *Social KLD* | The adjusted sum of social strengths scores minus the adjusted sum of social concerns scores across in environmental dimension from the MSCI KLD ESG database. Social includes community, employee relation, diversity and product. |
| *Social strength* | The adjusted sum of social strengths scores. Social includes community, employee relation, diversity and product. |
| *Social concern* | The adjusted sum of social concerns scores. Social includes community, employee relation, diversity and product. |
| *TPP patents filling* | The technological peer pressure based on the number of patents filled in a given year. |
| *TPP patents issue* | The technological peer pressure based on the number of patents issued in a given year. |
| *HHI* | The sum of the squared market share of all members in the focal firm's 2-digit SIC industry. |
| *TNIC-HHI* | The 10-K Text-based Network Industry concentration based on the Text-based Network Industry Classifications (TNIC) introduced by Hoberg et al. (2014) and Hoberg and Phillips (2016). |
| *CSR reports disclosure* | A dummy variable indicates whether a firm discloses a separate CSR report or a section on sustainability engagement in its annual report. |
| *Fluidity* | The similarity between a firm's products and the moves made by its competitors in the firm's product market introduced by Hoberg et al. (2014) and Hoberg and Phillips (2016). |
| *Tax credit* | The degree to which peer firms are exposed to state-level R&D tax credit. |
| *Environmental specialization* | The standard deviation of the performance on Environmental divided by the Environmental scores. |
| *Social specialization* | The standard deviation of the performance on Social divided by the Social scores. |
| *Innovation efficiency* | The annual patents applied or granted over the R&D expenditure. |
| *Financial slack* | The ratio of current assets to current liabilities. |
| *Cash* | Cash holding scaled by total assets. |
| *CEO retirement age* | A dummy variable that equals one if the CEO of the firm is above 60 years old, and zero otherwise. |
| *CEO tenure* | The number of years the CEO has become in the focal firm. |
| *CEO duality* | A binary variable that equals one if a sole individual acts as both CEO and chair of the board of a firm. |
| *Boardindependence* | The percentage of strictly independent board members on the board. |
| *R&D intensity* | The ratio of a firm's R&D expenditures to its total assets. |
| *High tech Industry* | The classification defined by Loughran and Ritter (2004). |
| *B2C industry* | The classification used by Lev et al. (2010). |
| *Dirty industry* | The classification defined by Berrone et al. (2013). |

***Note***: This table presents the variable definitions.

**Table A.2**
Refinitive ESG scores structure.

| Pillars | Categories |
|---|---|
| Environmental | Innovation: firm's ability to create new market opportunities through new environmental technologies and processes, or eco-designed products. |
| | Resource use: firm's performance and capacity in reducing the use of materials, energy or water and promoting supply chain management. |
| | Emissions: firm's commitment and effectiveness towards reducing environmental emissions and wastes. |
| Social | Product responsibility: firm's capacity to produce quality products, integrating the customer's health and safety, integrity and data privacy. |
| | Community: firm's commitment to protecting public health and adhering to business ethics. |
| | Human rights: firm's effectiveness in undertaking fundamental human rights initiatives. |
| | Workforce: firm's initiatives of providing job satisfaction, a healthy and safe workplace, maintaining diversity, and career development and training for its employees. |

***Note***: This table presents the Refinitive ESG scores structure and definitions of the subdimensions of Environmental and Social pillars.

based on the total amount of toxic emissions.[18] Table 11 Panel D reports the results. Column (1) and (3) indicate firms in the "dirty" industries are less likely to reduce their E&S initiatives under technological peer pressure. This finding indicates the importance of corporate sustainability to "dirty" industries and implies the cost of sustainability engagement.

## 6. Conclusion

With increasing attention to corporate sustainability, this paper sheds light on a less debated topic in relation to corporate sustainability, that is, the association between technological peer pressure and corporate sustainability. We use an extensive unbalanced panel dataset of 12 062 firm-year observations from 1536 public list firms in the U.S. over 20 years to empirically explore the effect of technological competition on firm-level sustainability engagement. Different from previous studies exploring the relationship between product market competition and firms' corporate sustainability, we use a measure of technological peer pressure to capture the threats from the technology dimension in the product market. The rationale is that technological competition is crucial for firms to succeed and possibly even survive in the knowledge-based economy.

We find compelling evidence indicating that technological peer pressure decreases corporate sustainability performance, as measured by the Refinitive Environmental and Social pillar scores. Our findings remain robust across various measures of corporate sustainability measures, additional controls for other aspects of competition and fixed effects, different model specifications, alternative patent-based TPP measures, and IV approach to control for endogeneity. In the analyses, our findings support the argument that the resource constraints and agency problem may explain the negative relationship between technological peer pressure and corporate sustainability. First, we highlight the significant role of financial slack in diminishing corporate social responsibility performance. Second, firms would focus on a narrow range of sustainability activities. Third, the impact is weaker for firms with high innovation efficiency. Fourth, from the CEO and board perspectives, we demonstrate the disciplinary role of corporate sustainability engagement by using information from CEOs. Moreover, we debate the industry's cross-sectional heterogeneity. We observe that the negative association is notably stronger for firms operating in R&D-intensive industries, high-tech industries, non-B2C industries and "green" industries.

Overall, our collective evidence enhances our understanding of the consequences of technological competition and the determinants of corporate sustainability. In contrast to prior studies that primarily focus on general product market competition, (e.g., Ding et al., 2022; Flammer, 2015), this paper provides a new perspective on technological competition and investigates the unexpected corporate consequences from the peers' R&D advances. Additionally, we establish a connection between technological peer pressure and corporate sustainability, contributing to the growing literature on the determinants of firms' ESG engagements (e.g., Bénabou and Tirole, 2010).

Given the increasing importance of corporate social responsibility and innovation in the knowledge-based economy, our findings hold practical relevance and provide implications for firms, shareholders and related stakeholders. Regulators should encourage firms to play a more proactive role in promoting sustainability, rather than viewing ESG as a strategic tool for pursuing private interests. Additionally, our findings suggest that firms need to should pursue an optimized resource allocation strategy to achieve synergies in integrating sustainability and R&D.

While our study has provided strong evidence regarding the impact of technological peer pressure on corporate sustainability performance, we admit a few limitations that could guide future research directions. First, in this paper, we focus on the technology competition in the product market. For future research, it would be interesting to examine the relationship between technological peer pressure and corporate sustainability within the technology sector. Second, due to the limitation of data availability, our paper utilizes the sample of publicly traded firms in the United States. Given the significant differences in competition landscapes and business environments across countries, future studies could expand our investigation to include global evidence.

[18] Berrone et al. (2013) identify 20 most pollution industries according to the total amount of toxic emissions from U.S. Environmental Protection Agency's (EPA) TRI (Toxic Release Inventory) program data. The top 20 most polluting industries in the U.S. as defined by two-digit SIC code are 10, 50, 33, 49, 28, 36, 12, 13, 20, 32, 30, 51, 26, 34, 29, 31, 35, 37, 24, and 27. We also use this classification and get the same results. Following Dupire and M'Zali (2018), we also use another dirty industries classification, the firms operating in SIC 2000–3999, to reestimate and get similar results.

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## Appendix

See Tables A.1 and A.2.

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