Product market competition and carbon disclosure: Evidence from China

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ABSTRACT

Based on a sample of Chinese publicly listed firms in eight high energy-consuming industries from 2015 to 2019, this study investigates the relationship between the intensity of product market competition and carbon disclosure and explores the moderating effect of earnings pressure and environmental legitimacy pressure on this relationship. Using content analysis to construct an integrated measure of corporate carbon disclosure, we find that the intensity of product market competition is negatively associated with carbon disclosure. The negative relationship between the intensity of product market competition and carbon disclosure is more pronounced among firms facing fewer earnings pressures and greater environmental legitimacy pressures. The additional tests also show that the effect of product market competition on carbon disclosure is more pronounced among state-owned firms and large firms. Our results are robust to various robustness tests. This study extends the literature on carbon disclosure and has important implications for different stakeholders to promote corporate climate-related disclosure in China.

KEYWORDS

Product market competition; carbon disclosure; earnings pressure; environmental legitimacy pressure

JEL

G32; Q5

Introduction

The redundancy theory highlights that firms engaging in environmental activities are trade-offs between the costs and benefits of their environmental management [18]. In practice, as one aspect of environmental strategies, carbon disclosure is regarded as an instrument for firms to maintain and strengthen their long-standing relationship with stakeholders. In response to rising stakeholder expectations around decarbonization, many firms voluntarily disclose the information on carbon emissions generated by products in CSR reports to show their environmental responsibility. However, such disclosure may also contain some sensitive information that could be exploited by firms’ competitors in the same industry, which will in turn hinder firms’ disclosure willingness. Thus, it is unclear whether and how carbon disclosure is affected by the intensity of product market competition, which is less explored by the existing literature. To fill this gap, we conduct the first study, to the best of our knowledge, by examining the relationship between product market competition and carbon disclosure based on a sample of Chinese listed firms in eight high energy-consuming industries.

China, as the largest emerging economy, provides an interesting setting for conducting this research. First, climate change caused by excess greenhouse gas emissions has posed the biggest long-term risk to the global economy and human welfare. Over the past few years, as one of the largest emitters of greenhouse gases, China has experimented with ways to cut carbon emissions, one of which is the carbon trading scheme (henceforth, ETS). In December 2017, China’s ETS was officially launched and initially started trading emissions in the power sector, covering more than 1,700 firms with around 30,000 tCO2 emissions per year. The volume accounts for 30% of national carbon emissions.

Second, according to China’s 14th Five-Year Plan, national carbon emissions are expected to hit a peak by 2030 to reach carbon neutrality by 2060. Given that climate change has been acknowledged as one of the top concerns in China, in the context of pursuing a low-carbon economy, stakeholders are concerned not only about how carbon emissions affect environmental and financial performance, but also demand detailed and comprehensive disclosure of carbon impact [1,2]. Since then, firms have been gradually increasing their awareness of carbon disclosure. However, in practice, due to the lack of mandatory
disclosure requirement for non-financial information, especially carbon emission information in China, the quality and reliability of disclosure are still inadequate, which calls for more research on the improvement of carbon disclosure.

Our motivation for linking the intensity of product market competition to firm carbon disclosure stems from the following considerations. First, carbon disclosure, perceived as an information governance tool, refers to the provision of information regarding corporate carbon management and the consideration of carbon risk to stakeholders via either mandatory or voluntary reporting of firms’ carbon footprints [3]. The central logic behind carbon disclosure is to translate corporate carbon profiles into an evaluation of the climate risks and market opportunities with clear financial implications for both internal and external stakeholders [4]. In response to concerns that stakeholders lack sufficient and timely information regarding firms’ carbon emissions and climate risk management efforts, several studies embarked on investigating the broader effects of firms’ carbon disclosure, including firm value [5,6], firm performance [7] as well as the value of investors’ decision-making [8]. Meanwhile, another strand of literature extends further by exploring the motivation and determinants of firms’ carbon disclosure behavior. For example, Jaggi et al. suggest that the extent to which firms engage in carbon disclosure is largely determined by environmental policy stringency, private sector resilience and market structure [9]. Similarly, Luo et al. provide evidence that regulatory requirements and public engagement are two major drivers of corporate carbon reporting [10]. Some other factors which might also affect firms’ willingness to disclose carbon information include legitimacy and information management systems [11] and resource constraints [12]. The pressures arising from legitimacy and stakeholders are two key contributors to carbon disclosure, which have been well-documented in the existing literature, while less attention has been paid to the product market competition, which is another important external factor.

Second, as a crucial external governance disciplinary mechanism, product market competition can exert an important influence on enterprise strategic decision-making and enterprise value. Existing research shows that competition in the productized market can reflect the extent to which one firm competes with other existing and potential competitors in the process of production, sales and profit-seeking, which gives rise to corporate disclosure to a large extent [13,14]. Potential and existing competitive threats can directly affect the quality and quantity of voluntary disclosure. As a significant part of voluntary information disclosure, there has been no attempt to examine whether carbon disclosure is determined by product market competition.

Third, so far, in the existing literature, the relationship between product market competition and corporate disclosure is inconclusive. On one hand, product market competition may have an interference effect on corporate disclosure [15]. The proprietary costs which aid competitors by revealing proprietary information are high when firms actively engage in corporate disclosure in a competitive environment [16]. On the other hand, firms can also benefit from voluntary disclosure as they can differentiate themselves, by creating an environmentally-friendly public image, from less well-managed firms in the competition [17]. In addition, Zhou et al. find a non-linear relationship between product market competition and information disclosure [18].

Based on the discussion above, we in this paper, borrowing from the theory of corporate disclosure, attempt to examine whether and how the intensity of product market competition affects corporate carbon disclosure. To examine the relationship between the intensity of product market competition and firms’ carbon disclosure, we use a sample of Chinese publicly listed firms in eight high energy-consuming industries from 2015 to 2019. Due to the lack of a well-developed database on corporate carbon disclosure information in China, the biggest challenge we face is the measurement of corporate carbon disclosure. As noted in prior literature, an assessment of corporate carbon disclosure can be realized either in the form of a questionnaire survey [19] or by employing content analysis based on different materials [20]. A typical example of the former is a commonly-used climate disclosure score developed by CDP based on an annual survey of firms on behalf of institutional investors and other stakeholders. The other approach involves content analysis, which is also broadly used in the prior literature [20–22]. Owing to the data availability, we address the issue of carbon disclosure measurement by constructing an integrated CDI index to capture the level of firms’ carbon disclosure. Specifically, we hand-collect all textual information about carbon profiles of firms in eight energy-intensive industries published in
stand-alone CSR reports and sustainability reports from 2015 to 2019 and convert them into a quantitative scale to evaluate how firms perform on carbon disclosure (See Appendix A for the detailed content of index construction). In this way, we have a final sample of 183 firms with 726 firm-year observations from 2015 to 2019. The baseline results show a negative relationship between the intensity of product market competition and carbon disclosure, suggesting that fierce product market competition results in a decline in the level of corporate carbon disclosure. Next, we explore the moderating effects of earnings pressure and environmental legitimacy pressure on the relationship between the intensity of product market competition and carbon disclosure. We find that earnings pressure and environmental legitimacy pressure moderate this relationship through which the negative association between the intensity of product market competition and carbon disclosure is more pronounced among firms facing fewer earnings pressures or greater environmental legitimacy pressures.

Moreover, given that state ownership is an influential factor in corporate decisions in China, we divide the full sample into two sub-samples: state-owned enterprises (SOEs) vs. non-SOEs. The results show that the negative relationship between the intensity of product market competition and carbon disclosure is more pronounced among firms with state ownership. Apart from corporate ownership, we dig deeper into the firm-level heterogeneity by examining whether the relationship between product market competition and carbon disclosure varies with firm size. Our results are robust to using different samples, regression models, measures of product market competition and endogeneity tests.

Overall, our study makes three contributions to the literature. First, owing to the data availability, this study addresses the issue of carbon disclosure measurement by constructing an integrated CDI index to comprehensively evaluate the level of firms’ carbon disclosure. Our measurement index system can enrich the research in the field of environmental accounting, promote research methods for investigating carbon disclosure, and provide a theoretical significance for related research.

Second, our study provides a deeper insight into the determinants of carbon disclosure. Most of the prior literature mainly covers a wide range of economic determinants and regulatory determinants [23]. Our study joins the growing literature that examines the relationship between product market competition and corporate disclosure by providing a key insight into another important non-financial dimension of corporate disclosure, which is carbon disclosure [24]. To the best of our knowledge, our study is the first to examine the relationship between product market competition and corporate carbon disclosure in China and, thus, contributes to the literature on the determinants of carbon disclosure from the perspective of product market competition.

Third, our moderating effect analysis and cross-sectional analysis provide evidence that the effect of product market competition on carbon disclosure may vary depending on different external environments and different firm characteristics. This study offers a framework and expands the research on the determinants of carbon disclosure.

The remainder of this paper proceeds as follows. Section 2 presents the institutional background. Section 3 reviews the theory and develops testable hypotheses. Section 4 describes our sample, data and research design. Section 5 reports the results. Section 6 conducts robustness checks. Section 7 concludes the paper.

Institutional background

Chinese listed firms have been long criticized for their poor quality and reliability of corporate disclosure, especially nonfinancial disclosure. This is because of the lack of mandatory disclosure requirements for nonfinancial information, including carbon emissions. Since 2016, China has introduced a series of environmental policies to improve firms’ carbon reporting. Recently, firms have been gradually increasing their awareness of carbon disclosure, which attracts mass attention from the stakeholders (i.e., consumers).

In 2016, China proposed the "13th Five-Year Plan for Controlling Greenhouse Gas Emissions" (henceforth, the Plan), which encourages enterprises to actively disclose greenhouse gas emissions information and promotes the establishment of an information disclosure system for firms’ greenhouse gas emissions. Meanwhile, the Plan proposes to establish a mandatory disclosure mechanism for listed firms’ environmental
protection information, as well as imposes penalties on firms that fail to meet disclosure requirements. However, since the release of the Plan, there have been no institutional provisions specifically for firms’ carbon disclosure. Therefore, at this stage, the carbon information of Chinese firms is mainly disclosed voluntarily.

While China does not have a dedicated carbon disclosure system, some policies address provisions for carbon disclosure. In August 2016, the People’s Bank of China and six other government agencies jointly issued the Guidelines for establishing the Green Financial System (henceforth, the Guidelines). The Guidelines propose the development of various types of carbon finance products and require relevant enterprises to strengthen carbon information disclosure. This improves institutional investors’ ability to analyze the carbon footprint of their managed assets and in turn reduces carbon-related financial risks.

After that, in December 2017, China’s ETS was officially launched and initially started trading emissions in the power sector. In December 2019, the Ministry of Finance issued the Interim Provisions on the Accounting Treatment of Carbon Emissions Transactions (henceforth, the Interim Provisions). The Interim Provisions require firms participating in ETS to disclose relevant information in the notes to financial statements, including carbon reduction strategies, carbon emissions, carbon allowances, carbon trading, carbon accounting methods, etc.

In July 2020, The Stock Exchange of Hong Kong Limited (“HKEX”) implemented the third edition of the Environmental, Social and Regulatory Reporting Guidelines (the “ESG Guidelines”). The ESG Guidelines require listed companies to disclose significant climate issues which have affected and may affect issuers, as well as direct (Scope 1) and indirect (Scope 2) greenhouse gas emission targets. The HKEX suggests that listed companies should deepen their understanding of climate risks through the Working Group Standards on Climate-related Financial Disclosure. In December 2021, the Ministry of Ecology and Environment issued the Administrative Measures for Environmental Information, requiring eligible enterprises and listed companies to disclose information including carbon emissions and carbon emission facilities. Subsequently, the Guidelines for Environmental Information refine the content of corporate environmental information disclosure, stipulating that firms should disclose information such as the actual carbon emissions and carbon accounting method.

Product market competition is a dynamic process affected by consumers’ and investors’ choice on products, which reflects their preferences toward goods and services according to their needs. Being aware of the climate risk, global consumers began to pay more attention to the carbon impact of their purchase decisions. For example, according to the data released by just Salad, a well-known American salad chain, the sales volume of their low-carbon foods increased by more than 20% since carbon labels have been displayed on menus in September 2020. Thus, an increasing demand for choosing sustainable products from consumers will impose substantial pressure on corporate emission reduction and carbon disclosure.

Apart from consumers, an increasing number of global investors under the target of carbon neutrality are also concerned about climate-related risks. For example, Sequoia China has begun to use the ESG and carbon emission management capabilities of enterprises as key indicators for due diligence, investment decisions and post-investment services, coupled with a set of well-established ESG quantitative reporting systems. It can be expected that in the future, more financial institutions will take the carbon footprint indicators and carbon management capabilities of enterprises as important considerations when making their own investment decisions.

Theoretical framework, literature review and hypothesis development

Product market competition and carbon disclosure

Potential positive relationship between product market competition and carbon disclosure

According to the stakeholder theory, firms should strive for creating value for stakeholders rather than only for shareholders to achieve their sustainability [25]. This view is suggested by Freeman [26], who argues that the success of a firm relies on a well-established stakeholder relationship, among which any individual or group affecting or being affected by the achievement of a firm’s objectives is defined as a stakeholder. The most important task for managers is to balance the conflicts of interests between various stakeholders (e.g., consumers, suppliers, employees and creditors) in the firm. To achieve this goal, corporate
Disclosure of non-financial information including carbon-related information is often perceived as an important way to create, maintain and strengthen the stakeholder association and thus garner sustainable competitive advantages in the market [24]. Indeed, Qian and Schaltegger, based on a sample of global 500 companies from 2008 to 2012, find that an increase in carbon disclosure level facilitates a subsequent improvement in carbon performance [27], which can eventually add firm value [6, 28]. The benefit of linking firms to stakeholders through carbon reporting can be further magnified under intense competition, especially when firms develop and maintain multidimensional stakeholder relationships [29].

The bright side of disclosing carbon information under fierce competition can be primarily manifested from the perspective of customers. As an important aspect of marketing strategy, firms actively engaging in societally oriented activities like disclosing carbon-related information may generate a favorable impact in terms of increased customer satisfaction, brand loyalty, and firm reputation, regardless of whether firms appear to be “greener” or really are [30–36]. This can ultimately lead to a better financial performance [37–39], which is particularly important when firms face more intense product market competition. This is due to the fact that severe competition may reduce firms’ income and increase cash flow risk, thereby leading to a higher external financing cost for firms [40]. Firms presumably facing more intense competition may choose to disclose more carbon information as a way to reduce information asymmetry between firms and investors so as to improve their access to external capital [24].

Furthermore, the stakeholder theory (legitimacy theory) posits that the relationship between the firm and the society can be regarded as an implicit “social contract”, in which a system of social norms, values, and beliefs has been established for firms to follow [41]. A heightened public awareness around environmental and climate change issues in recent years gives rise to a social expectation for an improvement in carbon disclosure and performance. In response to the strong demand for high-quality environmental information from stakeholders, managers who are subject to these external pressures have incentives to disclose more non-financial (carbon) information, thereby obtaining long-term institutional legitimacy [42,43]. Providing detailed carbon-related information helps firms to be well-positioned in a highly competitive market because firms can distinguish themselves from existing competitors based on their products’ attractiveness [24, 28]. In contrast, if firms do not incorporate carbon information into their disclosure policies, they are more likely to be penalized by stakeholders because of their failure to appropriately meet the social needs of those who have a stake in the firm [10]. Additionally, firms under intense competition can strategically disclose carbon information to discourage potential rivals from entering their fields [44].

Potential negative relationship between product market competition and carbon disclosure

Despite numerous benefits of carbon disclosure, the actual act of disclosure can be costly because of potential proprietary costs faced by the firm [44]. According to a comprehensive survey conducted by Graham et al. [45], who interviewed more than 400 CFOs of US firms, nearly three-fifths of CFOs believe that proprietary costs are important to voluntary disclosure decisions. The proprietary cost theory suggests that managers tend to withhold some material information rather than unconditionally disclosing all information, especially when facing intense competition because such proprietary information released to investors can also be observed and may be strategically used by existing or potential competitors, which results in a competitive disadvantage of the disclosing firm [44, 46, 47]. Previous studies generally support this view by exploring the relationship between proprietary costs and corporate disclosure in various contexts, including segment reporting [15, 48, 49], management earnings forecasts [50], R&D information [51], and customer information [52]. In particular, Cao et al. argue that not all types of corporate disclosure are relevant to competitors [53]. Due to the nature of the multidimensionality of competition and disclosure, only those disclosure including actionable information can impose costs on the disclosing firm. Thus, carbon disclosure is very likely to incur proprietary costs because it typically involves detailed information on firms’ environmental strategies, technologies, subsidies, and practices, which can be both commercially and socially sensitive.

The earlier discussion above suggests that carbon disclosure can be treated as a strategic tool that enables firms to stand out from rivals. This is because such disclosure may contain valuable information that makes business attractive to investors. It is unsurprising that industry peers can
also take advantage of this public information to enhance their competitive position in the market but at the cost of the disclosing firm’s interest. In the particular case of disclosures on environments, this information would involve some new business opportunities regarding how to redesign traditional products to meet environmental standards or social needs, or some considerations on how to apply innovative technologies and measures for reducing environmental impacts of the business. The availability of this know-how information may in turn attract greater copycat competitors who purposely imitate the successful business models of the disclosing firm, thereby surpassing the disclosing firm. Besides, the cost of environmental disclosure can be significant when firms release bad news such as an environmental liability because such information can be used by other informed external stakeholders (apart from industry competitors), including government agencies, environmental activists, and victims of environmental incidents, for jeopardizing the disclosing firm’s ability to negotiate with them [54].

Therefore, to the extent that carbon reporting has both its pros and cons, we, based on the above discussions, propose two competing arguments on the effects of product market competition on carbon disclosure as to our main hypothesis as follows:

**Hypothesis 1a:** The intensity of product market competition is positively associated with carbon disclosure.

**Hypothesis 1b:** The intensity of product market competition is negatively associated with carbon disclosure.

**Product market competition, earnings pressure and carbon disclosure**

While product market competition has an impact on carbon disclosure, the magnitude through which the intensity of competition affects carbon disclosure depends upon certain external factors, one of which is earnings pressure. In practice, CFOs, who are pervasively subject to earnings pressure, believe that firms’ earnings are the most important measure reported to outsiders [45]. Investors developing firm-level earnings expectations mainly rely on the information from either (both) management’s forecasts or (and) analysts’ forecasts. For one, because of having unique information advantages as insiders, managers often explain their earnings growth expectations by linking firms’ historical performance to expected changes in firms’ future earnings conditional on a series of internal and external factors. For another, financial analysts, as crucial intermediaries between firms and investors, also provide rich and informative individual earnings forecasts and recommendations to investors, which can be seen as an important performance benchmark [55]. Since the consensus of analysts’ earnings forecasts might surpass the firms’ internal earnings expectations, earnings pressure occurs when there is a divergence between analysts’ and managers’ earnings expectations [56].

As proposed by the agency theory, increased earnings pressure from capital markets may intensify the agency frictions between managers and shareholders [57,58]. In response to meeting near-term earnings targets, self-interested managers have strong incentives to maximize short-term earnings at the expense of long-term investments for value creation (e.g., green investment) [45]. When the intensity of competition is given, firms facing fewer pressures to increase earnings may be more willing to engage in carbon disclosure. One possible interpretation might be dedicating extra resources to environmental management in the near term at this time will not impose a severe financial and strategic burden on firms and affect firms’ position in the market [59]. Thus, we expect the relationship between the intensity of product market competition and carbon disclosure should be more significant when firms are subject to fewer pressures on meeting or beating analysts’ forecasts. We, therefore, propose our second hypothesis as follows:

**Hypothesis 2:** The relationship between the intensity of product market competition and carbon disclosure is more pronounced among firms facing fewer earnings pressures.

**Product market competition, environmental legitimacy pressure and carbon disclosure**

Environmental legitimacy pressure can also affect the association between the intensity of product market competition and carbon disclosure. The neo-institutional theory argues that apart from the efficiency motive, legitimization is a critical driver pushing firms to be dedicated to sustainability [60–62]. As one aspect of organizational legitimacy, environmental legitimacy refers to the extent to which firms’ decisions pertaining to the environment are made in a manner that is consistent with
social norms, values, and beliefs [63]. In practice, environmental legitimacy pressure comes from a variety of internal and external stakeholders, such as regulatory agencies, media coverage, public attention, and so on. In response to these institutional pressures for being socially responsible, firms may pretend to be “environmental-friendly” by symbolically adopting some sustainability policies but without bringing about any improvement in environmental performance [34, 64–67]. This is confirmed by an increasing number of empirical studies on the determinants of firms’ greenwashing behaviors, particularly in terms of the role of sustainability performance disclosure [68–70]. For example, Haque and Ntim document that UK-listed firms appear to have a strong commitment to decarbonizing the environment, but only by following global sustainability disclosure standards rather than making a real effort to reduce carbon emissions [34]. The evidence from thirteen European countries covering a period of fifteen years also indicates that firms with better process-oriented carbon performance can be rewarded by the market with higher value, whereas improving the actual carbon performance of firms seems to be useless [35].

To achieve environmental legitimacy, it is plausible that such a phenomenon might be more pervasive in the context of fierce competition. As Shelfier suggested, intense market competition could lead to the spread of unethical conduct such as greenwashing [71]. If greenwashing can benefit one firm by improving their images in the product market, an increasing number of peer firms will join in because being ethical (non-greenwashing) firms may disadvantage themselves in competition with other unethical firms [33]. Given that firms’ more greenwashing behaviors, usually observed as a more frequent carbon reporting, are triggered by higher environmental legitimacy pressure especially under intense competition, we therefore expect the relationship between product market competition and carbon disclosure will be reinforced in this case. Hence, our third hypothesis is developed as follows:

Hypothesis 3: The relationship between the intensity of product market competition and carbon disclosure is more pronounced among firms facing greater environmental legitimacy pressures.

Sample selection and research design

Data sources and sample selection

Our primary sample comprises all firms publicly listed on the Main and SME boards of China’s stock markets for the years from 2015 to 2019. We restrict our sample of firms to eight high energy-consuming industries (with 1,085 firm-year observations) because these firms are typically regarded as the big producers of carbon dioxide, which are often subject to stricter rules on the disclosure of carbon-related information. We first exclude 120 observations of firms that do not release any CSR reports, sustainability reports or ESG reports during our sample period. Then, we drop 32 observations of firms under financial distress or any other abnormal condition (ST stock) and those at risk of termination (‘ST stock). Firms with missing information on key variables (with 207 observations) are also removed from our initial sample. Finally, we are left with 183 firms with 726 firm-year observations throughout 2015–2019. Table 1 summarizes the sample selection process.

Table 1. Sample selection process.

| Observations (firm-years) | Chinese A-share companies listed on the Shanghai or Shenzhen Stock Exchanges in eight high energy-consuming industries during 2015–2019 | 1,085 |
|--------------------------|--------------------------------------------------------------------------------------------------|-------|
| Exclude: firms without releasing either CSR report or sustainability report | (120) |
| Exclude: firms under financial distress or any other abnormal condition (ST stock) and those at risk of termination (‘ST stock) | (32) |
| Exclude: firms with missing information on key variables | (207) |
| Final sample | 726 |

This table describes the selection procedure for a sample of firms in eight energy-intensive industries over the period of 2015 to 2019.

Our data come from several sources. We hand-collect data on corporate carbon disclosure from firms’ corporate social responsibility reports and sustainability reports on the website of Juchao.com and score firms’ annual carbon disclosure based on the content analysis. Data on environmental legitimacy pressures are obtained from the China Business News database. Data on firm characteristics and financial information are obtained from the China Stock Market and Accounting Research (CSMAR) database.
Following Gaspar and Massa [74], we measure and control variables is a good proxy for capturing the firm's market power, which is widely used in the economic literature [75–77]. Specifically in this paper, the LI equals the operating revenues minus operating costs minus SG&A, divided by operating revenues. In general, a lower value of LI indicates stronger product market competition.

To compare the PMC of firms across different industries, an industry-adjusted LI is used for the calculation of PMC to reflect the extent of product market competition across different firms within the same industry. It is computed as the LI of an individual firm weighted by each firm’s share in total sales of a given industry, which is shown as the following formula:

$$PMC_{i,j,t} = LI_{i,j,t} - \sum_{i=1}^{n} \omega_{i,j} LI_{i,j,t}$$

where $PMC_{i,j,t}$ represents the level of product market competition for firm $i$ within $j$ industry in year $t$. $LI_{i,j,t}$ represents the Lerner Index of firm $i$ in year $i$. $\omega_{i,j,t}$ captures the percentage of total sales of all firms within $j$ industry that firm $i$ owns in year $t$.

To purge the effect of other fundamental drivers of carbon disclosure, we incorporate several control variables that the literature has shown to associate with firms’ CDI in our model [20, 78]: financial leverage (Lev), financial performance (ROA), market-to-book ratio (MTB), institutional ownership (InstOwn), the largest shareholder’s ownership (Top1), and executive compensation (Pay). We also include year fixed effect and industry (firm) fixed effect. All continuous variables are winsorized at the levels of 1% and 99% for reducing the influence of outliers. Appendix C presents definitions for all variables in detail.

### Model specifications

We test the relation between product market competition and carbon disclosure by employing the following OLS model:

$$CDI_{i,t} = \beta_0 + \beta_1 PMC_{i,j,t} + \sum_{i=1}^{6} \gamma_i Control_{i,t} + \sum Year + \sum Industry + \epsilon_{i,t}$$

where the dependent variable, $CDI_{i,t}$, represents the level of carbon disclosure for firm $i$ in year $t$. The independent variable, $PMC_{i,j,t}$, represents the level of product market competition for firm $i$ within $j$ industry in year $t$. Year fixed effects (Year) and industry fixed effects (Industry) are also included.
Table 2 presents descriptive statistics for the measure of our primary CDI across eight high energy-consuming industries over our sample period.\textsuperscript{17} The average value of the primary CDI for our full sample of firms is only 17.56 out of a maximum of 100 scores, suggesting that the overall level of carbon disclosure in these industries is relatively low, which calls for an improvement in carbon disclosure. Meanwhile, the primary CDI exhibits considerable across-industry differences. Firms in the aviation industry disclose more carbon-related information with a mean value of 28.13 as the highest group, while firms in the building materials industry appear to be the lowest scoring group with a mean value of only 12.11.

Summary statistics for the full sample of firms are reported in Table 3. The results show that the average score (CDI) across eight industries is 17.56 with a standard deviation of 7.86, ranging from the minimum of 6.25 to the maximum of 43.75 over our sample period. As expected, the measure of carbon disclosure is significantly different across the firms in various industries, whereas both the coverage and quality of carbon reporting in these industries remain low indeed. We also find that the mean value of PMC is 0 with a standard deviation of 0.10, ranging from the minimum of −0.29 to the maximum of 0.36, which indicates a huge difference in the magnitude of product market competition between firms across industries. Concerning key control variables, we observe that the mean value of Lev is 0.50, the mean ROA is 0.04 and the average percentage of InstOwn is 42.45%. We also find that the average MTB is 0.74, the mean percentage of shares held by the largest shareholder is 36.75% and the natural logarithm of the average salary for executives is 14.77. Besides, two-thirds of firms in our sample have state ownership. These statistics are largely consistent with the prior literature [79].

We report correlations among key variables in Table 4. Most of the correlation coefficients of control variables are less than 0.5 with a weak correlation between each other, which rules out potential multicollinearity. Meanwhile, the correlation coefficient between PMC and CDI is positive but insignificant, implying that a multivariate regression analysis should be further conducted to confirm the causality.

Hypotheses testing

Baseline regression results

Our central research question explores the effect of product market competition on carbon disclosure. Table 5 presents the results of the first hypothesis testing. In the absence of any fixed effects as shown in column (1), a decline in product market competition leads to the better carbon disclosure significantly with an increased score of 7.094. The effect of product market competition on carbon disclosure is reduced slightly but remains statistically significant when only the year fixed effect is included in column (2). Interestingly, after controlling industry fixed effect but not year fixed effect, the relation between PMC and CDI is even strengthened as shown in column (3). Column (4) including both industry and year fixed effects shows that the coefficient on the test variable is 6.774, which is significant at the 10% level. These results are also economically significant. For example, in column (4), a one-unit decrease in PMC increases the overall carbon disclosure by around 40% (6.774/17.56). Taken together, our findings suggest that firms are more likely to provide less, rather than more, carbon disclosure in their CSR or sustainability reports when facing fierce product market competition, which is consistent with our Hypothesis 1b. This also supports the proprietary cost argument in explaining the motivations of corporate to disclose both financial information [80,81] and non-financial information [24].

The moderating effect of external pressures

We next examine whether the effect of product market competition on carbon disclosure varies with external pressures, such as earnings pressure and environmental legitimacy pressure. In terms of earnings pressure, as discussed before, we expect that the association between the
Table 4. Correlations matrix.

|        | CDI       | PMC       | Lev       | ROA       | InstOwn    | MTB       | Top1      | Pay       |
|--------|-----------|-----------|-----------|-----------|------------|-----------|-----------|-----------|
| CDI    | 1.000     |           |           |           |            |           |           |           |
| PMC    | 0.047**   | 1.000     |           |           |            |           |           |           |
| Lev    | 0.153***  | 0.175***  | 1.000     |           |            |           |           |           |
| ROA    | 0.003     | 0.517***  | 0.418***  | 1.000     |            |           |           |           |
| InstOwn| 0.212***  | 0.069*    | 0.239***  | 0.059     | 1.000      |           |           |           |
| MTB    | 0.229**   | 0.200***  | 0.440***  | 0.273***  | 1.000      |           |           |           |
| Top1   | 0.212***  | 0.041**   | 0.141***  | 0.003     | 0.490***   | 0.183***  | 1.000     |           |
| Pay    | 0.068*    | 0.238***  | 0.014     | 0.296***  | 0.061*     | 0.012     | 0.190***  | 1.000     |

This table reports the correlation coefficients between variables from main regressions over the period of 2015–2019. All variables are defined in Appendix C. * **, and *** denote significance at the 0.1, 0.05, and 0.01 level, respectively.

Table 5. Product market competition and carbon disclosure.

|        | CDI       | PMC       | Lev       | ROA       | InstOwn    | MTB       | Top1      | Pay       |
|--------|-----------|-----------|-----------|-----------|------------|-----------|-----------|-----------|
| PMC    | 7.094**   | 6.344**   | 7.532**   | 6.774*    |            |           |           |           |
| Lev    | 1.785     | 0.704     | 1.172     | 0.366     |            |           |           |           |
| ROA    | −1.858    | −0.093    | −4.014    | −2.250    |            |           |           |           |
| InstOwn| 0.032**   | 0.032**   | 0.018     | 0.019     |            |           |           |           |
| MTB    | 5.528***  | 6.974***  | 4.367***  | 5.601***  |            |           |           |           |
| Top1   | 0.080***  | 0.077**   | 0.072**   | 0.070**   |            |           |           |           |
| Pay    | 1.036**   | 1.259***  | 1.122**   | 1.333**   |            |           |           |           |
| Constant| −6.998   | −10.097   | −6.679    | −9.835    |            |           |           |           |
| Industry FE | NO | NO | YES | YES |            |           |           |           |
| Year FE | NO | YES | NO | YES |            |           |           |           |
| Observations | 726 | 726 | 726 | 726 |            |           |           |           |
| AdjR²  | 0.098     | 0.104     | 0.162     | 0.164     |            |           |           |           |

This table reports the regression results for testing the effect of product market competition on carbon disclosure based on a sample of 183 firms in eight energy-intensive industries over the period of 2015–2019. The dependent variable (CDI) is a self-constructed measure, capturing the level of carbon disclosure for firm i in year t. The independent variable is product market competition (PMC), representing the level of product market competition for firm i within industry j in year t, which is constructed based on an industry-adjusted Lerner Index of firm i in year t. All continuous variables are winsorized at the levels of 1% and 99%. p-values are computed using firm-clustered standard errors. t-statistics are reported in parentheses. *, **, and *** denote significance at 10%, 5% and 1% levels, respectively. All variables are defined in Appendix C.

The intensity of product market competition and carbon disclosure should be more pronounced among firms with fewer earnings pressures. To test this conjecture, we use the following regression model:

\[ CDI_{i,t} = \beta_0 + \beta_1 PMC_{i,t} + \beta_2 EP_{i,t} + \beta_3 PMC_{i,t} \times EP_{i,t} + \sum_{i=1}^{6} \gamma_i Control_{i,t} + \sum Year + \sum Industry + \epsilon_{i,t} \]  

(4)

where \( EP_{i,t} \) is a proxy for the earnings pressure felt by firm i in year t. Following Zhang and Gimeno [56], we measure the earnings pressure (EP) as the difference between the consensus of analysts’ earnings forecasts (\( F_{i,t} \)) and firms’ potential earnings (\( EPS_{i,t} \)) in a given year. All other variables are the same as those in the previous main test. Year fixed effects (\( Year \)) and industry fixed effects (\( Industry \)) are also included.

The result of the regression model presented in column (1) of Table 6 supports our second hypothesis. Specifically, we find that the coefficient on the interaction term between \( PMC \) and \( EP \) is negative and significant at the 1% level, suggesting a moderating effect of earnings pressure. In other words, by weakening the negative relationship between competition intensity and carbon reporting, earnings pressure can be seen as a substitute for product market competition.

For hypothesis 3, we examine whether the pressure from environmental legitimacy affects the relation between product market competition and carbon disclosure. As discussed before, we contend that the association between the intensity of product market competition and carbon disclosure should be more pronounced among firms with greater environmental legitimacy pressures. To test this hypothesis, we use the following regression model:

\[ CDI_{i,t} = \beta_0 + \beta_1 PMC_{i,t} + \beta_2 EP_{i,t} + \beta_3 PMC_{i,t} \times ELP_{i,t} + \sum_{i=1}^{6} \gamma_i Control_{i,t} + \sum Year + \sum Industry + \epsilon_{i,t} \]  

(5)

Where \( ELP_{i,t} \) is a proxy for the environmental legitimacy pressure felt by firm i in year t. Since media reporting represents one of sources to assess environmental legitimacy, following the prior literature [82,83], we use an indicator variable \( ELP \), which equals one if there is at least one piece of environmental reporting by mass media for firm i in year t, to capture the likelihood of environmental legitimacy pressure firms encountered in a given year. All other variables are the same as those in the previous main test. Year fixed effects (\( Year \)) and industry fixed effects (\( Industry \)) are also included.

The result of the regression model presented in column (2) of Table 6 supports our third hypothesis. We find the coefficient on \( PMC \) remains
positive and significant as in Table 5. Meanwhile, the economic benefit of relaxing market competition is expanded when more environmental legitimacy pressure is put on firms. This is confirmed by a positive coefficient on $PMC \times ELP$, which is significant both statistically and economically. Comparing the coefficients on $PMC$ and $PMC \times ELP$ (6.529 and 9.408, respectively), we infer that, relaxing market competition facilitates more carbon reporting, and this benefit is increased in magnitude by approximately 1.5 times when firms are more likely to be confronted with a higher level of environmental legitimacy pressure from media coverage. Therefore, our findings are indicative of the important role played by environmental legitimacy pressure, since the extent to which carbon disclosure can be promoted due to a less-competitive market environment largely depends on the level of environmental legitimacy pressure firms face.

This table presents the results of the influence of firm characteristics on the relationship between product market competition and carbon disclosure based on a sample of 183 firms in eight energy-intensive industries over the period of 2015–2019. Panel A shows the results of the influence of ownership structure on the relationship between product market competition and carbon disclosure by creating two subgroups based on whether a firm’s ultimate controlling shareholder is the state or not. Panel B reports the results of the influence of firm size on the relationship between product market competition and carbon disclosure by creating two subgroups based on the median value of a firm’s year-end total assets. All continuous variables are winsorized at the levels of 1% and 99%. p-values are computed using firm-clustered standard errors. t-statistics are reported in parentheses. *, **, and *** denote significance at 10%, 5% and 1% levels, respectively. All variables are defined in Appendix C.

**Additional tests**

So far, we provide evidence that firms in more competitive product markets tend to disclose less information on carbon emissions. However, such relationships might vary among firms with different types of ownership. State-owned enterprises (SOEs), owing to their roles in undertaking socially responsible actions rather than only pursuing profit-driven goals, are subject to certain political pressure and more likely to take initiatives to boost environmental engagement through government stakes, thus leading to a higher level of carbon disclosure embedded in environmental disclosure [84–86]. Meanwhile, SOEs are typically much less constrained financially and associated with a lower probability to report tougher competition in the product market than their counterparts non-SOEs (Jin et al., [94]). Thus, we expect the relationship between the intensity of product market competition and carbon disclosure should be more pronounced among firms with state ownership.

To perform this sub-sample test, we create two groups of firms based on whether a firm’s ultimate controlling shareholder is the state or not over the sample period. Panel A of Table 7 reports the
results estimated for SOEs and non-SOEs respectively. We find that the estimated coefficient on CDI is positive and significant at the 1 percent level in the group with state ownership (with the coefficient of 13.643) but insignificant in the group without state ownership (with the coefficient of −1.308). The Chi-square statistic shows that the difference between the two groups is significant at the 5 percent level, which lends support to our expectation.

Apart from corporate ownership, we dig deeper into the firm-level heterogeneity by examining whether the relationship between product market competition and carbon disclosure varies with firm size. Large firms often involve a broader range of stakeholders, including government regulatory agencies, environmental organizations, mass media and community, which may have more diversified demands for firms’ carbon disclosure [8]. The extent to which stakeholders pay attention to firms’ carbon information largely affects firms’ environmental disclosure strategies [87]. In a more competitive market, large firms prefer disclosing more carbon information to signal their positive attitudes toward reducing the carbon footprint at a lower cost to separate themselves from small firms [88–91]. If this is the case, we would expect the relationship between the intensity of product market competition and carbon disclosure should be more pronounced among large firms.

To test this conjecture, we divide our full sample into two, large firms and small firms, based on the median value of a firm’s year-end total assets. As presented in Panel B of Table 7, the results show that for large firms, the coefficient on CDI is positive and significant at the 5 percent level (with the coefficient of 9.725) but insignificant for small firms (with the coefficient of −2.345). The Chi-square statistic shows that the difference between the two groups is significant at the 10 percent level, which lends support to our expectation.

### Robustness tests

In this section, we conduct several robustness tests to validate our prior findings by estimating models on a sub-sample of firms with a longer duration, using alternative measures of product market competition and carbon disclosure, as well as employing various approaches to address endogeneity concerns.

### Alternative sample

Considering the potential impact of firm age on the quality of carbon disclosure, we restrict our sample by focusing on only those firms established no less than eight consecutive years to re-run the main regression. Similar to our earlier results, in the first column of Table 8, we still find that firms in this alternative sample tend to reduce carbon disclosure when product market competition is greater, with the coefficient of 6.802 (significant at the 5 percent level).

### Alternative measures of product market competition (PMC) and carbon disclosure (CDI)

To ensure our results are not driven by the choice of product market competition measures, we employ two alternative proxies for PMC intensity. For capturing the magnitude of product market competition, we use the original Lerner Index (LL_{j,t}) as our first proxy for PMC, which is calculated as the firm-level operating revenues

Table 8. Robustness tests.

|       | CDI      | CDI\_dummy | CDI\_t−1 |
|-------|----------|------------|----------|
|       | (1)      | (2)        | (3)      | (4)      | (5)      |
| PMC   | 6.802**  | 2.007**    | 7.955**  |
|       | (2.019)  | (2.108)    | (1.893)  |
| Li    | 5.488**  |            |          |
|       | (1.798)  |            |          |
| NPC   | −38.122***|            |          |
|       | (−2.642) |            |          |
| Lev   | 0.346    | 0.340      | −0.775   |
|       | (0.187)  | (0.185)    | (−0.406) |
| ROA   | −2.292   | −2.277     | 1.856    |
|       | (−1.303) | (−5.510)   |          |
| ROA   | −0.372   | −0.393     | 0.365    |
|       | (−0.706) | (−0.728)   |          |
| InstOwn| 0.019    | 0.019      | 0.023    |
|       | (1.300)  | (1.424)    | (1.567)  |
| MTB   | 5.632**  | 5.500**    | 1.875*** |
|       | (3.976)  | (4.039)    | (2.258)  |
|       |          | (4.161)    | (2.743)  |
| Top1  | 0.069**  | 0.070**    | 0.078*** |
|       | (3.150)  | (3.003)    | (3.022)  |
|       | (1.942)  | (3.079)    |          |
| Pay   | 1.323**  | 1.353**    | 1.887**  |
|       | (2.483)  | (2.755)    | (3.840)  |
|       | (2.423)  | (2.364)    |          |
| Constant | −9.704 | −10.517    | −15.911***|
|       | (−1.200) | (−1.409)   | (−2.143) |
|       | (−3.300) | (−1.121)   |          |
| Industry FE | YES   | YES        | YES      |
| Year FE | YES     | YES        | YES      |
| Observations | 724    | 726        | 634      |
|       | 726     | 516        |          |
| AdjR² | 0.164   | 0.184      | 0.165    |
|       | 0.165   | 0.170      |          |
| Pseudo R² | 0.059 |            |          |

This table presents the results of robustness tests. The column (1) shows the result based on a restricted sample of firms whose establishment year is no less than eight consecutive years. The column (2) and (3) display the results by using two alternative measures (LL_{j,t} and NPC_{j,t}) to proxy for PMC intensity. The column (4) reports the result based on a logistic regression model, where the dependent variable CDI\_dummy takes the value of one if a firm’s CDI is above the industry-median, and zero otherwise. The column (5) repeats the analysis in Table 5 using the one-year lagged explanatory variables. All continuous variables are winsorized at the levels of 1% and 99%, p-values are computed using firm-clustered standard errors. t-statistics are reported in parentheses. *, **, and *** denote significance at 10%, 5% and 1% levels, respectively. All variables are defined in Appendix C.
Table 9: Endogeneity tests.

|                        | PSM approach (1) | Instrumental variable (IV) estimation (2) | First stage: PMC (3) | Second stage: CDI (4) |
|------------------------|------------------|------------------------------------------|----------------------|----------------------|
| PMC                    | 6.884*           | 9.267*                                   |                      |                      |
| (1.798)                | (1.753)          |                                          |                      |                      |
| LogPM C                | 0.721***         |                                          |                      |                      |
| (28.194)               |                  |                                          |                      |                      |
| Lev                    | 0.060***         | -1.566                                   |                      |                      |
| (0.447)                | (4.104)          | (0.715)                                  |                      |                      |
| ROA                    | -4.334           | -4.123                                   |                      |                      |
| (-0.521)               | (10.254)         | (-0.493)                                 |                      |                      |
| InstOw                 | 0.020**          | 0.016                                    |                      |                      |
| (1.065)                | (0.850)          | (0.890)                                  |                      |                      |
| MTB                    | 4.323***         | 5.800***                                 |                      |                      |
| (2.447)                | (3.372)          |                                          |                      |                      |
| Top1                   | 0.066**          | 0.083***                                 |                      |                      |
| (2.475)                | (3.159)          |                                          |                      |                      |
| Pay                    | -0.004           | 1.454***                                 |                      |                      |
| (1.954)                | (2.341)          |                                          |                      |                      |
| Constant               | -7.856           | -10.076                                  |                      |                      |
| (-0.840)               | (-1.059)         |                                          |                      |                      |
| Industry FE            | YES              | YES                                      |                      |                      |
| Year FE                | YES              | YES                                      |                      |                      |
| F-test (p-value)       | 86.750           |                                         |                      |                      |
| (0.000)                |                  |                                          |                      |                      |
| Observations           | 470              | 516                                      | 516                  |                      |
| Adj.R²                 | 0.207            | 0.748                                    | 0.201                |                      |

This table presents the results of endogeneity tests. The column (1) shows the result based on a propensity-score matching (PSM) sample. The column (2)-(3) report the first-stage and second-stage results of a two-stage least squares (2SLS) regression using a one-year lagged PMC (LogPMC) as an instrument of PMC. All continuous variables are winsorized at the levels of 1% and 99%. p-values are computed using firm-clustered standard errors. t-statistics are reported in parentheses. *, **, and *** denote significance at 10%, 5% and 1% levels, respectively. All variables are defined in Appendix C.

Although we use lagged values as explanatory variables to partly address reverse causality, our finding may still invoke a series of endogeneity concerns, which makes it difficult to establish a causal effect. For example, our inference may be biased because of some omitted time-varying, and unobservable firm characteristics. In addition, a firm may use carbon disclosure strategically, as a mechanism to prevent potential rivals from getting a share of the market or curb competition from incumbent competitors, which might eventually alter the current market structure [92,93]. Thus, the direction of causality may go from carbon disclosure to product market competition. In this sub-section, we aim to alleviate these concerns by using two identification strategies: a propensity-score matching (PSM) approach and an instrumental variable (IV) approach.

Propensity-score matching (PSM) approach
Since our result may be driven by different fundamental characteristics between firms in a more or a less crowded market, we first use a propensity score matching (PSM) approach to ensure there are no significant differences in the characteristics between firms in a more competitive product market and those counterparts in a less competitive product market. After performing the caliper matching technique with replacement (with the width of 0.01), we end up with a group of matched firms (treated and control) with 470 observations and re-run the regression model. As presented in the first column of Table 9, the coefficient on PMC is still found to be significant, which is consistent with the baseline finding.

Instrumental variable (IV) approach
We employ an instrumental variable (IV) approach as our second identification strategy for addressing endogeneity issues. We rely on a two-stage least squares (2SLS) regression where a one-year lagged PMC (LogPMC) is our instrument in predicting product market competition. We expect LagPMC should be a valid IV because the degree of competition in markets is typically correlated between two consecutive years. However, the former year’s
market structure is less likely to directly affect the following year’s carbon disclosure. Columns (2)–(3) of Table 9 present the IV estimation results. In the first stage, we regress PMC on LagPMC, coupled with a series of control variables which are the same as those in the previous main test. The coefficient on our instrument LagPMC is significantly positive, with the $p$-value of the $F$-test of the instrument being close to zero, satisfying the relevance assumption. In the second stage, we estimate a pooled OLS model by regressing CDI on the fitted value of LagPMC calculated in the first stage and the same control variables. The coefficient on an instrumented PMC is significantly positive at the 10% level, which is in line with the result in Table 5.

Discussion and conclusion

Carbon disclosure has been central to stimulating the development of a climate change strategy in recent years. Given that product development and responsibility are important dimensions of firms’ climate commitment, many firms voluntarily provide such information through carbon reporting. Using a sample of Chinese publicly listed firms in eight high energy-consuming industries from 2015 to 2019, we in this paper explore the impact of product market competition on corporate carbon disclosure and investigate the moderating effect of earnings pressure and environmental legitimacy pressure. We find that the intensity of product market competition is negatively associated with firms’ carbon disclosure, and such association can be moderated by firms’ earnings pressure and environmental legitimacy pressure. In other words, compared with firms in a less competitive product market, firms in a more competitive product market are more reluctant to voluntarily disclose the information on carbon emissions. The impact of market competition on overall carbon reporting is more pronounced among firms facing fewer earnings pressures or greater environmental legitimacy pressures. The cross-sectional analyses also show that such negative relationship is more pronounced among firms with state ownership and large firms. Our results are robust for endogeneity and utilization of an alternative sample as well as alternative proxies of product market competition and carbon disclosure.

Our findings have three academic implications. First, this study enriches the research in the field of environmental accounting, particularly in terms of an improvement in the methods for measuring carbon disclosure. Our demonstrated index construction framework helps form the next stage of improving indicators of measurement for new carbon disclosure targets.

Second, this study contributes to the literature on the non-economic consequences of the intensity of product market competition. Most of the existing literature on market competition only focuses on its economic consequences, while this study provides evidence that market competition may also generate some social consequences (e.g., carbon disclosure).

Third, this study contributes to the literature on the determinants of carbon disclosure. We explore the relationship between the intensity of product market competition and carbon disclosure and consider the moderating role of earnings pressure and environmental legitimacy pressure in this relationship. This study offers a framework and expands the research on the determinants of carbon disclosure.

This paper also provides practical implications for regulators, investors, and firms. Firstly, because of the lack of guidelines/standards for carbon disclosure and independent auditing in China, governments should be accountable to set up concrete carbon management and carbon disclosure guidelines to reduce firms’ tendency to manipulate disclosure and the possibility of companies evading carbon management responsibilities, as well as to improve the effectiveness of government regulation. By implementing the concept of green development, policymakers will make enterprises realize that the economic and social benefits of carbon management behavior will exceed the cost, which can motivate enterprises to actively promote carbon emission reduction behaviors and voluntarily disclose carbon information. This eventually will be helpful to achieve the national goal of “carbon peak and carbon neutrality”.

Secondly, regulators should strengthen the supervision of carbon disclosure in industries with fierce product market competition so as to provide high-quality information for investors and ultimately achieve effective capital allocation.

Thirdly, to enhance investors’ investment confidence and attract sufficient capital, firms can flexibly adjust their carbon disclosure strategies according to the magnitude of product market competition and external pressures they need to face. Corporates should transform the product
competition pressure into the driving force of green transformation and upgrading, which can further improve corporate governance and enhance core competitiveness. At the same time, corporates with higher market positions often face less product market competition, and they can play an exemplary role in carbon disclosure, which is conducive to improving the level of carbon disclosure of the entire industry.

Lastly, investors can incorporate corporate carbon disclosure into investment decisions by either voting with their feet to force corporates to improve the quality of disclosure or adopting a diversified co-governance strategy to facilitate carbon management.

As with other studies, this paper is subject to limitations. First, the construction of a carbon disclosure index is achieved by using content analysis to extract carbon information from corporate social responsibility reports. However, one should be cautious with the results as the scoring process might be inevitably subjective to some extent. Second, the sample of firms used in this study are only from eight energy-intensive industries, and future research should examine whether our conclusions apply to other industries. Third, this study only examines the determinants of carbon disclosure from the perspective of product market competition. Therefore, further work can be extended to explore the economic consequences of carbon disclosure, such as firm value, investment preferences, and stock price crash risk.

Notes

1. See https://rhg.com/research/chinas-emissions-surpass-developed-countries/.
2. See www.tanpaifang.com (in Chinese).
3. See www.gov.cn/xinwen/2021-03/13/content_5592681.htm (in Chinese).
4. See https://www.cdp.net/en.
5. See http://www.gov.cn/zhengce/content/2016-11/04/content_5128619.htm (in Chinese).
6. See http://www.pbc.gov.cn/english/130721/3131759/index.html (in Chinese).
7. See http://www.gov.cn/xinwen/2019-12/25/content_5463857.htm (in Chinese).
8. See http://www.hkex.com.hk/Listing/Sustainability/ESG-Academy/Rules-and-Regulations?sc_lang=en.
9. See https://www.mee.gov.cn/xxgk2018/xxgk/xxgk02/202112/t20211221_964837.html (in Chinese).
10. See https://justsalad.com/carbonlabel.
11. See https://www.seqimco.com/about/esg/.
12. Our sample period starts from the year of 2015. This is because following the Paris Agreement in 2015, China accelerated the development of national carbon emissions trading market (ETC). In this context, Chinese listed firms have paid more attention to the carbon disclosure since 2015.
13. The high energy-consuming industries include iron and steel industry, non-ferrous metals industry, power industry, petrochemical industry, chemical industry, building materials industry, paper production industry and aviation industry. For more details, see https://www.163.com(dy/article/G8ERQ6T605310DBY.html (in Chinese).
14. See the website of Juchao.com: http://www.cninfo.com.cn/new/index.
15. The China Business News database is one of databases of China Infobank, an extensive database of China’s news, business and legal information. The China Business News database includes daily news clippings and extracts from China’s 600 leading newspapers and trading magazines. See https://www.ceibs.edu/infobank.
16. See Appendix B for more technical details in constructing the measure of CDI.
17. As announced by the National Development and Reform Commission (NDRC) in late 2017, the China’s national emissions trading scheme (ETS) initially covered eight industrial sectors, which are the same industries we target in this paper. See https://https://www.globalelr.com/2021/08/chinas-national-ets-launches-trading/.
18. See Appendix C for a detailed explanation of how EP is calculated.
19. To do this, we first estimate a logit model based on a vector of firm characteristics that may affect a firm’s decision on whether or not to disclose carbon-related information. These covariates are consistent with the control variables used in the baseline regression. The balancing test results show that the mean bias drops significantly from 15.5 percent (before PSM) to 5.8 percent (after PSM) (untabulated). Corresponding results are available upon request.
20. For each indicator within this dimension, we create a dummy variable that equals two for one for only qualitative descriptions, and zero otherwise.
21. In practice, since two research assistants work independently for one report, there might be a score disparity between one student and the other. For any inconsistency, if the disparity is very large, we ask them to score it again and then have a group discussion to determine which score should be chosen.
22. For more details, see en.hdpi.com.cn/site/487EN/index.html.

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Appendix A.

Components for measuring carbon disclosure index (CDI)

This table displays the components for the construction of the CDI. The index is constructed based on the hand-collected textual information about carbon profiles of firms in eight energy-intensive industries published in stand-alone CSR reports and sustainability reports from 2015 to 2019.

| Dimensions                      | Indicators                                      | Scoring criteria                                                                                                                                                                                                 |
|---------------------------------|-------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Timeliness**                  | Timing of disclosure                            | An indicator variable equals one if a stand-alone CSR report is released within four months subsequent to the end of fiscal year, and zero otherwise.                                                                |
| **Clearness**                   | Combination of text, data and graphics          | An indicator variable equals three for a stand-alone CSR report with text, data and graphics, two for a stand-alone CSR report with text and data, one for a stand-alone CSR report with only text, data or graphics, and zero otherwise. |
| **Terminology**                 |                                                  | An indicator variable equals two for a stand-alone CSR report with both terminologies (i.e., carbon footprint, carbon label) and explanations, one for a stand-alone CSR report with only terminologies, and zero otherwise. |
| **Reliability**                 | Audit and assurance                             | An indicator variable equals two if a stand-alone CSR report is verified by independent carbon assurance providers, one if a stand-alone CSR report is verified by common accounting firms than independent carbon assurance providers, and zero otherwise. |
| **Report collection process and system** |                                                  | An indicator variable equals two if a firm has set up an environmental protection department for monitoring, quantifying, and reporting on emission savings associated with a clear description of the departmental procedure, one if a firm has only set up an environmental protection department for monitoring, quantifying, and reporting on emission savings, and zero otherwise. |
| **Accuracy**                    | Criteria of carbon accounting                   | An indicator variable equals two if a standard carbon measuring system has been established with a quantitative description of the measurement methodology, one if a standard carbon measuring system has been established with a qualitative description of the measurement methodology, and zero otherwise. |
| **Balance**                     | Negative information                            | An indicator variable equals two for a quantitative description of environmental pollution and damage incidents, one for a qualitative description of environmental pollution and damage incidents, and zero otherwise. |
| **Comparability**               | Performance comparison                          | An indicator variable equals two if a stand-alone CSR report provides information on the comparison between current period’s carbon emissions with prior period’s carbon emissions, as well as the comparison between a firm’s carbon emissions and its industry-peers’, one if a stand-alone CSR report only provides information on the comparison between a firm’s carbon emissions and its industry-peers’, and zero otherwise. |
| **Completeness**                | Carbon reduction risk                           | Whether a firm has recognised any potential risk involved during the process of carbon reduction (i.e., regulatory or compliance risk).                                                                  |
|                                 | Carbon reduction strategy                        | Whether a firm discloses information on three types of carbon management strategies: carbon compensation (i.e., carbon emissions trading system), carbon reduction (i.e., directly or indirectly minimising carbon emissions through a mix of eco-design manufacturing process), and carbon offsetting. |
|                                 | Carbon reduction target                          | Whether a firm discloses information on target-setting, target-tracking and target-reviewing. An indicator is set to two for both qualitative and quantitative descriptions, one for only qualitative descriptions, and zero otherwise. |
|                                 | Carbon reduction management                      | Whether a firm discloses information on the adoption of low-carbon strategies (i.e., green offices and green supply chain management).                                                                  |
|                                 | Carbon reduction input                           | Whether a firm discloses its improvement in low-carbon technologies and investment in carbon reduction projects or schemes.                                                                                                                                         |
|                                 | Carbon reduction subsidy                         | Whether a firm discloses information on government subsidies and social grants that a firm received for carbon reduction.                                                                                                                                 |
|                                 | Carbon reduction accounting                      | Whether a firm discloses the methodology used to calculate carbon savings; Whether a firm discloses the total amount of energy savings.                                                                                                                                |
|                                 | Carbon reduction performance                     | Whether a firm discloses information on social awards that a firm received due to its environmental efforts.                                                                                                                                                    |
Appendix B.
Technical details in carbon disclosure index (CDI) construction

In this appendix, we provide descriptions and examples of steps taken to illustrate how the carbon disclosure index (CDI) is constructed.

We start by collecting all stand-alone CSR reports and sustainability reports of our interested firms through Juchao Website ([www.cninfo.com.cn](http://www.cninfo.com.cn/)). After obtaining 985 reports in total between 2015 and 2019, we work with two research assistants to read through these documents one by one. Since our coding units are set at the level of sentences, for each report, we read line by line and exclude those sentences that do not contain any information relevant to the firm’s carbon profile (i.e., general information on business activities). For the rest of the sentences, we check with our pre-defined scoring criteria of each indicator in Appendix A and make the corresponding coding decisions. After this step, all relevant information is aggregated and used to complete our carbon disclosure score. The results are compared with the scores of all indicators in Appendix B.

1. Timeliness: Since the 2019 CSR report is publicly released on 26 March 2020 (prior to 30 April 2020), a score of one should be awarded.

2. Clarity:
   (1) Combination of text, data and graphics:
   According to the following sentences (shown in a figure on page 42 of the report) “In 2018 and 2019, the total direct greenhouse gas emissions are estimated to be 16,785.8 ten thousand tons CO2. The total indirect greenhouse gas emissions are estimated to be 7.3 ten thousand tons CO2. The total greenhouse gas emissions are estimated to be 16,793.1 ten thousand tons CO2.”, a score of three should be awarded as it is illustrated with text, data, and graphics.

   (2) Terminology:
   According to the following sentence (shown on page 34 of the report) “In 2017, 2018 and 2019, but without further illustration or clarification is given for these terminologies. 3. Reliability:
   (1) Audit and assurance: Since no information is provided on whether this CSR report has been verified by external assurance providers, a score of zero should be awarded.
   (2) Report collection process and system: According to the following sentence (on Page 34 of the report) “In 2017, 2018 and 2019, the Ministry of Ecology and Environment of the PRC circulated the notice of implementing carbon emission reporting and verification. The Group has proactively implemented relevant measures. Depending on the Group’s carbon emission statistical information system, the Group continuously improves its carbon emission management to accomplish carbon emission monitoring and reporting.”, a score of one should be awarded. As described above, this firm actively monitors and reports carbon emissions in carbon management. Such information is disclosed in a qualitative way rather than a quantitative way.

4. Accuracy:
   According to the following sentence (on page 43 of the report) “In 2018 and 2019, the total direct greenhouse gas emissions are estimated to be 16,785.8 ten thousand tons CO2. The total indirect greenhouse gas emissions are estimated to be 7.3 ten thousand tons CO2.”, a score of three should be awarded as it is illustrated with text, data, and graphics.

5. Balance:
   According to the following sentence (on page 35 of the report) “In 2017, 2018 and 2019, but without further illustration or comparison analysis. Thus, a score of one should be awarded.

6. Comparability:
   The figure on Page 42 of the report displays the total amount of greenhouse gas emissions emitted by the firm in 2017, 2018 and 2019, but without further illustration or comparison analysis. Thus, a score of one should be awarded.

7. Completeness:
(1) Carbon reduction risk:

According to the following sentences (on pages 34 and 36 of the report) "自2018年以来，中国深入推进行对气候变化工作，采取一系列政策及措施控制温室气体排放，集团积极响应相关政策。集团严格遵守对集团有重大影响的相关温室气体排放的法律法规，包括但不限于《中华人民共和国环境保护法》、《燃煤火电企业环境守法行为》及《国家发展改革委关于组织开展重点企业（事）业单位温室气体排放报告工作》。" (In English, it is "China has further implemented the work of tackling climate change since 2018 and adopted a series of policies and measures to control greenhouse gas emissions. The Group proactively responds to relevant policies by promoting the transformation to a green, low-carbon, clean and efficient energy structure." and "The Group strictly abides by the relevant laws and regulations that have a significant impact on the Group relating to air and GHG emissions, discharges into water and land, and generation and disposal of waste, which include but are not limited to the Environmental Protection Law of the PRC, the Water Pollution Prevention and Control Law of the PRC, the Water and Soil Conservation Law of the PRC, the Law of the PRC on the Prevention and Control of Environmental Pollution by Solid Waste, the Environmental Protection Tax Law of the PRC, the Environment Compliance Guidance for Coal-fired Thermal Power Enterprise, the Emission Standard of Air Pollutants for Thermal Power Plants and the Notice of National Development and Reform Commission on Greenhouse Gas Emissions Reporting by the Major Enterprise and Public Institutions.")

(2) Carbon reduction strategy:

According to the following sentence (on page 37 of the report) "本集团通过技术改造，同时加强环保设施运营及维

护管理，全力降低污染物排放。于报告期，本集团主要用于环保大型技术改造的环保投入共144700万元，共完成3台容量总计达120万千瓦的脱硫机组超超排放改造项目，达到超超排放的脱硫机组容量达4196万千瓦，占燃煤机组总容量的94%" (In English, it is "The Group spares no effort to reduce pollutants emission by technological renovation and enhancing the operation and maintenance management of environmental protection facilities. During the reporting period, the investment in environmental protection used mainly for large technological renovation of the Group was 1,447.00 million RMB, and the construction of 3 coal-fired ultra-low emission power units with a capacity of 1,200 MW was completed. The Group's ultra-low emissions coal-fired power units comprised a total capacity of 41,960 MW, which accounted for 94% of the overall capacity of coal-fired power units.").

3) Carbon reduction input:

According to the following sentence (on page 37 of the report) "本集团主要用于环保大型技术改造的环保投入共144700万元" (In English, it is "The investment in environmental protection used mainly for large technological renovation of the Group was 1,447.00 million RMB.")

(3) In terms of other items (e.g., carbon reduction target) within the "Completeness" dimension, a score of zero is awarded as there is no relevant information provided.

In sum, for this report, we can get an overall carbon disclosure score: 1 (Timeliness) + 4 (Clearness) + 1 (Reliability) + 1 (Accuracy) + 2 (Balance) + 1 (Comparability) + 5 (Completeness) = 15. Based on the formula (1), a normalized score should be 46.875.
## Appendix C.

### Variable definitions

This table describes the key variables used in the paper.

| Variable          | Definition                                                                                                                                 |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| **Control variables** |                                                                                                                                 |
| CDI               | Carbon disclosure variable, representing the aggregate level of carbon disclosure for firm \( i \) in year \( t \). It is a composite index that aggregates information from seven dimensions of disclosures with respect to sixteen measurement indicators in total, which can be created with the formula (1). Information relevant to the calculation of CDI comes from stand-alone CSR reports and sustainability reports. More details and examples for the construction of CDI are shown in Appendices A and B. |
| CDI_dummy         | Alternative measure of CDI. It takes the value of one if a firm’s CDI is above the industry-median, and zero otherwise.                        |
| **Independent variables** |                                                                                                                                 |
| PMC               | The level of product market competition for firm \( i \) within \( j \) industry in year \( t \), which is constructed based on an industry-adjusted Lerner Index (LI) of firm \( i \) in year \( t \). It is computed as the LI of an individual firm weighted by each firm’s share in total sales of a given industry, which can be created with the formula (2). The LI equals to the operating revenues minus operating costs minus SG&A, divided by operating revenues in year \( t \). |
| LI                | Alternative measure of PMC, which is measured as the firm-level operating revenues minus operating costs minus SG&A, divided by operating revenues in year \( t \). |
| NPC               | Alternative measure of PMC, which is measured as the sum of firm’s advertising expenditure and R&D expenses divided by the sum of firm’s sales in an industry. |
| InstOwn           | Fraction of outstanding shares owned by institutional investors at the end of year.                                                          |
| Lev               | Sum of long-term debt and short-term debt divided by total assets at the end of year.                                                       |
| MTB               | Market value of assets divided over book value of assets. Market value of assets is book value of total assets minus book value of equity plus market value of equity at the end of year. |
| Pay               | The natural logarithm of the average pay of top three executives at the end of year.                                                         |
| ROA               | Return on assets, calculated as net profit divided by total assets at the end of year.                                                      |
| Top1              | Fraction of outstanding shares owned by the largest shareholder at the end of year.                                                       |
| **Other variables** |                                                                                                                                 |
| ELP               | Environmental legitimacy pressure variable. It is an indicator variable that takes the value of one if there is at least one piece of environmental reporting by mass media for firm \( i \) in year \( t \), and zero otherwise. |
| EP                | Earnings pressure variable, which is computed as the difference between the consensus of analysts’ earnings forecasts (\( F_{i,t} \)) and firms’ potential earnings (EPS\(_i\)) in year \( t \). Data on analysts’ earnings forecasts (\( F_{i,t} \)) is collected from the CSMAR database. To calculate the measure of firms’ potential earnings (EPS\(_i\)), we begin by estimating the rate of changes in the earnings per share (EPS) for firm \( i \) in year \( t \) based on the most recent historical closing price at the end of the year (\( P \)) and cumulative abnormal return (CRET). Then, we estimate the expected value of the changes in EPS by employing OLS regression (by industry). The measure of potential earnings of firm \( i \) in year \( t \) is calculated as the sum of the last round of EPS and the expected value of the changes in EPS. |
| FirmSize          | The year-end total assets of firm \( i \).                                                                                                   |
| LagPMC            | The instrumental variable, measured as the one-year lagged variable of PMC.                                                               |
| Ownership Structure | SOE (Non-SOE): The ultimate controlling shareholder of firm \( i \) is the state (or not) at the end of year.                                   |