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Abstract: Drawing on legitimacy theory, this study examines the relationship between environmental violations and firms' ESG scores, and explores how distinct forms of innovation (substantive and strategic) and media attention (positive and negative) influence this relationship. A staggered difference-in-differences model was used to test the hypothesized relationships. The study reveals significant negative impacts of environmental violations on firm ESG scores; however, the effects reverse in the second year post-violation. Notably, both substantive and strategic green innovations positively moderate the relationship between environmental violations and ESG performance. Furthermore, positive media attention also positively moderates the relationship, while the moderating effects of negative media attention are not statistically significant. The findings offer managers with insights for developing resilient green strategies to prevent and reduce the decline in their ESG scores during environmental crises.

Key words: Environmental violations; ESG; Green Innovation; Media attention; Legitimacy

1. Introduction

Being green is an expensive and difficult endeavour (York et al., 2018), but an important one linked to organizational legitimacy. Although debate regarding whether “being green pays off” continues, a growing consensus acknowledges that being green is crucial, not only for economic imperatives but also for safeguarding the society in which the firm operates against the so-called human-induced climate change (Bansal et al., 2024; Reber et al., 2022; Sachs, 2015). The academic literature richly documents its benefits (Bansal & Roth, 2000; Klassen & McLaughlin, 1996), primarily with regards to building stakeholder trust and reputation.

Conversely, what are the implications of being “ungreen” — engaging in environmentally harmful practices? Does being so yield financial returns? Current literature on this topic is scarce, but it suggests it does in the short term as such practices can be the reason for cost competitiveness. Such practices may be profitable until firms face regulatory investigation; firms tend to outperform competitors in fiscal years prior to the investigation but experience significant financial losses after violations are caught, which can impact firm profitability for several years (Lo et al., 2022). As such, polluting firms following cost leadership strategy tend to relocate their business operations to pollution havens, which are jurisdictions with lax environmental legislations (Levinson & Taylor, 2008; Millimet & Roy, 2016).

However, as the global community is moving towards carbon neutrality, pollution havens have become proponents of the Porter hypothesis, which is in favor of stringent environmental regulations (Farooq et al., 2024). As a result, costs of being ungreen have risen sharply. Recent literature on environmental violations documents the negative impact of firm ungreen practices on firm stock market returns, with abnormal returns serving as proxies for reputation loss (Bouzzine & Lueg, 2020; Karpoff et al., 2005; Xia et al., 2024). However, the market returns have caveats; they are volatile and only reflect short term consequences. Environment, Social, and Governance (ESG) scores, one of the most promising developments in the finance literature, provide a more reliable proxy for a firm’s reputation; their declines would indicate the decline in stakeholder confidence in the firm (Baldini et al., 2018; Diwan & Sreeraman, 2024; Drempetic et al., 2020; Tsang et al., 2023).

We define environmental violations as the instances when ungreen practices of a firm are caught by the regulatory authorities. These acts directly contradict the “Environmental” component of ESG score and can impact the other two components directly or indirectly, leading to a decline in overall ESG performance and introducing the legitimacy gap. While the impacts of environmental violations on firm market and financial performance have been well documented (Xia et al., 2024; Xu et al., 2012; Xu & Zhang, 2024), a significant research gap

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remains in understanding their effects on ESG scores and firms’ responses to mitigate these negative consequences. Previous studies have identified that green innovation leads to higher ESG scores (Zheng et al., 2022), but its role at the onset of environmental violations remains unexplored.

This study aims to examine whether firms are to embrace green innovation activities before or following violations and if so, which type of innovation. Based on quality and complexity, green innovation can be classified as substantive or strategic (Chen et al., 2024; Liao, 2020; Liu et al., 2024). Understanding the form of innovation a firm should pursue is crucial, as the two types have varying timeframes, investment requirements and subsequent effects during and aftermath the environmental violation. Substantive green innovation involves drastic changes in organizational technologies and/or processes entailing activities such as developing clean technologies, implementing energy-efficient systems, or redesigning products aligned with firm’s environmental sustainability objectives (Chen et al., 2024; Liu et al., 2023). Such innovations can significantly reduce regulatory non-compliance risks and also make firms eligible for government support in the form of fiscal incentives and tax subsidies (Xia et al., 2022). Conversely, strategic green innovation focuses more on symbolic actions, involving minor improvements to existing technologies and practices (Lyu et al., 2024).

Although substantive green innovation signals genuine environmental commitments of firms and can build lasting competitive advantages and stakeholder trust, it often requires significant resource investments and longer periods to yield tangible returns (Berrone et al., 2013). Many firms even fall into the “productivity paradox” as it takes time to integrate new technologies into their operations and train employees to use those technologies effectively (Czerny & Letmathe, 2024). Strategic innovation, on the other hand, may offer quicker reputational benefits; however, it may not provide sustainable environmental improvements in the long run. A critical empirical inquiry thus arises: what roles do these two distinct forms of innovation play in improving or preventing the erosion of ESG score during and following environmental violations. This question underscores the theoretical and practical challenges inherent in achieving organizational ambidexterity (Luger et al., 2018) within green innovation.

In addition to green innovation, a well-researched contextual factor that may influence the relationship between environmental violations and ESG scores is the media attention (Kim et al., 2025) a firm receives before, during, and after such violations. Firms often engage in public

relations activities to highlight their crises management efforts and CSR activities, which may mitigate negative impacts to some extent; however, extensive media coverage revealing new and relevant information about violations can potentially exacerbate these effects (Bouzzine & Lueg, 2020; Emma et al., 2024).

Drawing upon the legitimacy theory, we examine the relationship between environmental violations and ESG scores while exploring the moderating effects of distinct forms of green innovation and media attention. To do so, we deploy a staggered difference in differences (DID) empirical design with the firms with records of environmental violations serving as the treatment group while those without such violations constituting the control group. The analysis uses data on Chinese firms from 2015 to 2020. China presents a compelling context for this study, often referred to as the global manufacturing hub, which has faced criticism for its comparatively lenient environmental regulations. However, as of January 1, 2015, the strictest environmental law in the nation's history has been implemented and since then, environmental administrative offices across China have processed approximately 1.3 million cases related to environmental administrative penalties, accumulating a total fine of around 86 billion yuan (\$11.8 billion)¹. The findings of this study indicate that environmental violations significantly affect firms' ESG scores; however, these effects tend to reverse by the second year following the violation. Additionally, substantial moderating effects of both forms of green innovation and media attention were observed.

This study makes several important theoretical contributions. First, it develops a nuanced framework explaining the impacts of environmental violations on ESG performance. Second, it advances the understanding of organizational legitimacy by demonstrating how firms leverage green innovation as strategic organization resource during legitimacy crises. Third, it contributes to impression management literature by exploring media attention's role during corporate crises. Besides, this study utilizes more robust econometric approaches than prior research, which has predominantly relied on traditional methods prone to endogeneity concerns.

¹ <https://www.chinadaily.com.cn/a/202412/24/WS676aa5dda310f1265a1d4ae3.html>

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2. Theoretical background and hypothesis development

2.1 Theoretical framework: Legitimacy theory

Legitimacy theory provides a coherent theoretical framework for understanding how firms operate within the bounds of societal expectations. The theory posits the idea that firms are under an implicit social contract with the society in which they operate and for their continued success, credibility and even the right to exist, they must ensure that their values and behavior are in harmony with what the society deems acceptable, desirable and appropriate (Dowling & Pfeffer, 1975; Suchman, 1995; Suddaby et al., 2017). When there is a discrepancy between societal expectations and a firm's actual behavior, a “legitimacy gap” arises and in response, firms must engage in various reparatory actions to rebuild their legitimacy (Bansal & Roth, 2000; Noack et al., 2019).

An instance where a legitimacy gap arises is when a firm gets involved in environmental violation and thereby fails to meet the societal expectation of environmental stewardship (Tost, 2011). With the firm’s legitimacy at stake, the violating firm can exhibit heterogeneous strategic responses to environmental violations (Gillespie et al., 2014; Schembera & Scherer, 2017), with their maneuvers varying based on regulatory stringency and stakeholder pressure intensity. One of the most used tactics involves firms simply treating regulatory penalties as a cost of doing business, incorporating these fines into their financial planning as calculated risks. The regulatory system might potentially be incentivizing wrong behavior if this approach is being pursued by the majority of firms. Shevchenko (2021) observed that even after being heavily fined for violating environmental regulations, US public firms didn’t clean up their acts.

Other strategic responses to environmental violations include engaging in both related and decoupled corporate social responsibility (CSR) initiatives to regain organizational legitimacy (Bouzzine, 2021; Lee & Xiao, 2020; Nadeem, 2021). Firms also pursue governance-based responses, such as appointing environmental experts to top management positions (Connelly et al., 2016; Dong et al., 2024), aimed at restoring stakeholder confidence in the firm. Besides, they implement strategic environmental investments and pursue environmentally-oriented mergers and acquisitions (M&As) to enhance environmental compliance and financial performance (Chen & Ma, 2021).

2.2 Environmental violations and ESG performance

ESG scores serve as a metric using which stakeholders can evaluate a firm's alignment with environmental, social, and governance expectations, vis-à-vis the legitimacy (Afzali et al.,

2024; Drempetic et al., 2020; Reber et al., 2022); the legitimacy that must not only be obtained but also maintained (Aragón-Correa et al., 2016; Emma et al., 2024). The ESG score has evolved from a simple binary variable indicating whether a firm has disclosed a sustainability report to a holistic ESG score or grade that evaluates the firm across three main interconnected pillars, namely Environmental, Social, and Governance pillars (Tsang et al., 2023). These pillars are further measured by hundreds of indicators, using numerous data points, making the ESG score a comprehensive reflection of the firm's legitimacy. These ESG scores, thus obtained, have gained substantial practical significance with stakeholders using them in various ways for well-informed decision making. For instance, signatories of the Principles for Responsible Investment (PRI), numbering over 5000, leverage ESG scores to channel more than \$100 trillion in assets under management towards ESG investing (Drempetic et al., 2020; Narula et al., 2024).

However, environmental violations, defined as instances where firms violate environmental regulations in their business operations and are subsequently punished by the regulatory authorities (Jin et al., 2024), can introduce a legitimacy gap and trigger multiple mechanisms that affect ESG performance. First, ESG rating agencies incorporate these violations data into their environmental assessments and often downgrade the ESG rating for the violating firm. These violations, such as illegal carbon emissions or dumping of wastes, directly affect the physical environment; such misconduct would lead to a lower score in the environmental pillar (Afzali et al., 2024; Dong & Yu, 2024; Hersel et al., 2019).

Secondly, these negative effects can spill over into the social and governance aspects of ESG score. The literature on environmental misconduct observed significant reputational damage following environmental violations (Hossain et al., 2024), especially with repeated or severe violations (Hu et al., 2024), undermining investor confidence, customer loyalty, and market competitiveness, thereby resulting in indirect and intangible value depletion, which ultimately undermine the social pillar of the ESG score.

Besides, environmental violations signal weak environmental management, which is considered under governance pillar. Studies have shown that in addition to direct costs, such as legal penalties and environmental remediation expenses, the cost of capital (Chava, 2014; Ding et al., 2022; Wang et al., 2022) and audit fees (Yao et al., 2023) of the violating firm also go up following violations, which can be seen as a negative signal under the governance aspect. Besides, these violations attract increased attention and scrutiny from regulatory authorities

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and other stakeholders, which can further expose other social and governance related issues, leading to further decline in the ESG score of the firm. Therefore, in line with the legitimacy theory, we posit that:

Hypothesis 1. Environmental violation has a negative impact on the ESG performance of a firm.

2.3 The role of Green Innovation

Green innovation has emerged as a crucial strategic response for firms engaged in environmental violations, offering them pathways to both meet regulatory requirements and create sustainable competitive advantages while capturing emerging opportunities related to climate change (Brunnermeier & Cohen, 2003; Harting et al., 2006; Kolk & Pinkse, 2004). Unlike traditional responses such as solely paying penalties or engaging in CSR activities, green innovation can fundamentally transform organizational capabilities while reducing environmental impact (Andersén, 2021; Carrión-Flores & Innes, 2010). This dual benefit makes it particularly attractive as a strategic response, although its implementation varies between strategic green innovation and substantive green innovation.

The choice between strategic and substantive green innovation is influenced by institutional pressures and resource availability (Doran & Ryan, 2016; Huang & Chen, 2022). Firms with substantial “green slack” resources are better positioned to pursue more complex substantive green innovations, which can potentially lead to significant competitive advantages through invention patents and novel green technologies in the long run (Huang & Chen, 2022; Liu et al., 2024). This sort of innovation also reduces the likelihood of repeating environmental violations (Chen & Ma, 2021; Farooq et al., 2024). In contrast, resource-constrained firms or those facing immediate compliance pressures often default to strategic innovations, which require fewer resources and can yield short-term environmental benefits. Regardless of the form of innovation a firm adopts before, during or after an environmental violation, we propose that these innovations can enhance organizational legitimacy and can even mitigate the risk of reputation loss at the time of violations as it demonstrates a commitment to environmental stewardship. Therefore, we posit that:

Hypothesis 2a. Substantive green innovation positively moderates the relationship between firm environmental violation and the firm ESG performance.

Hypothesis 2b. Strategic green innovation positively moderates the relationship between firm environmental violation and the firm ESG performance.

2.4 The role of media attention

Existing literature has discussed the significant role of media in impression management and crisis management. After all, the media serves as the primary source of information and can trigger and shape the trajectory of crisis management following violation events (Emma et al., 2024). It plays a crucial role in reducing the information asymmetry between firms and other stakeholders (Dorobantu et al., 2024), especially when a firm engages in corporate misconduct.

Media coverage of the corporate misconduct tends to reduce firm value (Li et al., 2023), and can even lead to stakeholder sanctions such as boycotts and legal actions (Kölbel et al., 2017). The negative media attention, as a result, can significantly affect stakeholder perceptions and evaluations of the violating firms' sustainability performance (Zavyalova et al., 2012). This negative media attention can also pressure firms to take corrective actions, leading to investigations and enforcement by regulatory authorities (Jiang et al., 2022), as well as increased exposure to financial risks (Cheng et al., 2024; Ding et al., 2022; Kölbel et al., 2017).

Conversely, positive media attention on a firm's CSR activities can reduce the negative impact of environmental violations on firm value (Ouyang et al., 2023; Yang et al., 2024). We argue that this positive media attention can also help protect the firm's ESG rating from declining. Following this logic, we predict that:

Hypothesis 3a. Positive media attention positively moderates the relationship between firm environmental violations and the firm's ESG performance.

Hypothesis 3b. Negative media attention negatively moderates the relationship between firm environmental violations and the firm's ESG performance.

Fig. 1 illustrates the conceptual model of this research.

INSERT FIG. 1 ABOUT HERE.

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3. Research design

3.1 Sample data

The sample for this study comprises publicly listed firms in China. Specifically, the data were collected on A share² firms listed on the Shanghai and Shenzhen Stock Exchanges. To avoid the potential confounding effects of abnormal financial conditions, we excluded firms that had been designated as "Special Treatment" (ST) or "*ST," as these are firms that have been flagged for special regulatory treatment due to their uncertain financial situations and are at risk of being delisted from the stock exchanges. We also excluded financial firms from our sample, as they have different financial reporting standards and do not have significant direct impact on environmental emissions. We then collected data on these firms' basic information and financial indicators from the China Stock Market and Accounting Research (CSMAR) database. The sample period is defined as 2015 to 2020. We chose 2015 as the starting point as the Environmental Protection Law (EPL) of China was significantly amended in 2014 and came into effect on January 1, 2015.

Finally, we consolidated these firm information with firm-year environmental violation records, ESG scores, green innovation data, and media attention data to obtain the final sample. This resulted in 15,564 firm-year observations from 3,393 unique firms, of which 880 firms constituted the treated group and the remaining firms were in the control group. The variables of the study were winsorized at the 1st and 99th percentiles to mitigate the effects of extreme outliers in the data. The definitions of all the variables used in this study are provided in Appendix A1.

3.2 Variables

3.2.1 ESG scores

In this study, we utilize Huazheng ESG scores as the dependent variable. The Huazheng ESG scores are extensively used in academic research pertaining to the ESG performance of Chinese firms, as the rating methodology incorporates a comprehensive framework designed to evaluate the sustainability performance of firms in the Chinese securities market. The rating methodology uses a three-pillar structure: Environmental, Social, and Governance, with each pillar further divided into 16 second-tier themes, 44 third-tier key issues, 80 fourth-tier indicators, and over 300 underlying data points. The final ESG score is then derived as the

² A shares denote the shares of firms denominated in RMB and listed in stock exchanges of mainland China

weighted average of the three pillars. The higher the ESG score, the more a firm engages in ESG related issues.

3.2.2 Environmental violations

To obtain data on the environmental violations committed by the sample firms, we manually searched for administrative environmental violation records for each of these firms on the database maintained by the Institute of Public and Environmental Affairs (IPE), a Beijing-based non-profit environmental organization supported by the central government of China. The IPE database collects data on corporate environmental footprints from a variety of sources, including the websites of regulatory authorities at different government levels, news agencies, and listed firms. Most of the literature on environmental violations in China refer to this database as the source of the data on violation records (Jin et al., 2024; Li et al., 2023; Ouyang et al., 2023). To prepare the data for analysis, we first removed duplicate records. Additionally, since many firms had multiple violation records in a given year, we considered multiple records for a firm in each year as one record by summing the fines into one total fine in that particular year. After limiting the data to 2015-2020 timeframe and removal of duplicate records, we obtained 1910 yearly violation records by 860 firms. Fig. 2 depicts the trend in the number of violating firms among the Chinese A share listed firms. The environmental violation records by industry, along with total fine imposed, are provided in Appendix A2.

INSERT FIG. 2 ABOUT HERE.

3.2.3 Green innovation

Following Chen et al. (2024) and Liu et al. (2024), among others, we measure green innovation using two distinct dimensions - substantive green innovation and strategic green innovation. Substantive green innovation is proxied by the natural logarithm of sum of one and the number of invention patent applications in a given year filed by the sample firms, as invention patents are recognized for their creative, practical, and novel attributes, indicating more substantial innovative efforts. Similarly, Strategic green innovation is measured by the natural logarithm of one plus the number of utility patent applications submitted by the sample firms in the same year, as utility model patents tend to have a greater emphasis on practical applications, albeit with lower technical complexity compared to invention patents. The data for these two dimensions of green innovation are obtained from the Chinese Research Data Services platform (CNRDS).

3.2.4 Media attention

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Following Jiang et al. (2022), we operationalize negative media coverage as the natural logarithm of one plus the total number of negative news articles pertaining to each sample firm within a specified year. Similarly, positive media attention is defined as the natural logarithm of one plus the total number of positive news articles relevant to the sample firm within the same year. Data regarding the daily counts of negative and positive news articles associated with each firm are sourced from the Chinese Research Data Services Platform (CNRDS), which employs artificial intelligence algorithms to collect, organize, and analyse financial news concerning listed firms from over 400 online media outlets and more than 600 newspapers. Subsequently, we aggregated this data on an annual basis to derive yearly totals.

3.2.5 Control variables

We use the log-transformed values of total assets as a proxy for firm size, acknowledging the potential that larger firms may possess greater resources to address environmental misconduct, whether through innovative initiatives or public relations efforts (Drempetic et al., 2020). Additionally, we control for various corporate governance indicators, including CEO duality and the structure of institutional ownership. Furthermore, we considered the financial constraints of the firm by utilizing the leverage ratio, defined as the ratio of total liabilities to total assets.

3.3 Empirical model specification

3.3.1 Staggered DID model

Following previous literature (He et al., 2024; Zhou et al., 2024), we utilize the following staggered difference in differences (DID) framework to test the impact of environmental violations on ESG scores of firms:

$$ESG_{i,t} = \alpha_0 + \beta_1(Treated_i \times Post_t) + \beta_2X_{i,t} + \gamma_t + \mu_i + \delta_j + \varepsilon_{i,t} \tag{1}$$

Where $ESG_{i,t}$ denotes the ESG composite score for the firm i in the year t , α_0 is the intercept term. The dummy variable $Treated$ identifies firms that have engaged in environmental violations, while $Post_t$ indicates post-violation temporal periods. The interaction term $Treated_i \times Post_t$ is the core explanatory variable of interest, X_{it} is the matrix of control variables. β_1 captures the average treatment effect on the treated (ATT) and serves as the DID estimator, quantifying the marginal impact of environmental violations on ESG score. To account for unobserved heterogeneity and temporal trends, we incorporate year fixed effects (γ_t), firm-specific fixed effects(μ_i), and industry fixed effects (δ_j). $\varepsilon_{i,t}$ represents the disturbance term.

3.3.2 Moderating effect model

To further examine the moderating effects (Hypotheses H2a, H2b, H3a & H3b), this study specifies the following model:

$$ESG_{i,t} = \alpha_0 + \beta_1(Treated_i \times Post_t) + \beta_2(Treated_i \times Post_t \times Moderator_{i,t}) + \beta_3 Moderator_{i,t} + \beta_4 X_{i,t} + \gamma_t + \mu_i + \delta_j + \varepsilon_{i,t} \quad (2)$$

Where $Moderator_{i,t}$ refers to the moderating variable and the rest of the variables are consistent with Model (1). If the coefficient β_2 is significant, it indicates that there exists a moderating effect of the moderator on the relationship between firm environmental violations and ESG scores.

4. Results

4.1 Descriptive statistics

Table 1 reports descriptive analysis of variables examined in the study. As shown in the table, the ESG scores for both treated and control firms exhibit a relatively high average level of performance, with the treated firms having a mean ESG score of 73.3 and the control firms having a slightly higher mean score of 73.462. The scores for treated firms range from a minimum of 36.62 to a maximum of 90.93, while for control firms, the range is from 44.67 to 92.93. The standard deviation for treated firms is 5.927 while that for control firms is lower at 5.455. These indicate that while both groups have firms with high ESG scores, the treated firms have a higher degree of variation around the mean as compared to control firms. Besides, it can be observed from the table that the treated firms are more engaged in green innovations (both strategic and substantive) and gain more media attention as compared to control firms.

INSERT TABLE 1 ABOUT HERE.

4.2 Parallel Trend test

The parallel trend assumption is a fundamental prerequisite for the validity of the DID estimation framework. This assumption hypothesizes that in the absence of treatment, the treatment and control groups would have experienced similar trends for the outcome variable. Thereby, in line with event study method, model (2) was developed to test whether the parallel trend assumption holds in our study:

$$ESG_{i,t} = \alpha_0 + \beta_1 \sum_{k=-5, k \neq -1}^5 D_{i,t+k} + \beta_2 X_{i,t} + \gamma_t + \delta_j + \varepsilon_{i,t} \quad (3)$$

Where $D_{i,t+k}$ is an indicator variable assigned a value of 1 if the firm is in the k year before/after the environmental violation event; otherwise it takes value 0. Other variables have the same meanings as in model (1). The year preceding the environmental violation event is

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used as the benchmark year. Fig. 3 plots the coefficient estimates for each year. As illustrated, before the year of environmental violations, there are no significant difference in ESG scores between firms that committed environmental violations and those that did not; thus, the parallel trend hypothesis holds in this study.

INSERT FIG. 3 ABOUT HERE.

4.3 Baseline regression results

Table 2 presents the baseline model estimation results examining the relationship between environmental violations and firm ESG performance. The results show that environmental violations significantly reduce the ESG score of the violating firm. Regardless of whether the control variables are introduced or not, the coefficient of the DID term (Treated*Post) is significantly negative at the 5% significance level. This finding supports Hypothesis 1, which posited that environmental violations have a significant negative impact on the firm's ESG score. As shown in Column 2 of the Table 2, which is the specification with control variables, the results indicate that, on average, an environmental violation by a firm leads to a decline in the firm's ESG score by 0.457 points, keeping all other variables constant.

INSERT TABLE 2 ABOUT HERE.

4.4 Robustness checks

4.4.1 Heterogeneous treatment effects test

The impact of firm environmental violations on the ESG scores of the violating firms may vary across years, resulting in heterogeneous treatment effects across individual and temporal dimensions. This variability may introduce biased outcomes when employing staggered DID estimation (Goodman-Bacon, 2021). To address these issues, this study deploys three robust estimation techniques. First, as outlined by De Chaisemartin & D'haultfoeuille (2020), this study utilizes the did_multipligt estimator, to evaluate the immediate treatment effect within the treatment group. This methodology effectively mitigates the challenges associated with negative weighting that may arise from variations in treatment intensity by excluding observations that have already received treatment.

Secondly, we apply the Conditional Synthetic Difference-in-Differences (CSDID) estimator proposed by Callaway & Sant'Anna (2021). This doubly robust approach accounts for the dynamic effects and incorporates both untreated and not yet treated observations as control group, providing more nuanced understanding of treatment effects over time. Furthermore, we run extended Two Way Fixed Effects (TWFE) estimator as suggested by

Wooldridge (2021), who posits that an unbiased, consistent, and asymptotic efficient estimator for heterogeneous Average Treatment Effects (ATTs) in DID can be achieved by including interactions between treatment-time cohorts and time in the TWFE specification.

Fig. 4 depicts the results of dynamic effects derived from these three robust methodologies. Statistically significant negative impacts of violations on ESG scores were observed in the year of violation and the following year, after which the negative effect on ESG scores begins to reverse.

INSERT FIG. 4 ABOUT HERE.

4.4.2 Mixed Placebo test

Following Qu et al. (2025), this study adopts mixed placebo test to enhance the credibility of treatment effects. Unlike traditional placebo tests, this method considers both temporal and spatial dimensions, using both fake treatment units and fake treatment time. We ran 1000 simulations with different treatment firms and/or different treatment times. Fig. 5 presents the probability density distribution of the estimated coefficients from these simulations, with the red line indicating the coefficient value obtained from the baseline model. It can be observed that the coefficients from the simulations are normally distributed around zero and are significantly larger than the benchmark coefficient. Therefore, the findings in Table 2 are attributable to the environmental violations rather than unknown random factors.

INSERT FIG. 5 ABOUT HERE.

4.5 Mechanism test

The results from the previous section indicate that a firm's environmental misconduct results in a decline in its ESG score. However, additional analysis is required to determine how exactly this misconduct affects ESG score. As discussed in sections 2.3 and 2.4, we explore the internal mechanisms at play, highlighting the moderating roles of two dimensions of green innovation, as well as the external mechanisms, particularly the impact of media attention.

4.5.1 Role of Green Innovation

As shown in columns 1 and 2 of Table 3, both dimensions of firm green innovation have significant positive moderating effects on the relationship between environmental violations and ESG scores. Thus, both hypotheses H2a and H2b are supported. The moderating effects of both substantive innovation ($\beta = 0.379$) and strategic innovation ($\beta = 0.365$) are significant at 1% significance level.

INSERT TABLE 3 ABOUT HERE.

4.5.2 Role of Media Attention

Columns 3 and 4 of Table 3 present the results of tests of moderation effects of media attention on the relationship between environmental violations and ESG scores. It can be observed that while positive media attention significantly moderates the impact of environmental violation on ESG score, negative media attention doesn't have significant moderating impact. The moderating impact of positive media attention ($\beta=0.277$) is significant at 1% significance level.

4.6 Heterogeneity analysis

Table 4 reports results of heterogeneity analyses that we conducted to explore the varying impact of firm environmental violations on ESG scores across various types of firms. First, we tested if the impact varies across state-owned and non-state-owned firms. Previous research has indicated that state-owned firms are less adversely affected by environmental violations due to their strong political connections, which may provide them with support when necessary (Hossain et al., 2024; Xia et al., 2024). However, we observe a decline in ESG scores by similar magnitude following environmental violations across these firms. Additionally, our analysis reveals that the ESG scores of small-cap companies (defined as those with natural logarithm of total assets below the median) are hit harder compared to larger firms following environmental violations. This could be because larger firms tend to possess greater resources, which can enable them to comply with environmental regulations and invest in necessary technologies following violations.

Further, we categorized the sample into two groups based on institutional ownership levels: firms with institutional investor shareholding ratios exceeding the median were designated as the high institutional attention group, while those below the median were classified as the low institutional attention group. Our findings indicate that firms with higher institutional ownership tend to perform better in ESG scores than those with lower ownership levels during environmental violations. This could be due to the monitoring and pressure exerted by institutional investors to ensure compliance with environmental regulations.

INSERT TABLE 4 ABOUT HERE.

5. Conclusion, Implications and limitations

The main objective of this study was to understand the relationship between environmental violations and firms' ESG scores. As hypothesized and in line with legitimacy theory, we observed that violations have significant negative effects on ESG scores, with these effects lasting for two years before reversing. The results are robust across different econometric model specifications. This aligns with previous research, which had demonstrated negative consequences of environmental violations on firms' stock market and financial performance (Lo et al., 2022; Xia et al., 2024; Xu & Zhang, 2024). Thereby, this study reiterates that environmental stewardship matters; if they violate this stewardship, it will threaten their legitimacy.

The reversal of impacts on ESG score, that we observed in the second year following violation using event study specifications, might be attributed to green innovations pursued by firms in response to violations. We observed that green innovations, be it strategic or substantive, both have significant mitigating effects during the environmental violation events. In addition, we found positive media attention has statistically significant mitigating effects on the relationship between violations and ESG scores. While negative media attention itself had a significant negative impact on scores, no significant moderation effect was observed.

Thus, by integrating internal (green innovation) and external (media attention) mechanisms, this study provides a nuanced understanding of how firms can steer environmental violations in its favor in an era of increased stakeholder activism. When handled properly, violation events can be turned into opportunities through new knowledge acquisition, proactive implementation of ESG practices, and development of new sustainability-related revenue streams.

5.1 Theoretical implications

This study extends the organizational legitimacy literature by conceptualizing ESG as an indicator of legitimacy and empirically examining how this indicator is affected by environmental violations. In doing so, it highlights a dynamic legitimacy recovery mechanism revealing that legitimacy damage is not necessarily permanent. Furthermore, it enriches the reputation repair literature by suggesting the moderating roles of two distinct forms of innovation and media in the relationship between environmental violations and ESG scores.

Prior literature on environmental violations have predominantly relied on traditional two-way fixed effects model and TWFE DID approaches to establish the causality, despite these specifications being prone to endogeneity issues such as negative weighting issues and

heterogeneous treatment effects biases (Goodman-Bacon, 2021). In contrast, this study has introduced the use of the new efficient estimators robust to these concerns, thereby offering a more robust examination of the impact of environmental violations.

5.2 Managerial implications

This study underscores that prevention is better than cure —violations have significant negative impacts on ESG scores regardless of mitigating factors. Firms should prioritize ESG compliance and risk management systems to prevent violations in the first place. However, the findings of this study can provide support for crisis managers to formulate green innovation and media engagement strategies to prevent or reduce their firm’s ESG score from dropping amidst the environmental violation cycle. Given that both strategic and substantive green innovations have positive mitigating effects, managers can consider incorporating both sorts of innovations in their crisis management strategies. These innovations can not only help firms boost their ESG scores in the long run, but also help them prevent any environmental misconduct in the future.

Furthermore, managers are encouraged to engage in impression management as positive media attention could significantly reduce the impact. They can use news related to their green innovations or other ESG related activities to project a positive image of themselves as sustainability advocates of environmental stewardship and boost their sustainability credentials, which can substantially help the firm in evading the environmental violation crises by giving them the benefit of the doubt.

5.3 Limitations

As with all empirical studies, this study is subject to certain limitations that can constrain the generalizability of its findings. First, the analysis is confined to observations from 2015 onward as prior data would fall under different environmental regulatory framework of China. This choice to omit data prior 2015 may introduce sample selection bias and limit both the sample size and variability. Future study can examine how the relationships among the study variables have evolved following the implementation of the new environmental regulatory framework.

Second, we didn’t incorporate green innovation input dimensions, e.g. R&D expenditure. Instead, we only relied on the green innovation output dimensions, namely green utility patents and green invention patents as the indicators for green strategic and green substantive innovations, respectively. We made this decision because of challenges in segregating the

green innovation input from the traditional innovation inputs. Addressing this issue in future studies would require enhanced data collection efforts and increased transparency in the reporting of innovation inputs.

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Table 1 Descriptive statistics of variables

Variable	N	Mean	Std. Dev.	Min	Max
ESG	15564	73.412	5.607	36.62	92.93
lnuti	15564	.72	1.21	0	7.009
lninv	15564	.707	1.26	0	7.579
lnpos	15558	4.289	1.08	.693	9.812
lnneg	15564	3.864	1.082	.693	10.038
ROA	15563	.045	.064	-.231	.227
Size	15564	22.279	1.297	20.061	26.352
Leverage	15564	.406	.196	.059	.867
SOE	15564	.321	.467	0	1
Duality	15359	.304	.46	0	1
HHL10	15564	.16	.112	.017	.555
Insti	15553	.427	.251	.002	.907
Martobook	15560	2.558	2.293	.327	14.056
Age	15564	10.71	7.839	.307	27.052

All the variables are defined in Appendix A1.

Table 2 Baseline regression results

	(1) ESG	(2) ESG
treat*post	-0.367** (0.153)	-0.457*** (0.153)
ROA		3.691*** (0.902)
Size		1.418*** (0.176)
Leverage		-4.548*** (0.555)
SOE		0.101 (0.367)
Duality		0.152 (0.138)
HHL10		0.840 (1.432)
Insti		1.102* (0.654)
Martobok		0.0394 (0.0267)
Age		0.552 (0.358)
Constant	73.43*** (0.0437)	36.76*** (5.457)
Firm FE	Yes	Yes
Year FE	Yes	Yes
Industry FE	Yes	Yes
<i>N</i>	15126	14905
<i>R</i> ²	0.681	0.688

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3 Mechanism test

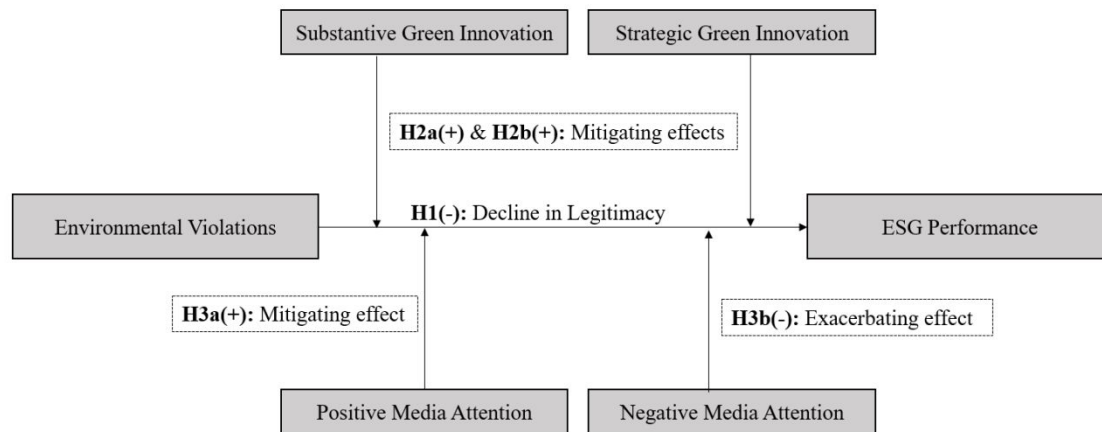
	(1) ESG	(2) ESG	(3) ESG	(4) ESG
treat*post	-0.898*** (0.178)	-0.884*** (0.175)	-1.632*** (0.474)	-0.696* (0.396)
treat*post*lnuti	0.365*** (0.0889)			
lnuti	0.108* (0.0634)			
treat*post*lninv		0.379*** (0.0858)		
lninv		0.157** (0.0647)		
treat*post*lnpos			0.277** (0.108)	
lnpos			-0.127** (0.0643)	
treat*post*lnneg				0.0669 (0.101)
lnneg				-0.599*** (0.0602)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
N	14905	14905	14898	14905
R ²	0.689	0.689	0.688	0.691

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4 Heterogeneity Analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	State-owned		Firm Size		Institutional ownership	
	SOE	Non SOE	large	small	high	low
treat*post	-0.531** (0.242)	-0.535*** (0.198)	-0.500** (0.200)	-0.900*** (0.268)	-0.404* (0.216)	-0.574** (0.235)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
<i>N</i>	4752	10083	7406	7204	7298	7312
<i>R</i> ²	0.734	0.675	0.701	0.696	0.719	0.675

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ **Fig. 1** Theoretical framework

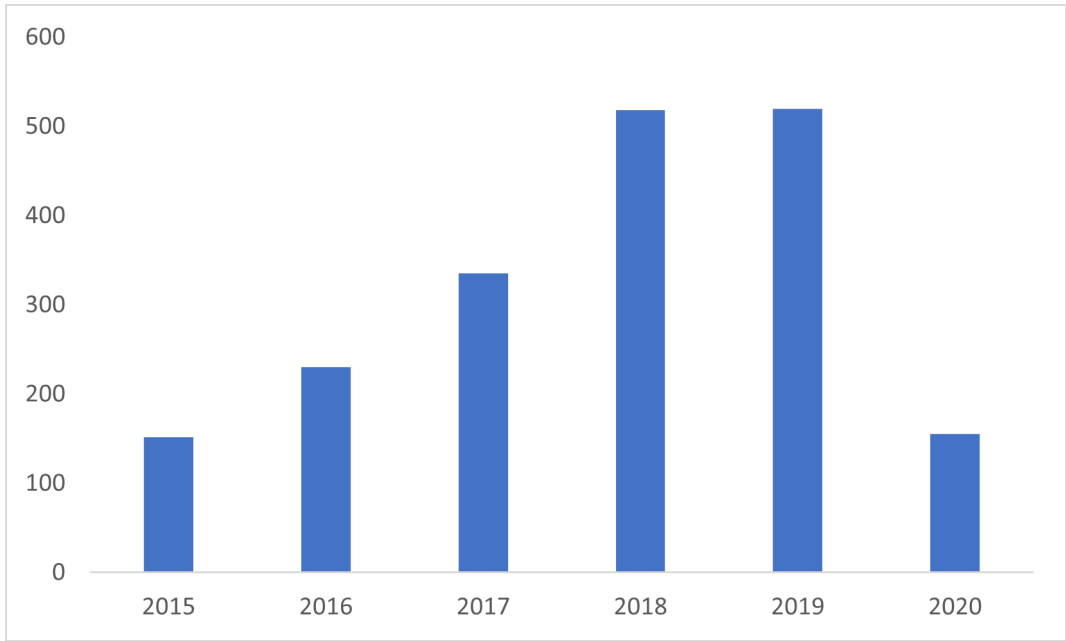


Fig. 2 Trend in the number of violating firms

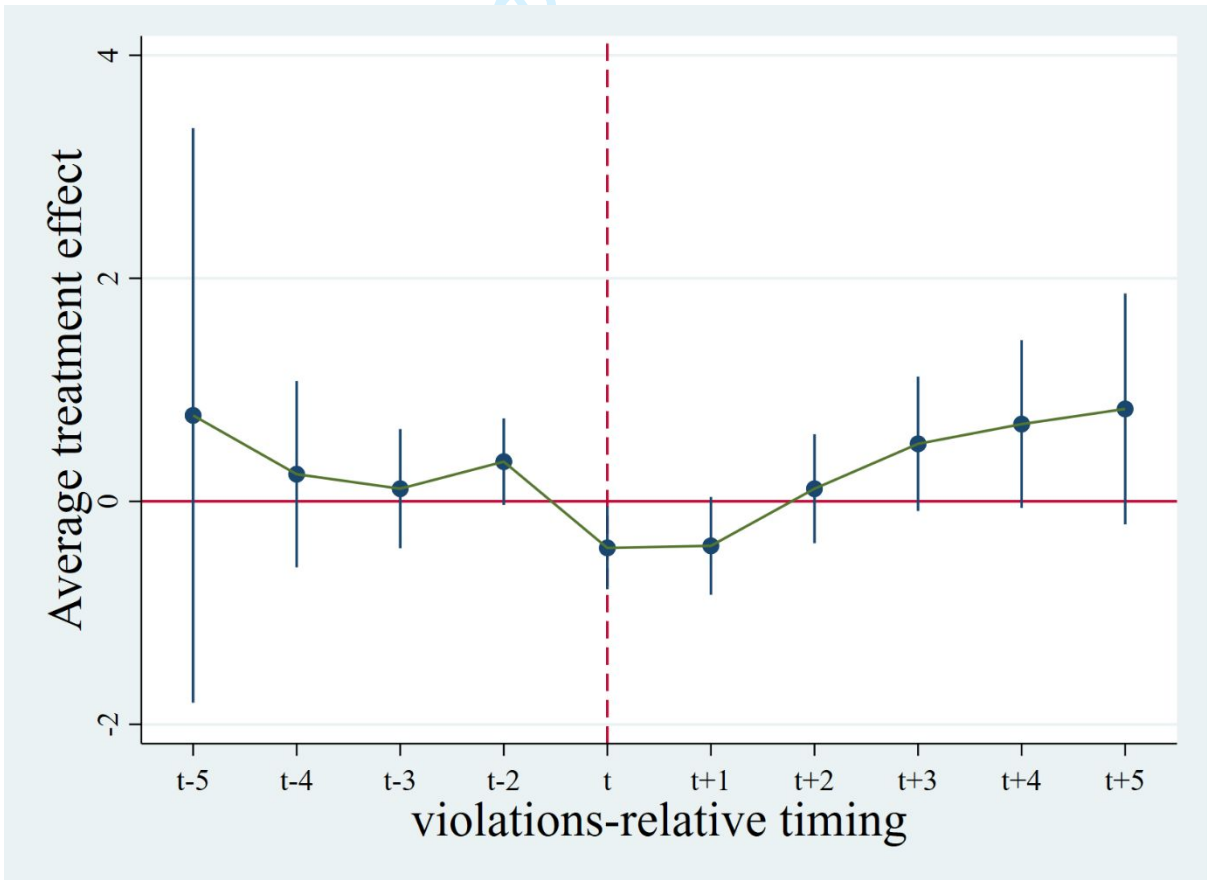
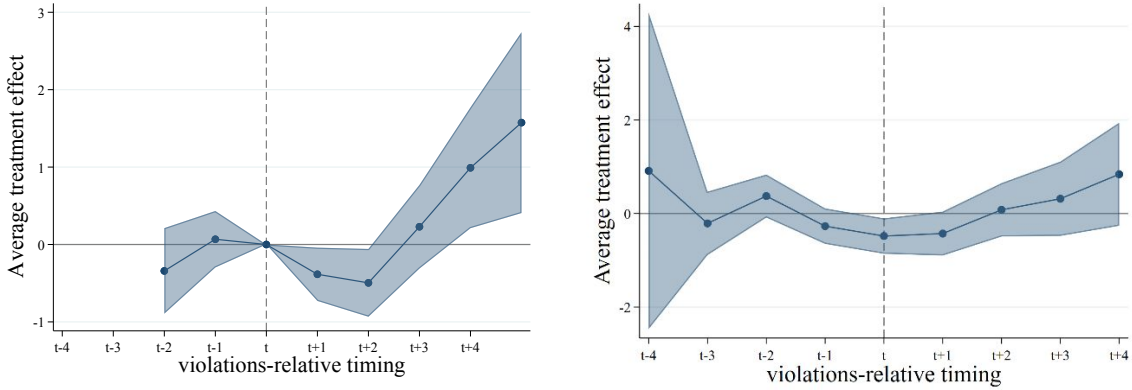
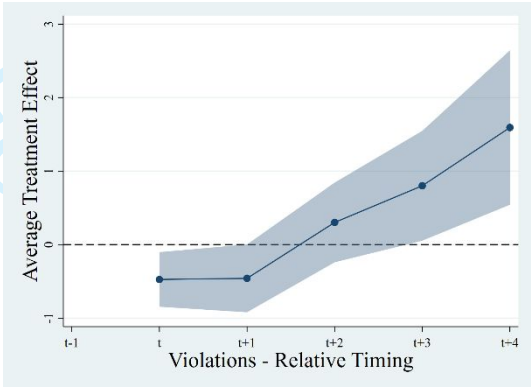


Fig. 3 Parallel trend test



(a) did_multiplegt estimator (b) CSDID estimator



(c) Extended TWFE estimator

Fig.4 Staggered DID heterogeneity-robust tests

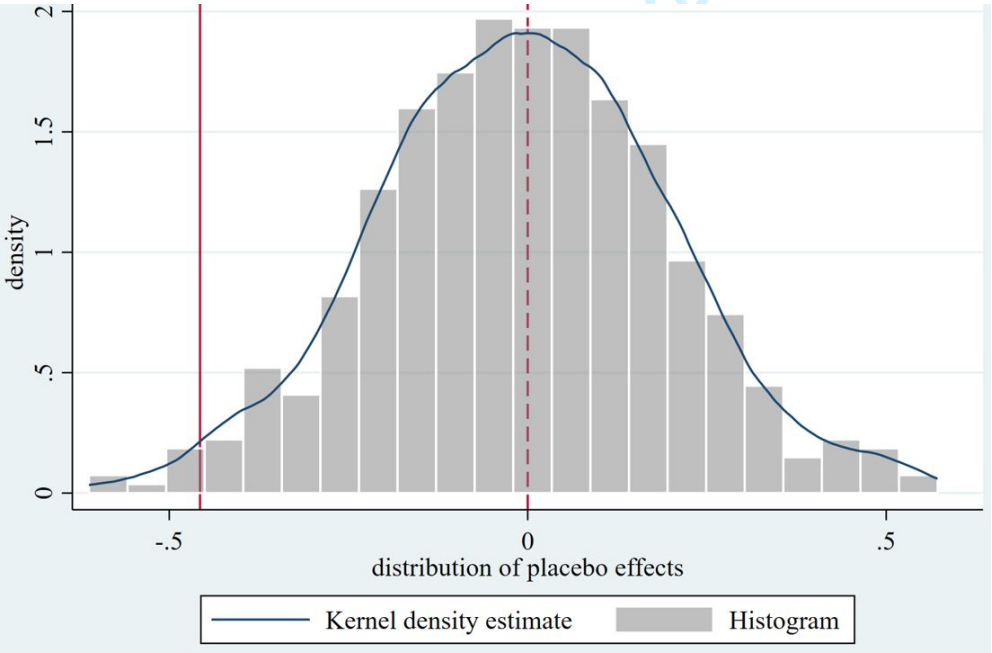


Fig. 5 Restricted mixed placebo test for staggered DID

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Table A1 Variable definitions

Variable	Description	Calculation method
ESG	The overall ESG performance score of the firm	Obtained from Huazheng ESG ratings database
treated	Environmental violation	A binary variable that equals 1 if the firm has violated environmental laws or regulations, and 0 otherwise
post	post violation period	A binary variable that equals 1 if the year is the violation year or year after the violation year, and 0 otherwise.
lnuti	Strategic green innovation	The natural logarithm of number of green utility patent applications plus 1
lninv	Substantive green innovation	The natural logarithm of number of green invention patent applications plus 1
lnpos	Positive media attention	The natural logarithm of the number of positive media articles about the firm plus 1
lnneg	Negative media attention	The natural logarithm of the number of negative media articles about the firm plus 1
ROA	Return on Assets	Net Income divided by total assets
Size	Firm size	The natural logarithm of the firm's total assets
Leverage	Leverage ratio	Total liabilities divided by total assets
SOE	State Ownership	A binary variable that equals 1 if the firm is state owned enterprise, and 0 otherwise
Duality	CEO duality	A binary variable that equals 1 if the CEO also serves as the board chair, and 0 otherwise
HHL10	10 largest institutional investors holding	The percentage of shares held by the firm's 10 largest institutional investors
Insti	Institutional holding	The percentage of shares held by institutional investors.
Martobook	Market to Book ratio	The ratio of the firm's market value to its book value
Age	Firm age	The number of years since the firm's establishment

Table A2 Violation records by industry from 2015 to 2020

Industry Code	Industry Name	Fine (10,000 RMB)	no. of violations
C26	Manufacturing of chemical raw materials and chemical products	54809.938	239
C29	Industry of rubber and plastic products	44784.929	35
C36	Automobile manufacturing	18023.371	68
C31	Industry of ferrous metal smelting and rolling processing	13298.899	74
E48	Civil engineering construction industry	8728.235	102
D44	Industry of electric power and heat production and supply	7718.068	90
B06	Coal mining and dressing industry	5646.490	58
B07	Oil and natural gas exploitation industry	4824.027	13
C32	Industry of non-ferrous metal smelting and rolling processing	4515.844	51
C30	Industry of non-metallic mineral products	3669.223	96
D46	Water production and supply industry	3105.147	21
C25	Industries of petroleum processing, coking, and nuclear fuel processing	2910.455	18
C13	Agricultural and sideline food processing industry	2532.782	64
C27	Pharmaceutical industry	2476.754	125
C39	Manufacturing of computers, communications and other electronic equipment	2328.546	82
C35	Special-purpose equipment manufacturing	2254.337	88
B09	Non-ferrous metal ore mining and dressing industry	2063.907	37
C33	Metal product industry	1800.197	37
N77	Ecological protection and environmental governance industry	1385.202	39
K70	Real estate industry	1357.286	55
C37	Manufacturing of railways, ships, aircrafts, spacecrafts and other transportation equipment	1349.697	34
C14	Food manufacturing	1336.325	26
C22	Papermaking and paper product industry	1238.400	24
F51	Wholesale industry	1190.808	33
C38	Electric machinery and equipment manufacturing	1014.369	76
F52	Retail industry	937.724	27
E47	Building construction industry	782.400	5
C15	Alcohol, beverage and refined tea manufacturing	708.561	27
C34	General equipment manufacturing	694.698	48
A03	Animal husbandry	482.039	18
S90	Diversified industries	408.500	11
C28	Chemical fiber manufacturing	345.674	14
G55	Waterway transport industry	228.100	20
A01	Agriculture	220.380	8
B08	Ferrous metal ore mining and dressing industry	164.585	4
C18	Textile garment and apparel industry	157.682	6
C41	Other manufacturing industries	147.750	8
E50	Architectural decoration and other construction industries	118.630	12
G54	Road transport industry	113.200	14
D45	Gas production and supply industry	103.185	7
G60	Postal service industry	102.390	6
C19	Leathers, furs, feathers and related products and footwear industry	80.438	5

C17	Textile industry	67.000	10
B11	Exploitation auxiliary activities	66.173	5
C42	Industry of comprehensive utilization of waste resources	66.000	5
R85	Press and publishing industry	65.000	5
C20	Wood processing and wood, bamboo, rattan, palm fiber, and straw product industry	52.694	7
C23	Printing and recording media reproduction industry	51.000	6
I63	Telecommunications, radio and television and satellite transmission services	51.000	1
I64	Internet and related services	51.000	5
A04	Fishery	46.500	4
G56	Air transport industry	43.100	4
N78	Public facility management industry	26.000	2
C40	Instrument and meter manufacturing	22.162	7
G58	Industry of loading/unloading handling and transport agency	22.050	4
M74	Professional technical service industry	18.500	5
Q83	Health	17.749	3
I65	Industry of software and information technology services	17.472	4
C24	Manufacturing of stationery, industrial arts, sports and entertainment supplies	15.200	2
B10	Non-metallic ore mining and dressing industry	10.500	1
M73	Research and experimental development	10.000	1
G53	Railway transportation industry	1.350	1
C21	Furniture manufacturing	0.600	1
R86	Radio, television, film, and film and television sound recording production industry	0.150	1
R87	Industry of culture and arts	0.000	1
Total		200880.371	1910

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