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Research article

# Double-edged sword of industrial internet of things: Empirical evidence from green transformation of enterprises

Liqun Liu [a], Lin Liu [a,**,1], Kai Liu [a,*,1], Ana Isabel Jiménez-Zarco [b]

[a] College of Economics and Management, Shihezi University, Shihezi, China
[b] Economic and Business Department, Open University of Catalunya, Barcelona, Spain

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ABSTRACT

The industrial revolution based on the Internet of Things brings new opportunities and challenges for enterprises' green and sustainable development. Therefore, this study explores the relationship between the Industrial Internet of Things (IIOT) and the Green Transformation of Enterprises (GT) based on the data of China's A-share listed companies from 2009 to 2023 using two-way fixed, mediated effect, and moderated effect models. The results show that for every unit increase in IIOT, the GT increases by 28.89 percent on average, indicating that IIOT can break down information barriers and effectively promote GT. However, after disaggregating the GT, it was found that the IIOT guided companies to implement the Symbolic Green Transformation (SGT) instead of adopting the Realistic Green Transformation (RGT). This strategic choice preference is more pronounced among firms that are larger, in energy-intensive industries, in regions with weaker environmental regulations and higher levels of development. The intermediary mechanism test proved that the IIOT can drive firms to implement comprehensive GT through paths that enhance investment attractiveness, productivity, technological innovation, and pay gaps. In particular, the masking effect reminds us that smart technology is a "double-edged sword". The negative effects of smart technologies hinder the implementation of RGT. Further analysis reveals an inverted U-shaped relationship between IIOT and RGT preferences. In addition, in companies that focus on Environmental, Social and Governance (ESG) performance and avoid financial speculation, the dark side of intelligent technology is suppressed. The findings of this study enrich the research scope of smart technology, GT, and provide important insights for enterprises in emerging economies to rationally utilize IIOT to seek green and sustainable development under the wave of rapid development of smart technology.

## 1. Introduction

Although the industrial system in the smart era is driving rapid changes in human civilization, the energy and environmental crises brought about by the excessive exploitation and utilization of fossil energy sources have become a fundamental obstacle to global green and sustainable governance [1,2]. Nowadays, in the world's major economies, such as the European Union, China, and the

* Corresponding author.
** Corresponding author.
*E-mail addresses:* richer2606@163.com (L. Liu), aspiration83lin@sina.com (L. Liu), liukai5850@163.com (K. Liu), ajimenezz@uoc.edu (A.I. Jiménez-Zarco).
[1] Lin Liu and Kai Liu contributed equally to this work.

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United States, corporate Green Transformation (GT) initiatives, which focus on energy transformation and environmental protection, have become the micro foundation for promoting global sustainable governance [3]. Especially for mining, thermal power, metallurgy, chemical, and other heavy polluters, they as a contradiction between economic development and a green sustainable base, whether they can successfully carry out GT has become the focus of social concern. In conclusion, GT, as an important foundation for achieving the goal of carbon neutrality, requires humans to explore new solutions in the smart era.

Especially after the financial crisis of 2008, countries around the world have recognized the important role of real businesses in their economies. In 2012, the concept of the Industrial Internet of Things (IIOT) was proposed by General Electric Company in the U.S. IIOT is regarded as the deep integration of information and communication technology and industrial economy, aiming to build a new manufacturing and service system covering the whole industrial chain and the whole value chain and to achieve industrial digitalization, networking, and intelligent development. IIOT, also known as the Industrial Internet or Industry 4.0, is an emerging technology that has fuelled the fourth industrial revolution and economic recovery [4]. While IIOT has brought disruptive changes to human economic development, whether it forms a global green revolution with longer-term goals still needs to be tested and dissected.

Throughout the world, the integration of green governance and IIOT has become the current international consensus. How to explore the green potential of IIOT to realize a green industrial revolution has become a hot topic of discussion. On the one hand, Under the Sustainable Development Goals of the UN, IIOT, as a new technology serving all mankind, should not only comply with the green conventions under the global governance system and promote GT [5]. On the other hand, countries worldwide are accelerating the integration of IIOT into sustainable development. Germany emphasizes that the application of IIOT can realize energy saving, emission reduction and efficient use of resources in the production process, forming a green manufacturing mode [6]. China is promoting the implementation of the "IIOT + Dual Carbon" program to promote industrial GT and achieve dual-carbon goals from the supply side [7]. The EU points to the need to accelerate the dual green and digital transformation and to make smart industry a key driver for building more sustainable and resilient societies and economies [8].

The convergence of IIOT and Green Transformation is highly regarded. However, the ability of IIOT to drive GT and the moral hazard hidden in the process has not yet been noticed. In current research on GT, scholars have mostly explored the motivation and influence mechanisms from the perspectives of financing credit [9,10], corporate governance [11], and government regulation [2]. However, few scholars have analyzed the impact of IIOT on GT in depth at the level of emerging technologies, and there is an even greater lack of discussion of the consequences of the hypocritical side of smart technologies in the field. Even though scholars have already seen the short-sightedness of smart technologies [12], there is still a lack of ethical research when smart technologies are embedded in IIOT. Therefore, our study not only fills in the relationship between IIOT and GT but more importantly, it digs into the ethical issues of IIOT to find a focus point to promote green sustainability for the Fourth Industrial Revolution.

To achieve the research objectives, first, we collated panel data of Chinese A-share listed heavy polluters from 2009 to 2023. Second, due to the need to control for the effects of unobservable heterogeneity and common trends during empirical analyses of panel data, as well as to reduce omitted variable bias, this paper employs a double fixed-effects model to more accurately estimate the effect of IIOT on GT. Third, to delve deeper into the path of IIOT on firms' GT and to test what factors trigger the variability of IIOT's impact on GT, we introduce mediating and moderating effects models. Finally, to verify whether there is a transition preference effect in IIOT, thus supporting the double-edged sword of IIOT. In this paper, the transition preference indicators of RGT and SGT are measured and verified using non-linear analysis.

Our findings found that the IIOT can drive GT and bring about a positive impact on green governance at the source. However, we further introduce the concept of dualistic GT, i.e., splitting GT into Realistic Green Transformation (RGT) and Symbolic Green Transformation (SGT). Among them, RGT is a realistic green transformation activity carried out by companies through altruistic approaches such as source control, cleaner production, and pollutant emission reduction. SGT is the symbolic egoistic green behavior of companies that specify standards, come up with slogans, and so on to glorify their green perceptions. RGT and SGT are two conflicting types of green transformation activities. It was found that the IIOT has a clear strategic bias towards SGT, i.e., the IIOT mostly provides firms with "greenwash" hypocritical decisions. This strategic choice preference is more pronounced among firms that are larger, in energy-intensive industries, in regions with weaker environmental regulations and higher levels of development. It is worth noting that the IIOT technology has planted multiple resistance to the practice of RGT, which is behind an ethical crisis that warrants vigilance.

This study may have made several contributions. Firstly, this study explores another factor that affects GT. Previous studies have confirmed that Digital Information Management Systems, Digital Transformation, Digital finance, and green bonds affect GT [13–16], but no study has explored their effect on GT from the IIOT perspective. Our study constructs the indicator system of IIOT from the micro-firm level, and at the same time introduces the concepts of SGT and RGT, which enriches the scope of green sustainability research. Secondly, it reveals the resistance in the IIOT's drive for GT, especially as the more valuable RGT is facing difficulties. Unlike existing studies exploring the good side of IIOT [17–19], this study warn of a crisis in which IIOT has not yet been ethically and effectively disciplined. Thirdly, the use of empirical evidence effectively validates the hypocrite of smart technologies that scientists fear. The study shows that IIOT has a U-shaped relationship with SGT preferences and an inverted U-shaped relationship with RGT preferences, exposing the egoistic and short-sighted motivations of smart technologies. This result differs from existing scholars' push for intelligent technology [20] and further confirms existing scholars' concerns [21]. Therefore, this study remind people about the importance of properly regulating intelligence with its agentic behavior.

The rest of the paper is organized as follows. Section 2 Provides a brief discussion of the literature related to IIOT and GT and analyses the mechanism of IIOT's role in facilitating GT to formulate a hypothesis. Section 3 Describes the data, models, and variables used in this study. Section 4 Analyze the empirical results, which include baseline outcome analysis, mechanism analysis, heterogeneity analysis, and non-linearity analysis. Section 5 Discussion of the results of the study, comparing previous studies. Section 6

Conclusions and policy recommendations.

## 2. Related works and hypotheses development

An analysis of organizational legitimacy from an institutional economics perspective. IIOT, as a microcosm of the Internet of Everything era in industry, connects multiple stakeholders such as the production side, supply chain, users, the public, and government. This phenomenon will make corporate behavior gain more attention than ever before [22]. Then, the IIOT must have the ability to coordinate the interests of all parties to gain broad legitimacy support. Among them, positive green actions of enterprises can meet the demands of stakeholders such as supply chain security, product greening, citizens' health pursuits, and government sustainable governance, which is a business license for enterprises to win long-term survival [23]. Firms can only maintain a competitive advantage in the industrial revolution if they garner broad legitimacy support, and green transformation is an important channel to achieve this goal [24]. Therefore, firms making green decisions require information technology, represented by IIOT, to be the medium through which organizations interact with the environment [25]. In the era of Industry 4.0, AI systems can accurately capture the public's concern for the environment, and finally, the environmental reputation level of enterprises can be analyzed by big data technology [26]. In conclusion, due to the IIOT's further improvement in the rate of information transfer, companies can respond to stakeholders on environmental issues promptly make green decisions to reduce pollution, and take environmental responsibility to gain organizational legitimacy through green transformation.

First, from a technical perspective. With IIOT, real-time industrial data can be acquired and data computing services can be extracted to support the stable operation of production lines. By optimizing the process capability of the equipment, the overall benefits of quality improvement, efficiency, cost reduction, and carbon reduction can be achieved [27]. IIOT is a new model of the fourth industrial revolution, in which smart technologies are at the core of the transformation of traditional enterprises, this transformation of the working environment intelligence and saving affects the whole process of green production [28]. Of course, IIOT can also collect finer carbon footprint data and drive low-carbon greening of production processes through analytical techniques [29]. At the end of production, the intensive application of information technology in the industry brings about a reduction in pollutant emissions, an increase in energy efficiency, and green innovations in production technologies [30]. Therefore, IIOT breaks through the traditional industrial operation mode, realizes the information link from the technical level, plays an important role in the whole production and manufacturing process, and provides new ideas to solve the environmental crisis [20].

Second, from an innovation perspective. IIOT initially got its breakthrough from the information technology end, in which sustainable innovations such as green processes, green adoption, green products, green value chain integration, and green talent management provide important support for GT [18,31]. On the one hand, the deeper integration of IIOT with green manufacturing technologies improves the level of green innovation and competitive advantage as a way to win goodwill and strengthen the organizational legitimacy of firms at the technological level [32]. On the other hand, as IIOT lowers the barriers to market entry and exit and breaks down the existing competitive landscape, it shifts the competition from the physical level to the virtual network where information interacts directly [33]. Thus, the innovation effect of the IIOT brings about a green revolution in the technological system of firms, but by introducing a competitive mechanism, it forces firms to adopt a more decisive green strategy [17].

Third, from a management perspective. Socio-Technical System (STS) is a macroscopic ergonomics model that views human activity, technology, and the organizational environment as an interacting system. On the one hand, when IIOT embeds technologies such as smart connectivity and green manufacturing in an enterprise's STS, the enterprise's green production activities and smart technologies will be perfectly integrated. Therefore, the greening of the technology system will lead the STS to upgrade towards green [34]. On the other hand, embedding IIOT in the manufacturing process, green products, and green supply chain direction can help traditional industrial enterprises to actively face the pollution effect in production and promote the green management revolution [35].

It follows that the application of IIOT has the potential to drive positive green actions in companies from the technological revolution, management, and decision-making levels to achieve organizational legitimacy goals. To this end, this paper proposes the following hypothesis.

**H1**. IIOT may have a facilitating effect on GT.

Nowadays, corporate management is still committed to replacing manual labor with smart technologies despite the controversial ethical consequences caused by them [36]. With the application and popularization of smart technologies, people continue to receive messages about corporate green responsibility on the surface, but it is hard to see green actions in reality. Based on the false propaganda of green initiatives by corporations, critics have linked the ethical behavior of smart technologies to the concept of business ethics, referring to the ethical motivations behind AI and machine learning as "machine cleansing" [37]. Therefore, the symbolic green behavior of adopting IIOT is highly insidious and inevitably raises ethical concerns about smart technologies among the public and politicians [38]. When IIOT-centred smart technologies pursue organizational legitimacy, they are often influenced by utilitarianism, with companies seeking to conform to stakeholder claims on a superficial level and writing unrealistic reports on green actions. With this kind of greenwashing behavior towards different stakeholders, companies may prepare for public scrutiny as early as the development stage of the smart technology [39], thus providing cover for their failure to implement valuable green actions.

Further, IIOT, to help companies gain organizational legitimacy, will offer a range of GT programs, among them the Greenwash program, which raises ethical issues. The motivations for these greenwashings are as follows: (1) Focus on the quality of green disclosures. (2) Well-considered decisions. (3) A general corporate phenomenon. Such companies that seem to be more environmentally responsible to win the public's trust in a short period. However, there is a moral hazard for companies to keep using IIOT to implement impractical green actions. In short, business elites are likely to choose either RGT, which is energy efficient and reduces emissions because of a focus on social responsibility, or SGT, which is more concerned with profitability and is good for business in the short term. Of course, both choices are good for the legitimacy of the organization.

To discuss in more depth the extent to which social ethics are valued, and to reveal whether there is a hidden dark side to IIOT, we split GT into RGT and SGT, and propose two opposing hypotheses.

**H2a**. IIOT can drive firms to make SGT decisions.

**H2b**. IIOT can drive firms to make RGT decisions.

In summary, to test the above hypotheses. The research logic of this paper is to select 18 heavily polluting industries in China as the research object and use two-way fixed model, mediated effect model, moderated effect model, endogeneity test, *U* test, etc., to systematically analyze whether the IIOT has a role to play in GT. If there is an effect, what is its specific intrinsic impact? What are the pathways of impact? Is there heterogeneity at the level of firms, regions, etc.? Are there hidden realities? To demonstrate the process of subsequent research, this paper draws Fig. 1 based on the above research logic.

## 3. Research design

### *3.1. Sample and data*

This paper examines the impact of IIOT on corporate GT using an initial sample of heavy-polluting listed companies A-shares from 2009 to 2023, specifically including 18 heavy-polluting industries.[1] The sample is selected mainly based on the following two reasons: (1) Data availability. Compared with unlisted companies, relevant data of listed companies can be collected from annual reports and other information, which facilitates the measurement of subsequent variables; (2) The specificity of heavy-polluting corporate. The Chinese government has clearly pointed out that promoting the GT of heavy-polluting enterprises is an important path to realize the “double carbon” goal. The data covered in this paper mainly includes information about the level of industrial internet of listed companies and other financial-related data. The former is primarily based on the information crawled from the annual reports of enterprises through Python, and the latter is mainly derived from the databases of Wind and China Stock Market & Accounting Research (CSMAR). In this paper, the initial samples are screened according to the following principles: (1) Excluding the company-year sample that was ST in the current year, such listed firms were flagged for treatment due to consecutive financial losses; (2) Company-year samples with missing data are excluded. After the above processing, this study obtains unbalanced panel data of 13,080 observations for 1188 listed companies. Among others, continuous and discrete variables are included in this dataset. In addition, to avoid the effect of extreme data values, all continuous variables are winsorized at the top and bottom 1 % in this paper.

### *3.2. Variable setting*

(1) Dependent variable: Enterprise green transformation (GT).

In this paper, we refer to the existing study [13], which categorized GT into RGT and SGT. The former achieves RGT through a variety of substantive ways, such as reduction of greenhouse gas emissions driven by energy transformation, reduction of pollutant emissions triggered by the implementation of green and clean production methods, and the direct assumption of environmental responsibility and practice of environmental protection actions; The latter is a symbolism-driven behavioral choice that falls under the category of “greenwashing”, e.g., embellishing persuasive reports to the public and investors.

Therefore, the specific indicators of GT, RGT, and SGT are shown in Table 1, including quantifiable and non-quantifiable indicators. In the former, a numerical description is given as 2, a written description is given as 1, and no description is given as 0. In the latter, the presence of the action is given as 1, and otherwise, it is given as 0. Based on the above assignments, GT, RGT, and SGT are summed up and calculated respectively.

Independent variable: IIOT. In this study, the information is obtained from the annual reports of the companies through Python, and the IIOT level is measured through textual analysis. The details are as follows: The first step is to parse the MD&A (Management Discussion and Analysis) text. The second step is to define the keyword “IIOT”. We looked for relevant cooperative heavy polluters from 26 IIOT platforms at home and abroad and carried out word frequency statistics for 90 keywords under the categories of digitalization, networking, intelligence, informatization, and platformization, which are shown in the specific indicators in Table 2. In the third step, MD&A text preprocessing. Firstly, crawl the public annual reports of listed companies and save them as PDF files; secondly, read the annual reports in PDF format, extract the text of the MD&A report, and convert the text into normalized panel data; thirdly,

[2] 18 heavily polluting industries: Coal Mining and Washing (B06), Oil and Gas Mining (B07), Ferrous Metal Ore Mining (B08), Non-ferrous Metal Ore Mining (B09), Non-metallic Ore Mining (B10), Textile Industry (C17), Textile Clothing and Apparel Industry (C18), Leather, Fur, Feather and Its Products and Footwear Industry (C19), Paper and Paper Products Industry (C22), Petroleum Processing, Coking and Nuclear Fuel Processing Industry (C25), Chemical Materials and Chemical Products Manufacturing Industry (C26), Pharmaceutical Manufacturing Industry (C27), Chemical Fibre Manufacturing Industry (C28), Rubber and Plastic Products Industry (C29), Non-metallic Mineral Products Industry (C30), Ferrous Metals Smelting and Rolling and Processing Industry (C31), Non-ferrous Metals Smelting and Rolling and Processing Industry (C32), Electricity and Heat Production and Supply (D44).

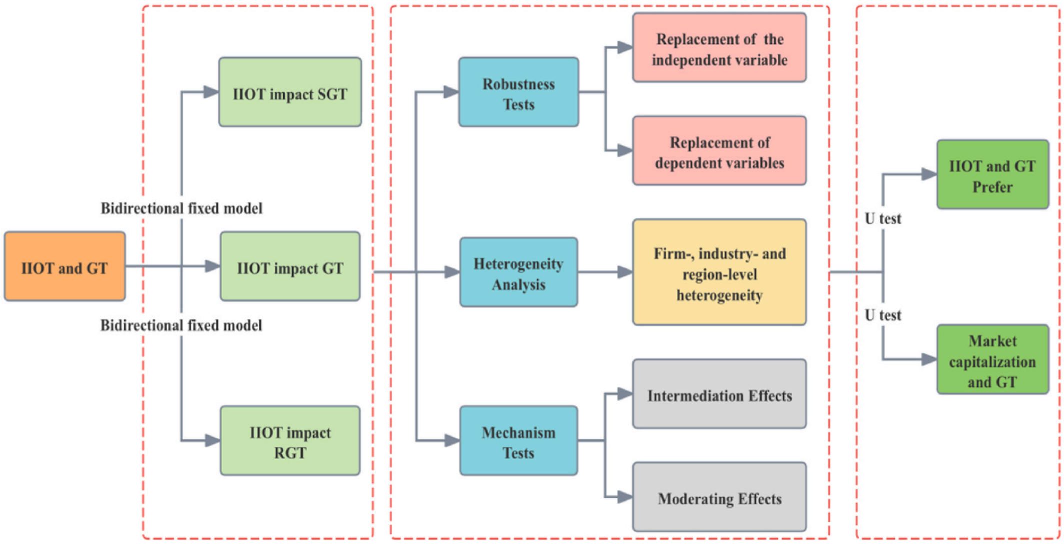


**Fig. 1.** Logic diagram of IIOT impact on GT.

**Table 1**
Enterprise green transformation indicator construction.

| GT | |
|---|---|
| RGT | SGT |
| CO2 emissions + COD emissions + SO2 emissions + Dust emissions + Industrial solid waste generation + Wastewater emissions + Implementation of cleaner production + Environmental protection actions + Priority pollution monitoring units + emergencies + Environmental petition cases | Environmental information disclosure + Social responsibility report + Environmental report + Whether through the ISO14001 certification + Environmental protection philosophy + Environmental protection goals + Management system + "Three simultaneous" + Training and education + Environmental emergency mechanism + Emission standards + Honor or award for environmental protection + ISO9001 + Emissions treatment of waste gas emission reduction + Wastewater reduction processing + Powder, smoke treatment + Disposal of solid waste utilization + Processing of noise, light pollution radiation |

**Table 2**
Enterprise IIOT indicator construction.

| Target Level | Indicator Layer | Specific Indicators |
|---|---|---|
| Digitization Level | Data, Numbers, Digitization | Blockchain, Cloud Services, Cloud Ecology, Cloud IT, Cloud Computing, Big Data, Digitization, Data Networks, Data Mining, Data Management |
| Networking Level | Internet Technology, Web Applications | Internet, Internet Ecology, Strategy, Marketing, Application, Mobile, Business, Action, Thinking, Technology, Solutions, IIOT, Mobile Internet |
| Intelligence Level | Intelligent, Intelligent, Automatic, CNC, Integrated, Integrated | Virtual Manufacturing, Virtualization, Manufacturing Execution Systems, Lifecycle Management, Intelligent Troubleshooting, Factory of the Future, Industrial Cloud, Integrated Systems, Integrated Controls, Integrated Solutions, Integration, Integration, CNC, Automated Production, Automated Inspection, Automated Monitoring, Automatic Monitoring, Intelligent, Automatic Control, Intelligent System, Intelligent Network, Intelligent Production, Intelligent Equipment, Technology, Warehousing, Manufacturing, Logistics, Factory, Management, Mobility, Terminal, Control, Mobile Intelligence, Industrial Intelligence, High-End Intelligence, Artificial Intelligence |
| Informatization Level | Information, Informatization | Information Sharing, Management, Integration, Software, System, Network, Terminal, Center, Industrial Information, Industrial Communication |
| Platformization Level | Platform-based Design | Data Platforms, Internet Platforms, Cloud Platforms |

count the length of the text of the MD&A report, as well as the length of the text that only retains the English and Chinese parts. In the fourth step, the IIOT word frequency breakdown is counted. Construct a dictionary of IIOT terms, expanding the vocabulary to the Python jieba library and removing stop words. Count the number of occurrences of the 90 "IIOT" keywords and eliminate the words preceded by a negative word. In the fifth step, the IIOT, the level of each dimension, is calculated. Referring to the word frequency breakdown of the sub-dimensions in Table 2, the total word frequency sum was added and denoted as IIOT. and the individual sub-dimensions were counted and denoted as Digitization Level, Networking Level, Intelligence Level, Informatisation Level, and Platformization Level.

Control variables. This paper from the enterprise level selected indicators that may affect the green transition, mainly including: Firm size (Size), a logarithmic measure of a firm's total market capitalization; Return on Assets (ROA), which is the ratio of net profit to total assets, reflects the profitability of a company; Capital Density (Density), the ratio of total assets to business revenues, reflects the capital position of the firm; Business growth (Growth), measured by the growth rate of total assets; Asset-liability ratio (Lev), higher levels of liabilities may limit firms' investment in green transformation; Board Activity (Meeting), measured by the frequency of board meetings; Independent directors (Independent) i.e. the number of independent directors as a percentage of the number of directors; The equity nature (Equity), which is categorized into SOEs and non-SOEs, and the difference between the actual controller may affect the enterprises green transition decision-making. Dual job title combined (Dual), i.e., whether the chairman and general manager are held by the same person, takes 1 if yes, and 0 otherwise; Enterprise age (Age), i.e., the time of establishment of enterprises. The control variables at the city level include: the economic development status of each city (GDP) and the degree of government intervention (Gov). The data for the city-level control variables are obtained from the China Urban Statistical Yearbook of the past years.

### 3.3. Measurement modeling

In order to test the effect of IIOT on the GT of enterprises, This paper constructs a baseline econometric model as in Formula (1):

$$\mathrm{GTE}_{i,t} = \alpha_1 + \beta_1 \mathrm{IIOT}_{i,t} + \gamma_1 X_{i,t} + \mu_i + \delta_t + \mathrm{City} + \varepsilon_{i,t} \tag{1}$$

Where $\mathrm{GTE}_{i,t}$ is the green transformation of enterprises, including GT, RGT and SGT. i and t represent enterprises and years, respectively, $IIOT_{i,t}$ is the level of enterprises' IIOT, $X_{i,t}$ denotes a series of control variables, $\mu_i$, $\delta_t$ are enterprise and year fixed effects, respectively. City are city dummy variables, and $\varepsilon_{i,t}$ denotes a randomized disturbance term.

To test whether enterprises have preferences for RGT and SGT, the model is set up in Formula (2) and (3):

$$\mathrm{Perfer1}_{i,t} = \alpha_2 + \beta_2 \mathrm{IIOT}_{i,t} + \gamma_2 X_{i,t} + \mu_i + \delta_t + \mathrm{City} + \varepsilon_{i,t} \tag{2}$$

$$\mathrm{Perfer2}_{i,t} = \alpha_3 + \beta_3 IIOT_{i,t} + \gamma_3 X_{i,t} + \mu_i + \delta_t + \mathrm{City} + \varepsilon_{i,t} \tag{3}$$

Where Perfer1 is the absolute value of the difference between SGT and RGT, which is used to verify whether enterprises have a preference between RGT and SGT; Perfer2 is the value of the difference between SGT and RGT, which is used to verify whether the enterprises have more preference for SGT.

### 3.4. Descriptive statistics and correlation analysis

The results of the descriptive statistics in this paper are shown in Table 3. It can be seen that the mean value of GT is 11.1340, the maximum value is 40.0000, and the minimum value is 1.0000, which is a large difference in the GT of enterprises. The mean value of SGT is larger than that of RGT, which indirectly suggests that there is a phenomenon of symbolic green transition preference in the process of carrying out GT by enterprises. The mean of IIOT is 2.2510 the data of main control variables, such as the government intervention level (mean 0.1730), the equity nature (mean 0.3732), and the growth of enterprises (mean 0.1301), are all within a reasonable range.

In addition, correlation analysis can verify the degree of correlation between variables. Therefore, this study is represented by the Pearson correlation coefficient, the higher the correlation coefficient, the stronger the correlation between the variables. The results are shown in Appendix Table 1 and the results shown are all within reasonable limits. Notably, the results show that the correlation

**Table 3**
Results of descriptive statistics.

| Variables | mean | standard | min | max | N |
|---|---|---|---|---|---|
| GT | 11.1340 | 8.0320 | 1.0000 | 40.0000 | 13,080 |
| RGT | 2.6261 | 3.1893 | 0.0000 | 13.0000 | 13,080 |
| SGT | 8.1509 | 5.4279 | 1.0000 | 27.0000 | 13,080 |
| IIOT | 2.2510 | 0.9898 | 0.0000 | 5.5013 | 13,080 |
| Size | 22.6252 | 0.9934 | 19.8400 | 27.8873 | 13,080 |
| ROA | 0.0409 | 0.0648 | −0.3638 | 0.6444 | 13,080 |
| Density | 2.2126 | 1.6175 | 0.3632 | 13.6784 | 13,080 |
| Growth | 0.1301 | 0.3242 | −0.7496 | 3.8635 | 13,080 |
| Lev | 0.4095 | 0.2057 | 0.0210 | 0.9901 | 13,080 |
| Meeting | 3.3907 | 3.0568 | 1.0986 | 33.0000 | 13,080 |
| Independent | 3.6772 | 10.7295 | 0.1667 | 66.6700 | 13,080 |
| Equity | 0.3732 | 0.4837 | 0.0000 | 1.0000 | 13,080 |
| Dual | 0.2694 | 0.4437 | 0.0000 | 1.0000 | 13,080 |
| Age | 2.8866 | 0.4108 | 0.6931 | 4.7274 | 13,080 |
| GDP | 60.5844 | 30.2431 | 0.2070 | 113.9330 | 13,080 |
| Gov | 0.1730 | 1.2621 | 0.0086 | 115.8537 | 13,080 |

coefficients between IIOT and GT, RGT, and SGT are 0.2881, 0.1044, and 0.3130, respectively, which are all significant at the 1 % level. For this reason, it was possible to verify the statistical relationship between the independent and dependent variables.

## 4. Analysis of results

### 4.1. Benchmark regression

Table 4 reports the impact of the IIOT on the green transformation of enterprises. In particular, columns (1) (2) are the results of adding robust standard errors, and columns (3) (4) are the results of clustering to individual variables.

The results show that all the estimated coefficients of IIOT are significantly positive, which proves that the IIOT has a significant promotional effect on the green transformation of enterprises and verifies the H1 hypothesis.

To further explore whether there is a preference for green transformation among enterprises, after clustering to the individual level, the regression results of IIOT with RGT and SGT are shown in columns (5) (6) of Table 4. From the regression results, it can be seen that the IIOT does not have a significant effect on RGT, while it has a significant positive effect on SGT. It can be tentatively stated that the IIOT is more biased towards facilitating the SGT of enterprises. In contrast to existing scholars, who validate the SGT actions of enterprises only in terms of "greenwashing" behaviors [40], we find more convincing motivations for "greenwashing" from its opposite side. In summary, our preliminary finding that the IIOT is more biased towards results that promote firms' SGT supports H2a.

### 4.2. Robustness tests

#### 4.2.1. replacement of the independent variable

Considering that there may be a text acquisition bias problem in the process of text analysis of the IIOT, for robustness considerations, the indicators of the IIOT are processed by adding or subtracting text acquisition, and the regression results are shown in Table 5.

Among them, IIOTA is to increase the level of digitization in the IIOT related to terms such as machine learning, digital marketing and other terms. In column (1) it can be seen that the estimated coefficient of IIOTA is significantly positive. It can be seen in columns (2) (3) that IIOT positively affects SGT and remains insignificant on RGT. IIOTB is to reduce the words and phrases related to the level

**Table 4**
Benchmark regression results.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | GT | GT | GT | GT | RGT | SGT |
| IIOT | 0.3406*** | 0.2889*** | 0.8981*** | 0.2889*** | 0.0443 | 0.2029*** |
| | (4.72) | (3.97) | (6.00) | (2.83) | (1.00) | (3.13) |
| Size | | 0.6921*** | | 0.6921*** | 0.2213*** | 0.4049*** |
| | | (5.72) | | (3.83) | (2.80) | (3.63) |
| ROA | | −1.0569 | | −1.0569 | 0.0210 | −1.3942 |
| | | (-1.03) | | (-0.76) | (0.03) | (-1.60) |
| Density | | −0.1729*** | | −0.1729** | −0.0164 | −0.1405*** |
| | | (-3.51) | | (-2.34) | (-0.52) | (-3.05) |
| Growth | | −0.5509*** | | −0.5509*** | −0.1336* | −0.4019*** |
| | | (-3.71) | | (-3.25) | (-1.78) | (-3.64) |
| Lev | | 0.5700 | | 0.5700 | 0.2655 | 0.6483 |
| | | (1.29) | | (0.83) | (0.93) | (1.50) |
| Meeting | | 0.0478 | | 0.0478 | −0.0274 | 0.0042 |
| | | (1.36) | | (1.15) | (-1.64) | (0.14) |
| Independent | | −0.0443 | | −0.0443 | 0.0069 | −0.0389 |
| | | (-1.54) | | (-1.52) | (0.57) | (-1.58) |
| Equity | | 0.1760 | | 0.1760 | −0.1211 | 0.4037 |
| | | (0.55) | | (0.36) | (-0.59) | (1.29) |
| Dual | | −0.2696* | | −0.2696 | −0.1183 | −0.1720 |
| | | (-1.83) | | (-1.25) | (-1.31) | (-1.26) |
| Age | | 0.9646*** | | 0.9646 | 0.4751* | 0.3101 |
| | | (2.80) | | (1.64) | (1.90) | (0.89) |
| GDP | | −0.0065 | | −0.0065 | −0.0151*** | −0.0073 |
| | | (-0.93) | | (-0.75) | (-3.96) | (-1.12) |
| Gov | | −0.0286* | | −0.0286*** | −0.0360*** | −0.0341*** |
| | | (-1.72) | | (-8.89) | (-28.52) | (-14.17) |
| Constant | 10.3673*** | −7.2888** | 9.1124*** | −7.2888 | −2.8453 | −1.7325 |
| | (61.86) | (-2.54) | (25.59) | (-1.63) | (-1.47) | (-0.64) |
| Year | Yes | Yes | Yes | Yes | Yes | Yes |
| City/Id | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 13,080 | 13,080 | 13,080 | 13,080 | 13,080 | 13,080 |
| $R^2$ | 0.726 | 0.728 | 0.352 | 0.728 | 0.647 | 0.738 |

Note: (.) for the value of t. *** $p<0.01$. ** $p<0.05$. * $p<0.1$.

of enterprise intelligence in IIOT, such as integrated control, integrated solutions and other words and phrases. In column (4), it can be seen that the estimated coefficient of IIOTB is significantly positive. It can be seen in columns (5) (6) that the IIOT still has a preference for SGT. In summary, the baseline regression results are robust as can be seen by replacing the independent variables.

#### *4.2.2. Replacement of dependent variables*

In order to make the research results more convincing, this paper adjusts the measure of green transformation of enterprises and conducts a robustness test of transformation type preference by the difference between SGT and RGT, the results are shown in Table 6.

First, this paper adopts principal component analysis to re-measure GT from the five aspects of green culture, green management [41], green emission, green governance and green innovation [42], which is denoted as GT1. From column (1), the estimated coefficient of IIOT is significantly positive, further validating the credibility of the benchmark regression results, Support for hypothesis H1.

Second, for the measure of transition type preference, the absolute value of the difference between SGT and RGT (Prefer1) is first calculated to initially explore the bias. Next, the difference between SGT and RGT (Prefer2) is calculated to further analyze the robustness of firms' preference for SGT. The regression results shown in columns (2) and (3) indicate that IIOT does have a selection preference for GT, favoring SGT more. Therefore, it is consistent with the results of the previous test, hypothesis H2a is again supported.

Third, in order to verify again the existence of avoidance behavior of enterprises for RGT, this paper introduces five quantitative indicators representing the substantial green transformation carried out by enterprises, namely, the amount of environmental investment (EInvest), the amount of green investment (GInvest), the efficiency of green innovation (Ginno) and green patents (Gpat). As can be seen from columns (4)–(7), the relevant indicators representing substantial green transformation are not significant, further validating firms' transformation preferences and thus corroborating the benchmark regression results, conclusion is consistent with hypothesis H2a.

Fourth, while we verify the fact that firms' green transition preferences under IIOT popularization. However, whether this decision preference comes from active strategic choices or passive technology spillovers still deserves further discussion. This paper measures the corresponding carbon emissions (Carbon) according to the "Guidelines for Corporate Greenhouse Gas Emissions Accounting Methodology and Reporting". On the one hand, provide robustness evidence for the existence of preferences. On the other hand, verify the original motivation for choosing preferences. As can be seen from column (8), the application of industrial Internet brings about a significant increase in carbon emissions. It indicates that the Industrial Internet does not directly show a strong energy transition effect, and the introduction of the Industrial Internet did not increase the energy efficiency of enterprises and reduce carbon emissions.

### *4.3. Treatment of endogenous problems*

In order to exclude endogeneity problems, we selects appropriate instrumental variables for the independent variables and further tests the results of the benchmark regression using a two-stage model (2SLS).

In this paper, the spherical distance between city and Hangzhou (distance), 1984 fixed telephone ownership per 100 people (phone) and post office per million people (post) are selected as instrumental variables for IIOT. First, Hangzhou's Internet development is in a leading position, i.e., the closer to Hangzhou geographically, the higher the degree of Internet development, with relevance; in addition, Hangzhou is only a member of the smart city, the smaller distance from Hangzhou does not mean the higher degree of wisdom, the smaller impact on the GT, and the exogenous approximation of satisfaction. Second, the number of post offices and fixed-line telephones in each city in 1984, which reflects the level of regional communications development and meets the relevance requirement; on the other hand, it has little impact on the GT of firms and satisfies the exclusivity assumption. Specifically, the amount of Internet investment in the year is used as an instrumental variable with distant, phone, and post constructed interaction terms, respectively.

**Table 5**
Robustness results with replacement of independent variables.

| Variable | Expanded thesaurus | | | Reduced-sized thesaurus | | |
|---|---|---|---|---|---|---|
| | GT | RGT | SGT | GT | RGT | SGT |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| IIOTA | 0.2690*** | 0.04257 | 0.1861*** | | | |
| | (1.85) | (0.97) | (2.86) | | | |
| IIOTB | | | | 0.2497** | 0.0412 | 0.1801*** |
| | | | | (2.44) | (0.93) | (2.79) |
| Constant | −7.3163 | −2.8469 | −1.7574 | −7.4187* | −2.8600 | −1.8152 |
| | (-1.64) | (-1.47) | (-0.65) | (-1.66) | (-1.48) | (-0.67) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes |
| City/Id | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 13,080 | 13,080 | 13,080 | 13,080 | 13,080 | 13,080 |
| $R^2$ | 0.728 | 0.647 | 0.738 | 0.728 | 0.647 | 0.738 |

Note: (.) for the value of t. *** p<0.01. ** p<0.05. * p<0.1.

**Table 6**
Robustness results with replacement of the dependent variable.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | GT1 | Prefer1 | Prefer2 | EInvest | GInvest | Ginno | Gpat | Carbon |
| IIOT | 0.4552** | 0.1473*** | 0.1585*** | 0.0151 | −0.0005 | 0.0005 | −0.1561 | 0.0382*** |
| | (4.11) | (3.13) | (3.22) | (0.22) | (-0.48) | (0.91) | (-0.41) | (3.39) |
| Constant | 21.6277*** | 1.5407 | 1.1128 | 0.6160 | 0.0325 | 0.0176 | 41.1084 | −6.5462*** |
| | (4.99) | (0.77) | (0.55) | (0.17) | (0.67) | (0.57) | (1.17) | (-10.47) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| City/Id | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 11,296 | 13,080 | 13,080 | 1404 | 1828 | 8830 | 11,230 | 11,229 |
| $R^2$ | 0.740 | 0.741 | 0.734 | 0.450 | 0.495 | 0.623 | 0.772 | 0.916 |

Note: (.) for the value of t. *** $p<0.01$. ** $p<0.05$. * $p<0.1$.

The results are shown in Table 7. In columns (1), (3), and (5), the relationships between the instrumental variables and the IIOT are reported respectively, i.e., the instrumental variables are selected to satisfy the correlation requirements. Meanwhile, the instrumental variables all passed the K-PLM and K-PWF statistic tests, i.e., the instrumental variables do not suffer from under-identification, weak identification and over-identification problems, and satisfy the exogenous conditions. The regression coefficients for IIOT are all significant at 1 % level as seen in columns (2), (4) and (6) reporting the results. The above conclusion that IIOT has an enhancing effect on the level of GT is still valid, again supporting the previous hypothesis of H1.

### *4.4. Heterogeneity analysis*

Considering that the IIOT to promote the GT of enterprises may be affected by the heterogeneity of enterprise capital strength and industry, the strength of regional environmental regulations and economic development status. Firstly, this paper selects the market capitalization size of enterprises, divides them into three equal parts according to their size, and takes the first and last two groups as 1 and 0 for the group test, which are recorded as Size_big and Size_small, respectively; Secondly, the firms were categorized into high energy-consuming firms (Enger_high), and low energy-consuming firms (Enger_low), which were recorded as 1 and 0 respectively for the group test. Again, according to the strength of regional environmental regulation, firms in high environmental regulation areas (Envir_stro) is recorded as 1, and firms in low environmental regulation areas (Envir_weak) is recorded as 0. Finally, according to the level of regional development and openness is divided into areas with Developed (Dev_high) and areas with backward (Dev_low).

In this paper, we first conduct a Fisher Combined Group Regression test based on Bootstrap (500 repeated samples) to determine whether the coefficients of the IIOT are significantly different between groups, followed by group regressions, as well as to infer whether the degree of impact is comparable within groups. The results of the four heterogeneity tests are shown in Table 8. Overall, the effect of the IIOT in promoting GT is more significant in enterprises that are larger in scale and belong to high-energy-consuming industries, as well as in enterprises that are in regions with weaker environmental regulations and higher levels of economic development.

The reasons for the above results are the following. Firstly, due to the greater social scrutiny pressure on firms when they are larger, more energy-intensive, and located in developed regions [26], the IIOT can easily be used promptly to respond to external environmental pressures to behave in a GT manner. Secondly, it is known based on the cost effect and innovation compensation effect of environmental regulation [43]. In regions with high environmental regulatory pressures, the productivity and resources released by

**Table 7**
Estimation results of instrumental variable method.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | IIOT | GT | IIOT | GT | IIOT | GT |
| IV | 0.2854*** | | 0.2860*** | | 0.2989*** | |
| | (0.0115) | | (0.01213) | | (0.01257) | |
| IIOT | | 5.8232*** | | 5.9397*** | | 5.8643*** |
| | | (0.3714) | | (0.3980) | | (0.3923) |
| Control | Yes | | Yes | | Yes | |
| Year FE | Yes | | Yes | | Yes | |
| City/Id FE | Yes | | Yes | | Yes | |
| K-P LM | 316.8040 | | 300.0970 | | 302.1660 | |
| | [0.0000] | | [0.00000] | | [0.0000] | |
| K-P WF | 612.7850 | | 555.4070 | | 565.2370 | |
| | {16.3800} | | {16.3800} | | {16.3800} | |
| N | 12,785 | | 11,519 | | 11,519 | |

Note:
(.)are robust standard errors, [ ] are p-values, and { } are critical values at the 10 % level of the Stock-Yogo weak identification test. *** $p<0.01$. ** $p<0.05$. * $p<0.1$.

**Table 8**
Analysis of grouped regression results.

| Variable | Size_big | | | Size_small | | |
|---|---|---|---|---|---|---|
| | GT | RGT | SGT | GT | RGT | SGT |
| IIOT | 0.3626* | 0.1713* | 0.2007* | 0.0879 | 0.0670 | 0.0202 |
| | (1.86) | (1.90) | (1.65) | (0.62) | (1.05) | (0.22) |
| Constant | −17.8654* | −11.5475** | −1.4516 | 8.2345 | 0.5130 | 7.757 |
| | (−1.76) | (−2.36) | (−0.20) | (0.78) | (0.11) | (1.12) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes |
| Year - City - Id | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 4,231 | 4,231 | 3,579 | 3,423 | 3,423 | 3,423 |
| $R^2$ | 0.725 | 0.703 | 0.699 | 0.748 | 0.723 | 0.718 |
| Variable | Enger_high | | | Enger_low | | |
| | GT | RGT | SGT | GT | RGT | SGT |
| IIOT | 0.2847** | 0.04825 | 0.2017** | 0.2842* | 0.0508 | 0.1910** |
| | (2.00) | (0.77) | (2.07) | (1.94) | (0.84) | (2.18) |
| Constant | −9.2889 | −5.0360 | −4.7619 | −11.4461* | −3.0819 | −2.5468 |
| | (−1.53) | (−1.95) | (−1.15) | (−1.70) | (−1.05) | (−0.69) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes |
| Year - City - Id | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 7,085 | 7,085 | 7,085 | 5,986 | 5,986 | 5,986 |
| $R^2$ | 0.728 | 0.6572 | 0.7453 | 0.731 | 0.6401 | 0.734 |
| Variable | Envir_weak | | | Envir_stro | | |
| | GT | RGT | SGT | GT | RGT | SGT |
| IIOT | 0.3341** | 0.1005 | 0.2310** | 0.2409 | −0.0059 | 0.1921* |
| | (2.20) | (1.47) | (2.33) | (1.50) | (−0.08) | (1.84) |
| Constant | 10.7966 | 3.9126 | 7.1055 | 3.3386 | 3.1776 | 5.0359 |
| | (1.32) | (1.04) | (1.37) | (0.38) | (0.81) | (0.94) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes |
| Year - City - Id | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 3,652 | 3,652 | 3,652 | 3,828 | 3,828 | 3,828 |
| $R^2$ | 0.766 | 0.719 | 0.756 | 0.8014 | 0.725 | 0.810 |
| Variable | Dev_high | | | Dev_low | | |
| | GT | RGT | SGT | GT | RGT | SGT |
| IIOT | 0.2918** | 0.0314 | 0.1612** | 0.2755 | 0.1647 | 0.1414 |
| | (2.43) | (0.60) | (2.00) | (1.42) | (1.41) | (1.22) |
| Constant | −4.6668 | −2.1139 | 9.0225** | −13.7943 | −6.7007 | −2.1222 |
| | (−0.93) | (−0.99) | (2.03) | (−1.49) | (−1.24) | (−0.35) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes |
| Year - City - Id | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 9,578 | 9,578 | 9,578 | 3,502 | 3,502 | 3,502 |
| $R^2$ | 0.744 | 0.668 | 0.729 | 0.684 | 0.708 | 0.682 |

Note: () for the value of t. ***$p < 0.01$. **$p < 0.05$. *$p < 0.1$.

IIOT are invested in policy objectives rather than in promoting the green transformation of production methods. Finally, based on the regression results, it can be seen that firms are more inclined to make short-sighted decisions when utilizing the IIOT for GT, leaving aside financial strength. On the one hand, when firms are under greater scrutiny pressure, they are more willing to use the IIOT to make a bleaching green action on environmental disclosure to maintain their external image. On the other hand, when the pressure of environmental regulation is high, companies choose to reduce pollution and carbon emissions by upgrading their equipment; when the pressure of environmental regulation is low, they respond to the concerns of investors by engaging in greenwashing behaviors.

### *4.5. Mechanism tests*

#### *4.5.1. Intermediation effects*

To explore the pathways by which IIOT affects GT. This paper chooses the ratio of the book-to-market value of total assets of a enterprises (Bm) to represent the investment attractiveness of a enterprises, the LP method to calculate the total factor productivity of firms (TPF_LP), the enterprise's market capitalization/replacement cost (TobinQ) represents the enterprise's value or value creation ability, the difference between the average salary of management and employees (Gap) represents the pay gap, and the number of patents of the enterprise (PN) represents the enterprise's innovation ability. In this case, a three-step approach was used to test the

**Table 9**
Results of the mediation effect test.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | M | GT | GT | RGT | RGT | SGT | SGT |
| M = Bm (PanelA) | | | | | | | |
| IIOT | 0.0368*** | 0.3163*** | 0.1524** | 0.0130 | −0.0470 | 0.2535*** | 0.1587*** |
| | (15.41) | (4.46) | (2.15) | (0.44) | (−1.60) | (5.51) | (3.45) |
| Bm | | | 4.4483*** | | 1.6275*** | | 2.5727*** |
| | | | (16.99) | | (14.97) | | (15.10) |
| Constant | 0.5020*** | −55.7550*** | −57.988*** | −19.281*** | −20.098*** | −31.1958*** | −32.4873*** |
| | (8.26) | (−30.94) | (−32.46) | (−25.83) | (−27.09) | (−26.67) | (−27.95) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year - City - Id | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 12,897 | 12,897 | 12,897 | 12,897 | 12,897 | 12,897 | 12,897 |
| $R^2$ | 0.3858 | 0.4549 | 0.4672 | 0.4070 | 0.4174 | 0.4974 | 0.5064 |
| Sobal test | | P = 0.000 (Z = 11.415) | | P = 0.000 (Z = 10.738) | | P = 0.000 (Z = 10.786) | |
| M = TPF_LP (PanelB) | | | | | | | |
| IIOT | 0.5983*** | 0.3158*** | 0.2259*** | 0.0098 | −0.0223 | 0.2561*** | 0.2030*** |
| | (11.14) | (4.28) | (3.06) | (0.32) | (−0.73) | (5.34) | (4.23) |
| TPF_LP | | | 0.1504*** | | 0.0536*** | | 0.0888*** |
| | | | (11.90) | | (10.23) | | (10.81) |
| Constant | −59.4034*** | −56.0367*** | −47.1021*** | −19.2995*** | −16.1180*** | −31.3069*** | −26.0321*** |
| | (−43.59) | (−29.92) | (−23.46) | (−24.91) | (−19.38) | (−25.75) | (−19.96) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year - City - Id | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 12,042 | 12,042 | 12,042 | 12,042 | 12,042 | 12,042 | 12,042 |
| $R^2$ | 0.8049 | 0.4564 | 0.4629 | 0.4097 | 0.4149 | 0.4098 | 0.5042 |
| Sobal test | | P = 0.000 (Z = 8.131) | | P = 0.000 (Z = 7.533) | | P = 0.000 (Z = 7.758) | |
| M = TobinQ (PanelC) | | | | | | | |
| IIOT | −0.2096*** | 0.3163*** | 0.2471*** | 0.0130 | −0.0114 | 0.2535*** | 0.2108*** |
| | (−9.46) | (4.46) | (3.49) | (0.44) | (−0.39) | (5.51) | (4.59) |
| TobinQ | | | −0.3302*** | | −0.1161*** | | −0.2035*** |
| | | | (−11.62) | | (−9.85) | | (−11.02) |
| Constant | −0.6753 | −55.7550*** | −55.9779*** | −19.2815*** | −19.3599*** | −31.1958*** | −31.3332*** |
| | (−1.20) | (−30.94) | (−31.23) | (−25.83) | (−26.03) | (−26.67) | (−26.91) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year - City - Id | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 12,897 | 12,897 | 12,897 | 12,897 | 12,897 | 12,897 | 12,897 |
| $R^2$ | 0.1847 | 0.4549 | 0.4607 | 0.4070 | 0.4116 | 0.4974 | 0.5022 |
| Sobal test | | P = 0.000 (Z = 7.335) | | P = 0.000 (Z = 6.822) | | P = 0.000 (Z = 7.178) | |
| M = Gap (PanelD) | | | | | | | |
| IIOT | 1.6622*** | 0.3057*** | 0.2796*** | 0.0121 | −0.0051 | 0.2439*** | 0.2269*** |
| | (5.37) | (4.35) | (3.98) | (0.42) | (−0.17) | (5.34) | (4.98) |
| Gap | | | 0.0157*** | | 0.0042*** | | 0.0102*** |
| | | | (7.80) | | (5.08) | | (7.84) |
| Constant | −250.9815*** | −55.76*** | −51.8193*** | −19.2750*** | −18.2108*** | −31.2418*** | −28.6709*** |
| | (−31.84) | (−31.12) | (−27.90) | (−25.97) | (−23.63) | (−26.86) | (−23.77) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year - City - Id | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 13,048 | 13,048 | 13,048 | 13,048 | 13,048 | 13,048 | 13,048 |
| $R^2$ | 0.3856 | 0.4555 | 0.4581 | 0.4060 | 0.4072 | 0.4978 | 0.5002 |
| Sobal test | | P = 0.000 (Z = 4.425) | | P = 0.000 (Z = 3.690) | | P = 0.000 (Z = 4.432) | |
| M = PN (PanelE) | | | | | | | |
| IIOT | 0.1058*** | 0.1272* | 0.1273* | −0.0044 | −0.0065 | 0.1363** | 0.0301** |
| | (2.99) | (1.66) | (1.69) | (−0.13) | (−0.20) | (2.86) | (2.32) |
| Gpn | | | 0.0591*** | | 0.0197*** | | 0.13307*** |
| | | | (2.88) | | (2.20) | | (2.79) |
| Constant | −2.1137* | −42.7818*** | −51.5910*** | −20.3258*** | −20.2841*** | −29.2350*** | −29.1714*** |
| | (−1.82) | (−11.88) | (−20.90) | (−18.81) | (−18.78) | (−18.75) | (−18.71) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year - City - Id | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 11,094 | 11,094 | 11,094 | 11,094 | 11,094 | 11,094 | 11,094 |
| $R^2$ | 0.0824 | 0.4280 | 0.4352 | 0.3958 | 0.3961 | 0.4212 | 0.4214 |
| Sobal test | | P = 0.038 (Z = 2.072) | | P = 0.077 (Z = 1.769) | | P = 0.067 (Z = 1.831) | |

Note: () for the value of t. ***$p < 0.01$. **$p < 0.05$. *$p < 0.1$.

mediating dynamics. The specific model is shown in formulas (4) - (6):

$$GTE_{i,t} = \gamma_0 + \gamma_1 IIOT_{i,t} + \gamma_2 X_{i,t} + \mu_i + \delta_t + City + \varepsilon_{i,t} \tag{4}$$

$$M_{i,t} = \alpha_0 + \alpha_1 IIOT_{i,t} + \alpha_2 X_{i,t} + \mu_i + \delta_t + City + \varepsilon_{i,t} \tag{5}$$

$$GTE_{i,t} = \beta_0 + \beta_1 IIOT_{i,t} + \beta_2 M_{i,t} + \beta_3 X_{i,t} + \mu_i + \delta_t + City + \varepsilon_{i,t} \tag{6}$$

Where M are denoted as Bm, TPF_LP, TobinQ, Gap and PN variables, respectively. GTE is for GT, RGT, and SGT. $IIOT_{i,t}$ is for Industrial Internet Level. Specifically, Equation (4) is used to test the total effect of IIOT on GTE, Equation (5) is used to test the effect of the impact of IIOT on M, and Equation (6) is used to test the effect of M on GTE after controlling for the impact of IIOT. The specific test results are shown in Table 9.

Column (1) shows that the regression coefficients of IIOT on the mediating variables are all significant at the 1 % level. The Sobal test results in columns (2) (3) as well as (6) (7) are significant, indicating that the IIOT motivates GT and SGT through the paths of increasing book-to-market ratio, total factor productivity, TobinQ value, pay gap, or decreasing value.

However, when we combine the results in columns (1), (4), and (5) in our analyses, we find that there is a masking effect of IIOT on the incentives of RGT. The reason why the total effect in column (4) (the coefficient on IIOT) is not significant is that in column (1) (the coefficient of IIOT) and column (5) (the coefficient on M) is always the same as the coefficient of IIOT in column (5) with the opposite sign. This means that the indirect effect ($\alpha_1 * \beta_2$) and the direct effect ($\beta_1$) have an offsetting relationship, thus leading to the total effect ($\gamma_1$) of being insignificant.

The masking effect is understood in several ways. On the one hand, IIOT can incentivize firms to make strategic decisions about RGT through paths that increase book-to-market ratios, total factor productivity, compensation incentives, innovation, or value reduction. However, on the other hand, IIOT is directly involved in SGT decision-making in opposition to RGT, pushing companies to maintain a green image by disclosing green reports and environmental indicators instead of high-cost altruistic actions such as pollution control and low-carbon environmental protection. Specifically, IIOT does improve RGT levels through the above pathways. However, these path mechanisms with sustainable value are counteracted by the short-sighted self-interested behavior of the firms. Eventually, this short-sighted SGT becomes the dominant GT model, creating an impact on RGT incentives and leading to the drowning of IIOT's efforts. In short, the IIOT does bring a range of foundational underpinnings and incentive paths to RGT with sustainable value, except that companies fall into the greenwashing trap when using the IIOT. This is where the dark side of IIOT overpowers its light side and ultimately does not create significant incentives in RGT.

#### *4.5.2. Moderating mechanism test*

To verify what factors moderate the process of driving GT by IIOT of workers. This paper introduces firm ESG (ESG), financialization level (FIN), and information asymmetry (ASY). In this paper, we add the interaction terms of regulating variables, IIOT and regulating variables in model (1), and decentralize them in advance to construct the model as in Formula (7):

$$GTE_{i,t} = \beta_0 + \beta_1 IIOT_{i,t} + \beta_2 A_{i,t} + \beta_3 IIOT_{i,t} * A_{i,t} + \beta_4 X_{i,t} + \mu_i + \delta_t + City + \varepsilon_{i,t} \tag{7}$$

**Table 10**
Moderating effects test results.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | GT | RGT | SGT | GT | RGT | SGT | GT | RGT | SGT |
| IIOT | 0.2480** | 0.0513 | 0.1663** | 0.2675** | 0.0542 | 0.1824*** | 0.2708*** | 0.0556 | 0.1837*** |
| | (2.48) | (1.19) | (2.60) | (2.67) | (1.27) | (2.86) | (2.72) | (1.30) | (2.88) |
| ESG | 0.5419*** | 0.1050*** | 0.3760*** | | | | | | |
| | (7.08) | (3.05) | (7.56) | | | | | | |
| ESG * IIOT | −0.1698*** | −0.0071 | −0.0902*** | | | | | | |
| | (-3.28) | (-0.29) | (-2.63) | | | | | | |
| FIN | | | | 0.0457 | 0.0756 | −0.0196 | | | |
| | | | | (0.43) | (1.64) | (-0.26) | | | |
| FIN * IIOT | | | | −0.1248 | −0.0833** | −0.0266 | | | |
| | | | | (-1.41) | (-2.23) | (-0.43) | | | |
| ASY | | | | | | | −0.2969** | −0.1050* | −0.1402* |
| | | | | | | | (-2.14) | (-1.91) | (-1.68) |
| ASY * IIOT | | | | | | | −0.3482** | −0.1547** | −0.1524 |
| | | | | | | | (-2.12) | (-2.11) | (-1.52) |
| Constant | −4.7412 | −2.1468 | −0.1957 | −6.5688 | −2.5942 | −1.2997 | −3.9838 | −1.6816 | 5.3799 |
| | (-1.07) | (-1.10) | (-0.07) | (-1.47) | (-1.34) | (-0.48) | (-0.88) | (-0.86) | (1.55) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year - City - Id | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 12,847 | 12,847 | 12,847 | 13,067 | 13,067 | 13,067 | 13,067 | 13,067 | 13,067 |
| $R^2$ | 0.7316 | 0.6492 | 0.7407 | 0.7281 | 0.6476 | 0.7376 | 0.7281 | 0.6478 | 0.7374 |

Note: (.) for the value of t. *** p<0.01. ** p<0.05. * p<0.1.

Where $A_{i,t}$ represent ESG, FIN and ASY, respectively. $IIOT_{i,t}*A_{i,t}$ denote the interaction terms, $IIOT_{i,t}*ESG_{i,t}$, $IIOT_{i,t}*FIN_{i,t}$, $IIOT_{i,t}*ASY_{i,t}$. The results are shown in Table 10.

(1) Moderating effects of ESG performance

According to columns (1)–(3) in Table 10, ESG regression coefficients indicate that ESG positively affects GT, RGT, and SGT. And the ESG*IIOT regression coefficient indicates that ESG has a significant negative moderating effect on the IIOT affecting GT and SGT, i.e., the IIOT is more capable of promoting the SGT to obtain a higher social evaluation in enterprises with a low level of ESG performance. On the contrary, enterprises with higher ESG performance levels (i.e., enterprises with higher social fulfillment responsibilities) are less likely to make SGT using the IIOT.

(2) Moderating effects of financialization

De-emphasis mainly refers to the financialization of real enterprises, so this paper takes the financialization level of enterprises as a proxy variable for de-emphasis. Columns (4)–(6) in Table 10 show that the level of financialization negatively moderates the RGT of enterprises by the IIOT, i.e., the IIOT is more capable of promoting the RGT of enterprises in enterprises with low levels of financialization. This result suggests that enterprises with a low level of financialization will have sufficient funds to invest in enterprise technological innovation and make RGT behaviors that are conducive to the sustainable development of the enterprise. And the funds of enterprises with high financialization will be tempted by the high rate of return of financial assets, resulting in enterprises focusing more on short-term returns and ignoring long-term sustainable development, which leads to the result of under-allocation of funds to RGT behaviors.

(3) Moderating effects of information asymmetry

Regarding the information asymmetry indicator, we first construct the liquidity ratio indicator (LR) and the illiquidity ratio indicator (ILL), and then compute the yield inversion indicator GAM to characterize the stock market liquidity, and based on the three stock liquidity indicators, we conduct a principal component analysis to compute the information asymmetry indicator ASY, in which the stock liquidity is the most important indicator of information asymmetry.

According to columns (7)–(9) in Tables 10 and it can be seen that information asymmetry plays a negative moderating effect on the impact of the IIOT on the RGT and SGT, i.e., the IIOT is more capable of promoting RGT and SGT with a low level of information asymmetry. This result suggests that the application of the IIOT reduces the degree of information asymmetry and improves information transparency, which is important for enterprises to make rational sustainable development decisions. Therefore, both RGT and SGT will benefit from the IIOT to alleviate the information asymmetry of enterprises, and then realize the benign synergistic promotion of RGT and SGT.

**Table 11**
Results of U-shaped relationship test.

| Variable | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Prefer3 | Prefer4 | GT | RGT | SGT |
| IIOT | 0.0106** | −0.0129** | | | |
| | (1.85) | (-2.05) | | | |
| IIOT * IIOT | −0.0027** | 0.0031** | | | |
| | (-2.11) | (2.06) | | | |
| Value | | | −13.9801*** | −5.4676*** | −6.0737*** |
| | | | (-4.27) | (-3.53) | (-3.20) |
| Value * Value | | | 0.3290*** | 0.1245*** | 0.1512*** |
| | | | (4.54) | (3.36) | (3.62) |
| Constant | −0.0459 | 1.1531*** | 162.2007*** | 61.5555*** | 75.4776*** |
| | (-0.45) | (9.99) | (4.34) | (3.51) | (3.45) |
| Control | Yes | Yes | Yes | Yes | Yes |
| Year - City - Id FE | Yes | Yes | Yes | Yes | Yes |
| N | 13,080 | 13,080 | 12,894 | 12,894 | 12,894 |
| $R^2$ | 0.5988 | 0.5529 | 0.7289 | 0.6605 | 0.7161 |
| extreme point | 1.9419 | 2.0753 | 21.2446 | 21.9597 | 20.0806 |
| independent variable interval | [0.0000 | [0.0000 | [20.0098 | [20.0098 | [20.0098 |
| | 5.5013] | 5.5013] | 28.7263] | 28.7263] | 28.7263] |
| slope of the endpoints | [0.0106 | [-0.0129 | [-0.8127 | [-0.4855 | [-0.0214 |
| | −0.0194] | 0.0175] | 4.9232] | 1.6848] | 2.6150] |
| *U* Test P Value | 0.0320** | 0.0300** | 0.0450** | 0.0143** | 0.4710 |
| U Type | inverted U | U | U | U | – |

Note: (.) for the value of t. *** p<0.01. ** p<0.05. * p<0.1.

### 4.6. Further analysis

To further investigate the nonlinear impact of IIOT on GT preference, the regression models as in Formulas (8) and (9):

$$Perfer3_{i,t} = \alpha_3 + \beta_3 IIOT_{i,t} + \gamma_3 IIOT_{i,t}^2 + \theta_3 X_{i,t} + \mu_i + \delta_t + City + \varepsilon_{i,t} \quad (8)$$

$$Perfer4_{i,t} = \alpha_4 + \beta_4 IIOT_{i,t} + \gamma_4 IIOT_{i,t}^2 + \theta_4 X_{i,t} + \mu_i + \delta_t + City + \varepsilon_{i,t} \quad (9)$$

To further analysis the nonlinear relationship between enterprises' market capitalization and GT, RGT, and SGT, a model such as Formula (10) is constructed:

$$GTE_{i,t} = \alpha_1 + \beta_1 Value_{i,t} + \gamma_1 Value_{i,t}^2 + \theta_1 X_{i,t} + \mu_i + \delta_t + City + \varepsilon_{i,t} \quad (10)$$

Where the dependent variable Perfer3 (RGT/GT) represents the RGT tendency during GT, the dependent variable Perfer4(SGT/GT) represents the SGT tendency during GT. The independent variable in Equation (10) value indicator in Eq. (10) represents the market capitalization of the enterprise. This paper use the three-step U-shaped relationship discrimination method, the results of correlation estimation and *U* test are shown in Table 11.

#### 4.6.1. U-shaped test between IIOT and GT preferences

According to column (1) of Tables 11 and it can be found that the coefficient of the primary term of IIOT is significantly positive and the coefficient of the secondary term is significantly negative at the 5 % level. It shows that IIOT has an inverted U-shaped relationship with RGT preference that increases first and then decreases. In column (2), the results show a U-shaped relationship between IIOT and SGT preference that decreases and then increases. All the above tests of the U-shaped relationship are significant, indicating that with the development and popularity of IIOT, firms show opposite tendencies towards RGT and SGT in the GT process. In other words, RGT is gradually being replaced by short-sighted SGT, and IIOT is adopting greenwashing programs to gain wider stakeholder acceptance for the firm. Our findings again support hypothesis H2a.

#### 4.6.2. U-shaped relationship test between enterprises' market capitalization and GT

In columns (3)–(5) of Table 11, the independent variables Value and its quadratic term have significant coefficients, and the estimated coefficients of the primary term are negative and the estimated coefficients of the quadratic term are positive. Initially, it is verified that there is a U-shaped relationship between enterprises' market capitalization and GT, RGT, and SGT. Further through the *U* test, it can be seen that, except for SGT, the market capitalization of enterprises and GT, RGT pass the *U* test. This result suggests that in the short term, when the enterprise market value increases, the enterprise may reduce the investment in enterprise green transformation to a certain extent in order to reduce costs and maximize profits. However, in the long run, when the market capitalization of enterprises further expands, enterprises also care more about sustainable development. In order to gain long-term competitiveness and public acceptance, enterprises turn to realize the importance of green sustainability, thus raising the level of substantive green transformation again.

## 5. Discussion

Moral concerns about AI have been raised algorithmically as machinewashing [39]. our study also finds empirical evidence that IIOT has a greenwashing motive to steer firms away from socially beneficial RGT programs. With the popularity of IIOT, the problem of business ethics in heavily polluting companies has become more serious. So much so that under IIOT, business elites have not only become good at faking a green image but have also become more selfish. The application of the IIOT facilitated ordinary workers to achieve inflation-hedging pay rises, but the biased pay system favored the elite group, rapidly creating polarisation [44]. Our study complements the ethical risk studies of IIOT by exposing the fact that greenwashing behaviour is latent in IIOT.

In addition, scholars have already expressed concerns that AI may affect human social privacy, digital security, and human intelligence [45]. In fact, due to the immaturity of ethical and legal constraints on AI and big data analytics technologies, as well as the lack of oversight bodies [46]. Then, based on the lack of ethical scrutiny of IIOT, entrepreneurs do not make RGT decisions due to the increased productivity and enterprise value of IIOT, but instead, they convert this gain into excess income for the elite layer and make SGT attract investors' attention. This short-term gain driven by the IIOT leads entrepreneurs to overlook ethical pitfalls. Scholars have noted the ethical issues of smart technology in employee management and have found negative feelings of job discrimination against low-skilled groups by smart technology [47]. Our findings are more anxious for low-skilled people because IIOT technology is taking away their pay. In short for the bottom workers, the technological divide of the IIOT not only makes them feel job anxiety, but also increases the pay gap between them and the management, and this severance needs the attention of politicians and more social groups to avoid the impact of the IIOT on social equity.

There have been studies warning of AI-induced liabilities and marginalized traditional small firms [38]. There are similarities between this study and previous studies. It shows that while IIOT improves the financial situation of firms and promotes large-scale heavy polluters to actively make RGT actions, those smaller heavy polluters do not show any signs of green actions. The above result is because small businesses have difficulty integrating into the IIOT ecosystem due to the technological barriers and high costs compared to large companies that can introduce IIOT technology. Our study is a reminder that attention should be paid to the impact on small firms in the process of IIOT penetration, which may give rise to new monopolies.

## 6. Conclusions and implications

### 6.1. Conclusions

IIOT is the breakthrough technology of the fourth industrial revolution, providing new momentum for global economic recovery. Therefore, there is an urgent need to verify whether IIOT can drive the green revolution of heavy polluters at the source, which determines the fundamental factor of whether mankind can achieve sustainable governance in the smart era. For this reason, this paper is based on the GT perspective and splits it into two decision forms, RGT and SGT, to study the incentive effects and decision preferences of IIOT in practice. The main research conclusions are as follows:

(1) IIOT can drive GT, but the process is characterized by a clear preferential selection between the two decisions, RGT and SGT, making the GT goal in most cases accomplished through SGT. (2) The strategic choice of IIOT for SGT is more significant when firms are larger or belong to high energy-consuming industries, when regional environmental regulations are weaker, or when economic development is better. (3) IIOT can enhance GT and SGT levels by improving enterprises' investment attractiveness, productivity, technological innovation, and pay gap, or by reducing enterprises' value creation capacity. Through the masking effect, it was found that although the IIOT allowed RGT levels to increase through these mediating pathways, firms always utilized the IIOT for greenwashing activities and to reduce their focus on RGT. Ultimately, the incentives of the IIOT for RGT are canceled out and wiped out by two opposite forces. (4) The IIOT has an inverted U-shaped incentive process for RGT and a U-shaped incentive process for SGT, and the two processes have significant here-and-there characteristics, culminating in the fact that greenwashing behavior became popular when the IIOT became more widespread.

Although we always conclude that the IIOT favors incentives for SGT, it is actually the result of a game between RGT and SGT. In fact, the tendency of enterprises to utilize the greenwashing attribute of the IIOT is due to the higher cost of investment required for RGT relative to SGT. As a result, the incentives of the IIOT for RGT are more highly valued among enterprises that focus on physical investment rather than financial speculation. On the contrary, the incentives of the IIOT for SGT are more permissible among enterprises that are less socially responsible.

From the perspective of enterprise production activities, IIOT, as a technology that requires arithmetic and power for basic support, still has the underlying logic of energy consumption in its impact on GT. IIOT does not directly show strong environmental effects in the initial stages of a full technology substitution cycle. This is because the increase in arithmetic power and energy consumption attached to the introduction of information and smart technologies is also the cost of technological updates that directly lead to increased carbon emissions. Therefore, the decision-making process of IIOT's gradual inclination towards SGT has not only the self-interested motivation of companies actively greenwashing but also the passive factor of increased energy consumption due to technological overlay.

### 6.2. Policy implications

First, the advantages of informatization can enable the IIOT to improve the information asymmetry dilemma and promote green transformation. Therefore, the government should encourage the application of IIOT technologies with RGT capabilities, so that enterprises, technologies and society can get efficient information transfer efficiency and realize the synergistic promotion of informatization and greening. Of course, the government can organize industrial alliances to jointly promote the research and application of green IIOT through joint R&D and application demonstration projects to achieve the sharing of technology and experience.

Second, policy-based subsidies are more precise. Funding subsidies will be provided for IIOT technologies with RGT functions, guiding enterprises to use the IIOT toward green and sustainable goals. Small and medium-sized enterprises may not be able to keep up with the technical facilities due to the lack of capital, and green transformation may not be able to turn around. Therefore, the government can formulate relevant tax breaks, reduce technology procurement costs and other ways to incentivize small and medium-sized enterprises to actively adopt IIOT technology and promote green transformation. In addition, the government can stimulate the innovation potential of SMEs through policy support and promote the continuous upgrading of IIOT technology.

Third, the government strengthens the ethical supervision of IIOT. On the one hand, the government promotes ethical and moral supervision for IIOT, to guard against hypocritical behaviors of IIOT. This supervision should penetrate the whole industry chain of IIOT, such as program development, data processing, deep learning, artificial intelligence, and work applications, to reduce the ethical risks generated by the technology with a precise responsibility mechanism. On the other hand, IIOT influences not only green production but also green decision-making in corporate activities. Therefore, the ethical review of IIOT curbs greenwash at the source compared to environmental regulations that incur more institutional costs and trigger greenwash consequences.

Fourth, optimizing the green system. On the one hand, the government can introduce regulations and systems to encourage RGT for enterprises that are large in scale and belong to high-energy-consuming industries and strengthen the supervision of enterprises' green-bleaching behavior. On the other hand, governments should leverage ESG trends to promote corporate environmental responsibility ratings at the level of substantive green governance, focusing on actions related to greenhouse gas emissions data, wastewater treatment volumes, renewable energy consumption, and so on. Finally, green trading markets, such as the carbon emissions market, should be developed to form a green governance mechanism with total control and reasonable transfers.

Fifth, Governments should increase the dissemination of green knowledge. In developing countries, public awareness of environmental protection and green health lags compared to developed countries. Developing countries should popularise green knowledge so that more people understand the importance of green products, green consumption, and the ecological environment, thus strengthening the intensity of ethical supervision in society. As more environmental issues are brought to the forefront and brought to light, social pressure for corporate green action will develop. This convention of organizational legitimacy, established through the entire population, is the social basis for RGT action.

### 6.3. Limitations and further research

There are some limitations of this study that need to be addressed in future research. First, this study develops a model based only on highly polluting listed firms in China. The scope of influence of the study results may be constrained. Therefore, consideration could be given to including data from unlisted firms in future studies, along with tests and experiments. Such a comparative analysis will provide a broader perspective for understanding the importance of IIOT. Second, it is limited by the attributes of IIOT in China. Our study discusses the double-edged sword of platform IIOTs under the GT objective, which may differ from the green governance mechanism under other IIOT growth models. Finally, due to data limitations, this study only analyses the GT of a sample of Chinese-listed companies. Therefore, future research could include samples of firms from different economies in the dataset. It is committed to identifying the improvements that China needs to make in GT through comparative analysis.

Future scholars can form larger teams to conduct cross-national studies to discuss green governance options under different IIOT development models. At the same time, they can explore the institutional costs that enterprises in different economies need to pay when facing different IIOT ecologies, and the ethical choices they ultimately make. Of course, as far as the dark side of IIOT is concerned, future research can further discuss the ethical crisis of IIOT in different scenarios and develop safe IIOT technologies based on this study.

## Disclosure statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability statement

The data will be available upon request from the corresponding author liukai5850@163.com.

## CRediT authorship contribution statement

**Liqun Liu:** Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Data curation, Conceptualization. **Lin Liu:** Writing – review & editing, Conceptualization. **Kai Liu:** Writing – review & editing, Software, Resources, Methodology. **Ana Isabel Jiménez-Zarco:** Writing – review & editing, Validation, Formal analysis.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.


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## Appendix

**Table 1**
Correlation Analysis

| | GT | RGT | SGT | IIOT | Size | ROA | Density | Growth |
|---|---|---|---|---|---|---|---|---|
| GT | 1 | | | | | | | |
| RGT | 0.7523*** | 1 | | | | | | |
| SGT | 0.9349*** | 0.5179*** | 1 | | | | | |
| IIOT | 0.2881*** | 0.1044*** | 0.3130*** | 1 | | | | |
| Size | 0.3611*** | 0.2957*** | 0.3260*** | 0.2238*** | 1 | | | |
| ROA | 0.0450*** | 0.0542*** | 0.0282*** | 0.0756*** | 0.2730*** | 1 | | |
| Density | −0.1128*** | −0.1190*** | −0.0861*** | −0.0711*** | 0.0642*** | −0.1997*** | 1 | |
| Growth | −0.0263*** | 0.0355*** | −0.0515*** | 0.0431*** | 0.1328*** | 0.2914*** | −0.0878*** | 1 |
| Lev | 0.0958*** | 0.1132*** | 0.0747*** | −0.0164* | 0.0926*** | −0.4293*** | −0.0184** | −0.0297*** |
| Meeting | 0.2933*** | −0.1911*** | 0.4156*** | 0.2852*** | 0.1096*** | −0.0483*** | 0.0459*** | −0.0494*** |
| Independent | 0.2039*** | −0.2205*** | 0.3768*** | 0.2008*** | 0.0265*** | −0.0574*** | 0.0415*** | −0.1185*** |

(continued on next page)

**Table 1** (*continued*)

| | GT | RGT | SGT | IIOT | Size | ROA | Density | Growth |
|---|---|---|---|---|---|---|---|---|
| Equity | 0.1220*** | 0.1481*** | 0.0903*** | −0.1097*** | 0.1745*** | −0.1295*** | −0.0185** | −0.0851*** |
| Dual | −0.0664*** | −0.0879*** | −0.0452*** | 0.0613*** | −0.1115*** | 0.0431*** | 0.0392*** | 0.0406*** |
| Age | 0.2129*** | 0.0799*** | 0.2258*** | 0.1536*** | 0.0923*** | −0.0742*** | 0.0452*** | −0.0893*** |
| GDP | −0.2236*** | 0.2050*** | −0.3391*** | −0.1490*** | 0.0324*** | 0.0618*** | −0.0377*** | 0.0893*** |
| Gov | 0.0178** | −0.0044 | 0.0166* | 0.0174** | 0.0360*** | 0.0106 | 0.0044 | 0.0014 |
| | Lev | Meeting | Independent | Equity | Dual | Age | GDP | Gov |
| Lev | 1 | | | | | | | |
| Meeting | 0.0362*** | 1 | | | | | | |
| Independent | −0.0228*** | 0.5779*** | 1 | | | | | |
| Equity | 0.3562*** | −0.0396*** | −0.0459*** | 1 | | | | |
| Dual | −0.1546*** | 0.0253*** | 0.0417*** | −0.2994*** | 1 | | | |
| Age | 0.1168*** | 0.2678*** | 0.2042*** | 0.1017*** | −0.0289*** | 1 | | |
| GDP | −0.0206** | −0.6949*** | −0.5262*** | 0.0046 | −0.0093 | −0.1725*** | 1 | |
| Gov | 0.0005 | 0.0027 | 0.0112 | −0.0061 | −0.0083 | 0.0194** | −0.0302*** | 1 |

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