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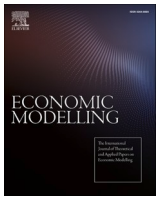

Can enterprise digitization improve ESG performance?☆

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ABSTRACT

In the era of digital economy, every enterprise has to face digitization, but there is limited literature to investigate the impact of enterprise digitization on ESG performance. This paper examines the impact of enterprise digitization on ESG performance using Chinese listed companies during 2012–2020. We find that the digitization of companies significantly improves ESG scores. Heterogeneity analysis shows that the positive effect is more pronounced for non-politically connected companies and companies located in regions with high quality institutions. We identify two channels through which digitization affects ESG performance. First, digitization enables companies to reduce agency costs and increase governance (G) scores. Second, digitization facilitates companies to improve goodwill and further increase social (S) scores. However, we do not find that digitization improves companies' environmental (E) scores. The findings have important policy implications in motivating enterprises to engage more in ESG activities.

1. Introduction

Environmental, Social and Governance (ESG) has become a mainstream business activity for enterprises.[1] Even in emerging markets like China, enterprises are increasingly engaged in ESG activities. In 2021, 1130 Chinese A-share listed companies issued ESG reports, a jump from only 872 in 2018. However, the proportion of companies publishing ESG reports is still less than one third of all A-share listed companies. The question of how to encourage more ESG participation has become a challenge for many researchers and practitioners. Researchers have examined the reasons affecting the ESG performance of enterprises from various perspectives, including market characteristics, corporate governance and leadership characteristics (Gillan et al., 2021), providing insights into solving this challenge. However, so far there is a scant amount of literature examining the impact of digitization on ESG performance. This paper attempts to fill that gap.

In the era of digital economy,[2] digitization has become one of the biggest challenges and opportunities for Chinese economy and its enterprises. As a developing country, China is a latecomer to the digital economy. The size of China's digital economy reached $5.4 trillion in 2020, second only to the United States' $13.6 trillion. Meanwhile, the share of the digital economy in China's GDP grew from 27% in 2015 to 38.6% in 2021.[3] For Chinese enterprises, digitization has become one of the most important technological innovations. Digitization is the process by which enterprises use digital technologies such as the Internet, Big Data, and Blockchain to reduce transaction costs, increase productivity, and create more value for customers (Goldfarb and Tucker, 2019).[4] A survey by the international consulting company Accenture found that

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[1] An equivalent concept to ESG is corporate social responsibility (CSR); both indicate enterprises that invest resources in public goods to reduce negative externalities to levels below what is required by law (Kitzmueller and Shimshack, 2012; Gillan et al., 2021).

[2] The narrow definition of the "digital economy" constitutes economic activity in the information and communication technology (ICT) sector, while the broad definition includes the combined value of ICT production and digital inputs to the rest of the economy (Chen, 2020).

[3] China Academy of Information and Communications Technology (2021). White Paper on the Global Digital Economy (In Chinese). http://www.caict.ac.cn/kxyj/qwfb/bps/202108/P020210913403798893557.pdf.

[4] Since digital technologies such as the Internet, Big Data, and Blockchain can be collectively referred to as ICT, some economic literature uses ICT as a proxy for digitization, e.g., Bloom et al. (2014), DeStefano et al. (2018), Chen (2020). However, some management literature uses the concept of "digitalization" or "digital transformation", e.g., Matarazzo et al. (2021). In this paper, digitization, digitalization, and digital transformation are used synonymously.

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80% of Chinese companies deployed telecommuting systems and 63% established online sales channels during the COVID-19 pandemic in 2020.[5]

Digitization has revolutionized the way enterprises conduct business, how they create relationships with consumers, suppliers, and other stakeholders, and has fostered business model innovation and customer value creation (Matarazzo et al., 2021). The digitization case of Lenovo, the world's largest personal computer (PC) company, provides evidence for how this works. At the beginning of the pandemic, Lenovo was forced to close 65.3% of its offline stores, resulting in a sharp decline in sales. Then, Lenovo used the WeChat applet to help 1000 offline stores conduct business online and utilized Big Data to integrate data from memberships, stores, marketing and logistics. With the help of digitization, Lenovo has brought profits to its shareholders, and simultaneously secured the employment of employees and met the needs of its customers.[6] Since digitization brings value to stakeholders, and since maintaining stakeholder value is the essence of ESG activity (Edmans, 2020), we infer that enterprise digitization will improve ESG performance.

To test the relationship between enterprise digitization and ESG performance, we collect annual reports and financial data of Chinese A-share listed companies from 2012 to 2020, excluding state-owned enterprises (SOEs). We plot each company's digitization on an index based on its annual reports using textual analysis, and then we match that to ESG scores from the Bloomberg database. Baseline regression analysis shows that the digitization of companies significantly improves ESG scores. On average, digitization accounts for about 7.69% of the increase in ESG scores over the period of 2012–2020. The results remain robust when we use the digital fixed asset ratio (Digi_fix) and the digital intangible asset ratio (Digi_int) to measure the digitization level.

One possible endogenous concern is that companies with higher ESG performance tend to have better financial performance and are therefore more capable of undertaking digitization. To mitigate this reverse causality concern, we regard the establishment of the National Big Data Comprehensive Pilot Zone in ten regions as an exogenous shock to enterprise digitization.[7] Then we estimate the impact of this policy shock on enterprises' ESG performance using the Difference-in-Differences (DID) approach. Regression results show that companies located in the National Big Data Comprehensive Pilot Zone significantly improve their ESG scores relative to those in other regions. In addition, to further address endogeneity concerns such as omitted variables, we construct a Bartik instrumental variable (Bartik, 1991), which is the sample mean value of the digitization in the first year (2012) by two-digit industry multiplies the annual growth rate of the industrywide digitization. Both the DID estimation and instrumental variable regressions demonstrate a causal relationship between enterprise digitization and ESG performance.

Through heterogeneity analysis, we first find that the positive effect of digitization on ESG performance is more pronounced for non-politically connected companies relative to politically connected companies. This is because politically connected companies lack incentives to use digital technology to improve ESG performance and are instead more likely to use digital technology to improve financial performance. We then find that the positive effect of digitization on ESG performance is more pronounced for companies located in regions with high quality institutions relative to those located in regions with low quality institutions. This implies that digital technologies and institutional environments are complementary to some extent.

Finally, we explore two channels through which enterprise digitization affects ESG performance. First, digitization enables companies to reduce agency costs and increase governance (G) scores. Second, digitization facilitates companies to improve goodwill and enhance social (S) scores. In addition, we do not find that digitization significantly reduces environmental pollution or improves energy efficiency, suggesting that digitization does not affect companies' environmental (E) scores.

This paper contributes to the existing literature in the following three respects. First, it sheds light on the impact of technological innovation on ESG performance. In recent years, researchers have examined factors that influence the ESG engagement or ESG performance of enterprises from different perspectives (Gillan et al., 2021), including economic development, culture and institutions at the national level (Cai et al., 2016); legal origins (Liang and Renneboog, 2017), equity structure (Ghoul et al., 2016), the personal characteristics of CEOs (Hegde and Mishra, 2019), and CEO compensation structure (Ferrell et al., 2016) at the enterprise level. However, there is little literature analyzing the relationship between technological innovation and ESG performance. Therefore, this paper aims to add a new perspective to the ESG literature by identifying the causal relationship between enterprise digitization and ESG performance.

Second, this study enriches the literature on the impact of digital technologies on enterprise behavior. Economists have found that the use of digital technologies such as information and communication technology (ICT), software and Big Data motivates enterprises to increase R&D (Branstetter et al., 2018), scale up investments (DeStefano et al., 2018) as well as change organizational structures (Bloom et al., 2014). In contrast to the existing literature, our study finds that enterprise digitization increases ESG engagement. This implies that digitization changes not only the internal behavior of the enterprise, but also the relationship between the enterprise and external stakeholders. In addition, this study uses a broader measure of enterprise digitization, including not only digital technologies such as ICT and Big Data, but also new automation technologies such as robots and AI.

Third, this paper is related to the rapidly increasing empirical studies of the Porter hypothesis in recent years. The Porter hypothesis argues that strict environmental regulatory policies induce enterprises to engage in technological innovation and that technological innovation improves both environmental and economic performance (Porter, 1991; Jaffe and Palmer, 1997). However, the Porter hypothesis remains controversial in terms of empirical evidence (Ambec et al., 2013). Moreover, existing empirical studies focus on the impact of environmental regulation on enterprise innovation (Martínez-Zarzoso et al., 2019), and on the impact of environmental regulation on productivity (Berman and Bui, 2001). In contrast, this paper analyzes the impact of digitization on environmental performance. We find that enterprise digitization improves the overall ESG performance, but it does not significantly reduce pollution emissions and improve energy efficiency. This implies that technological innovation does not necessarily improve environmental performance, relying on the direction in which technological innovation is applied.

The rest of the paper proceeds as follows. Section 2 presents the hypotheses. Section 3 describes our data, variables, and model specification. Section 4 provides empirical results and robustness tests. Section 5 analyzes heterogeneity and channel analyses, and Section 6 concludes.

2. Hypotheses development

2.1. The impact of digitization on ESG performance

Enterprise ESG engagement includes three aspects: Environmental (E), Social (S), and Governance (G). Enterprises no longer emphasize solely generating profits for shareholders, but instead strive to grow the

[5] Accenture, "China Enterprise Digital Transformation Index 2020", https://www.accenture.com/cn-en/insights/consulting/china-digital-maturity-index-report.

[6] Accenture, "China Enterprise Digital Transformation Index 2020", https://www.accenture.com/cn-en/insights/consulting/china-digital-maturity-index-report.

[7] The policy provides infrastructure and financial support for the digitization of enterprises. We will explain it in detail later.

pie together with stakeholders (including employees, customers, suppliers, communities, and governments) to achieve a multi-win goal (Edmans, 2020). That is the purpose of ESG. Meanwhile, digitization is the process through which enterprises use digital technology to improve management efficiency and productivity, and ultimately improve the welfare of stakeholders. Therefore, digitization will improve ESG performance. We analyze digitization in the following three aspects: digitization and agency costs; digitization and goodwill; digitization and environmental performance. Let's look at each in turn.

Digitization and agency costs. Because of the separation of ownership and control in modern companies, one of the most prominent costs of corporate governance is agency costs (Berle and Means, 1932). Agency costs arise mainly from information asymmetry between shareholders and managers (Jensen and Meckling, 1976). ICT and internet-based digitization can reduce information asymmetries and agency costs between stakeholders (Canarella and Miller, 2018). First, the use of information storage and processing software (e.g., ERP) allows for better information gathering, which increases the productivity of workers (Bloom et al., 2014). Second, the use of Intranet or computer-assisted manufacturing (CAD) software can reduce coordination costs for managers (McElheran, 2014), and the reduction in coordination costs clearly helps to increase the value of managers (Garicano, 2000). Third, digitization can effectively reduce corruption and commercial bribery in purchasing and sales departments (Fan et al., 2021), thus better protecting the interests of shareholders and creditors. Because digitization helps reduce information asymmetries in transaction processes, promoting transparency and accountability. Fourth, social media decrease the probability of a corporate governance violation, such as share dilution, shareholder disenfranchisement (Dyck et al., 2008), or the violation of information disclosure rules (Kouwenberg and Phunnarungsi, 2013). To sum up, digitization can help reduce information asymmetries between managers and employees, external investors and managers, thus reducing agency costs, improving corporate governance, and ultimately increasing enterprise governance (G) scores.

Digitization and goodwill. Besides reducing information asymmetry, the benefits of digitization to enterprise management include reducing verification costs (Goldfarb and Tucker, 2019). Research on E-commerce shows that online rating systems offered by enterprises to consumers can provide reliable quality signals in various settings (Dellarocas, 2003; Cabral and Hortacsu, 2010), leading to building trust relationships with consumers in long-distance transactions. Moreover, the online feedback system not only effectively enables market transactions in the Internet scenario, but also reduces the cost of verification in the offline scenario. Therefore, enterprises with a high degree of digitization can improve their goodwill with consumers. Furthermore, social media play a vital role in improving stakeholder engagement, because they enable a direct, two-way dialogue between the enterprise and the stakeholders (Schultz et al., 2013). We believe that with digital communication tools (e.g., websites, social media accounts), enterprises can better communicate their achievements in environmental protection, philanthropy, and poverty alleviation to communities and governments, leading to improved goodwill and higher Social (S) scores.

Digitization and environmental performance. In recent years, scholars have focused on the channels through which digitization can influence environmental (E) performance. First, digitization can help enterprises control their pollution emissions. The application of digital technology can be considered as an efficient way of tackling dynamic environmental problems, such as air pollution, carbon emissions, wastewater treatment, and climate change (Kanabkaew et al., 2019). Second, digitization can improve energy efficiency and help achieve sustainable development. For example, in terms of energy efficiency or renewable energy consumption, enterprises can implement smart and sustainable manufacturing as a result of digital technology applications. Therefore, theoretically, digitization can improve enterprises' Environmental (E) scores.

[1 and 2]Based on the theoretical analysis of the above three channels (See Fig. 1), we obtain the following hypothesis.

Hypothesis 1. Digitization will improve enterprises' ESG performance.

2.2. Moderating effect of political connections

The impact of enterprise digitization on the ESG performance can be influenced by enterprise characteristics and the external environment. We first analyze the heterogeneity due to political connections. First, enterprises can obtain preferential policies by establishing relationships with government officials, including higher acquisition prices (Faccio et al., 2006) and lower financing costs (Li et al., 2008), thus enhancing enterprise value. Second, government officials will protect politically connected enterprises from strict environmental regulation for their private benefit. Correia (2014) finds that politically connected companies are subject to fewer enforcement actions and face lower penalties for violations. Xiao and Shen (2022) subtly exploit an exogenous shock and find that companies that lost their political connections experience significant environmental rating improvements. The above studies show that politically connected enterprises receive government protection from accountability over environmental pollution and thus lack incentives to improve ESG performance. Hence, politically connected enterprises are more likely to use digital technologies for non-ESG projects, such as improving financial performance. Therefore, we conjecture that digitization does not have a positive effect on ESG performance for politically connected enterprises; conversely, digitization has a positive effect on ESG performance for non-politically connected enterprises.

Hypothesis 2. The positive effect of digitization on ESG performance is more pronounced for non-politically connected enterprises.

2.3. Moderating effect of institutional quality

Next, we analyze the heterogeneity due to the institutional environment. Institutions usually include two dimensions: first, property rights institutions, which measure the degree of government protection for enterprises and residents; second, contracting institutions, which measure the level of contract enforcement between enterprises or residents (Acemoglu and Johnson, 2005). The literature on institutional economics has amply proven that institutions are a fundamental factor in long-term economic growth because they determine the incentives of economic agents to invest (North, 1990; Acemoglu et al., 2005). Only in regions with high quality institutions can enterprises develop stable expectations and have incentives to invest in technological innovation to obtain long-term returns. In contrast, in regions with low quality institutions, enterprises may have more incentives to invest in political connections or rent-seeking for short-term gains. The use of digital technologies is also dependent on the institutional environment. First,

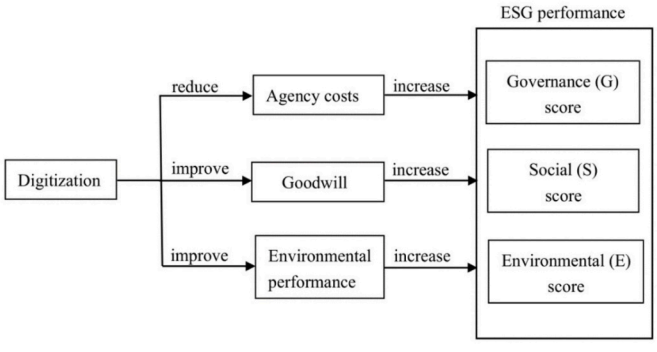

Fig. 1. Digitization and ESG

digital technology, whether as a hardware device or as intellectual property (software), itself requires that the government protects its ownership, use and benefit rights. Otherwise, it will not be able to improve management efficiency and productivity of enterprises, and certainly it will be unlikely to have a positive effect on ESG performance. Second, as a technological innovation, enterprise digitization requires a large initial capital investment and involves a greater risk of failure. Therefore, digitization may require a more stable and predictable institutional environment as well as general technological innovation. Fan et al. (2021) find that the anti-corruption function of ICT is more pronounced in countries with better institutional and political systems, and in those with better property rights protection. This is consistent with our analysis.

Hypothesis 3. The positive effect of digitization on ESG performance is more pronounced for enterprises located in regions with high quality institutions.

3. Data and methodology

In this section, we discuss data, sample characteristics, and variables construction. We also outline our empirical methodology.

3.1. Data and sample

We use Chinese A-share listed companies as our sample. On this basis, we exclude state-owned companies,[8] because they rely primarily on administrative monopolies and are insensitive to economic efficiency. Our ESG-scores data are from the Bloomberg database, the digitization level and other company-level variables are retrieved from the China Stock Market and Accounting Research Database (CSMAR). Specifically, the digitization level is calculated based on the text of the company's annual report. Then, we match these databases and exclude companies that lack ESG scores. It is notable that the missing values of ESG scores are due to the fact that the corresponding companies do not issue ESG reports. We exclude companies with Special Treatment (ST) and those in the financial sector. Then we winsorize all numerical variables at the 1% and 99% levels. Finally, our sample is an unbalanced panel of 2776 company-year observations for 394 non-state-owned listed companies from 2012 to 2020.[9]

3.2. Measuring ESG performance

We measure a company's ESG performance using a score that reflects the extent of the company's involvement in ESG activities (ESG_score). This measure is constructed based on the Bloomberg database, which has been used extensively in prior ESG/CSR literature (Buchanan et al., 2018; Avramov et al., 2022). The Bloomberg ESG data are collected from company-sourced filings such as CSR reports, annual reports, company websites and a proprietary Bloomberg survey.[10] The Bloomberg ESG scores cover the three pillars of ESG, Environment (Environ_score), Social (Social_score), and Governance (Govnce_score), each with a 33% weighting.[11] For instance, the Environmental pillar consists of seven topics, including Air Quality, Climate Change, Ecological & Biodiversity Impacts, Energy, Materials & Waste, Supply Chain, and Water, the weight of each topic is about 4.75%. Finally, each topic contains several fields.[12] The detailed components and weights of the Bloomberg ESG scores can be seen in Table A2 in the Appendix. Unlike other ESG/CSR ratings, Bloomberg ESG scores are also tailored to different industry sectors. In this way, each company is evaluated only in terms of the data that are relevant to its industry sector.

In robustness tests, we construct four alternative measures of ESG performance. Similar to Kong et al. (2021), we first sort through the ESG_score and divide the sample into 100 groups based on those scores. Then we construct a discrete variable (ESG_Rank) as the new dependent variable ranging from 1 to 100; a higher ESG_Rank means higher ESG performance. Second, we use the natural logarithm of the ESG scores (Log (ESG)) as an alternative measure of ESG performance. Third, we use the data of the HuaZheng ESG rating. The HuaZheng ESG rating is divided into eight categories: AA, A, BBB, BB, B, CCC, CC, C. We then define the dummy variable HZ_Rate which equals zero if the HuaZheng ESG rating is CCC or CC or C, and one otherwise. Fourth, we use the data of the HeXun CSR rating. The HeXun CSR rating is split into five categories: A, B, C, D, E. We then define the dummy variable HX_Rate which equals zero if the HeXun CSR rating is D or E, and one otherwise.

It is undeniable that some companies may act strategically when issuing ESG reports, such as exaggerating or hiding some important information. However, we believe that it is unlikely that Chinese companies will engage in systematic falsification or distortion in their ESG or CSR reports. There are two reasons. First, studies have shown that the relationship between ESG and corporate financial performance (CFP) of listed companies generally remains mixed (Gillan et al., 2021), and studies based on Chinese listed companies also show that ESG disclosure leads to a decrease in profitability (Chen et al., 2018). Therefore, companies' falsification in ESG does not necessarily lead to improved financial performance. Second, the disclosure of ESG reports is voluntary for Chinese listed companies (except for few heavy polluting industries). This weakens the incentive for companies to falsify.

3.3. Measuring digitization

The key explanatory variable is the digitization level of companies. Digitization is an important transformation process that involves changes in aspects of internal management, organizational structure, sales system, and company culture (Sieble, 2019). As a result, the digitization level is difficult to measure through the financial indicators of listed companies. However, digitization is a highlight of listed companies' performance, and there is a strong desire by companies to disclose it in their annual reports to gain favor with investors. Therefore, annual reports are an obvious candidate for measuring the digitization level of listed companies (Zhao et al., 2021). We build the digitization index of companies using the following four steps. First, we construct a thesaurus of digitization keywords by culling from representative publications on digitization, such as Siebel (2019) and Ratajczak-Mrozek and Marszałek (2022), and Chinese policy documents[13] on the digital economy from 2012 to 2020. The thesaurus contains approximately 100 keywords in total, including "big data", "cloud computing", "artificial intelligence", "e-commerce", "internet marketing", etc. We read the texts of annual reports of representative listed companies in each

[8] In this paper, state-owned enterprises are defined as those whose ultimate controller or largest shareholder is the government.

[9] Some samples are missing because of the lack of ESG scores, hence, our sample includes only 394 non-state-owned listed companies. Meanwhile, we choose 2012 as the beginning of our sample because the earliest Bloomberg ESG scores available are from 2012.

[10] Bloomberg, "Look beyond: Bloomberg for environmental, social and governance data". Available at: https://www.cfaboston.org/docs/ESG/BloombergLookBeyond2014.pdf.

[11] We use these three scores in the channel part as enlightening results.

[12] For example, the topic Air Quality (one of the components of the Pillar Environment) is composed of five fields: Nitrogen Oxide Emissions, VOC Emissions, Carbon Monoxide Emissions, Particulate Emissions and Sulphur Dioxide/Sulphur Oxide Emissions.

[13] To list some examples, The Opinions on Vigorously Promoting the Development of Informatization and Effectively Safeguarding Information Security (2012), The Guidance of the State Council on Actively Promoting the "Internet+" Action (2015), and The Guidance on Deepening the Integration and Development of New Generation Information Technology and Manufacturing (2020).

industry to ensure that our keywords cover all the main aspects of the digitization level of the company.[14]All keywords are listed in Table A3 in the Appendix. Second, we develop web crawlers in Python to collect annual reports of listed companies for all the companies in our dataset,[15] and take the section Management Discussion and Analysis (MD&A) from each listed company's annual report using regular expressions. MD&A is the section in the annual report where executives analyze a company's performance and describe the events and management decisions that may influence a company's operations. Third, we use the programming language Python and the jieba word splitting module to split each sentence in the MD&A section and remove stop words[16] while splitting. Fourth, we calculate the word frequency of keywords based on the digitized thesaurus, and get the Digitization index for each company-year from the following equation:

$$Digitizationi,t = \frac{Number \text{ of } digitization \text{ keywords}_{i,t}}{Number \text{ of all words in MD\&A}_{i,t}} \times 100 \quad (1)$$

In robustness tests, we also include two alternative measures of Digitization. Referring to Brynjolfsson and Hitt (2003), we use companies' ICT investments as the alternative measure of enterprise digitization. Specifically, we construct two variables Digi_fix and Digi_int based on the nature of ICT investments. First, we calculate companies' digitization-related investment in fixed assets, which is equal to the office electronics investment plus self-service equipment investment. Then we define the variable Digi_fix as a company's digitization-related investment in fixed assets as a percentage of total assets. Second, the variable Digi_int is defined as a company's digitization-related investment in intangible assets as a percentage of total assets, which is measured by the net value of the software.

3.4. Econometric model

To measure the effect of enterprise digitization on ESG performance, we use an OLS regression to estimate the following equation:

$$ESG\_score_{i,t} = \alpha + \beta Digitization_{i,t-1} + \gamma X_{i,t-1} + \tau_i + \delta_t + \varepsilon_{i,t} \quad (2)$$

where for company i and year t, the dependent variable ESG_score is the Bloomberg ESG scores, the key explanatory variable Digitization represents the digitization level of companies. We lag the variable Digitization by one year in the regression to alleviate concerns over potential reverse causality. The coefficient β indicates the degree of influence of lagged Digitization on the ESG_score. $Xi, t-1$ is the set of control variables of companies' characteristics; we also lag all control variables by one year in the econometric model to mitigate concerns about a delay between companies' characteristics and their ESG performance (Giuli and Kostovetsky, 2014). In addition, we also control for firm fixed effects τi and year fixed effects δt. $\varepsilon i, t$ denotes the residual term.

Following the existing literature (Kong et al., 2021; Cronqvist and Yu, 2017; Ferrell et al., 2016; Giuli and Kostovetsky, 2014), we include the following company-level characteristics as our control variables. (1) Company size (Size), which is equal to the natural logarithm of the total number of employees. (2) Company age (Age), which is equal to the number of years that the company has been listed. (3) Dividends, which is equal to cash dividends over total assets. (4) Leverage ratio (Leverage), which is equal to total debts over total assets. (5) Roa, which is equal to net profit over total assets. (6) Cash, which is equal to cash balances over total assets. (7) Largest, which is equal to the ratio of the largest shareholders' stake. (8) Top10, which is equal to the shareholding ratio of top ten shareholders. (9) Boardnum, which is equal to the number of directors. (10) Inboardratio, which is equal to the ratio of independent directors to the total number of directors. And lastly, (11) Duality, which is a dummy variable that equals one if the CEO also serves as the Chairman, and zero otherwise.

In addition, to rule out alternative explanations for the impact of digitization on companies' ESG performance, we control for two CEO-specific variables in robustness checks: Femceo and Ceoage. Femceo is a dummy variable which equals one if the company has a female CEO in a given year and zero otherwise. The variable Ceoage is measured by the natural logarithm of CEO age.

3.5. Descriptive statistics

Table 1 presents the descriptive statistics for the main variables used in this study. Panel A reports summary statistics on companies' ESG performance and digitization level. The average value and standard deviation of the ESG_score are 19.888 and 6.01, respectively. However, Digitization experiences a greater volatility, and the average value and standard deviation of the Digitization score are 0.084 and 0.108, respectively. Panel B of Table 1 presents summary statistics on control variables such as financial characteristics and governance characteristics of companies. Panel C of Table 1 shows the summary statistics on other variables which are used in robustness checks and channel analysis.

Next, Fig. 2 depicts the time trend of the ESG_score and the Digitization. Fig. 2(a) demonstrates the average value of the ESG_score per year. This figure shows a steady growth of the ESG_score during the 2012–2020 period. Fig. 2(b) represents the time trend of the Digitization. The solid line in Fig. 2(b) demonstrates the standardized average value of the Digitization per year (relative to 2012). This figure displays a rapid growth of Digitization, and the average value of Digitization in 2020 is about 4.5 times what it was in 2012. The dotted line in Fig. 2(b) demonstrates the standardized average value of the scale of digital economy per year (relative to 2012).[17] As is shown in Fig. 2(b), the time trend of the Digitization is highly similar to the time trend of the scale of the digital economy in China, which shows that our calculation of the indicator of Digitization is reasonable.

4. Results

4.1. Baseline results

In Table 2, we examine the relation between our main independent variable, a company's digitization index calculated by the company's annual report text, and a company's ESG scores. In our panel of companies, we run the OLS regression defined in Eq. (2). Columns 1 and 2 are the results after including firm-fixed effects, with and without year-fixed effects. In Column 2 of Table 2, we see that the estimated coefficient β on the lagged Digitization from a univariate regression (without control variables) is 3.028 (t-statistic of 2.63). What fraction of the overall ESG score increase during this period can be attributed to digitization? In 2012, the average ESG scores is 17.948. In 2020, the ESG score has increased to 22.789, an increase of 4.841 points or 27%. Over the sample period, the digitization increases from 0.034 to 0.157. Therefore, the increase of digitization could account for about 7.69 percent (=(0.157–0.034) × 3.028/(22.789–17.948)) of the increase in ESG scores over this period. In Column 3 of Table 2, we add several control variables to examine whether company-level variables might explain this univariate result. We find that the coefficient on our variable

[14] For example, big data, smart manufacturing, Internet business models, information technology, etc.

[15] We get annual reports from the JuChao Information Website, which is designated by the China Securities Regulatory Commission as the information disclosure website for listed companies; see http://www.cninfo.com.cn/new/index.

[16] Including words that are commonly used but have no relevant meaning, such as inflectional auxiliaries, adverbs, prepositions, conjunctions, etc.

[17] The data of the scale of digital economy come from the China Academy of Information and Communications Technology (CAICT), 2022.

Table 1
Descriptive statistics.

Variables	Observations	Mean	Median	S.D.	Min	Max
Panel A: ESG_score and Digitization						
ESG_score	2776	19.888	19.422	6.01	5.785	60.744
Digitization	2776	0.084	0.047	0.108	0	0.573
Panel B: Control Variables						
Size	2776	8.312	8.344	1.11	4.205	12.342
Age	2776	17.647	18	5.685	5	32
Dividends (over assets)	2776	0.029	0.024	0.02	0.001	0.115
Leverage	2776	0.437	0.44	0.183	0.064	0.849
Roa	2776	0.053	0.046	0.052	−0.134	0.21
Cash (over assets)	2776	0.145	0.112	0.107	0.014	0.529
Largest	2776	31.766	29.225	14.683	7.63	72.63
Top10	2776	57.093	57.505	15.886	12.72	92.33
Boardnum	2776	8.635	9	1.628	4	18
Inboardratio	2776	0.374	0.333	0.054	0.182	0.667
Duality (dummy)	2776	0.28	0	0.449	0	1
Panel C: Other Variables						
Digi_fix	2762	0.002	0	0.003	0	0.018
Digi_int	2762	0.002	0	0.005	0	0.081
ESG_Rank	2776	50.072	50	28.625	1	100
Log (ESG)	2776	2.951	2.966	0.274	1.755	4.107
HZ_Rate (dummy)	2753	0.784	1	0.412	0	1
HX_Rate (dummy)	2545	0.212	0	0.409	0	1
Femceo (dummy)	2656	0.104	0	0.306	0	1
Ceoage	2656	3.893	3.912	0.144	3.296	4.277
Environ_score	2354	9.994	9.302	7.273	1.55	54.264
Social_score	2758	22.445	22.807	8.336	3.509	77.193
Govnce_score	2776	42.857	42.857	4.703	28.571	62.5

Note: This table presents descriptive statistics for the variables used in this study. The definitions and sources of all the variables can be seen in Table A1 in the Appendix. Our sample contains 2776 company-year observations for 394 non-state-owned listed companies from 2012 to 2020. Panel A shows summary statistics on the ESG_score and Digitization, Panel B represents company-level controls, Panel C includes other variables used in the paper (see Fig. 1).

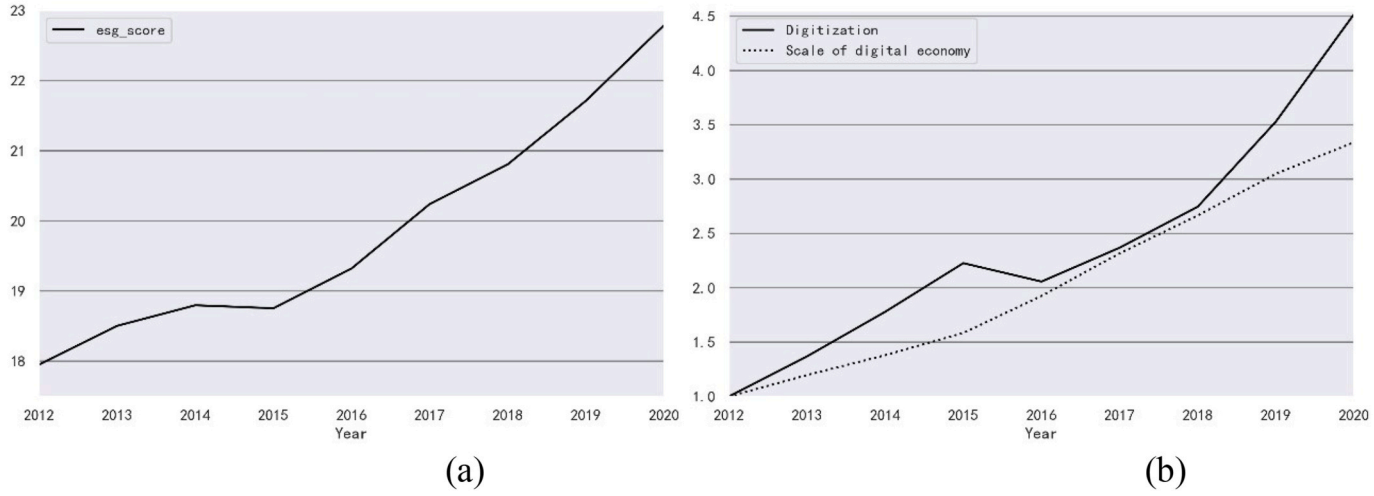

Fig. 2. The time trend of ESG_score and Digitization. Notes: Fig. 2(a) represents the average value of ESG_score per year. Fig. 2(b) represents the time trend of Digitization. The solid line shows the average value of the Digitization per year relative to 2012 while the dotted line shows the average value of the scale of the digital economy per year relative to 2012.

of interest is still a statistically and economically significant determinant of company ESG performance. These data support Hypothesis 1.

We find that lagged terms of Size, Leverage and Largest are significantly and positively correlated with the ESG_score, which means that larger companies and companies with more concentrated equity are more willing to engage in ESG activities. These findings are consistent with the existing literature (Deng et al., 2013; Cronqvist and Yu, 2017).

4.2. Robustness tests

We further conduct a battery of checks to investigate the robustness of our results, including (1) Use alternative measures of Digitization; (2) Use alternative measures of ESG performance; (3) Add additional controls; (4) Difference-in-differences specification; (5) Use the Bartik instrumental variable.

4.2.1. Alternative measures of digitization

In the baseline regression, we use the variable Digitization calculated by companies' annual report text as the key explanatory variable. To test the robustness of baseline results, we employ two alternative measures of Digitization in this section: Digi_fix and Digi_int, which are discussed in Section 3.3. We define Digi_fix as companies' digitization-related investment in fixed assets over total assets, and Digi_int as companies' digitization-related investment in intangible assets over total assets. We

Table 2
Baseline results: Impact of digitization on ESG_score.

Variable	(1)ESG_score	(2)ESG_score	(3)ESG_score
L.Digitization	9.890***	3.028***	2.564**
	(8.40)	(2.63)	(2.23)
L.Size			0.932***
			(4.56)
L.Age			0.248
			(0.43)
L.Dividends			−6.415
			(-1.23)
L.Leverage			2.844***
			(3.05)
L.Roa			2.837
			(1.40)
L.Cash			1.803*
			(1.75)
L.Largest			0.041***
			(2.63)
L.Top10			0.018
			(1.48)
L.Boardnum			−0.032
			(-0.34)
L.Inboardratio			−2.200
			(-0.90)
L.Duality			0.348
			(1.35)
Obs	2251	2251	2251
Firm FE	Yes	Yes	Yes
Year FE	No	Yes	Yes
R^2	0.037	0.190	0.218

Note: This table presents the OLS regression results of lagged Digitization on ESG_score described in Eq. (2). The dependent variable is ESG_score. Column 1 includes firm fixed effects and Column 2 includes both firm and year fixed effects. Column 3 includes all control variables and control for firm and year fixed effects. All the variables are defined in Table A1 in the Appendix. Numbers in brackets are *t*-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

Table 3
Regressions with alternative measures of digitization.

Variable	(1)ESG_score	(2)ESG_score
L.Digi_fix	136.936***	
	(3.20)	
L.Digi_int		70.450**
		(2.05)
L.Size	0.885***	0.928***
	(4.30)	(4.52)
L.Age	0.165	0.200
	(0.29)	(0.35)
L.Dividends	−6.860	−6.601
	(-1.32)	(-1.27)
L.Leverage	3.029***	2.861***
	(3.25)	(3.06)
L.Roa	2.704	3.092
	(1.34)	(1.53)
L.Cash	1.940*	1.823*
	(1.88)	(1.76)
L.Largest	0.037**	0.039**
	(2.38)	(2.50)
L.Top10	0.016	0.018
	(1.32)	(1.48)
L.Boardnum	−0.013	−0.028
	(-0.14)	(-0.30)
L.Inboardratio	−2.305	−2.229
	(-0.94)	(-0.91)
L.Duality	0.385	0.353
	(1.48)	(1.36)
Obs	2241	2241
Firm FE	Yes	Yes
Year FE	Yes	Yes
R^2	0.220	0.217

Note: This table presents the robustness tests for the baseline regression by using alternative measures of Digitization. In Column 1, we use the variable Digi_fix as an alternative measure of Digitization, and in Column 2, we use the variable Digi_int as an alternative measure of Digitization. The dependent variable is ESG_score. All the variables are defined in Table A1. We control for year fixed effects and firm fixed effects. Numbers in brackets are *t*-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

then replace our key explanatory variable Digitization in the baseline model with the two new variables: Digi_fix and Digi_int, and we also lag them by one year. Table 3 presents the results. We can see that both Digi_fix and Digi_int are positively correlated with ESG_score. The findings are consistent with our baseline results.

4.2.2. Alternative measures of ESG performance

To test the robustness of the baseline results, we also employ four alternative measures of ESG performance: ESG_Rank, Log (ESG), HZ_Rate, and HX_Rate, which we have discussed in Section 3.2. To construct the variable ESG_Rank, we sort through the ESG_score and divide the sample into 100 groups, assign a value of 1–100 to each group separately, and a higher ESG_Rank means higher ESG performance. Log (ESG) equals the natural logarithm of the ESG_score. Then, the dummy variable HZ_Rate equals zero if the HuaZheng ESG rating is CCC or CC or C, and one otherwise. Finally, we define the dummy variable HX_Rate which equals zero if the HeXun CSR rating is D or E, and one otherwise. Next, we replace the original dependent variable ESG_score with these four alternative measures. Table 4 presents the results. Note that the HZ_Rate and HX_Rate are dummy variables, so we run the logit regression in Columns 3 and 4 and only control for year fixed effects. We see that the coefficients of lagged Digitization in Columns 1 through 4 are positive and statistically significant, which are in line with our baseline results.

4.2.3. Additional controls

To mitigate concerns over potential omitted variables in the baseline regression, we include additional controls that have been shown in the literature to affect ESG/CSR. Table 5 presents the results. Firstly, based on the baseline model, we additionally control for CEO-specific variables that capture their age and gender (Cronqvist and Yu, 2017). To capture CEO gender, we compute a binary variable Femceo, which equals one if the company has a female CEO in a given year and zero otherwise. The variable Ceoage is measured by the natural logarithm of CEO age. Column 1 of Table 5 shows the results. Secondly, existing literature shows that ESG performance is also associated with industry characteristics (Giuli and Kostovetsky, 2014; Cronqvist and Yu, 2017). Therefore, on the basis of the regression in Column 1, we additionally control for Year × Two-digit industry fixed effects.[18] The results are reported in Column 2 of Table 5. We see that the coefficients on Digitization in Columns 1 and 2 are still positive and statistically significant, suggesting that our baseline results are robust.

4.2.4. Difference-in-differences specification

The company's digitization depends on the degree of development of its city's digital economy and digital infrastructure. To further address the omitted variable and reverse causality problems, we use regional digitization policy shocks as a quasi-natural experiment to mitigate the endogeneity concerns.

To promote the construction of big data, in February 2016, the National Development and Reform Commission, the Ministry of Industry and Information Technology, and the Central Internet Information Office agreed to build the National Big Data Comprehensive Pilot Zone in Guizhou Province. Then, in October 2016, these three departments agreed to promote the construction of National Big Data Comprehensive

[18] The classification of Two-digit industry is based on the CSRC Industry Code.

Table 4
Regressions with Alternative Measures of ESG performance.

Variable	(1)ESG_Rank	(2)Log (ESG)	(3)HZ_Rate	(4)HX_Rate
L.Digitization	17.193***	0.135***	1.136*	1.880**
	(3.45)	(2.79)	(1.78)	(2.22)
L.Size	3.697***	0.042***	0.156***	0.115
	(4.16)	(4.85)	(2.91)	(1.30)
L.Age	−0.820	−0.003	0.010	0.062***
	(-0.33)	(-0.13)	(1.00)	(4.25)
L.Dividends	−26.708	−0.332	−3.829	−1.526
	(-1.18)	(-1.51)	(-1.24)	(-0.41)
L.Leverage	1.894	0.086**	−0.475	−0.707
	(0.47)	(2.19)	(-1.35)	(-1.35)
L.Roa	8.724	0.083	9.294***	1.315
	(0.99)	(0.97)	(7.03)	(0.75)
L.Cash	3.135	0.053	0.769	−0.918
	(0.70)	(1.21)	(1.28)	(-1.31)
L.Largest	0.288***	0.002***	0.005	−0.009
	(4.26)	(3.22)	(1.07)	(-1.38)
L.Top10	0.105**	0.001*	−0.004	−0.004
	(2.01)	(1.73)	(-0.93)	(-0.63)
L.Boardnum	0.297	−0.001	0.024	−0.043
	(0.73)	(-0.23)	(0.59)	(-0.84)
L.Inboardratio	−5.655	−0.093	3.821***	0.373
	(-0.53)	(-0.90)	(3.15)	(0.26)
L.Duality	0.755	0.015	−0.253**	−0.071
	(0.67)	(1.33)	(-2.11)	(-0.43)
Obs	2251	2251	2239	2036
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	No	No
R^2	0.240	0.243	0.057	0.312

Note: This table presents the robustness tests for the baseline regression by using alternative measures of ESG performance. Four measures of ESG performance are used as the dependent variable in Columns 1 to 4. All the variables are defined in Table A1. In Columns 1 and 2, we control for year fixed effects and firm fixed effects. In Columns 3 and 4, we run logit regressions, and only control for year fixed effects. Numbers in brackets are *t*-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

Pilot Zones in nine regions, including Beijing, Tianjin, Hebei, the Pearl River Delta,[19] Shanghai, Henan, Chongqing, Shenyang and Inner Mongolia.

As an important part of digital technology, big data plays a vital role in driving the digitization of companies. Therefore, we believe that the policy of the National Big Data Comprehensive Pilot Zone can effectively promote the digitization of local companies through the following three mechanisms. First, local governments in the pilot zones will vigorously develop the big data industry and improve the infrastructure of the digital economy, providing a solid foundation for the digitization of enterprises. Second, local governments in the pilot zones will provide preferential policies or financial subsidies for companies' digitization in terms of land, financing, talents and asset evaluation, which directly accelerate the digitization of companies. Third, local governments in the pilot zones will promote e-government and government data sharing, which provides a useful impetus for the digitization of companies.[20]

We then construct the following Difference-in-Differences (DID) model to check it:

$$ESG\_score_{i,t} = \alpha + \lambda(Treat_i \times Post_t) + \gamma X_{i,t} + \tau_i + \delta_t + \varepsilon_{i,t} \quad (3)$$

where for company i and year t, *Treati* equals one for the treatment group, which includes companies located in Guizhou, Beijing, Tianjin, Hebei, the Pearl River Delta Shanghai, Henan, Chongqing, Shenyang and Inner Mongolia, and zero for other companies. Moreover, the policy year is 2017; therefore, *Postt* equals one if year t is greater than or equal to 2017, and zero otherwise. The coefficientλ indicates the average policy effects of the National Big Data Comprehensive Pilot Zone on companies' ESG_score. *Xi*, *t* represents a vector of control variables which are the same as Eq. (2), τi andδt represent firm and year fixed effects, respectively. $\varepsilon i, t$ is the residual term.

Table 5
Regressions with additional controls.

Variable	(1)ESG_score	(2)ESG_score
L.Digitization	2.713**	3.377**
	(2.32)	(2.51)
L.Size	0.955***	0.922***
	(4.54)	(4.10)
L.Age	0.418	0.980
	(0.70)	(1.59)
L.Dividends	−6.784	−4.130
	(-1.28)	(-0.73)
L.Leverage	2.685***	3.591***
	(2.77)	(3.38)
L.Roa	3.015	2.526
	(1.40)	(1.09)
L.Cash	1.990*	2.030*
	(1.89)	(1.75)
L.Largest	0.042***	0.037**
	(2.64)	(2.12)
L.Top10	0.019	0.019
	(1.57)	(1.38)
L.Boardnum	−0.041	0.078
	(-0.43)	(0.76)
L.Inboardratio	−2.020	0.055
	(-0.80)	(0.02)
L.Duality	0.322	0.490
	(1.13)	(1.63)
L.Femceo	0.434	0.113
	(1.06)	(0.26)
L.Ceoage	0.307	−0.214
	(0.38)	(-0.25)
Obs	2189	2076
Firm FE	Yes	Yes
Year FE	Yes	Yes
Year × Industry FE	No	Yes
R^2	0.218	0.845

Note: This table presents the robustness tests for the baseline regression by adding additional controls. In Column 1, we include the variables Ceoage and Female. In Column 2, we further control for Year × Two-digit industry fixed effects. The dependent variable is ESG_score. All the variables are defined in Table A1. Numbers in brackets are *t*-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

Table 6
DID regression of the exogenous shock.

Variable	(1) ESG_score	(3) ESG_score
Treat × Post	1.289***	1.349***
	(4.99)	(5.22)
Controls	No	Yes
Obs	2776	2776
FirmFE	Yes	Yes
YearFE	Yes	Yes
R^2	0.220	0.245

Note: This table presents the year-to-year impact of the National Big Data Comprehensive Pilot Zone policy on companies' ESG performance. The treatment group includes companies in Guizhou, Beijing, Tianjin, Hebei, the Pearl River Delta, Shanghai, Henan, Chongqing, Shenyang and Inner Mongolia. The variable D equals one if company *i* is in the treatment group and the year *t* is greater than or equal to 2017. In Column 1, we do not add any control variables, and in Column 2 we include all the control variables. The dependent variable is ESG_score. All the variables are defined in Table A1. We control for year fixed effects and firm fixed effects. Numbers in brackets are *t*-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

[19] The Pearl River Delta includes 9 cities: Guangzhou, Foshan, Zhaoqing, Shenzhen, Dongguan, Huizhou, Zhuhai, Zhongshan and Jiangmen.

[20] Refer to "Several Opinions of the Henan Provincial People's Government of the CPC Henan Provincial Committee on Accelerating the Construction of National Comprehensive Pilot Zone for Big Data", available at http://newpaper.dahe.cn/hnrb/html/2017-07/05/content_161715.htm.

Table 7
Examining pre-trends: The dynamic impacts.

Variable	(1) ESG_score	(2) ESG_score
Treat × $Before_{2013}$	0.230	0.229
	(0.31)	(0.33)
Treat × $Before_{2014}$	0.303	0.174
	(0.37)	(0.22)
Treat × $Before_{2015}$	0.907	0.889
	(1.59)	(1.49)
Treat × $Before_{2016}$	1.074	0.984
	(1.46)	(1.30)
Treat × $Current_{2017}$	1.304**	1.225*
	(2.22)	(2.01)
Treat × $After_{2018}$	1.737**	1.714**
	(2.57)	(2.42)
Treat × $After_{2019}$	1.765***	1.823**
	(2.82)	(2.70)
Treat × $After_{2020}$	3.136***	3.197***
	(3.76)	(3.63)
Controls	No	Yes
Obs	2776	2776
Firm FE	Yes	Yes
Year FE	Yes	Yes
R^2	0.225	0.240

Note: This table presents the parallel trend test for the National Big Data Comprehensive Pilot Zone policy. The treatment group includes companies in Guizhou, Beijing, Tianjin, Hebei, the Pearl River Delta, Shanghai, Henan, Chongqing, Shenyang and Inner Mongolia. We use the first year in the sample (2012) as the baseline year. $Before_t$ are dummies for year t before the policy, the variable $Current_{2017}$ represents the dummy for the policy year, and $After_t$ denotes dummies for year t after the policy. The dependent variable is ESG_score. We do not add control variables in Column 1, and in Column 2 we include all the control variables. All the variables are defined in Table A1. We control for year fixed effects and firm fixed effects. Numbers in brackets are t-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

We then run the DID regression defined in Eq. (3). Table 6 reports the results. Column 1 of Table 6 contains the results from a univariate regression after controlling for firm and year fixed effects. In Column 2 of Table 6, we add all control variables and control for firm and year fixed effects. We can see that the estimated coefficient on the interaction *Treat* × *Post* is 1.349 and significant at the 1% level. This implies that those listed companies that have enhanced their digitization due to policy shocks significantly increase their ESG performance relative to those that have not been impacted by the policy.

Equation (3) identifies the average effect on treatment group before and after the policy. In practice, it is likely that the impact of the National Big Data Comprehensive Pilot Zone policy shock is more obvious two or three years after the start of the policy, and there may be a time lag effect of the policy. Therefore, we allow for more flexible specifications and evaluate the dynamic effects. Equation (4) includes interactions between the treatment group dummy and all years' dummies in the regression. This way, we can also test whether the concern of different pre-trends matters. The specification is as follows:

$$ESG\_score_{i,t} = \alpha + \sum_{t=2013}^{2016} \beta_t (Treat_i \times Before_t) + \mu (Treat_i \times Current_{2017}) + \sum_{t=2018}^{2020} \omega_t (Treat_i \times After_t) + \gamma X_{i,t} + \tau_i + \delta_t + \varepsilon_{i,t} \quad (4)$$

where we use the first year in our sample (the year of 2012) as the baseline year, and *Beforet*

Are dummies for year t before the policy (t = 2013, 2014, 2015, 2016), and *Current*2017 represents

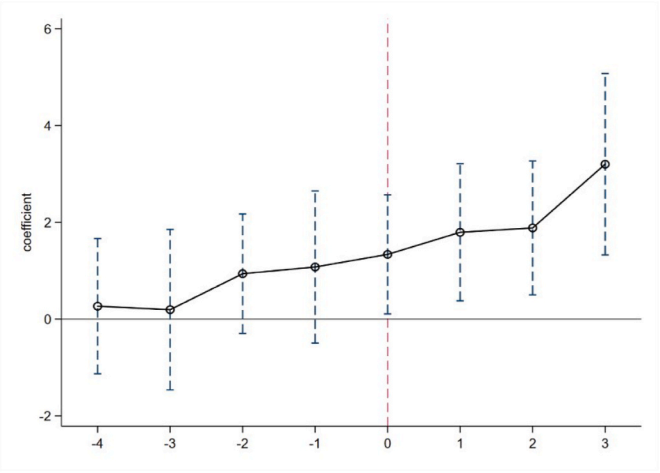

Fig. 3. The Dynamic Impacts. Notes: The figure graphs the results in Column 2 of Table 7. The X-axis represents the year relative to the policy year (2017). The dashed line indicates the 95% confidence intervals. It shows the positive effect on ESG after the policy.

The dummy for the policy year (the year 2017). Finally, *Aftert* denotes dummies for year t after

The policy (t = 2018, 2019, 2020). The definitions of other variables are the same as Eq. (3).

The results are presented in Table 7. We do not include any control variables in Column 1, and in Column 2 we add all the control variables. We can see that all coefficients of interaction *Treat* × *Beforet* are insignificant, which implies that there are no significant differences in pre-trends. However, the coefficients of *Treat* × *Current*2017 and *Treat* × *Aftert* are positive and statistically significant. The impact of the National Big Data Comprehensive Pilot Zone policy shock is gradually increasing after the initial policy year, which is consistent with our expectations.

The results in Table 7 are graphed in Fig. 3. The dashed line indicates the 95% confidence interval. Every estimated effect is relative to the year 2017. It can be seen clearly that there was no significant influence on companies' ESG performance before the National Big Data Comprehensive Pilot Zone policy. However, there exists a significant positive effect on ESG after the policy that has an upward trend with each increasing year. Table 7 and Fig. 3 actually provide parallel trend tests, which show that the prerequisite of DID is satisfied.

4.2.5. The Bartik instrumental method

To further mitigate the endogeneity concerns, we construct an instrumental variable (IV) by using the share shift method, which is also known as the Bartik instrumental method (Bartik, 1991). The Bartik instrumental method has been widely used in the literature (Goldsmith-Pinkham et al., 2020). The Bartik instrument combines two accounting identities. The first is the initial shares of the endogenous variable, which measures the differential exogenous exposure to the common shock. The second is the overall growth rate of the endogenous variable, representing a common shock. The Bartik estimator is highly correlated with the actual value of the endogenous variable, but not with the residual term.

In this paper, we use the sample mean value of the Digitization in the first year (2012) by two-digit industry as the initial share (exogenous variable). Then we use the annual growth rate of the industrywide digitization as the overall growth rate (a common shock). We multiply

Table 8
2SLS regression for the bartik instrumental variable.

Variable	First Stage (1)L.Digitization	Second Stage (2)ESG_score
L.IV	0.817*** (9.00)	
L.Digitization		10.857** (1.97)
Controls	Yes	Yes
Obs	1887	1887
Firm FE	Yes	Yes
Year FE	Yes	Yes
	F-Value:80.93	

Note: This table presents the 2SLS regression for the Bartik instrumental variable. The Bartik instrumental variable equals the sample mean value of the Digitization in the first year (2012) by two-digit industry multiplies the annual growth rate of the industrywide Digitization. To alleviate endogeneity concerns, we exclude the 2012 sample. Column 1 reports the First Stage results, and Column 2 reports the Second Stage results. We include all the control variables, and their definitions can be seen in Table A1. We control for year fixed effects and firm fixed effects. Numbers in brackets are t-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

these two terms to construct the Bartik instrument for each company's digitization level. Meanwhile, to alleviate endogeneity issues, we exclude the 2012 sample.

We then run the two-stage least squares (2SLS) regression defined in Equation (1), and the results are represented in Table 8. Column 1 presents the results of the first stage regression, the coefficient on the Bartik instrumental variable is 0.817 and is significant at the 1% level with an F-value of 80.93, excluding weak instrumental variable problems.[21] Column 2 indicates that digitization significantly enhances companies' ESG scores after taking into account possible endogeneity issues.

5. Additional analyses

5.1. Heterogeneity

In the baseline regression, we find that enterprise digitization can significantly improve company ESG scores. Next, we further explore the heterogeneity of enterprise digitization affecting ESG scores in terms of political connections and institutional quality.

5.1.1. Political connections

Following Hypothesis 2, we argue that the positive effect of digitization on ESG performance is more pronounced for companies without political connections. To test this hypothesis, we divide companies into two subgroups according to their political connections. We classify company *i* into the politically connected group when the chairman or CEO of the company has served as a party representative, NPC deputy, CPPCC member, or has served in government or the military; for all other cases, companies are allocated to the non-politically connected group.

Then we run the regression defined in Eq. (2) for the two subgroups. Columns 1 and 2 of Table 9 present the results. In Column 1, we include only companies with political connections, and we can see that the estimated coefficient on the lagged Digitization is insignificant. In Column 2 we include only the companies without political connections and we can see that the estimated coefficient is positive and significant at the 1% level. The results support the argument that digitization of non-politically connected companies can better increase their ESG scores. The potential explanation is that politically connected companies receive government protection from accountability for environmental pollution and thus lack incentives to improve ESG performance. Therefore, Hypothesis 2 is supported by the evidence.

5.1.2. Institutional quality

In Hypothesis 3, we believe that the positive effect of digitization on ESG performance is more pronounced for companies located in regions with high quality institutions. Therefore, we divide all provinces into two subgroups, based on the provincial marketization index which plots the degree of quality of a region's institutions (Fan et al., 2011). To mitigate endogeneity concerns, we take the mean value of the marketization index for each province in the five years prior to our sample period (i.e., 2007–2011), and provinces with a marketization index value higher than the mean are noted as provinces with high quality institutions.

Then companies located in provinces with high quality institutions are classified into the group with high quality institutions, while other companies are classified into the group with low quality institutions. We run the regression defined in Eq. (2) for the two subgroups; Columns 3 and 4 of Table 9 represent the results. In Column 3, we only include the group with high quality institutions, and the estimated coefficient of the lagged Digitization is positive and significant at the 1% level, while this coefficient is insignificant in Column 4. The results indicate that digitization can best increase ESG scores of companies that are located in provinces with high quality institutions. One possible explanation is that companies located in provinces with high quality institutions can develop stable expectations and have incentives to invest in long-term projects such as ESG. Therefore, Hypothesis 3 is supported by the evidence.

5.2. Exploring channels

In the baseline regression, we find that digitization can significantly improve enterprise ESG scores. In this section, we first explore the relationship between enterprise digitization and their E/S/G scores as enlightening results, then we further explore three potential channels for the increase in ESG scores. Specifically, digitization increases ESG scores through reducing agency costs, improving goodwill, and improving environmental performance.

5.2.1. The impact of digitization on environmental/governance/social scores

Before we analyze specific channels, an interesting question arises: what is the impact of digitization on the E, S, and G scores? Specifically, the Bloomberg ESG score is composed of three pillars: Environmental scores (Environ_score), Social scores (Social_score), and Governance scores (Govnce_score), each with a 33% weighting. The detailed components and weights of the Bloomberg ESG scores can be seen in Table A2 Therefore, in this section, we use each of the three pillars of the Bloomberg ESG score as the dependent variable and lagged digitization as the key explanatory variable to explore the impact of digitization on E/S/G scores.

Table 10 presents the results. In Column 1 of Table 10, we can see that the coefficient on lagged Digitization is positive but insignificant, which implies that digitization cannot improve companies' Environmental scores. However, in Columns 2 and 3 of Table 10, the coefficients on lagged Digitization are positive and significant at the 10% and 5% level, respectively. The results show that companies' digitization mainly improves their Social and Governance scores.

5.2.2. Digitization and agency costs

The first channel through which digitization can improve enterprise ESG scores is by reducing agency costs within the company. We believe that digitization helps the enterprise to reduce information asymmetry between external investors and managers, and between managers and employees, thus reducing agency costs, improving corporate governance, and ultimately enhancing ESG scores.

[21] In the first-stage regression, the inclusion of IV increases the R2 by 40.76% and the F-value by 40.29%. This also implies that there is no weak instrument problem.

Table 9
Heterogeneity analysis.

	Politically connected	Non-politically connected	High quality institutions	Low quality institutions
Variable	(1)ESG_score	(2)ESG_score	(3)ESG_score	(4)ESG_score
L.Digitization	0.631	6.033***	3.121***	0.894
	(0.36)	(3.30)	(2.69)	(0.17)
Controls	Yes	Yes	Yes	Yes
Obs	999	1028	1928	323
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R^2	0.214	0.216	0.220	0.346

Note: This table presents the heterogeneity analysis of political connections and institutional quality. Column 1 contains companies with political connections, while Column 2 contains companies without political connections. Column 3 includes companies located in provinces with high quality institutions while Column 4 includes companies located in provinces with low quality institutions. The dependent variable is ESG_score. We include all the control variables; their definitions can be found in Table A1. We control for year fixed effects and firm fixed effects. Numbers in brackets are *t*-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

Table 10
The Impact of Digitization on Environmental/Governance/Social scores.

Variable	(1)Environ_score	(2)Social_score	(3) Govnce_score
L.Digitization	1.163	2.596*	1.646**
	(0.68)	(1.66)	(1.96)
Controls	Yes	Yes	Yes
Obs	1961	2241	2251
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
R^2	0.162	0.093	0.178

Note: This table presents the impact of Digitization on Environmental/Social/Governance scores. The dependent variable in Column 1 is Environ_score, while the dependent variables in Columns 2 and 3 are Social_score and Govnce_score, respectively. We include all the control variables; their definitions can be seen in Table A1. We control for year fixed effects and firm fixed effects. Numbers in brackets are *t*-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

Table 11
Channel analysis: Agency costs and goodwill.

Panel A			
Variable	(1) Agency	(2) Posinews	(3) Posiratio
L.Digitization	−0.110***	0.419**	0.071*
	(-8.78)	−2.05	−1.65
Controls	Yes	Yes	Yes
Obs	2241	2251	2251
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
R^2	0.249	0.373	0.137
Panel B			
Variable	(1)ESG_score	(2)ESG_score	(3)ESG_score
Agency	−7.444***		
	(-3.82)		
Posinews		0.544***	
		(-4.56)	
Posiratio			1.653**
			(-2.53)
Controls	Yes	Yes	Yes
Obs	2761	2773	2773
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
R^2	0.231	0.242	0.238

Note: This table presents the analysis of three potential channels through which enterprise digitization impacts ESG scores. Panel A represents how digitization affects channel variables, and Panel B shows how channels affect ESG scores. Column 1 shows that digitization reduces agency costs, which enhances ESG scores. Columns 2 and 3 illustrate that digitization increases positive media exposure, which leads to higher ESG scores. We include all control variables; their definitions can be seen in Table A1. We control for year fixed effects and firm fixed effects. Numbers in brackets are *t*-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

Therefore, we construct the variable Agency to measure companies' agency costs, which is equal to administrative expenses divided by total sales. Column 1 of Panel A in Table 11 represents the results, where the dependent variable is the Agency and the key explanatory variable is the lagged Digitization. The estimated coefficient on the lagged Digitization is significantly negative, indicating that the digitization of companies reduces their agency costs.

Then in Column 1 of Panel B in Table 11, we use the ESG_score as the dependent variable and the channel variable Agency as the key explanatory variable. The coefficient of the Agency is significantly negative, which implies that reducing agency costs can improve a company's ESG scores.

5.2.3. *Digitization and goodwill*

The second channel for the increase in ESG scores is the improvement of goodwill. Specifically, we argue that with digital communication tools, companies can better communicate their achievements in environmental protection, philanthropy and poverty alleviation to communities and governments, thereby enhancing their goodwill and improving their ESG scores. Specifically, we use media exposure as a proxy for goodwill, and we construct two measures of media exposure: Posinews and Posiratio.

In this section, we use the data of online financial news, derived from the Financial News Database of Chinese Listed Companies (CFND). The database includes news report data from more than 400 important online media in China.[22] Meanwhile, the CFND database provides news sentiment indicators, including positive, neutral and negative. We want to know whether enterprise digitization has improved the exposure of positive news. Therefore, we define the variable Posinews as the natural logarithm of the number of positive news items and define the variable Posiratio as the number of positive news items to over total news.

Columns 2 and 3 of Panel A in Table 11 represent the results, where the dependent variables are the Posinews and the Posiratio, and the key explanatory variable is the lagged Digitization. The estimated coefficient on the lagged Digitization is significantly positive, which implies that digitization increases their positive media exposure.[23]

In Columns 2 and 3 of Panel B in Table 11, we use the ESG_score as the dependent variable and the channel variables Posinews and Posiratio as the key explanatory variable, respectively. The coefficients on the Posinews and Posiratio are significantly positive, suggesting that

[22] Including Hexun.com, Sina Finance, Oriental Fortune, Tencent Finance, Netease Finance, Phoenix Finance, China Economic Network, Sohu Finance, Financial Sector, Huaxun Finance, FT Chinese, Panorama.com, CICC Online, China Securities Network, Securities Star, Caixin.com, Surfing News, First Financial, 21CN Financial Channel, and Finance.com.

[23] When we use the natural logarithm of the number of total news as the dependent variable, the coefficient is positive but insignificant.

positive media exposure will increase a company's ESG scores.

5.2.4. Digitization and environmental performance

Finally, we examine whether environmental performance can serve as a channel through which enterprise digitization affects ESG scores. We construct four variables to represent companies' environmental performance. Firstly, we define the variable Airpollution as the natural logarithm of the company's total air pollution emissions. Similarly, the variable Waterpollution is defined as the natural logarithm of the company's total water pollution emissions. Then the variable Power represents a company's energy consumption, which equals the natural logarithm of the company's total power consumption. Finally, the dummy variable Penalize represents whether the company is penalized for its environmental lapses.

Table 12 represents the results, where the dependent variables are these four variables representing environmental performance, and the key explanatory variable is the lagged Digitization. We can see that the coefficient on the lagged Digitization in Columns 1 through 4 are all negative but insignificant, which implies that the improvement of environmental performance is not a main channel.[24] The findings are consistent with the discussion in Section 5.2.1, where digitization does not significantly increase companies' Environmental scores. We conjecture that the primary purpose of digitization for many Chinese firms is to survive in a highly competitive market, and therefore they will use digital technologies mainly to improve enterprise financial performance, including the previously mentioned reduction in agency costs, and improvement in reputation. In contrast, using digital technologies to reduce pollution does not necessarily increase enterprise profits in the short term. In fact, studies based on Chinese-listed companies prove that the effect of enterprise digitization is mainly an improvement in financial performance (Zhao et al., 2021).

Table 12
Channel analysis: Environmental performance.

Variable	(1)Airpollution	(2)Waterpollution	(3)Power	(4)Penalize
L.Digitization	−1.580	−1.569	−8.174	−7.355*
	(-1.00)	(-0.76)	(-0.24)	(-1.82)
Controls	Yes	Yes	Yes	Yes
Obs	352	402	56	1170
Firm FE	Yes	Yes	Yes	No
YearFE	Yes	Yes	Yes	Yes
R^2	0.428	0.078	0.733	0.137

Note: This table presents analysis of the channel to improve Environmental performance. The dependent variables in Columns 1 through 4 represent air pollution, water pollution, power consumption, and whether the company is penalized for its environmental conduct. We include all control variables; their definitions can be seen in Table A1. We control for year fixed effects and firm fixed effects in Columns 1 through 3. The dependent variable Penalize in Column 4 is a dummy variable, so we only control for year fixed effects in Column 4. Numbers in brackets are *t*-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

6. Conclusion

China, as the world's largest emerging market, has shown two outstanding features in recent years. First, its digital economy has grown rapidly. Not only does China have the world's second largest digital economy, but it has also seen the emergence of several world-class digital companies, such as Alibaba and Tencent. Second, ESG is gradually becoming a mainstream business activity for Chinese companies.

This paper connects these two prominent features and examines the impact of enterprise digitization on ESG performance. Using data from 2012 to 2020 for Chinese non-state-owned listed companies, we find that enterprise digitization significantly improves ESG performance. Moreover, the results remain robust after using different measures of digitization and different sources of ESG scores, as well as adopting DID and IV estimation. The positive effect of digitization on ESG performance is more pronounced for companies that are not politically connected and for companies located in regions with high quality institutions. We identify two channels through which digitization improves ESG performance: first, digitization reduces agency costs; second, digitization improves goodwill. However, we do not find that digitization significantly improves environmental performance.

The findings have important policy implications. In general, ESG not only helps to increase enterprise value, but also helps to protect stakeholders' interests and reduce social externalities (e.g., corruption and environmental pollution) (Kitzmueller and Shimshack, 2012; Gillan et al., 2021). However, motivating enterprises to engage more in ESG still faces difficulties in emerging markets like China. Because emerging market enterprises usually lack good profitability and international competitiveness, they usually do not have the incentive or ability to provide public goods. Since digitization can improve both enterprises' economic efficiency (Goldfarb and Tucker, 2019) and their ESG performance, encouraging enterprise digitization by governments is a mutually beneficial policy. Moreover, emerging markets have the advantage of being late comers to digital technologies, so the experience of China is expected to be extended to developing countries.

The sample of this paper is limited to listed companies, which usually outperform non-listed companies in terms of size and profitability. Therefore, our findings cannot be directly generalized to non-listed small and medium-sized enterprises (SMEs). Moreover, limited by the availability of data, we reveal only two channels through which digitization affects ESG performance in this paper; other channels may also exist, suggesting an important topic for further research.

Author contribution

All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscriptThe following authors have affiliations with organizations with direct or indirect financial interest in the subject matter discussed in the manuscript:

Declarations 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.

Data availability

Data will be made available on request.

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[24] In our database, only 56 observations report energy consumption, and through regression analysis of a small sample, we find no significant effect of digitization on energy consumption. Meanwhile, although the regression in Column 4 of Table 12 is significant at the 10% level, the results are insignificant when we run the regression using Penalize as the key explanatory variable and ESG_score as the dependent variable.

Appendix

Table A1
Definitions and Sources of Variables.

Variables	Definition	Source
Panel A: ESG_score and Digitization		
ESG_score	Bloomberg ESG Disclosure Score.	Bloomberg
Digitization	Author's calculations based on the text of the company's annual report, equaling the number of digitization keywords over all words in the "Management Discussion and Analysis" section of the annual reports of listed companies.	Author's calculation
Panel B: Control Variables		
Size	The natural logarithm of total number of employees.	CSAMR
Age	Number of years that the company has been listed.	CSAMR
Dividends	Cash dividends over total assets.	CSAMR
Leverage	Total debts over total assets.	CSAMR
Roa	Return on Assets, equal to net profit over total assets.	CSAMR
Cash	Cash balances over total assets.	CSAMR
Largest	Shareholding ratio of the largest shareholder.	CSAMR
Top10	Shareholding ratio of top ten shareholders.	CSAMR
Boardnum	Number of directors.	CSAMR
Inboardratio	Ratio of independent directors to the number of directors.	CSAMR
Duality	Dummy variable, which equals one if the CEO also serves as Chairman, and zero otherwise.	CSAMR
Panel C: Other Variables		
Digi_fix	Digitization-related investment in fixed assets (office electronics plus self-service equipment) over total assets.	Author's calculation, iFind
Digi_int	Digitization-related investment in Intangible assets (software net value) over total assets.	Author's calculation, iFind
ESG_Rank	Sort through the ESG_score and divide the sample into 100 groups, assign a value of 1–100 to each group separately, a higher ESG_Rank means higher ESG performance.	Bloomberg
Log (ESG)	The natural logarithm of the ESG_score	Bloomberg
HZ_Rate	Dummy variable, which equals zero if the HuaZheng ESG rating is CCC or CC or C, and one otherwise.	HuaZheng Index
HX_Rate	Dummy variable, which equals zero if Hexun ESG rating is D or E, and one otherwise.	HeXun
Femceo	Dummy variable, which equals one if the CEO is female, and zero otherwise.	CSAMR
Ceoage	The natural logarithm of CEO age.	CSAMR
Environ_score	Bloomberg Environmental Disclosure Score.	Bloomberg
Govnce_score	Bloomberg Governance Disclosure Score.	Bloomberg
Social_score	Bloomberg Social Disclosure Score.	Bloomberg
Agency	Administrative expenses over total sales.	CSAMR
Posinews	The natural logarithm of the number of positive news.	CFND
Posiratio	The number of positive news over total news.	CFND

Note: This table list definitions and sources of all variables used in the paper. Panel A presents two main variables: ESG_score and Digitization. Panel B illustrates all the control variables. Panel C presents other variables used in the sections of Robustness tests and Channel analysis.

Table A2
Components and Weights of the Bloomberg ESG Scores.

Pillar (Weight)	Topic (Weight)
Environmental (33%)	Air Quality (4.78%)
	Climate Change (4.70%)
	Ecological & Biodiversity Impacts (4.79%)
	Energy (4.73%)
	Materials & Waste (4.74%)
	Supply Chain (4.79%)
	Water (4.79%)
Social (33%)	Community & Customers (5.53%)
	Diversity (5.49%)
	Ethics & Compliance (5.57%)
	Health & Safety (5.58%)
	Human Capital (5.55%)
	Supply Chain (5.54%)
Governance (33%)	Audit Risk & Oversight (4.17%)
	Board Composition (4.16%)
	Compensation (4.16%)
	Diversity (4.17%)
	Independence (4.18%)
	Nominations & Governance Oversight (4.18%)
	Sustainability Governance (4.18%)
	Tenure (4.18%)

Note: This table shows the composition and weight of the Bloomberg ESG scores. The Bloomberg ESG scores consist of three Pillars: Environmental, Social, and Governance, each with a 33% weighting. Meanwhile, each Pillar is composed of several Topics which are listed in the table.

Table A3
Keywords in the Digitization Thesaurus.

Digitization Keywords
'big data', 'cloud computing', 'artificial intelligence', 'data management', 'data mining', 'data network', 'data platform', 'data center', 'data science', 'digital control', 'digital technology', 'digital communication', 'digital network', 'digital intelligence', 'digital terminal', 'digital marketing', 'digitization ', 'cloud IT', 'cloud ecology', 'cloud Services', 'Cloud Platform', 'Blockchain', 'Internet of Things', 'Machine Learning', 'ERP', 'High-end Intelligence', 'Industrial Intelligence', 'Mobile Intelligence', 'Smart Control', 'Smart Terminal', 'Smart Mobile', 'Smart Management', 'Smart Factory', 'Smart Logistics', 'Smart Manufacturing', 'Smart Storage', 'Smart Technology', 'Smart Equipment', 'Smart Production', 'Intelligent Network', 'Intelligent System', 'Intelligent', 'Automatic Control', 'Automatic Monitoring', 'Automatic Monitoring', 'Automatic Inspection', 'Automatic Production', 'CNC', 'Integration', 'Integration', 'Integrated Solution', 'Integrated Control', 'Integrated System', 'Industrial Cloud', 'Factory of the Future', 'Intelligent Troubleshooting', 'Lifecycle Management', 'manufacturing execution system', 'virtualization', 'virtual manufacturing', 'AI', 'CAD', 'CAM', 'computer-aided design', 'computer-aided manufacturing', 'information sharing', 'information management', 'information integration', 'information software', 'information system', 'information network', 'information terminal', 'information center', 'informatization', 'networking', 'Industrial Information', 'Industrial Communication', 'e-commerce', 'internet marketing', 'mobile internet', 'industrial internet', 'industrial internet', 'internet solutions', 'internet technology', 'internet thinking', 'internet action', 'internet business', 'internet mobile', 'internet application', 'internet strategy', 'internet platform', 'internet model', 'internet business model', 'internet ecology', 'e-commerce', 'online sales', 'internet', 'internet+', 'online to offline', 'online and offline', 'O2O', 'B2B', 'C2C', 'B2C', 'C2B', '5G', 'WeChat', 'intranet'

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