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Uncovering the impact of digital transformation on corporate environmental responsibility: Evidence from China

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Abstract. Under the current turbulent global situation, digital transformation has become a key force in restructuring the elements of world resources and new kinetic energy to promote the sustainable development of firms. In contrast, its internal and external driving factors at the firm level have not yet been identified. This study is dedicated to examining the impact of digital transformation on corporate environmental responsibility. The methodological foundations of the research are resource-based view, stakeholder theory, and information asymmetry theory. For verifying the proposed hypotheses, the study takes the panel data of Chinese listed firms from 2014 to 2023 (6,483 observations) as the research sample. It adopts statistical and regression analysis methods. Empirical results suggest that digital transformation positively correlates with corporate environmental responsibility by increasing companies' engagement in green practices; economic policy uncertainty negatively moderates the analysed relationship, reducing the positive effect of the introduction of new technologies; media attention and financial constraints positively mediate the analyzed relationship. It is shown that the media serve as a key mechanism for external oversight and improving corporate governance in the capital market. By easing financial constraints, companies can obtain more external investment and resources, thereby increasing their ability to assume environmental responsibility.

Keywords: corporate environmental responsibility; digital transformation; media attention; financing constraints; economic policy uncertainty; corporate sustainability; China.

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Влияние цифровой трансформации на корпоративную экологическую ответственность: опыт Китая

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Аннотация. В условиях глобальной турбулентности цифровая трансформация стала ключевым драйвером реструктуризации мировых ресурсов, а также новой кинетической энергией, способствующей устойчивому развитию компаний. Тем не менее ее внутренние и внешние движущие факторы на уровне фирм еще не определены. В статье исследуется влияние цифровой трансформации на корпоративную экологическую ответственность. Методологической основой работы являются ресурсно ориентированный подход, теория заинтересованных сторон и теория информационной асимметрии. Выборка включает панельные данные китайских фирм, зарегистрированных на бирже с 2014 по 2023 г. (6 483 наблюдения). Для анализа данных применялись методы статистического и регрессионного анализа. Результаты исследования показывают, что цифровая трансформация положительно влияет на корпоративную экологическую ответственность за счет усиления вовлеченности компаний в «зеленые» практики; неопределенность экономической политики негативно модерирует анализируемую взаимосвязь, снижая положительный эффект от внедрения новейших технологий; внимание СМИ и финансовые ограничения положительно опосредуют анализируемую взаимосвязь. Доказано, что средства массовой информации служат ключевым механизмом внешнего надзора и улучшения корпоративного управления на рынке капитала, а посредством смягчения финансовых ограничений компании получают возможность привлечь больше внешних инвестиций и ресурсов, которые они в дальнейшем могут направить на расширение своей экологической ответственности.

Ключевые слова: корпоративная экологическая ответственность; цифровая трансформация; внимание СМИ; финансовые ограничения; неопределенность экономической политики; корпоративная устойчивость; Китай.

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INTRODUCTION

High-quality firm development maximizes the comprehensive value, including economic, social, and ecological benefits. Businesses worldwide face the social and ecological challenges posed by global climate change while promoting economic growth [Zhang et al., 2024], and balancing the relationship between economic development and environmental protection has become an urgent problem [Gao et al., 2024]. Corporate environmental responsibility, as one of the core contents of corporate social responsibility [Zhang, Nedospasova, 2023], refers to the fact that firms, while pursuing the maximization of profits, must assume the essential responsibility of protecting the ecosystem and promoting the sustainable development of human society [Zhang, Shi, Liu, 2024]. Many countries have regulations requiring firms to disclose environmental, social, and governance (ESG) practices or non-financial information in their social responsibility reports [Hsu, Chen, 2023; Zhang, Nedospasova, 2024b]. Moreover, the concerns of consumers, competitors, suppliers, and other stakeholders have led firms to place greater emphasis on environmental responsibility [Ruan, Chen, Zhu, 2022]. On one front, assuming environmental responsibility may significantly increase firms' production and operation costs, making it difficult for some firms to fully assume environmental responsibility due to cost pressure [Yan et al., 2023]. In other respects, developing new economic growth points while assuming environmental responsibility is a significant challenge for firms to realize sustainable development [Zhao et al., 2024].

From the perspective of access to resources, the key to promoting corporate environmental responsibility lies in obtaining and maintaining the supply of necessary resources. The development of the digital economy has revolutionized business operation models, development methods, and organizational structures [Song et al., 2022]. Digital transformation has become a meaningful way to achieve high-quality and sustainable development [Veile, Schmidt, Voigt, 2022; Zhang, Nedospasova, 2024a], which can solve the cost and technological difficulties firms face in environmental responsibility practices [Luo et al., 2023]. Based on the resource-based view, digitalization can help firms access critical resources and reduce the uncertainty associated with resource scarcity, which can help firms fulfil their environmental responsibilities more effectively. As a result, digital transformation provides new opportunities to promote corporate environmental responsibility and green development.

The article aims to examine the impact of digital transformation on corporate environmental responsibility. Based on the aforementioned theoretical analysis, we answer the following questions:

Q1. Does digital transformation promote corporate environmental responsibility?

Q2. Does economic policy uncertainty negatively moderate the relationship between digital transformation and corporate environmental responsibility?

Q3. Does media attention mediate the relationship between digital transformation and corporate environmental responsibility?

Q4. Do financing constraints mediate the relationship between digital transformation and corporate environmental responsibility?

To answer the above questions, the authors empirically investigate the association between digital transformation and corporate environmental responsibility using data from Chinese A-share listed firms from 2014 to 2023. To elucidate the relationship between digital transformation and corporate environmental responsibility and to contribute to the realization of the research purpose, the study proposes specific research objectives: (1) to scrutinize the internal and external impact factors of digital transformation on corporate environmental responsibility; (2) to discuss the differences in the impact of digital transformation on corporate environmental responsibility in terms of the degree of industry competition, the degree of emission pollution, and the nature of corporate ownership.

The scientific novelty of the article may lie in the following. First, the paper explores the association between digital transformation and corporate environmental responsibility through theoretical analysis for the first time, which enriches the research findings on the social benefits of corporate digital transformation. Second, the study finds that the facilitating effect of digital transformation on corporate environmental responsibility is more potent when economic policy uncertainty is low. This finding emphasizes the importance of a stable policy environment in promoting corporate digital transformation and environmental responsibility and provides evidence for governments and policymakers to formulate and improve policies related to sustainable development. Third, the article provides insights into how digital transformation impacts corporate environmental responsibility through both internal and external factors. Regarding the external path, digital transformation increases media attention on corporate behaviour and promotes positive corporate initiatives in fulfilling environmental responsibility. As for the internal path, digital transformation enhances the operational efficiency of firms by alleviating financing constraints. The interaction of such internal and external paths enhances the positive effects of digital transformation on corporate environmental responsibility. Simultaneously, it provides empirical evidence on the role of the digital economy in corporate governance, economic resource allocation, and external monitoring.

This article is organized as follows. Section 2 outlines the study's theoretical basis and puts forward scientific hypotheses. Section 3 describes the research methodol-

ogy. Section 4 demonstrates the results of empirical analysis. Section 5 discusses the results obtained. At the end of the article, we summarize the research results, address implications, and point out the study's limitations and directions for future research.

THEORETICAL BACKGROUND

Digital transformation and corporate environmental responsibility. Digital technologies include blockchain, cloud computing, big data, virtual reality and augmented reality, digital manufacturing, artificial intelligence, the Internet of Things, and more. Digital transformation is a strategy for organizations to reshape their value creation processes and strategies to better adapt to environmental changes by integrating various digital technologies [Wang et al., 2022; Lin, Zhang, 2023]. Existing studies have found that digital transformation has acted on various aspects of corporate technological innovation, investment and financing activities, and strategic decision-making [Xu, Li, Guo, 2023; Liu et al., 2024], while the assumption of environmental responsibility is vital for firms to gain sustainable competitive advantage, and to a certain extent will also be affected by digital transformation. Digital transformation has a positive impact on the performance of corporate environmental responsibility.

Firstly, this impact is reflected in the fact that digital transformation improves firms' ability to assume environmental responsibility. Digital transformation improves total factor productivity and reduces pollutant emissions and resource wastage [Cohen, Gil, 2021] by expanding corporate innovation opportunities and enhancing the efficiency of corporate resource utilization [Kurniawan et al., 2021], thus improving corporate environmental performance while maintaining production growth [Trahan, Hess, 2021]. At the same time, digital transformation can alleviate the problem of corporate information asymmetry [Verhoef et al., 2021], improve the level of information sharing, and realize the delicate management of the whole life cycle of products by continuously scanning, capturing, and analysing all kinds of complex information. For this reason, digital transformation can improve the efficiency of production, management, and green innovation of enterprises [Ren, Li, Li, 2024], which in turn facilitates the fulfilment of corporate environmental responsibility.

Secondly, from a stakeholder perspective, digital transformation enhances the motivation for firms to take on environmental responsibility. Digital transformation helps firms better understand and meet the needs of stakeholders by strengthening the connection between firms and various stakeholders, which, following stakeholder theory, contributes to fulfilling environmental responsibility [Zhou et al., 2021]. At the same time, digital transformation not only optimizes the operational processes of firms but also broadens the scope of potential stakeholders. Firms can attract these new stakeholders

by actively fulfilling their environmental responsibilities and leveraging this attraction to compete for resources, thereby increasing their overall value. In accordance with the above analysis, the first hypothesis was formulated in the following way:

H1: Digital transformation promotes corporate environmental responsibility.

The moderating effect of economic policy uncertainty. Existing research shows that the stability of economic policies is closely related to corporate digital transformation and environmental performance [Chen et al., 2024; Gao, Huang, 2024].

Firstly, uncertainty about economic policies aggravates the problem of information asymmetry. Subsequently, this problem leads to higher risk and tighter financing constraints for firms according to the theory of information asymmetry. Under the dual pressure of risk avoidance and resource acquisition, firms will reduce their investment in environmental responsibility. In an environment with high economic policy uncertainty, firms will be more cautious in investing in digital transformation and assuming environmental responsibility, which hinders the process of digital transformation, such as intelligent production operations and digital technology systems, resulting in a negative impact on the high-quality development of firms [Gupta, Bose, 2022].

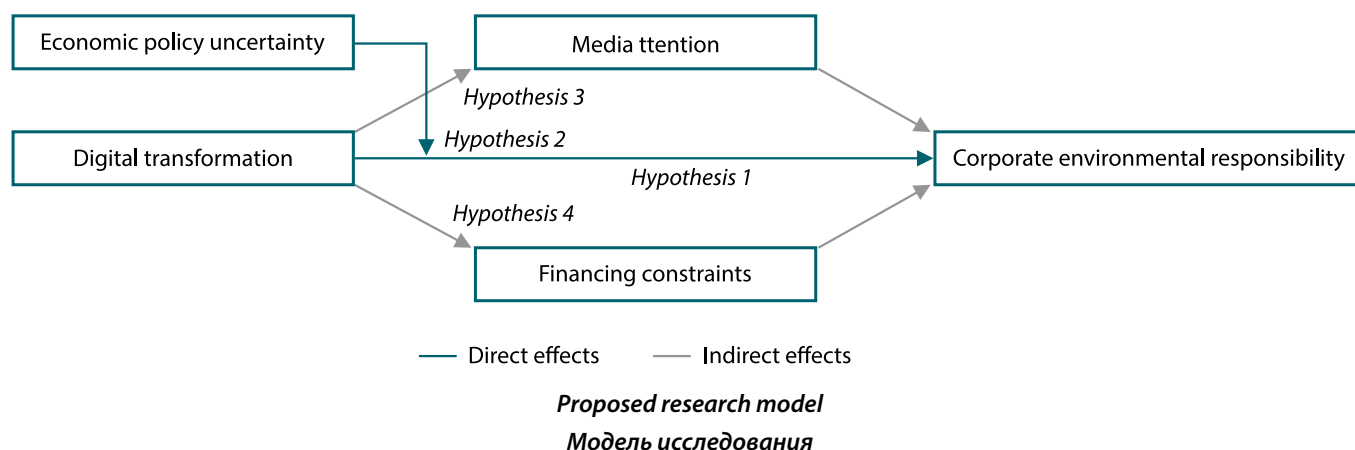
Secondly, when economic policy uncertainty increases, firms will delay investment in digital transformation and environmental responsibility, waiting for a more stable investment environment [Cong, Howell, 2021]. This tendency not only slows down the pace of digital transformation but also reduces firms' investment in environmental responsibility. With the preceding in mind, the second hypothesis was proposed:

H2: Economic policy uncertainty has a negative moderating effect on the relationship between digital transformation and corporate environmental responsibility.

Impact factors. This study selects two paths to further explore the impact of digital transformation on corporate environmental responsibility, namely the external factor (media attention) and the internal factor (financing constraints). The theoretical framework is shown in Figure.

Media attention reflects the public's supervision of corporate environmental behaviour and the process of corporate reputation building, which plays an essential role in evaluating how digital transformation promotes environmental responsibility by affecting the public image of firms. As an indicator of the ability of firms to obtain and use funds, financing constraints are of great significance in analysing how digital transformation affects the investment behaviour and resource allocation of firms, especially in environmentally responsible investments.

Digital transformation promotes firms to assume environmental responsibility by increasing **media attention**. The media plays a role in external supervision and improving corporate governance in the capital market. For one



thing, in its 14th Five-Year Plan¹, China has proposed to build a “Digital China” and has introduced a series of policies to support digital construction. Implementing digital transformation in firms aligns with the government’s policy guidelines. Therefore, firms’ disclosure of digital transformation information in their annual reports shows to the outside world that the firm is actively responding to the national call and accelerating its integration into the digital economy, which can attract more media attention. The media generates and disseminates information of great value to the firm through verification, evaluation, and integration of information. In particular, positive media reports can effectively enhance the firm’s image and improve investors’ perception of the firm [An et al., 2022]. At the same time, it can encourage firms to take more actions conducive to improving their reputation, such as assuming corporate social responsibility [Peng, Zhou, 2023]. For another, as the external supervision factor, media attention is a critical way to promote corporate environmental responsibility. On February 8, 2024, the Shenzhen Stock Exchange, the Shanghai Stock Exchange, and the Beijing Stock Exchange simultaneously released the Sustainable Development Report (Trial) (Draft for Comments)². All the three reports require listed firms to incorporate sustainable development into their development strategies and management activities, continuously strengthen ecological and environmental protection, fulfil their social responsibilities, enhance corporate governance, and constantly improve sustainable development. These listed firms are benchmark firms in their industries, so their ESG information naturally receives more media attention. Firms that enjoy more media attention will have more substantial social responsibility pressure, primarily environmental responsibility [Chen et al., 2023]. Therefore, under the pressure of the mandatory ESG reporting policy, firms are paying more attention to fulfilling their environmental responsibilities to avoid being penalized.

On this basis, the study formulates the third hypothesis:

H3: Media attention plays a mediating role in the relationship between digital transformation and corporate environmental responsibility.

Digital transformation promotes corporate environmental responsibility by alleviating corporate **financing constraints**. In the short term, corporate environmental responsibility may squeeze financial resources and lead to financing constraints. As a result, when firms face financing constraints, they may reduce their investment in environmental responsibility [Forcadell, Aracil, Ubeda, 2020]. However, under the mandatory ESG disclosure policy requirement, firms must always focus on fulfilling their environmental responsibilities. Fortunately, corporate digital transformation can alleviate financing constraints and significantly improve firms’ difficulty and high cost of financing, enhance corporate financing capabilities [Li, Wei, 2024], and thus empower them to take responsibility for the environment. The financing constraint-alleviating effect of corporate digitalization is reflected in the following aspects. Firstly, digital transformation enables firms to send signals of good development prospects to the outside world, prompting them to obtain support from the capital market. Secondly, digital transformation can integrate a large amount of data and information within the firm and output valuable information [Hristov, Appoloni, 2022], thus reducing information asymmetry problems within the firm [He, Li, Ren, 2024], and lowering the information search cost and external transaction cost for investors. Thirdly, digital transformation conforms to the government’s policy orientation, which is conducive to firms obtaining more government policy support and resource investment. In short, corporate digital transformation is helping to alleviate financing constraints and attract more external investment and resources that provide financial support for corporate environmental responsibility. Given these considerations, the study proposes the fourth hypothesis:

H4: Financing constraints play a mediating role in the relationship between digital transformation and corporate environmental responsibility.

¹ Major targets in The 14th Five-Year Plan. <https://english.www.gov.cn/w/14thfiveyearplan/>.

² Sustainable Development Report (Trial) (Draft for Comments). https://www.bse.cn/uploads/6/file/public/202402/20240208220141_ivsr749iv2.pdf.

MATERIALS AND METHODS

Data sources and sample selection. The article takes the data of A-share listed firms on the Shanghai and Shenzhen stock exchanges from 2014 to 2023 as the sample and carries out the following sorting and screening work: (1) deleting the samples of firms with incomplete data; (2) excluding the samples of firms in the financial industry; (3) eliminating all the samples of firms labelled with “ST” and “*ST”.

“ST” (Special Treatment) refers to a firm that has experienced two successive years of losses or whose net assets are lower than the par value of its stock. In this case, the stock exchange adds the label “ST” before the stock name, which signifies that the firm is under “special treatment”. In turn, “*ST” implies that the firm has not improved its position and continues to operate at a loss for the third year. This tag indicates that the firm is at risk of delisting. Generally, the presence of “ST” and “*ST” labels signals that the firm’s operating conditions are not optimistic.

After processing, 6,483 observations from 592 listed firms were selected as research objects. Indicators on digital transformation are derived from public firms’ annual reports, corporate environmental responsibility data are from the CNRDS¹ database, and other financial data are extracted from the CSMAR² database. Additionally, this study has also been winsorized to the upper and down 1% of the data distribution to diminish the effect of significant outliers in the empirical analysis.

Definition and measurement of variables. *Independent variable.* Digital Transformation (Digit). This study follows the approach of Li et al. [2023] and Wang et al. [2024], crawls the keywords related to digital transforma-

tion in the annual reports of listed firms on Cninfo.com³ through Python technology and extracts their frequency of occurrence to measure digital transformation. Digital transformation indicators include underlying technology application (UTA) and practical application of technology (PAT). The UTA level involves four dimensions: blockchain, big data, cloud computing, and artificial intelligence. The indicators at this level mainly measure the application of digital technology in technical support, production decision-making, and management and operation within the firm. The PAT level focuses on applying digital technology (ADT), especially the integration and innovation of digital technology in various specific behavioural scenarios in work and life.

The five dimensions of these two levels represent the digital transformation process from technology innovation to profound business change and from technology enablement to market adoption. Therefore, the word frequencies of the 76 keywords extracted from these five sub-indicators can more comprehensively reflect the level of corporate digital transformation. This study carries out logarithmic processing to deal with the data’s “right skewness”.

Dependent variable. Corporate environmental responsibility (CER). To measure corporate environmental responsibility, the authors refer to the studies of Chen et al. [2021] and Shi and Huang [2024], and uses the CNRDS database to sort out the information disclosure of listed firms from 8 indicators in 3 dimensions: environmental awareness, front-end governance, and back-end governance. If there is a corresponding disclosure for an indicator, the authors mark 1 point; otherwise, 0 points. There are eight indicators, and the full score is 8 points. Table 1 reports the specific measurement indicators of corporate environmental responsibility.

³ Cninfo.com. <http://www.cninfo.com.cn/>.

¹ CNRDS (Chinese Research Data Services Platform). <https://www.cnrd.com/>.

² CSMAR (China Stock Market & Accounting Research). <https://data.csmar.com/>.

Table 1 – Indicators for measuring corporate environmental responsibility
Таблица 1 – Индикаторы измерения корпоративной экологической ответственности

Environmental responsibility	Indicators	Description	Disclose or not
Environmental awareness	Environmental recognition	The firm has received environmental awards or other positive reviews	1/0
	Environmental certification	The firm’s environmental management system has passed ISO 14001 certification	1/0
	Green office	The firm has green office policies or measures	1/0
	Other advantages	Other advantages related to the corporate environment that are not mentioned in the above green behaviours	1/0
Front-end governance	Environmentally friendly products	The firm develops or utilizes innovative products, equipment or technologies that are beneficial to the environment	1/0
	Circular economy	The firm has policies and measures to use renewable energy or adopt a circular economy	1/0
	Energy saving	The firm has policies, measures or technologies for energy conservation	1/0
Back-end governance	Measures to reduce emissions	The firm has policies and measures to reduce emissions of waste gas, waste water, waste residue and greenhouse gases	1/0

Moderating variable. Economic Policy Uncertainty (EPU). This article uses the monthly data on the Chinese Economic Policy Uncertainty Index¹ provided by Baker, Bloom and Davis [2016] for annual processing. In other words, the sum of the monthly data for that year was divided by 12 to evaluate the degree of uncertainty in Chinese economic policy.

Mediating variables. Media Attention (MA) and Financing Constraint (FC). Firstly, this study uses the number of reports on listed firms on the Internet and in newspapers as a proxy variable for media attention. The number of media reports can, to a certain extent, reflect the public's attention to a firm and the firm's influence on the public.

Secondly, the study draws on the research of Kaplan and Zingales [1997] and uses the KZ Index² to measure the degree of financing constraints firms face. The KZ Index comprehensively evaluates the tension in a firm's financing environment by considering multiple financial indicators. It is one of the commonly used indicators for measuring financing constraints.

Control variables. This article builds on the existing related studies [Gao et al., 2024] and sets the following control variables: (1) firm age (Age); (2) firm size (Size); (3) equity concentration (Share10); (4) debt-to-asset ratio (Lev); (5) return on assets (ROA); (6) Tobin's Q (TobinQ). In addition, to control the differences between different firms and years, this study also adds dummy variables for the firm (Firm) and year (Year). The specific definitions of each variable are described in Table 2.

Econometric model. This article uses an unbalanced panel data sample and a fixed effect model to analyse

¹ The Economic Policy Uncertainty Index. <https://www.policyuncertainty.com/>.

² The KZ-Index (Kaplan-Zingales Index). https://ycharts.com/glossary/terms/kz_index.

and test the research hypotheses. To verify Hypothesis 1, the study constructs model (1):

$$CER_{i,t} = \alpha_0 + \alpha_1 Digit_{i,t} + \sum Controls_{i,t} + \varepsilon_{i,t}. \quad (1)$$

To verify Hypothesis 2, the study constructs a moderating effect model (2):

$$CER_{i,t} = \beta_0 + \beta_1 Digit_{i,t} + \beta_2 EPU_{i,t} + \beta_3 Digit_{i,t} EPU_{i,t} + \sum Controls_{i,t} + \varepsilon_{i,t}. \quad (2)$$

To verify Hypotheses 3 and 4, this study draws on the mediating effect test method proposed by Zheng and Zhang [2023] to construct mediation models (3) and (4):

$$Mediator_{i,t} = \gamma_0 + \gamma_1 Digit_{i,t} + \sum Controls_{i,t} + \varepsilon_{i,t}, \quad (3)$$

$$CER_{i,t} = \theta_0 + \theta_1 Mediator_{i,t} + \theta_2 Digit_{i,t} + \sum Controls_{i,t} + \varepsilon_{i,t}. \quad (4)$$

In the above equations (1)–(4), i represents the firm, t is the year; CER stands for corporate environmental responsibility; $Digit$ indicates the degree of digital transformation of the company; EPU means economic policy uncertainty; $Mediator$ replaces media attention (MA) and financing constraint (FC); $Controls$ represents control variables; ε is the error term.

RESEARCH RESULTS

Descriptive statistics. Table 3 presents descriptive statistical results of major variables.

As seen from Table 3, the maximum value of digital transformation is 5.106 and the mean value is 2.058. Such figures reveal that the general level of digital transformation of Chinese listed firms is relatively low, suggesting that Chinese firms still have a long way to go in adopting

Table 2 – Variable selection and measurement

Таблица 2 – Выбранные переменные и методы их измерения

Type of variable	Name	Code	Measurement
Independent variable	Digital transformation	Digit	Ln (total frequency of digital transformation keywords in corporate annual reports +1)
Dependent variable	Corporate environmental responsibility	CER	If the indicator has a corresponding disclosure, score 1; otherwise, score 0
Moderating variable	Economic policy uncertainty	EPU	The monthly data of Chinese economic policy uncertainty is summed up and divided by 12
Mediating variables	Media attention	MA	Ln (number of online and newspaper media reports +1)
	Financing constraint	FC	KZ Index
Control variables	Firm age	Age	Current year – the year of listing
	Firm size	Size	Ln (total assets of the firm)
	Equity concentration	Top10	Proportion of shares held by top 10 shareholders
	Debt-to-asset ratio	Lev	Total liabilities / total assets
	Return on assets	ROA	Net income / total assets
	Tobin's Q	TobinQ	Market value / total assets
	Firm fixed effect	Firm	Dummy variable to control individual fixed effect
	Year fixed effect	Year	Dummy variable to control time fixed effect

Table 3 – Descriptive statistics of variables
Таблица 3 – Описательная статистика переменных

Variables	Observation	Mean	Std. Dev.	Min	Max
CER	6,483	3.402	1.840	0	8
Digit	6,483	2.058	0.241	0.705	5.106
EPU	6,483	4.453	2.327	1.208	8.062
Age	6,483	18.026	5.74	5	25
Size	6,483	24.173	1.506	16.264	29.153
Top10	6,483	58.329	15.372	12.032	90.241
Lev	6,483	0.514	0.201	0.007	1.715
ROA	6,483	0.053	0.076	−0.189	0.627
TobinQ	6,483	0.935	0.248	0.176	4.073

and applying emerging digital technologies. The mean value of corporate environmental responsibility is 3.402, the maximum is 9, and the minimum is 0, indicating that the overall performance of Chinese listed firms in environmental responsibility is at a lower-middle level, which reflects that many firms need to strengthen further their efforts and investment in environmental protection and sustainable development. The mean value of Top10 (equity concentration) is 58.329, indicating that the equity concentration of Chinese listed firms is relatively high. Moreover, the numerical distributions of other control variables are all within a reasonable range. In other words, the sample data are valid.

Baseline regression. The regression results of the impact of digital transformation on corporate environmental responsibility are summarized in Table 4. The study controls the firm and year-fixed effects and performs heteroscedasticity treatment to control the individual differences of the research sample.

As shown in column (1) of Table 4, after controlling only for the firm and year effects, the regression coefficient of digital transformation on corporate environmental responsibility is 0.215, which is a significant positive value at the 1% statistical level. Right after that, the entire sample regression in column (2) of Table 4 reports that after adding all control variables, the regression coefficient of digital transformation on corporate environmental responsibility is 0.132, which is also significantly positive at the 1% statistical level. As a result, Hypothesis 1 is verified; that is, corporate digital transformation can significantly improve corporate environmental responsibility.

The above results may be explained by the fact that the economic value created by digital transformation by improving corporate innovation, productivity, and management efficiency exceeds the value of the resources they require for corporate environmental responsibility. Simultaneously, by strengthening the connection between firms and their stakeholders, the overall increase in value that digital transformation brings to firms outweighs the resources consumed by corporate environmental responsibility.

Table 4 – Baseline regression results
Таблица 4 – Результаты базовой регрессии

Variables	CER	CER
	(1)	(2)
Digit	0.215*** (12.42)	0.132*** (8.01)
Age	–	−0.018 (−0.47)
Size	–	0.257*** (10.93)
Top10	–	−0.081*** (−3.80)
Lev	–	−0.032 (−1.14)
ROA	–	−0.024 (−0.90)
TobinQ	–	0.037*** (5.02)
_cons	4.263*** (33.68)	4.179*** (24.04)
Firm	Control	Control
Year	Control	Control
Prob>F	0.000***	0.000***
R-squared	0.746	0.713
Number of obs	6,483	6,483

Note: Results were obtained using Stata 17. (***) indicates statistical significance at 1% significance level. The *t*-statistics are in parentheses.

Robustness check. Table 5 shows the regression results of PSM-DID (Propensity Score Matching – Difference in Differences), Heckman two-stage model, and the instrumental variable method.

Firstly, this study conducts one-to-one nearest-neighbour matching without replacement based on firm characteristics to ensure sample comparability. Column (1) of Table 5 displays the regression results for the matched samples. The coefficient of digital transformation is a significant positive value at the 1% statistical level, revealing that the positive impact of digital transformation on corporate environmental responsibility remains significant after adjusting for differences in firm characteristics.

Table 5 – Results of the robustness check for the proposed model
Таблица 5 – Результаты проверки модели на робастность

Variables	PSM-DID	Heckman two-stage model	First stage regression with instrumental variables (2SLS)	Second stage regression with instrumental variables (2SLS)
			Digit	CER
	(1)	(2)	(3)	(4)
Digit	0.264*** (5.84)	0.172*** (5.80)	–	0.190*** (12.35)
Inverse Mills Ratio	–	0.078 (0.54)	–	–
Level of digital infrastructure construction	–	–	0.103** (19.30)	–
Control variables	Control	Control	Control	Control
Firm	Control	Control	Control	Control
Year	Control	Control	Control	Control
F-test (First stage)	–	–	118.528	–
Exclusive test	–	–	–	155.032
Weak instrumental variable test	–	–	–	168.791***
R-squared	0.625	0.619	0.752	0.730
Number of obs	3,562	6,483	6,483	6,483

Note: Results were obtained using Stata 17. ** $p < 0.05$; *** $p < 0.01$. The t -statistics are in parentheses.

Secondly, given that there may be inherent differences between firms that disclose and those that do not disclose their environmental responsibility, the authors use the Heckman two-stage model to deal with potential sample selection bias. In the first stage, this study uses variables such as firm age (Age), firm size (Size), equity concentration (Share10), debt-to-asset ratio (Lev), and return on assets (ROA) to construct a Probit model to predict whether a firm discloses its environmental responsibility, thereby the authors obtain the Inverse Mills Ratio (IMR). In the second stage, we add IMR as a control variable to the original model and re-regresses. According to the results of column (2) of Table 5, the IMR coefficient is insignificant. Nevertheless, the coefficient of digital transformation is significant and positive at the 1% level, suggesting that the positive impact of digital transformation on corporate environmental responsibility is still stable even after accounting for sample selection bias.

Thirdly, this study uses the level of digital infrastructure construction (whether the city where the firm is located is a pilot city of "Broadband China"), a factor related to the degree of digital transformation but has no direct impact on corporate environmental responsibility, as an instrumental variable. The study uses the two-stage least square (2SLS) method for regression analysis. According to the results in column (3) of Table 5, the Wald F-statistic of the instrumental variable from the first-stage test is 118.528, stating that the instrumental variable chosen for this study does not have the issue of a weak instrumental variable. Besides, the estimated coefficient of the instrumental variable is significant and positive at 1% statistical level. The exclusive and weak instrumental variable test

results in the second stage further support the rationality of this study's selection of instrumental variables. Simultaneously, the core independent variable is still significantly positive at the 1% significance level, which shows that the conclusion of this study is still valid. In other words, it confirms that the positive effect of digital transformation on corporate environmental responsibility remains robust even after controlling for potential endogeneity issues.

Moderating effect test. Table 6 summarizes the results of testing the moderating effect of economic policy uncertainty on the association between digital transformation and corporate environmental responsibility.

Table 6 – The moderating effect of economic policy uncertainty
Таблица 6 – Модерирующее воздействие неопределенности экономической политики

Variables	CER	CER
	(1)	(2)
Digit	0.125*** (5.40)	0.131*** (5.62)
EPU	–0.023 (–1.79)	–0.028 (–1.77)
Digit×EPU	–0.022** (–2.28)	–0.026** (–2.29)
Control variables	–	Control
F	43.017	38.945
R-squared	0.643	0.627
Number of obs	6,483	6,483

Note: Results were obtained using Stata 17. (**) and (***) indicate statistical significance at 5% and 1% significance levels, respectively. The t -statistics are in parentheses.

The regression results in columns (1) and (2) of Table 6 illustrate that the coefficients of the interaction term (*Digit* × *EPU*) between digital transformation and economic policy uncertainty in the regressions of corporate environmental responsibility are -0.022 and -0.026 , respectively, and both pass the 5% significance level test. The coefficients of the interaction terms are all significantly negative, which indicates that economic policy uncertainty has a negative moderating effect between digital transformation and corporate environmental responsibility. As a result, Hypothesis 2 is verified. These results suggest that when economic policy uncertainty increases, firms will be more cautious in investing in digital technology and assuming environmental responsibility.

Impact factor test. Table 7 reports the test results of the impact factors.

As shown in column (1) of Table 7, digital transformation and media attention are positively significant at the 1% level. In column (2) of Table 7, digital transformation and corporate environmental responsibility, as well as media attention and corporate environmental responsibility, are positively significant at the 1% level. Such a result implies that media attention plays a mediating role in the relationship between digital transformation and

corporate environmental responsibility. For this reason, Hypothesis 3 is verified.

As shown in column (3) of Table 7, digital transformation and financing constraints are positively significant at the 1% level. In column (4) of Table 7, digital transformation and corporate environmental responsibility, along with financing constraints and corporate environmental responsibility, are positively significant at the 1% level. This result identifies that financing constraints play a mediating role in the relationship between digital transformation and corporate environmental responsibility. Thus, Hypothesis 4 is verified. Overall, Table 8 summarises the results of the hypothesis testing.

DISCUSSION

This article chose Chinese firms as the research subject because digital transformation and environmental issues are happening in China. China is indisputably a world leader in this process. This conclusion has been confirmed by many studies, such as the study by Zhang and Zhao [2023]. In this respect, Chinese firms' digital transformation and environmental responsibility can be considered very representative, and the research results are of reference value to researchers from different countries.

Table 7 – Test results of the impact factors

Таблица 7 – Результаты тестирования факторов воздействия

Variables	MA	CER	FC	CER
	(1)	(2)	(3)	(4)
Digit	0.031*** (2.91)	0.129*** (6.82)	0.048*** (3.61)	0.030*** (7.23)
MA	–	0.052*** (4.19)	–	–
FC	–	–	–	0.015*** (2.76)
Control variables	Control	Control	Control	Control
Firm FE	Control	Control	Control	Control
Year FE	Control	Control	Control	Control
F	8.974	109.272	145.053	42.749
R-squared	0.637	0.614	0.741	0.658
Number of obs	6,483	6,483	6,483	6,483

Note: Results were obtained using Stata 17. (***) indicates statistical significance at 1% significance level. The *t*-statistics are in parentheses.

Table 8 – Summary of hypothesis testing results

Таблица 8 – Обобщение результатов проверки гипотез

Hypotheses	Description	Result
H1	Digital transformation promotes corporate environmental responsibility	Verified
H2	Economic policy uncertainty has a negative moderating effect on the relationship between digital transformation and corporate environmental responsibility	Verified
H3	Media attention plays a mediating role in the relationship between digital transformation and corporate environmental responsibility	Verified
H4	Financing constraints play a mediating role in the relationship between digital transformation and corporate environmental responsibility	Verified

To further understand how digital transformation affects corporate environmental responsibility under different conditions, the authors have the following three conjectures.

First, firms in highly competitive industries prefer to gain a critical competitive advantage through digital transformation to achieve a low-cost and efficient mode of operation [Sui et al., 2024]. Based on this, we assume that the contribution of digital transformation in facilitating corporate environmental responsibility is more pronounced in industries with a higher degree of competition. The study can draw on the method of Amini, Kumar and Shome [2024] and measure the degree of competition in each firm's industry using the Herfindahl-Hirschman Index (HHI). Further, the study can divide the samples into groups and re-regress them. Suppose the interaction term coefficient between digital transformation and industry competition is significantly positive at the 1% or 5% level. In that case, it will suggest that in a highly competitive market environment, while firms gain competitive advantages through digital transformation, they also attach more importance to fulfilling their environmental responsibilities. Such a conclusion may be because, in a highly competitive environment, firms need to win the favour of consumers and investors by improving their environmental performance.

Second, due to strict environmental regulations and public attention, heavily polluting firms tend to reduce their pollution emissions through digital transformation [Li, Jin, Gao, 2023]. Correspondingly, this study assumes that digital transformation has a more noticeable effect on promoting firms to fulfil their environmental responsibilities in heavily polluting firms. Referring to the research of Xing, Li, and Feng [2024], this study can divide the entire sample into heavy-polluting firms and non-heavy-polluting firms. Then, the study can assign a value of 1 to heavy polluting firms and 0 to non-heavy polluting firms and re-regress. Suppose the interaction term coefficient between the degree of emission pollution and digital transformation is significant and positive at the 1% or 5% level. In that case, it indicates that environmental pressure is essential in promoting firms to strengthen their environmental responsibilities in digital transformation. This potential finding may highlight the critical role of environmental and public supervision in promoting corporate environmental responsibility in the digital age and complement the existing understanding of the drivers of environmental responsibility.

Third, regarding the nature of corporate ownership, state-owned enterprises (SOEs) are more influenced by government policies and social responsibility guidance and supervision in the digital transformation process than non-SOEs. As a result, they pay more attention to environmental protection and sustainable development [Su, Wu, 2024]. Accordingly, this study assumes that the effect of digital transformation in contributing to cor-

porate environmental responsibility is even more pronounced among SOEs. Referring to the research of Song et al. [2024], this study can divide the entire sample into SOEs and non-SOEs. Then, we can assign a value of 1 to SOEs and 0 to non-SOEs and re-regress. Suppose the interaction term coefficient between digital transformation and corporate ownership is significant and positive at the 5% or 1% level. In that case, it signifies that the environmental performance of SOEs is partly driven by government policies and social responsibility, which sharply contrasts non-SOEs that act under market competition and stakeholder pressure. Meanwhile, SOEs may have more resources and incentives to use digital tools and strategies to improve their environmental performance, possibly due to their closer relationship with the government and greater sensitivity to policy changes.

In summary, one of the directions for future research, grounded in the above analysis, is to further examine these conjectures in order to better comprehend the ways in which digital transformation affects corporate environmental responsibility.

CONCLUSION

In this paper, the authors firstly elucidate the intrinsic and extrinsic factors of digital transformation affecting corporate environmental responsibility from the theoretical level, and then empirically examine the impact of digital transformation on corporate environmental responsibility, and eventually draw the following main conclusions:

- 1) digital transformation significantly contributes to corporate environmental responsibility and is particularly prominent in raising firms' environmental awareness. This finding underscores the potential of digital technologies to help firms take on environmental responsibility;
- 2) economic policy uncertainty negatively moderates the positive association between digital transformation and corporate environmental responsibility. Such a finding reveals that the effect of digital transformation on promoting corporate environmental responsibility may be weakened in environments with high policy uncertainty;
- 3) the impact factor analysis shows that digital transformation can promote corporate environmental responsibility through internal factor that improve corporate financing constraints and external factor that increase media attention.

Practical implications. For government departments, there is a need to further improve the policy system related to the digital economy and encourage firms to take the initiative to assume environmental responsibility. According to the conclusions of the study, digital transformation can promote an increased awareness of corporate environmental responsibility. Nevertheless, economic policy uncertainty may adversely influence this effect. For this reason, first of all, the government should reduce the frequency of policy changes and maintain the stability and continuity of economic policies in order to enhance the

expectations and confidence of firms in the future development environment. Second, concerning different types of enterprises, such as SOEs, private enterprises, and critical emitters, the government should formulate differentiated policies according to their characteristics in order to promote their effective assumption of environmental responsibility in the process of digital transformation. Last but not least, the government and financial institutions should accelerate the improvement of relevant policies such as green credit policy and environmental information disclosure system so that firms can better solve the problems of insufficient transparency of internal information and financing constraints after digital transformation.

Firms face the challenge of maximizing the comprehensive value of economic, social, and ecological benefits because they have to achieve a harmonious symbiosis between economic development and environmental protection to promote a sustainable development strategy. In the digital transformation process, firms can be more efficiently environmentally responsible by improving their corporate governance structures, increasing information transparency, overcoming traditional financing constraints, and raising media attention. Adopting these measures can help firms use digitization to achieve a harmonious symbiosis between environmental protection and economic development and accelerate the transition to a green and low-carbon environment.

Limitations and future research. The limitations of this article mainly lie in the following. First, the study measures digital transformation by extracting and screening key-

words associated with digital technologies in the financial reports of listed firms. The reason is that listed firms do not disclose the costs related to digital transformation in their annual reports, and the industry gives no authoritative evaluation indexes, so this part of the data may be flawed. Second, for a long time, China's crude economic development model that excessively pursues economic efficiency has triggered a series of environmental problems. With the introduction of the "carbon peak" and "carbon neutral" targets, green development has received widespread attention from all levels of Chinese society. As the micro subjects of the market economy and emitters of environmental pollution, Chinese firms play a key role in improving the ecological environment, enhancing the stability of the ecosystem, and realizing clean energy production. Therefore, this article chooses Chinese listed firms as the research object, which inevitably produces research results with Chinese characteristics. In the future, more studies from other countries and regions are needed to check the validity of the findings of this article. Third, although factors such as the degree of industry competition, the degree of emission pollution, and the nature of corporate ownership have been considered in the discussion section, there may still be other internal and external factors within and outside the organization that affect the relationship between digital transformation and corporate environmental responsibility. Consequently, future research should further explore these potential factors to gain a more comprehensive understanding of the impact of digital transformation on corporate environmental responsibility. ■

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