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The impact of corporate digital transformation on firms' performance in utilities sector

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ABSTRACT

In the evolving business landscape, utility firms are undergoing transformative digital changes. The purpose of this study is to examine the unexplored link between utility firms' digital transformation and performance, by utilizing unique data from Chinese listed utilities. Empirical findings show a positive correlation between digital transformation and enhanced performance, with financial constraints and environmental performance as identified mechanisms. The research enriches understanding of digital transformation's economic consequences, providing practical insights for implementation, especially for environmentally conscious firms. Considering textual analysis and sample size limitations, future studies could assess utility firms' digital transformation across diverse economies with a more thorough evaluation of a firm's level of digital transformation.

1. Introduction

Utilities sector, providing basic needs and services, such as electricity, water and gas, plays a vital role in modern industrial society, especially when over 56 % of world population live in cities with more than 80 % of global GDP generated in the urban area [1]. However, driven by the fourth industrial revolution, digital technologies, such as cloud, big data, artificial intelligent and internet of things, are in a rapid development and are now changing business models across a wide range of industries, and promoting business transformation at the organization level [2]. Digital transformation is "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" [3]. Therefore, like other industries, utilities sector is also undergoing a rapid and dramatic transformation initiated by such changes in the business environment where more and more incumbent companies are integrating digital technologies into products, services and business processes and an increasing number of firms have made digital transformation with the help of such technologies [4].

However, digital transformation does not always result in significant benefits for firms. A survey conducted by Accenture in 2022 reveals that 17 % of companies have gained distinct performance on their digital transformation. Extant studies have different views on the impact of digital transformation on firms' performance. Some studies have found that digital transformation has negative effect on firms' ROA as application of digital technologies could incur huge costs on firms' IT and technologies investment with returns not realized immediately [5]. ICT (Information and communication technologies) usage is not bound to generate a better business performance unless it is proper used and managed by entrepreneurial orientation [6].

Other studies have found positive association between digital transformation and firms' performance [4,7]. Additionally, research

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has highlighted other favorable impacts of digital transformation on firms, marked by improvements in efficiency, cost reduction, and innovation encouragement. First, firms' digital transformation optimizes structure and boosts technology innovation [8], and thus enhance total factor productivity or input-output efficiency [4,9], which in turn is one of critical factors in business financial performance [10]. Second, firms adopting big data predictive analytic outperform peers in cost performance [11] due to fast responses, actions and solutions powered by digitalization which provides richer and current information [12]. Third, firms' innovation capabilities are benefited from the digital transformation strategy. Companies adopting a R&D collaboration strategy, under the context of Industry 4.0 and digital transformation, are crucial to boost digital innovation with external partners [13]. Besides, digital transformation improves in-house innovation and ability to grasp and absorb technology disruption, and with these effects, firms are favored with better return to scales [4,14].

Although the extant research illustrates the association between digital transformation and firm performance and some positive effects that firms could benefit from it, there is a lack of research in clarifying the association for companies in the utilities sector. Second, previous research related to digital impact on utilities sectors focused on operational efficiency [15] and productivity [16], but other effects of digital transformation on utilities firms have not yet been touched. Third, scholars focused on examining other factors that may have association with business performance of utilities companies, such as environmental performance [17], corporate social responsibility [18], regulatory incentives and governance [19–21] as well as firms' ownership structures [22], but digital transformation and its mechanisms that impact utilities performance remains unexplored.

In terms of how digital transformation strategy influences utilities performance and what factors could create heterogeneity in firm performance within the context of digital transformation, the authors consider two factors: financial constraints as the mediating effect and environmental performance as the moderating effect. The subsequent paragraphs provide concise backgrounds on financial constraints and environmental performance, along with a brief justification of the authors' concerns.

The progress of any industry is intricately linked to its financial backing. In the absence of sufficient financial support, industries and enterprises may struggle to achieve sustainable development [23]. Additionally, corporate financial risks stemming from high financial leverage and challenges in securing financing, often due to substantial financing constraints, play a pivotal role in shaping the development of enterprises [15]. Embracing digital transformation can send positive signals to the market and simplify the process of accessing financing for companies [24]. This shift also contributes to the reduction of information asymmetry, as financial information becomes more transparent within the context of digital transformation [15]. Therefore, financial constraints emerge as a potential mechanism underlying the enhancement of utility firm performance resulting from digital transformation.

The global environment is evolving, and firms are increasingly expected to consider environmental and social issues alongside their financial goals [25]. Neglecting environmental concerns can lead to reputational and regulatory risks, with direct financial implications. Therefore, considering environmental performance is not just a matter of ethical responsibility but also a matter of financial prudence in today's business environment. Besides, firms are motivated to engage in environmental activities not just for their intrinsic benefits but also because they can serve as a signal to investors and stakeholders [26]. Companies with a superior environmental performance are more likely to disclose their environmental strategies, which can attract investors and positively affect their financial performance. Hence, the distinct environmental performance of utility firms has the potential to create heterogeneity in firm performance within the context of digital transformation.

Based on the preceding discourse, the research gap lies in the limited exploration of digital transformation's influence on utilities performance and the lack of attention to potential mechanisms. Therefore, this paper aims to address the research gap by investigating the impact of digital transformation on firms' performance in the utilities sector. Specifically, the potential mediation and moderation roles of financial constraints and environmental performance in shaping this relationship are also explored in this study. In addition to this, heterogeneity among firms is also studied.

Therefore, a vital contribution of this paper is the focus on the impact of digital transformation on firms performance of those utilities companies based on micro-level data from Chinese listed utilities firms with potential mechanisms justified. The empirical results not only contribute to the extant literature on the determinants of utilities firms performance, but also the economic consequences brought by digital transformation. Besides, current studies measuring a utility firm's performance are based on accounting outcomes [21,22,27]. However, an accounting-based measure for firms facing dramatic shift and technological disruption is limited in past performance and not forward-looking [28] and future-oriented [29]. Therefore, another contribution of this study is the measurement of firms' performance by Tobins'Q ratio. The remainder of the paper is structured as follows: in section 2, relevant literature review and mediation and moderation mechanisms are discussed and hypotheses are formulated; in section 3, data sources, variables in interest and econometric models are presented; in section 4, empirical analysis and interpretation of results are conducted and put; in section 5, conclusion, implications, contributions and limitations are discussed.

2. Literature review and hypotheses development

2.1. Measuring utility firms' performance using Tobins'q

Tobin first introduced q ratio and justified it as an indicator of firm's future investment measured by the value of capital relative to its replacement costs [30]. Later, the ratio of market value to replacement costs was further mentioned as an important measure of financial markets [31]. Based on Tobin's groundbreaking theory, the q ratio has been used by scholars in various aspects. Chen and Lee (1995) [32]found the traditional performance measure, ROI, does not reflect a firm's underlying profit and Tobin's q ratio generates more information in reflecting a business performance than ROI. Wernerfelt and Montgomery (1988) [33]and Lang and Stulz (1994) [34]used the q ratio to examine the importance of focus and found that firms with less diversification do better than those with more

diversification. Besides, Tobin's q ratio has also been used as the measures of intangible assets [35] and technological assets [36].

The biggest advantage of Tobin's q ratio is the element of forward-looking in measuring a firm's performance [37], which are the limitations of traditional accounting measure [38]. Since the q ratio incorporates market performance and could be arrived at using companies financial accounting data [39], many scholars use the q ratio as an indicator for firms performance in studying the effects that market power, industry characteristics and firm factors have on a firm's performance [40–42]. Besides, figures recorded in financial statements represent a firm's performance in the past and assets and debts that are quantifiable and able to be measure, but intangible values are not totally reflected in companies' financial statements and should be measured using the q ratio which is close to unity [28].

In this paper, q ratio is used as an indicator of firms' performance to gauge the impact of digital transformation as it enables firms to uncover new pathways of value creation, transforming value creation process [3] but such transformation entails a long range of period [24] and the investment in such strategy scarcely generates returns in the year of implementation, which cannot be measured by traditional accounting data. Therefore, the q ratio can better reflect the impact of digital transformation as it includes market information that captures a firm's long-term performance and intangible values.

2.2. Digital transformation and firms' performance

Digital transformation does not equal to digitization and digitalization. The former (digitization) is just to convert offline data into analogue digital values in order to facilitate internal users operate and conduct them on digital platforms [43] and the latter (digitalization) refers to a more advanced application of digitized figures where business activities and operational processes are conducted with the help of them [44]. Digital transformation does not mean establishment of platform where digitized data could be used nor business processes being digitalized. Instead, it is more an infrastructural change where not only all aspects and operations are integrated with digital technologies [45], but also organizational culture, attitudes, mindset and way of working are totally transformed [46]. Therefore, digital transformation refers to mainly three aspects, including improvement of operational efficiency, changes in production and organizational methods and new business models [47]. In this paper, in terms of the level of digital transformation, the authors shift focus beyond the digital technologies alone and extend the focus to include the application of these technologies. This dual emphasis is crucial, as it signifies a comprehensive process of transformation [3], as merely gauging a firm's technological tools provides only a glimpse into the extent of its digital transformation [44]. This distinction sets our paper apart from other studies that solely focus on a firm's digital technology [6,11].

Total factor productivity or productivity are one of key effects of digital transformation on firms [16,48] as in the process of transformation, firms adjust their corporate structures to fit an optimal form with innovation capabilities being boosted [8] as well as internal quality control being strengthened [48]. Therefore, the improvement in productivity could further benefit firms with edges in competition and enhance corporate performance [10]. The second benefit that digital transformation bring to firms is cost reduction [11]. The mechanism that lies in such phenomena is that digital transformation reduces adjustment costs through effective cost control [49], restrains management optimistic expectation and alleviate agency problem [50]. Innovation encouraging is another effect of digital transformation that has been studies by scholars. Usai et al. (2021) [51]found that adoption of digital technologies does not necessarily improve a firm's innovation performance. Instead, with the whole transformation under such digital technologies, innovative resources and capabilities could be released and dynamic organization and continuous learning be generated, which enhances corporate innovation performance [4]. Moreover, digital transformation shapes innovation process at different stages by augmenting products and services performance [52]. These literature implies that digital transformation could enhance firms' performance, including utility firms. Therefore, the authors hypothesize that digital transformation improves utility firms' performance.

H1. Utility firms' performance is positively associated with the level of digital transformation.

2.3. Mediating role of mitigating financial constraints

The important mechanism underlying the impact of digital transformation and firms' performance is the mitigating of financial constraints. Zhou and Li (2023) [23]found that digital transformation eases firms' financial constrains, where firms are easier to get bank loans other than financing from trade credit. First, information related to corporate financial and credit would be easier obtained by external financial institutions with the help of digital technologies integrated in the business [15]. One of the primary advantages of employing digital technologies in digital transformation is the enhancement of information transparency [53]. This alleviates the information asymmetry between corporate and financial market as well as reduces credit risk costs [54] and thus facilitating firms and financial institutions easier to seal a deal. Second, since digital transformation has gained much attention by academia and industries, firms in the process of digital transformation are more favored by markets with positive expectations transmitted to investors [24]. Except for private investors being attracted, government is inclined to grant subsidies and supportive policies to firms applying digital transformation, as digital economy is viewed as the core of smart cities [55]. Third, firms' finance strategies and instruments in conjunction with digital technologies due to the process of transformation could provide firms with diversified financing channels and products. In other words, firms can take advantage of digital transformation to obtain external financing information, and thus lowering firms difficulties in financing [56]. In summary, the literature underscores the multifaceted impact of digital transformation on financial constraints, including improved information access, market perception, and financial strategy diversification.

Therefore, firms conducting digital transformation could get advantages in financing as the mismatch between financial institutions firms is mitigated, and more positive attentions could be attracted from government and investors and financial channels are

widened and diversified. Hence, firms are easier and are more likely to get funds from external investors or subsidies from governments, which promotes the upgrading of existing facilities and implementation of digital strategies, further boosting firms' performance. Thus, the authors hypothesize that digital transformation can improve utility firms' performance via alleviating financial constraints.

H2. Utility firms' performance can be improved by digital transformation, with indirect effect of mitigation of financial constrains.

2.4. Moderating role of environmental performance

The services that utility firms provide are closely bound up with household and businesses. The sources of water, carbon emissions due to power generation and waster sector solutions are received considerable attentions from the public [25]. Therefore, utility firms could have incorporated environmental sustainability in their corporate strategy [57]. Firms with better environmental performance are supposed to get benefits from the environmental knowledge learning, access to resources and transmitting positive information to outsiders [26]. These merits are now highly advocated by academia as well as financial investors since sustainable and circular economy has become global consensus [25] with 4902 financial institutions and investors being PRI signatories and an estimated total of Assets Under Management (AUM) of USD121.3 trillion [58]. In summary, the extant studies highlight the knowledge learning and signaling effects associated with companies exhibiting superior environmental performance.

Therefore, firms with better environmental performance are more likely to have their firms' performance improved since they get favored from investors due to implementation of digital transformation and good environmental performance. Thus, the authors hypothesize that environmental performance has moderating effect in the association between digital transformation and firms performance.

H3. Environmental performance of utility firms plays a moderating role in the relationship between digital transformation and firms performance.

3. Research design

3.1. Data sources

Since this study aims at investigating the impact of digital transformation on utility firms' performance. A total of 118 utility firms listed on Chinese securities market were first selected. Among them, 5 firms were excluded from the initial sample as these firms were in danger of being delisted and designated "ST" or "Special Treatment" in front of the firms' ticker. Then, 8 utility companies were further excluded as their figures are not complete. Finally, 105 utility firms are included and construct as our final sample with 1005 firm-year observations that lie in the period between 2010 and 2022. To minimize the influence of outliers, all continuous variables are winsorized at the 1 % and 99 % quantiles. The data for all variables is derived from various sources, including China Stock Market and Accounting Research Database (CSMAR), Sino-securities ESG Index and annual reports.

3.2. Variables

3.2.1. Dependent and independent variables

The dependent variable is designated by Tobin's q ratio, which reflects a firm's performance as firms in the process of digital transformation entail a certain large of investment in all aspects and the returns of the investment are not reflected in accounting data which stands for firms' performance in the past.

The independent variable is the degree of digital transformation of utility firms. Previous studies have used two methods in gauge such degree, ratio of digitalization assets to intangible assets [23] and textual analysis of corporate annual reports [59]. Since a firm's degree of digital transformation does not equal its level of digitalization, the simple calculation of the digitalization ratio is not appropriate. The textual analysis of corporate annual reports could grasp a firm's strategic orientation [15], which could be an indicator of a firm's degree of digital transformation. Therefore, Python crawler was used first to obtain annual reports of utility firms selected in our sample, followed by extraction of all text contents.

To build a lexicon on digital transformation, we integrate insights from academic studies and industry perspectives, including national policies and reports. Academic research provides a technical foundation, aligning with digital transformation as organizational infrastructural changes driven by digital technology integration [14,60]. Then, we extend to national policies, like *the* 14th *Five-Year Plan Roadmap for Digital China*, and industrial reports, like *the Digital China Development Report (2022)* by the China Academy of Information and Communications Technology (CAICT).

Based on insights from academic literature, national policies, and industrial reports, we discern that digital transformation involves the establishment of digital systems utilizing tools such as cloud computing, big data analytics, and blockchain techniques. These technologies are harnessed to manage changes in value proposition, realization, and creation, manifesting in alterations to business models, product innovation, and intellectualization.

Our comprehensive lexicon covers Artificial Intelligence, Big Data, Cloud Computing, and Blockchain, reflecting technological aspects. Additionally, it includes applications driving shifts in value paradigms, covering new business models, intellectualization of processes, and digital innovations. We eliminate negative expressions and irrelevant keywords for clarity.

Following this, we utilize Python to extract text from listed companies' annual reports, forming a comprehensive data pool. The text

undergoes a thorough process involving search, match, and word frequency counting based on the feature words outlined in Appendix A of the lexicon. Additionally, to address the "right skewness" of the data, we apply a logarithmic process to derive an overall indicator that characterizes the digital transformation of utility enterprises.

3.2.2. Mediating variables

In order to measure a firm's degree of financial constraints, SA index is used as an indicator. SA index is widely used in measuring a firm's level of financial constraints [15,24,54].

3.2.3. Moderating variables

The environmental performance of firms is measured using Sino-securities E Index, where environmental rating of firms is measured as scores ranging from 1 to 100.

3.2.4. Control variables

In consistent with previous literature focusing corporate performance [28,61], the following variables are incorporated as control variables, firm size (*SIZE*), liability ratio (*LEV*), operating revenue growth rate (*GROWTH*), operating cash flow to assets ratio (*CASHFLOW*), the shareholding ratio of Top1 shareholder (*TOP1*), ratio of independent director (*INDEPENDENT*), the natural logarithm of the number of executives (*TMTSIZE*), firm age (*Age*), whether a firm is state-owned (*SOE*), and whether the chairman and CEO is the same person (*DUAL*). See Table 1 for details.

3.3. Regression models

Our primary purpose is to figure out the association between digital transformation and utility firms' performance. Therefore, OLS model is used as our baseline regression model, which is presented in Equation (1) as follows:

$$FP_{i,t} = \beta_0 DIGITAL_{i,t} + \beta_1 Controls_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (1)$$

where i represents a firm and t for a year. λ_i represents individual fixed effect, μ_t represents time fixed effect, and $\varepsilon_{i,t}$ the error term. β_1 is the core explanatory parameter to be tested and *Controls* stand for all control variables included in the regression model.

In order to explore the underlying mechanism, the following two models are constructed, i.e. Equations (2) and (3), to test whether there is an indirect effect of financial constraints in terms of the relationship between digital transformation and firms performance:

$$SA_{i,t} = \beta_0 DIGITAL_{i,t} + \beta_1 Controls_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (2)$$

$$FP_{i,t} = \beta_0 DIGITAL_{i,t} + \beta_1 SA_{i,t} + \beta_2 Controls_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (3)$$

Finally, the following model, i.e. Equation (4), is used to test the moderating effect of environmental performance:

Table 1
Variable definitions.

Variable categories	Variables	Symbols for variables	Variable definitions	Source
Dependent variables	Firms performance	*FP*	Tobins' q ratio	CSMAR
Independent variables	Digital transformation	*DIGITAL*	Ln(Word frequencies of 77 words related to digital transformation+1)	Annual reports
Mediating variables	Financial constraints	*SA*	The SA index	CSMAR
Moderating variables	Environmental performance	*EP*	Environment scores	Environmental pillar from Sino-securities ESG Index
Control variables	Firm size	*SIZE*	Natural logarithm of total assets at a year end	CSMAR
	Leverage ratio	*LEV*	Debt-to-asset ratio	CSMAR
	Operating revenue growth rate	*GROWTH*	(Current operating income - previous operating income)/previous operating income	CSMAR
	Operating cash flow to assets ratio	*CASHFLOW*	Net operating cash for the current period/total assets at the end of the period	CSMAR
	Shareholding ratio of Top1 shareholder	*TOP1*	Number of shares held by Top1 shareholder/ total number of shares	CSMAR
	Ratio of independent director	*INDEPENDENT*	Number of independent directors/total directors	CSMAR
	Natural logarithm of the number of executives	*TMTSIZE*	Natural logarithm of number of executives	CSMAR
	Firm age	*AGE*	Number of years from listing to the current year	CSMAR
	Properties	*SOE*	1 for state-owned company and 0 for the otherwise	CSMAR
	Chairman and CEO	*DUAL*	1 for Chairman and CEO are the same person and 0 for the otherwise	CSMAR

$$FP_{i,t} = \beta_0 DIGITAL_{i,t} + \beta_1 EP_{i,t} + \beta_2 DIGITAL_{i,t} \times EP_{i,t} + \beta_3 Controls_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (4)$$

4. Empirical analyses and discussion

Table 2 presents descriptive statistics for each variable. The average FP is 1.436, with the lowest and highest values being 0.815 and 5.493 respectively. This suggests significant variation in utility firms' performance. The distribution of the degree of digital transformation of firms is left-skewed, with a median of 0 and an average of 0.420. This suggests that utility firms perform differently in terms of their involvement in digital transformation with most of firms not yet to conduct a certain degree of transformation. The overall environmental performance of companies is good, with an average of 59.32 and a median of 59.49.

Stepwise regression analysis, in line with prior research [15,60], was used to investigate the relationship between digital transformation and utility firms' performance. Column (1) of Table 3 reports the relationship between digital transformation and the firms' performance without controls for year and firm fixed effects with coefficient for digital transformation being significantly positive at the 1 % level.

For robustness of the result, control variables and time and individual fixed effects were added in the regression model. Columns (2) and (3) of Table 3 present the results with only year or firm fixed effect included, respectively. The coefficients are statistically and economically significant at the 1 % level.

Both firm and year fixed effects are incorporated in the fourth regression analysis, with the coefficient for digital transformation remaining positively significant at the 1 % level. This finding supports H1, indicating that firms with a higher degree of digital transformation are associated with better performance.

In summary, these findings indicate that digital transformation has a significant positive impact on utility firms' performance.

Our findings may also be subject to endogenous bias due to potential association between regressor and the error terms. To address this issue, an instrumental variable approach is employed. The average level of digital transformation in a particular region and within a year is associated with a firm's degree of digital transformation, but it does not have relationship with a firm's performance [15,60]. Therefore, the regional average degree of digital transformation in a single year could be used as an instrumental variable. Column (1) of Table 4 presents the regression results for the first stage of the instrumental variables, where the estimated value is 0.911 and significant at the 1 % level, indicating a strong correlation between the instrumental variable and firms' digital transformation levels.

Column (2) reports the second stage estimation results, where the estimated coefficient is 0.073 at the 10 % level, indicating that the instrumental variable satisfies the endogenous assumption without any weak instrumental variable problems. Therefore, our findings of a positive relationship between digital transformation and utility firms' performance are still valid even after addressing the endogenous issue.

In summary, our instrumental variable approach provides reassurance that our findings are robust to endogenous bias, reinforcing the positive relationship between digital transformation and utility firms' performance.

The concern on reverse causality was addressed by incorporating a one-period lag for the independent variable as firms with greater performance are inclined to adopt a transformation strategy in order to maintain its sustainable competitiveness. As shown in Table 5, the degree of digital transformation of a firm one period prior has a significant positive impact on both the firm's performance and financial constraints. Similarly, when SA index is lagged by one period, the results remain statistically significant.

Due to the limitations associated with using a lexicon of 78 keywords to measure digital transformation, the frequency of occurrence of five key indicator words in firms' annual reports was applied in the textual analysis for robustness: "artificial intelligence technology", "big data", "cloud computing technology", "block-chain technology" and "digital technology application". Despite this change, the estimated coefficient remains statistically significant, as demonstrated in column (1) of Table 6. Controlling for cross-multiplication of industry-year and province-year in column (2) does not diminish the significance of the results, which remain robust at the 1 % level.

Table 7 presents the regression results of financial constraints as a mediator between digital transformation and utility firms' performance. Column (1) displays the regression of digital transformation to utility firms' performance, while column (2) reveals a

Table 2
Descriptive statistics.

Variables	Observations	Mean	SD	Min	Mid	Max
FP	1005	1.436	0.702	0.815	1.200	5.493
DIGITAL	1005	0.420	0.682	0.00	0.00	2.639
SA	1005	−3.864	0.266	−4.430	−3.881	−3.056
EP	1005	59.32	6.801	43.20	59.49	75.73
SIZE	1005	23.19	1.497	19.77	23.02	26.67
LEV	1005	0.574	0.170	0.0920	0.579	0.897
GROWTH	1005	0.166	0.421	−0.505	0.0890	2.724
CASHFLOW	1005	0.0650	0.0560	−0.111	0.0650	0.227
TOP1	1005	38.49	16.64	11.18	37.40	76.13
INDEPENDENT	1005	36.67	4.529	30	33.33	50
TMTSIZE	1005	6.336	2.095	3	6	13
AGE	1005	2.635	0.579	1.099	2.833	3.367
SOE	1005	0.739	0.439	0	1	1
DUAL	1005	0.129	0.336	0	0	1

Table 3
Regression results.

Variables	(1)	(2)	(3)	(4)
	FP	FP	FP	FP
DIGITAL	0.119***	0.095***	0.134***	0.104***
	(0.036)	(0.031)	(0.037)	(0.031)
SIZE	−0.357***	−0.354***	−0.460***	−0.461***
	(0.060)	(0.065)	(0.091)	(0.093)
LEV	0.111	0.176	0.175	0.263
	(0.350)	(0.365)	(0.369)	(0.386)
GROWTH	−0.054	−0.038	−0.025	−0.009
	(0.053)	(0.053)	(0.047)	(0.047)
CASHFLOW	−0.322	−0.438	−0.168	−0.293
	(0.547)	(0.544)	(0.547)	(0.527)
TOP1	0.000	−0.000	0.001	0.000
	(0.002)	(0.002)	(0.003)	(0.003)
INDEPENDENT	0.001	0.002	0.001	0.003
	(0.007)	(0.007)	(0.008)	(0.007)
TMTSIZE	−0.027*	−0.028**	−0.028*	−0.028*
	(0.015)	(0.014)	(0.016)	(0.015)
AGE	0.058	0.076	0.222	0.247
	(0.070)	(0.067)	(0.136)	(0.169)
SOE	−0.080	−0.085	−0.300**	−0.293***
	(0.098)	(0.090)	(0.122)	(0.109)
DUAL	−0.210**	−0.224**	−0.243**	−0.259**
	(0.097)	(0.093)	(0.109)	(0.101)
_cons	9.690***	9.642***	11.747***	11.725***
	(1.366)	(1.425)	(1.882)	(2.013)
Firm	No	No	Yes	Yes
Year	No	Yes	No	Yes
N	1005	1005	1005	1005
r2			0.273	0.413

Note: All firm-level continuous variables are winsorized at the 1st and the 99th percentiles. Firm and year fixed effects are included, and robust standard errors are clustered by firm. *, **, and *** represent significance levels of 10 %, 5 %, and 1 %, respectively. The other tables follow the same rule.

Table 4
Results after using instrumental variable.

Variables	(1)	(2)
	DIGITAL	FP
IVdigital	0.911***	
	(0.068)	
$\widehat{DIGITAL}$		0.073*
		(0.042)
_cons	−2.474**	11.620***
	(0.944)	(1.997)
Controls	Yes	Yes
Firm	Yes	Yes
Year	Yes	Yes
N	1005	1005
r2	0.423	

positive correlation at the 5 % level between digital transformation and financial constraints. This finding affirms that improvements in digital transformation lead to less financial constraints. Column (3) presents the regression results of all variables. Notably, digital transformation retains a statistically significant positive impact on firms' value at the 1 % level, although the impact coefficient is lower than in column (1). Additionally, the mitigation of financial constraints has a positive impact on firms' performance at the 1 % level, supporting H2. These results suggest that the alleviating financial constraints partially explains how digital transformation affects utility firms' performance.

To enhance the reliability of the mediating results, bootstrap sampling was performed on the stepwise regression outcomes described above, extracting 1000 self-service samples. The findings indicate that the direct effect of digital transformation and the mediating effect of financial constraints do not include 0 within the upper and lower limits of the 95 % confidence interval. This outcome confirms, with greater confidence, the mediating role of mitigating financial constraints in the relationship between digital transformation and utility firms' performance.

The statistical analysis illustrated in Table 8 indicates that the interaction term of digital transformation and the environmental

Table 5
Results of lead-lag test.

Variables	(1)	(2)	(3)
	FP	SA	FP
L.DIGITAL	0.103**	0.006**	0.093**
	(0.041)	(0.003)	(0.040)
L.SA			1.562***
			(0.450)
_cons	11.711***	−3.707***	17.128***
	(2.048)	(0.464)	(2.496)
Controls	Yes	Yes	Yes
Firm	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	864.000	864.000	864.000
r2	0.402	0.816	0.437

Table 6
Results of independent variables being replaced.

Variables	(1)	(2)
	FP	FP
Robust_digital	0.104***	0.115***
	(0.028)	(0.043)
_cons	11.775***	12.003***
	(1.993)	(2.202)
Controls	Yes	Yes
Firm	Yes	Yes
Year	Yes	Yes
*Provinc*Year*	No	Yes
N	1005	1005
r2	0.416	0.599

Table 7
Results of the mediating role of mitigating financial constraints.

Variables	(1)	(2)	(3)
	FP	SA	FP
DIGITAL	0.104***	0.004**	0.093***
	(0.031)	(0.002)	(0.029)
SA			2.504***
			(0.468)
_cons	11.725***	−3.610***	20.765***
	(2.013)	(0.441)	(2.644)
Controls	Yes	Yes	Yes
Firm	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	1005	1005	1005
r2	0.413	0.821	0.500

performance is significant at the 1 % level, implying that the environmental performance has a moderating effect on the overall relationship between digital transformation and utility firms' performance. Indeed, utility firms with a high degree of environmental performance have more noticeable improvements in corporate performance through digital transformation.

State-owned and non-state-owned companies may have different attitudes towards realizing economic value and investing in digital transformation, leading to heterogeneity in the impact of digital transformation on firms' performance [15]. Firms were grouped into state-owned and non-state-owned based on the identity of their ultimate controlling shareholder. Our findings demonstrate that non-state-owned firms can significantly improve their performance through digital transformation, but state-owned firms cannot (as illustrated in columns (1) and (2) of Table 9). This may be due to short-term political goals or career demands of management at state-owned firms, which could result in less willingness to invest in digital transformation for economic benefits. Beside of that, state-owned enterprises may be subject to particular expectations from the market regarding digital transformation. However, unlike non-state-owned enterprises, their digital transformation actions may not convey more positive signals to the market.

Table 8
Results of moderating effect of environmental performance.

Variables	(1)	(2)
	FP	FP
DIGITAL	0.104***	−0.615***
	(0.031)	(0.228)
EP		−0.004
		(0.005)
*EP*DIGITAL*		**0.012*** **
		(0.004)
_cons	11.725***	12.300***
	(2.013)	(2.032)
Controls	Yes	Yes
Firm	Yes	Yes
Year	Yes	Yes
N	1005	1005
r2	0.413	0.425

Table 9
Results of heterogeneity test.

	(1)	(2)
	FP	*FP*
	Soe	*Non-soe*
DIGITAL	0.06*	0.14**
	(0.03)	(0.07)
_cons	9.32***	14.96***
	(1.41)	(3.29)
Controls	Yes	Yes
Firm	Yes	Yes
Year	Yes	Yes
N	743.00	262.00
r2	0.36	0.60

5. Discussion and implications

5.1. Discussion

Digital transformation and its impacts are currently highly debated topics among academia with many researches focusing on the business performance [4,19], organizational changes [45], operational efficiency [15], productivity [16], cost performance [7] and innovation [14,59].

Despite some studies focus on the influence of digital transformation on firms in resource and energy sectors [2,15,16,62], no prior studies have shed light on the performance impact of digital transformation in utilities sector nor mechanism that lies in such influence. To address this research gap, the authors examined all listed utility firms in China, resulting in 1005 firm-year observations. The study investigated the relationship between digital transformation and utility firm performance, alongside mediation and moderation mechanisms.

The empirical findings in the study, which passed robustness and endogenous tests, confirm our hypothesis. They show a positive coefficient of 0.104 at a significance level of 1 %, substantiating the presence of a positive relationship between digital transformation and utility firm performance. This positive association is attributed to digital transformation's positive impact on productivity [48], cost reduction [11] and innovation performance [4]. Tobin's q ratio is used in this study as a proxy for measuring utility firm performance. This approach offers a forward-looking perspective compared to accounting-based measures, which are restricted to past performance and do not incorporate future considerations [29].

In addition, considering the effect of digital transformation on alleviating financial constraints [54,56] and its role in the betterment of firms performance [15], this study has proposed the hypothesis that digital transformation can mitigate financial constraints, subsequently driving improvements in utility firm performance. Our empirical results, which show positive coefficients at a significance level of 1 % or 5 % in a two-stage regression, corroborate our initial hypothesis regarding the mediating role of financial constraints alleviation. Moreover, in terms of environmental performance, the empirical results, which show a positive coefficient at a significance level of 1 % for EP*DIGITAL, affirm our hypothesis that it moderates the association between digital transformation and utility firm performance due primarily to firms with better environmental performance signaling more positive information to external stakeholders [26].

5.2. Theoretical implications

The study theoretically broadens extant literature in regards to the impact of digital transformation on firms' performance in the context of an essential industry for modern society. Besides, environmental performance is widely regarded as determinants of a certain phenomena [17,26] or moderating role in a certain relationship [63] or outcomes of digital transformation [62,64], but in this paper, it plays a moderating role in the digital transformation's impact on utility firm performance. The rationale behind it is that utility firms are more focused by the public as it provide essential services to household and they are more likely exposed to market and investors. Better environmental performance may suggest that firms are operating in a good condition and manner, and are more likely get favored by investor.

5.3. Managerial implications

Based on the findings, the authors suggest utility firms embrace digital transformation as it could enhance a firm's performance in a long run. The private information that the management holds is a double-edged sword, as it though protects companies from the leak of competitive secrets but hinders companies cooperating with others. Therefore, digital transformation supports utility firms in alleviating financial constrains due to less information asymmetry with financial institutions. Furthermore, utility companies should be aware of its practice in environment performance as the public and investors are more focused on it. Finally, private utility companies should be more committed to digital transformation as their performance improvement could get more benefits from such strategy than state-owned companies.

5.4. Research limitations and future research directions

Despite the theoretical and practical contributions made by this study, there are still some limitations. First, the independent variable, degree of digital transformation, is arrived at based on textual analysis of corporate annual reports, which may deviate true degree of digital transformation of utility firms. Future studies could use a more comprehensive framework comprising of incorporate strategies, phases and other indicators to systematically evaluate a firm's digital transformation level. Second, the sample is constructed based on utility firms in China. Therefore, the results may have limited generalization. Future researches could expand sample size and incorporate utility firms in both developed and emerging market. Moreover, understanding the drivers of digital transformation success warrants further investigation to guide organizations in effective implementation of such strategies [65].

6. Conclusion

Current studies extensively explore digital transformation's impact on various business aspects, yet a research gap exists concerning its influence on the utilities sector and associated mechanisms. This study addresses this gap by examining all listed utility firms in China, comprising 1005 firm-year observations. The findings contribute to literature by uniquely investigating the positive relationship between digital transformation and utility firms' performance. Financial constraints' alleviation is identified as a potential mechanism, and environmental performance emerges as a moderating factor. The study recommends utility firms embrace digital transformation for long-term performance benefits, emphasizing its role in alleviating financial constraints and highlighting the importance of environmental performance to the public and investors, particularly for private ones.

Data availability

Data will be made available on request.

Additional information

No additional information is available for this paper.

Level	Indicator	Key words
Technology	Artificial Intelligence	artificial intelligence, machine learning, face recognition, business intelligence, identity verification, deep learning, biometrics, investment decision support system, image understanding, semantic search, voice recognition, natural language processing
	Big Data	big data, mixed reality, data visualization, data mining, text mining, virtual reality, heterogeneous data, credit reporting, and augmented reality
	Cloud Computing	EB level storage, multi-party secure computing, brain-like computing, streaming computing, green computing, in-memory computing, cognitive computing, fusion architecture, graph computing, information physics systems, billion level concurrency, cloud computing
	Block Chain	Differential privacy technology, distributed computing, block-chain, digital currency, consensus mechanism, smart contracts, decentralization
Application		B2B, B2C, C2B, C2C, Fintech, NFC payment, O2O, third-party payment, e-commerce, Industrial Internet, Internet finance, Internet health, financial technology, open banking, quantitative finance, digital finance, digital marketing, Internet

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(*continued*)

Level	Indicator	Key words
		connection, unmanned retail, Internet of Things, mobile Internet, mobile payment, smart agriculture, smart wear, smart grid, smart environmental protection, smart robots, smart home Intelligent transportation, intelligent financial contracts, intelligent customer service, intelligent energy, intelligent data analysis, intelligent investment advisory, intelligent culture and tourism, intelligent healthcare, intelligent marketing, autonomous driving

CRediT authorship contribution statement

Disheng Wang: Writing – original draft, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Xiaohong Xia:** Writing – review & editing, Visualization, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Xiaohong Xia reports financial support was provided by Bureau of Science and Technology Nanchong City. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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