Digital Transformation, Dynamic Capability and Green Technology Innovation: Empirical Evidence Based on Text Analysis Methods

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Abstract: Digital transformation is one of the important ways for enterprises to enhance their core competitiveness and achieve sustainable development. Based on the data of listed resource-based enterprises in China from 2012 to 2019, this paper uses python and crawler technology to collect the key words of "digital transformation" in the annual report of enterprises, and combines the dynamic capability theory and social network theory to empirically test the impact of digital transformation on enterprises' green technology innovation and its transmission mechanism. The research found that digital transformation can significantly improve the level of green technology innovation of enterprises; Digital transformation has a significant positive impact on innovation ability, growth ability and resource integration ability; Innovation ability, growth ability and resource integration ability all have a partial intermediary effect between digital transformation and green technology innovation. The research conclusion provides research ideas for the follow-up resource-based enterprises to promote green technology innovation and guide the digital transformation of enterprises.

Keywords: Digital Transformation, Text Recognition, Dynamic Capability, Green Technology Innovation.

1 INTRODUCTION

With the development of big data, cloud computing and other technologies, the digital economy has gradually become an important support for high-quality economic development. The progress of digital economy can reduce the consumption of social resources and energy, and consider economic and ecological benefits. Under this background, resource-based enterprises with the characteristics of serious environmental damage, low resource utilization and high energy consumption complete the digital transformation and promote green technology innovation has profound significance.

The application of digital technology can reshape the internal management mechanism of enterprises [18], promote the intelligent production management of enterprises, and enhance the collaborative innovation ability of enterprises [8]. The progress of digital technology has created opportunities for enterprise innovation, but only a few scholars have linked digitization with enterprise green technology innovation. According to the literature review, the existing research on the mechanism of digital transformation and green technology innovation of enterprises is

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not sufficient, and at the same time, the research on dynamic capability of enterprises is also ignored. The dynamic capability is the ability to organize and coordinate internal and external resources to respond more flexibly to the unstable external environment [21]. Based on this, it is of profound practical significance to study the relationship between digital transformation and green technology innovation of listed resource-based enterprises in China.

The possible research contributions of this paper are as follows: on the one hand, it explores the mechanism between digital transformation and green technology innovation, and reveals the internal mechanism of dynamic capability of enterprises; On the other hand, it provides constructive solutions for green technology innovation of resource-based enterprises and provides reference for subsequent relevant research.

2 LITERATURE REVIEW

2.1 Dynamic Capability

Teece et al. (1997) first believed that dynamic capability is the ability of enterprises to integrate, build and reconfigure internal and external resources. Dynamic capability includes adaptability, absorption, and innovation. Adaptability refers to the ability of an organization to identify and seize opportunities, and absorptive ability refers to the ability of an organization to identify, absorb and apply new information, and innovative ability represents the ability of an organization to create new products and explore new markets [24]. Based on the actual situation of Chinese enterprises, scholars have different views. For example, He et al. (2006) believed that dynamic capability can be divided into market potential, organizational flexibility, strategic isolation, organizational learning， and organizational change; Luo et al. (2009) found that dynamic ability consists of absorption ability, perception ability, relationship ability and integration ability. Dynamic capability is a high-level capability of an organization, which can change ordinary capabilities [28]. The simple application of digital technology is a shallow capability that is easy to be imitated [16], but digital transformation can promote the improvement of dynamic capability, enabling enterprises to quickly adjust their production and operation activities to meet the challenges brought by the changes in the internal and external environment [13].

2.2 Digital Transformation and Green Technology Innovation

According to the social network theory, social networks breed innovative activities [17]. When organizations are faced with development bottlenecks, they usually choose to seek cooperation with organizations that complement their own capabilities through social networks (Croft et al. 2006). In the era of digital economy, digitalization has changed the technological and economic environment and the operation of social institutions [12], and social networks have expanded rapidly.

Green technology innovation is a series of creative activities that follow ecological laws, reduce environmental pollution and energy and resource consumption, and achieve sustainable development [11]. On the one hand, resource-based enterprises face the problem of high technical complexity and weak independent innovation capability. On the other hand, they face high risks due to the impact of policy and market uncertainty [6]. In this context, digitalization can help resource-based enterprises greatly expand social networks, share technology dividends [4], and spread risks through cooperation. The following assumption is derived:

Hypothesis 1. Digital transformation is positively affecting green technology innovation.

2.3 The Intermediary Role of Dynamic Capability

Digital technology is radically changing business networks and key inter-enterprise relationships [5]. Digital transformation is not only the process of updating the production mode of the organization, but also the process of building dynamic capability for the continuous strategic update of the organization [26]. Using the digital infrastructure such as the Internet of Things and the platform based on artificial intelligence, enterprises can collect and analyse large-scale real-time data for forecasting [7], greatly improving the dynamic ability of enterprises to respond to environmental changes. The following assumption is derived:

Hypothesis 2. Digital transformation is positively affecting dynamic capability.

According to the theory of dynamic capability, dynamic capability is the core driving factor of strategic renewal [3], which can improve the green innovation performance of enterprises [15]. Therefore, enhancing dynamic capability is the strategic choice for the transformation and upgrading of resource-based enterprises in the future. With reference to Teece et al. (1997), Wang et al. (2007) and other studies, this paper divides dynamic capability into innovation capabilities, growth capabilities and resource integration capabilities. Among them, the integration ability is the ability to achieve sustainable and green development through operation and integration of resources [20]; Innovation capability is the ability of enterprises to explore innovative technologies and unknown fields [30] and respond quickly to changes in cutting-edge information of green innovative technologies; The growth ability lays the material foundation for the long-term green technological innovation of enterprises. Lack of resources will have a negative impact on innovation [1]. Digital transformation improves the ability of integrating resource. Stakeholders of green technology innovation can achieve collaborative research and development and resource connectivity by building innovation alliances. Based on this, the following assumptions are made:

Hypothesis 3a. Innovation ability positively affects green technology innovation;

Hypothesis 3b. The ability of resource integration has a positive impact on green technology innovation;

Hypothesis 3c. Growth ability is positively influ-encing green technology innovation.

As mentioned above, digital transformation has improved the dynamic capability of resource-based enterprises. On the one hand, the ability of enterprises to utilize resources is enhanced, and on the other hand, it provides new opportunities for enterprises to explore green technology innovation. It can be seen that digital transformation fosters dynamic capability of enterprises to promote green technology innovation, and dynamic capability plays an intermediary role between the two. To sum up, the following assumptions are made:

Hypothesis 4. Digital transformation has a positive impact on green technology innovation through dynamic capability.

Based on the above discussion, the theoretical research framework of this paper is constructed, as shown in Figure 1:

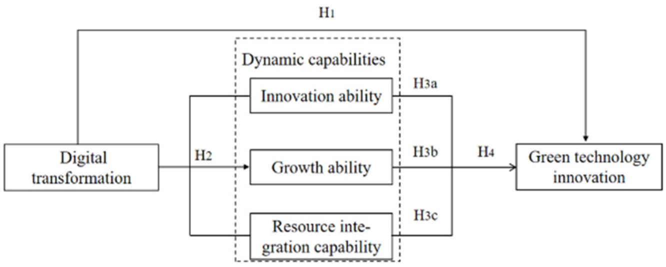

Figure 1: The theoretical framework of this paper.

3 METHODOLOGY

3.1 Data Collection

Resource-based industries can be divided into narrow sense and broad sense. With reference to the relevant literature [19, 25], this paper chooses its narrow definition, namely, the industry of mining, washing and primary processing of energy and mineral resources.

Considering the availability of data and the convenience of research, this paper takes the resource-based enterprises listed in Shanghai and Shenzhen A-shares in China from 2012 to 2019 as a sample, and excludes the enterprises with ST and * ST and those with serious data loss. Enterprise financial indicator data comes from CSMAR database, and green patent data comes from CNRDS database. After screening, 250 enterprises with a total of 2000 observations were finally determined. In addition, in order to reduce the impact of extreme values on the model, the upper and lower 1% quantiles of all continuous variables are shrunk.

3.2 Measures

3.2.1 Interpreted Variable

Green technology innovation level. Green invention patents can measure the level of green technological innovation of enterprises. With reference to the research of Tang et al. (2022), this paper selects the number of green patent applications add 1 and then takes the logarithm as the measurement index of green technological innovation of enterprises.

3.2.2 Explanatory Variable

Digital transformation level. With the progress of natural language processing (NLP) and other technologies, text analysis has been used by scholars in the fields of economics and management in the past two years. Referring to Wu Fei et al. (2021) (Wu et al. Further, the word frequency of the words related to "digital technology application" in the annual report of the sample enterprises is counted. In order to improve the accuracy and matching of word frequency analysis, this paper constructs a digital word segmentation dictionary from six dimensions: intelligent production, mobile internet, digital technology, data management, modern information system, and universal digitalization, and then carries out word frequency statistics. Finally, the frequency of the calculated digital technology application-level word is processed with logarithm to make its distribution more stable.

3.2.3 Intermediary Variable

As mentioned above, this paper selects innovation ability, resource integration ability and growth ability as the dynamic capacity proxy variables of this study. Among them, the innovation ability is measured by the ratio of R&D expenditure to operating income with reference to the research of Guo et al., (2019); The resource integration capacity is measured by the ratio of net profit to the total assets of the enterprise; For growth ability, refer to Zhou (2014) and other studies, and use sustainable growth rate to measure the sustainable development ability of resource-based enterprises. Sustainable growth rate = return on net assets * earnings retention rate / (1 - return on net assets * earnings retention rate) = (net profit / total closing balance of owner's equity) * [1 - pre-dividend tax per share / (current value of net profit / current value of paid-in capital)] / (1 - numerator).

3.2.4 Control Variable

Referring to relevant research, this paper selects control variables including enterprise size, enterprise age, etc. The variables selected in this paper are described in Table 1 below:

Table 1: Variable Description.

Variable Type	Variable Name	Symbolic	Variable Definition
Control variable	Equity concentration	CR_{10}	Sum of shareholding ratio of top ten shareholders
	Enterprise age	Age	The natural logarithm of the current year minus the year of listing
	Leverage	Leverage	Total liabilities/assets
	Enterprise nature	Soe	Soe=1，Others= 0
	Enterprise size	Size	The natural logarithm of the total assets of the enterprise
	Proportion of fixed assets	Tang	Net fixed assets/total assets

3.3 Model Settings

In order to test the research hypothesis proposed in this paper, the following three models are finally set:

$$GInnovation_{i,t} = \beta_0 + \beta_1 DI + \Sigma\beta_m Control_{i,t} + \Sigma Year + \Sigma Industry + \varepsilon_{i,t} \quad (1)$$

$$Med_{i,t} = \beta_0 + \beta_1 DI + \Sigma\beta_m Control_{i,t} + \Sigma Year + \Sigma Industry + \varepsilon_{i,t} \quad (2)$$

$$GInnovation_{i,t} = \beta_0 + \beta_1 DI + \beta_2 Med_{i,t} + \Sigma\beta_m Control_{i,t} + \Sigma Year + \Sigma Industry + \varepsilon_{i,t} \quad (3)$$

Among them, i and t represent enterprises and time respectively, and GInnovation is the explained variable, representing the level of green technology innovation of enterprises. DI is the core explanatory variable, representing digital transformation level. Med includes three intermediary variables, namely innovation ability, growth ability and resource integration ability. Control indicates a series of control variables, such as enterprise scale. ε Represents the random error term of the model.

4 RESULTS AND DISCUSSION

4.1 Descriptive Statistical Analysis

Table 2 below shows the descriptive statistics of the main variables. The maximum value of GInnovation is 4.2973, the minimum value is 0, and the standard deviation is 1.0469. There is a large difference in the level of green technology innovation among enterprises, which is basically consistent with the existing research results. The maximum value of DI is 4.4128, the minimum value is 0, and the standard deviation is 1.0112, which also reflects the large differences in the application of digital technology among enterprises, and is consistent with the slow digital transformation of resource-based enterprises. The maximum value of innovation capacity is 0.0795, the average value is 0.0225, and the median value is 0.0209, which indicates that a considerable number of resource-based enterprises have innovation levels above the average level, reflecting the overall high innovation capacity.

Table 2: Descriptive statistical results of variables

Variables	N	Mean	S.D.	Min	Max
GInnovation	2000	0.829	1.047	0.000	4.297
DI	2000	1.893	1.011	0.000	4.413
Age	2000	2.403	0.590	0.693	3.239
CR10	2000	58.906	15.286	23.675	92.515
Tang	2000	0.342	0.172	0.036	0.788
Size	2000	22.831	1.405	20.271	26.602
Soe	2000	0.535	0.499	0.000	1.000
Leverage	2000	0.476	0.192	0.093	0.908
Innovation	2000	0.023	0.018	0.000	0.080
Growth	2000	0.035	0.101	-0.411	0.397
Integration	2000	0.029	0.051	-0.164	0.184

The correlation analysis shows that DI, Inno-vation, Growth, and Integration are all related to GInnovation, and through the significance test at the level of 1%, the variable selection is representative; At the same time, the level of digital transformation is also significantly related to innovation ability, growth ability and resource integration ability, and has passed the significance test of 1% level. Further, the variance expansion factor of all variables is calculated, and the mean value is 2.14, which is far less than 10, indicating that there is no multicollinearity problem.

4.2 Regression results

The results of regression analysis are shown in Table 3 and Table 4 below. Model (1) is the benchmark regression model of this paper, which only adds all control variables. Model (2) adds digital transformation level (DI) to the benchmark regression model, and it can be found that the coefficient is 0.096, and it has passed the significance test at the level of 1%. Hypothesis 1 has been verified, and the improvement of digital transformation level is conducive to improving the level of green technology innovation of enterprises.

Table 3: Regression analysis results (Model 1-4)

	Explained variable			
	GInno	GInno	Inno	GInno
Explanatory variable	Model(1)	Model (2)	Model (3)	Model (4)
DI		0.096***	0.003***	0.083***
		-4.6	-7.02	-3.94
Innovation				4.997***
				-4
Growth				
Age	-0.078*	-0.114**	-0.005***	-0.089*
	(-1.73)	(-2.50)	(-6.16)	(-1.94)
CR10	-0.002	-0.002	-0.000***	-0.001
	(-1.23)	(-1.20)	(-2.94)	(-0.94)
Tang	-0.240*	-0.195	0.001	-0.202
	(-1.81)	(-1.47)	-0.6	(-1.53)
Size	0.420***	0.400***	-0.003***	0.414***
	-21.25	-19.87	(-8.11)	-20.34
Soe	0.137***	0.175***	-0.001	0.179***
	-2.61	-3.32	(-0.72)	-3.39
Leve	-0.613***	-0.545***	-0.016***	-0.467***
	(-4.88)	(-4.33)	(-6.99)	(-3.68)
Constant	-8.150***	-7.863***	0.108***	-8.405***
	(-21.56)	(-20.62)	-15.91	(-20.84)
Observations	2,000	2,000	2,000	2,000
R^2	0.258	0.266	0.213	0.272

Table 4: Regression analysis results (Model 5-8)

	Explained variable			
	Growth	GInno	Integ	GInno
Explanatory variable	Model (5)	Model (6)	Model (7)	Model (8)
DI	0.004*	0.095***	0.002*	0.094***
	-1.73	-4.52	-1.72	-4.51
Innovation				
Growth		0.474**		
		-2.28		
				1.083**
				-2.43
Age	0.011**	-0.119***	0.005**	-0.119***
	-2.2	(-2.62)	-2.26	(-2.63)
CR10	0	-0.002	0	-0.002
	(-0.56)	(-1.17)	-1.43	(-1.28)
Tang	-0.026*	-0.182	-0.012*	-0.182
	(-1.85)	(-1.38)	(-1.74)	(-1.38)
Size	0.017***	0.392***	0.009***	0.390***
	-7.85	-19.2	-9.33	-18.98
Soe	-0.020***	0.185***	-0.016***	0.193***
	(-3.52)	-3.49	(-5.94)	-3.61
Leve	-0.157***	-0.471***	-0.122***	-0.412***
	(-11.62)	(-3.62)	(-19.38)	(-3.01)
Constant	-0.286***	-7.728***	-0.138***	-7.714***
	(-6.97)	(-20.05)	(-7.20)	(-20.00)
Observations	2,000	2,000	2,000	2,000
R^2	0.09	0.268	0.208	0.268

Further, this paper uses the research of Wen et al. (2014) for reference to test the intermediary effect. Model (3) tests the relationship between digital transformation level and innovation capability, and the result shows that there is a significant positive correlation (1% level) between the two. Model (4) adds digital transformation level and innovation capability to the benchmark model at the same time. It can be seen from the table that the regression coefficient of digital transformation decreases from 0.096 to 0.083, but it is still significant, indicating that there is a mediating effect between innovation capability and digital transformation level and green technology innovation. Hypothesis 2 Assumption 3a holds; The model (5) test found that there was a significant correlation between growth ability and digital transformation. The model (6) that included both digital transformation level and growth ability in the benchmark regression model found that the regression coefficient was still significant (at the level of 1%) before digital transformation, and the regression coefficient was reduced, so the hypothesis 3c was established; The model (7) test found that there is a significant correlation between the resource integration capability and the digital transformation level. After the digital transformation and resource integration capability are added, the regression coefficient before the digital transformation level is still significant (1% level). Therefore, assuming that 3b is established, the resource integration capability has a mediating effect between the digital transformation and green technology innovation.

In order to enhance the reliability of the intermediary effect test, Sobel test and nonparametric percentile Bootstrap test are conducted in this paper. Sobel test results show that Z value is 3.45, which is significant at 1% level. The Bootstrap sampling method is set to 5000 times. The results show that the 95% level confidence interval of the direct effect is (0.006, 0.0202), and the 95% level confidence interval of the indirect effect is (0.041, 0.125). It can be seen that the confidence interval of both effects does not contain 0, and both effects pass the 1% level significance test, which once again proves that the intermediary effect exists.

4.3 Robustness

In order to further increase the explanatory power of the model, this paper makes the following robustness tests: (1) The explained variable lags. The green patent itself has a certain time lag effect, so the green technology innovation level is added to the model after a period of lag, and the results are basically consistent with the previous research conclusions; (2) Tendency score matching method (PSM). Influenced by many factors, the level of green technology innovation, the level of digital transformation, and the dynamic capacity variables may have a causal relationship with each other, and the existence of self-selection of samples may lead to the existence of endogenous problems in the model. This paper uses the method to further test. The results showed that the t-test before unmatching was significant (7.98), and the average processing effect () after matching was still significant (t statistic value was 3.00).

5 CONCLUSIONS

Based on the sample of resource-based enterprises listed in Shanghai and Shenzhen A shares in China, this paper empirically tests that digital transformation has a positive effect on improving the level of green technology innovation of enterprises. It uses the sequential test method, Sobel test and Bootstrap method to test the dynamic capability including innovation ability, growth ability and resource integration ability to play an intermediary role between digital transformation and green technology innovation, It reveals the internal mechanism of the impact of digital technology on green technology innovation. Finally, the following conclusions are drawn: the digital transformation has significantly improved the level of green technology innovation of enterprises. The specific transmission mechanism is that enterprises can improve the application level of digital technology to enhance the higher level of dynamic capability, enable technological innovation, and improve the level of green technology innovation.

Resource-based enterprises should accelerate the digital transformation, introduce green and intelligent production and manufacturing equipment, and comprehensively promote the deep integration of digital technology and green technology innovation, to improve the efficiency of resource and energy utilization and achieve win-win economic and ecological benefits. In addition, make full use of digital technology to break information barriers and improve dynamic capability.

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