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Research on the Practical Path of Resource-Based Enterprises to Improve Environmental Efficiency in Digital Transformation

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Abstract: Increasingly serious environmental problems force resource-based enterprises to find effective means to break through the original resource dilemma. With the acceleration of the digital transformation process, digital technology can guarantee the green transformation process and realize the sustainable development of economic growth and environmental protection. Based on the perspective of efficiency, this paper selects 46 resource-based enterprises as research object, adopts a strategic triangle research framework of "operational capability–policy environment–value objective" and, through the fuzzy-set qualitative comparative analysis method, analyzes the formation mechanism and practice pathways of sustainable development in the resource-based enterprises' digital transformation. Research suggests that: (1) The realization path of high-level enterprise environmental efficiency includes four configurations: technology guarantee type, strategy driven type, pressure lead type and policy pulled type. (2) The characteristics and strategies of resource-based enterprises using digital technology to deal with changes in the business environment and achieve sustainable development can be divided into two models: the "capability-oriented" model and "environment-oriented" model. (3) The heterogeneity study shows that the green development of the power supply industry and the material processing industry is more suitable for the "capability-oriented" model, and the green development of the iron and steel manufacturing industry and energy extraction industry is more suitable for the "environment-oriented" model. The research results can provide a new theoretical perspective and strategy for resource-based enterprises to use digital technology for green development and provide a new optimization pathway for China's industrial practice.

Keywords: digital technology; sustainable development; strategic triangle model; environmental efficiency; qualitative comparative analysis

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1. Introduction

The development of resource-based enterprises is limited by the non-renewability of natural resources. Their traditional business model and prominent externalities leads to irreversible damage to the ecological environment [1,2]. Therefore, the sustainable development of resource-based enterprises is an urgent realistic issue [3]. The 14th Five-Year Plan for China's economic and social development takes the green development of resource-based enterprises as a core issue and proposes to accelerate industrial transformation and upgrading and the conversion of old and new energy. Additionally, the direction of green and low-carbon development was adjusted to digital transformation [4–6]. At the same time, a variety of environmental policy tools have also prompted resource-based enterprises to apply digital technology to break through the original development model of heavy pollution and high energy consumption and take green innovation based on the advantages of resource endowments to achieve the goal of green development [7,8]. In addition to appropriate policy guidance, there is a wealth of successful digital applications cases in China, such as digital monitoring and digital energy saving applications. At present, the practical value of digital technology for environmental protection and green transformation is gradually spreading to resource-based enterprises, breaking the boundary of green innovation and providing a strong guarantee [9,10].

Digital transformation will cause resource-based enterprises to face more severe social and environmental pressures and industry development challenges and, at the same time, provide new opportunities for sustainable development. Resource-based enterprises can use digital technology to realize the efficient flow of green innovation resources [11–13], and good policies and institutional innovation mechanisms also provide a strong guarantee [14–16]. At present, Chinese resource-based enterprises have carried out a series of digital practices around sustainable development goals [17,18]. For example, China Nanjing Iron & Steel Co., Ltd. has comprehensively promoted in-depth digital transformation, built a global data governance system, reduced the cost of production and realized the development of green energy driven by data. Enterprises relying on artificial intelligence, Internet of Things and big data analysis can carry out efficient business practices [19], thereby reducing carbon emissions and waste of other environmental resources, verifying the effectiveness of digital technology in improving the environmental performance by comparing nine cases in different countries. Current Chinese enterprises' practice and theoretical research shows that it is a relatively complicated process for digital development to promote resource-based enterprises to achieve green development [20], which will be affected by many aspects such as the internal resource endowment of enterprises and the external policy environment [21,22]. Therefore, exploring how digital technology can help resource-based enterprises to quickly achieve sustainable development of environmental benefits is a practical problem that enterprises, governments and academia need to solve urgently.

Based on the above research, this paper focuses on the interaction mechanism of digital transformation on the green development of resource-based enterprises. Among them, some scholars have carried out related research on this issue [23–26], but there are still the following shortcomings: Firstly, although the existing research provides relevant reference for the sustainable development of resource-based enterprises, they are all from the perspective of environmental results, which make it impossible to explore the vitality and potential of sustainable development. Secondly, the improvement of environmental efficiency of resource-based enterprises is interdependent rather than independent of conditions. The existing empirical analysis literature is mainly based on statistical regression to explore the marginal net effect of a single factor, which limits the choice of pathways for improving environmental efficiency. Thirdly, in the process of practice, the green transformation of resource-based enterprises is the interaction and matching relationship between the synergistic linkage of different conditions and the result. However, the existing research has not paid attention to the complexity of the causal relationship of the environmental efficiency of resource-based enterprises.

In conclusion, this paper proposes the following three related questions in view of the existing research shortcomings: (1) How can resource-based enterprises make full use of digital technology to achieve sustainable development? (2) What are the factors influencing the sustainable development of resource-based enterprises in the context of digital transformation? (3) What are the mechanisms and practical paths for resource-based enterprises to achieve sustainable digital and green development? In view of this, this paper introduces the classic strategic triangle model to explore the green development mechanism of resource-based enterprises from the efficiency perspective. At the same time, a configuration analysis is widely used to study the causal complexity of the internal mechanism of complex systems [27], therefore, the fsQCA method is used to explore the complex mechanism of multiple conditional configurations during the process of using digital technology to achieve sustainable development [28]. Research shows that resource-based enterprises using digital technology can realize efficiency of enterprise environment and, at the same time, the implementation of a high-level enterprise environmental efficiency practice path is diversification and differentiation. The research results help to clarify the process and mechanism of the green development of resource-based enterprises [29–31] and further improve the connotation of resource-based enterprise environment theory.

2. Literature Review

2.1. The Background of the Resource-Based Enterprises Digital Transformation

At present, most research focuses on the digital transformation in the field of internal operation management; considering that the purpose is to optimize the level of enterprise management, improve innovation ability and achieve organizational value goals, the realization is embedding digital technology into organization. Shinkevich's [32] research shows that resource-based enterprises can effectively save petrochemical energy by using digital technology, so as to improve the efficiency of resource use. Litvinenko [33] took the Russian Federation as an example to explore the possibility of using direct-through digital technology in the exploration, design, development and utilization of mineral resources, promoting the development of applied digital technology. The above research on the digital development of resource-based enterprises shows that the impact of digital transformation is mainly reflected in the aspects of optimizing resource allocation and innovating development models. On the one hand, digital technology can not only realize the integration of various resource elements in the industry through digital infrastructure such as the Industrial Internet and improve the efficiency of resource allocation, but it can also accelerate the matching link between innovation elements, Reduce the cost of information search and resource consumption, and improve the green creativity of resource-based enterprises [34]. On the other hand, digital technology can improve the production process, improve the accuracy of production process management, realize the "double improvement" of production efficiency and energy saving and emission reduction, accelerate the construction of a green and low-carbon industry system and reduce energy utilization, provide effective technology supply to these resource-based enterprises with a low degree of industrial chain perfection, fully stimulate the green vitality and development potential of enterprises [35] and help them break through the limitations of their original resource endowments.

Under the all-round reshaping of the business model, innovation processes and social green demand of resource-based enterprises by digital technology, the sustainable development ability of resource-based enterprises cannot be fully reflected from the perspective of environmental performance and other results. Therefore, it needs to be analyzed from a more comprehensive efficiency perspective. Environmental efficiency, also known as ecological efficiency, is an important indicator to measure the sustainable development capability of an enterprise. The World Business Council for Sustainable Development defines environmental efficiency as a business development concept for the first time, defines it as the value environmental load of environmental efficiency products or services and uses the ratio of the economic added value of production activities to the environmental damage brought as the evaluation standard of environmental efficiency [36–38]. In addition, although digital transformation is one of the solutions of sustainable development, it can also effectively reduce the pollution of resource-based enterprises and improve the environmental efficiency of enterprises, but it will bring in the process of transformation of development such as digital carbon printing; 3D printing increases carbon dioxide and other greenhouse gases [39], on the basis of a study exploring how, through digital means, to effectively improve the environmental efficiency of resource-based enterprises. At the same time, in the process of continuous digital transformation, it is inevitable for resource-based enterprises to quickly apply and absorb the technological dividends brought by digital technology. In order to fully reveal the complex mechanism between digital technology and the green sustainable transformation of resource-based enterprises, this paper selects environmental efficiency as a result which cannot only take into account both the effect and quality of green transformation [40] but can reflect the sustainable development vitality of resource-based enterprises in the context of digitalization

2.2. Sustainable Development of Resource-Based Enterprises under Digital Transformation

It has become necessary for resource-based enterprises to carry out green innovation activities through digital technology to adapt to the trend of digital development and improve the environmental efficiency of enterprises. With the all-round reshaping of resource-based enterprises' innovation methods, resource matching and business environment due to digital transformation, enterprises not only need to deeply integrate digital technology with enterprise value orientation but also need to achieve an interaction model between green goals and digital applications; it is also necessary to match digital technology with the external environment, such as regional policies where the enterprise is located. This study mainly discusses the digitalization process in resource-based enterprise sustainable development from the following three aspects.

2.2.1. Operational Capability

Operational capability mainly emphasizes the interaction situation between resource-based enterprises and digital technology and the impact of the interaction between organization and technology on green value creation, which is mainly reflected in digital leadership and digital technology capability. Among them, digital leadership can reflect digital strategic and talent development planning, enhance the adaptability of digital technology through the reconstruction of strategy and value and break through the original path to achieve green and low-carbon development [41,42]. Furthermore, managers with higher digital leadership levels can quickly perceive the changes and disruptions brought about by the digital environment, improve the organization's technical operation capabilities and digital management efficiency in all aspects and lay a solid foundation for the sustainable and green development of enterprises [43,44]. Digital capability is specifically represented by the degree of resource endowment of an organization's application of digital technology, which can reflect an enterprise's ability to master and respond to the digital environment. It can reduce the cost of technology application, improve the efficiency of technology [45,46], promote resource-based enterprises to expand the path of green transformation, accelerate the process of green value creation and then significantly improve environmental efficiency.

2.2.2. Policy Environment

The policy environment focuses on examining the interaction between stakeholders in the external environment and the application of digital technology in resource-based enterprises. According to the theory of resource dependence, the organization needs to cooperate with the external environment for symbiotic development, which is mainly reflected in the government support and regional environmental governance for resource-based enterprises [47–49]. By providing policy support, financial subsidies and tax incentives to enterprises, the government breaks the resource constraints faced by enterprises in the process of digital innovation and provides a good policy atmosphere for the green development of enterprises. At the same time, digital policies can stimulate the abundance of digital resources and public digital demand in the region and improve the digital industrial cooperation network for regional development [50,51]. In particular, under environmental regulation, enterprises actively responding to the government's green demand can establish a positive image for them, and it is easier to obtain government policy inclination and external social financing, offsetting the compliance cost brought by environmental regulation [52]. In addition, reasonable environmental regulation will not only reduce the cost burden of resource-based enterprises but also force them to carry out technological innovation by imposing necessary environmental constraints, thereby improving environmental efficiency [53].

2.2.3. Value Objective

The value objective primarily focuses on exploring how organizations can integrate digital technologies to achieve established sustainability development goals, which is mainly reflected in the environmental information disclosure and green technology innovation. Among the value objectives, environmental information disclosure can reflect the environmental protection awareness of the enterprise, establish its image with a high sense of social responsibility [54,55] and enhance the comprehensive competitiveness of the enterprise [56]; at the same time, active disclosure is also an effective way for the government and the public to supervise the enterprise. By expanding the channels and scope of social stakeholders' information on management and operation, energy conservation and emission reduction, the trust and support of the government, the public, investors and other entities to the enterprise will be further enhanced [57,58]. This can play a positive role in improving the environmental efficiency of enterprises [59,60]. Green technology innovation is the technological innovation and improvement of energy saving, pollution prevention, waste recycling and green product design. Enterprises can make up for environmental costs through green technology innovation, reduce energy consumption and pollutant emissions [61]. In addition, digital technology with the characteristics of high efficiency and cleanliness can establish a closed-loop channel for green information collection and feedback and establish a two-way data interaction guarantee for environmental information disclosure [62]. At the same time, it can change the organizational structure and innovation model, provide technical support for green technology innovation, shorten the research and development cycle and reduce research and development costs, thereby improving the green innovation efficiency of enterprises [63].

2.3. Research Framework

The green practices of resource-based enterprises have huge differences in terms of digital technology endowments, organizational value objectives and external authorization environments. At the same time, multiple influencing factors will have complex interactions, and synergies will be generated through the linkage matching process. Therefore, this paper adopts the strategic triangle framework to explore the green development mechanism and formation path of resource-based enterprises under digital transformation. Specifically, referring to the strategic triangle model [64], a research framework including operational capability, policy environment and value objective is constructed. The internal logic of the model for public value creation is consistent with the green value of resource-based enterprises in this study and is used to analyze the application situation of technology, the value objective of the organization and the coupling relationship between technology and policy environment. Operational capability is used to analyze the coordination relationship between technology and organizational structure, application capabilities and potential benefits; the policy environment includes the organization's policy and institutional background and regional economic environment, and the value objective primarily reflects the planning choices that an organization implements to achieve its goals.

At present, there is a wealth of empirical research around the strategic triangle model in differentiated technical contexts, especially in the fields of business and public management, which have opened up a research paradigm that combines theoretical analysis and empirical application. For example, Chul [65] used the strategic triangle model and public value model to examine the importance of public value in public sector policy decision making and enhances the internal power of regions in socio-economic and cultural aspects through the analytical framework. Brandt [66] used a strategic, data-driven triangle model of "value, legitimacy, and operational capabilities" to evaluate a departmental normative analysis plan, building six guiding issues of the evaluation process. This paper draws on the existing research results, combines the status of digital development in China, the practical foundation of resource-based enterprises and sustainable development goals and builds a strategic triangle model, as shown in Figure 1.

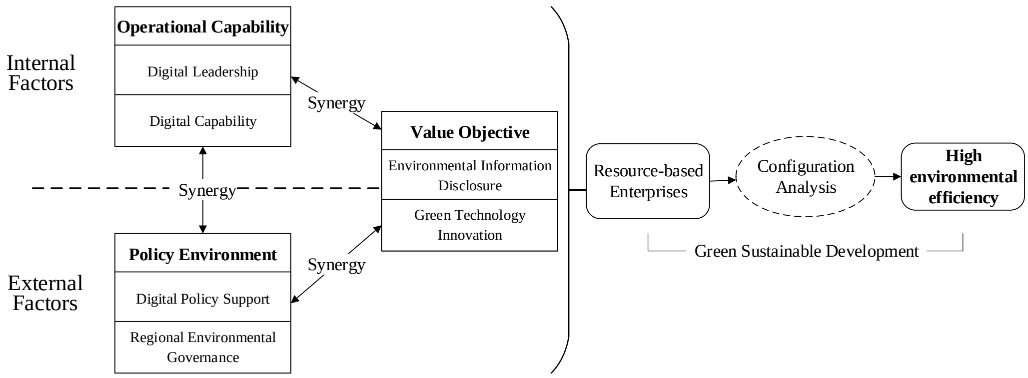

Figure 1. The Research Framework.

3. Materials and Methods

3.1. Method

Fuzzy qualitative ratio analysis (QCA) can realize the matching combination of different conditions to produce the same result through multi-case analysis, and then dig out the synergistic effect of multiple condition configurations based on the causal complexity [67]. QCA includes three types of multi-valued sets: Mv QCA, clear set (Cs QCA) and fuzzy set (Fs QCA). Since the variables in this study are continuous, and there is an interactive synergistic effect between multiple variables, single-dimensional research cannot deeply explore the internal synergy mechanism of resource-based enterprises' green development. Therefore, this paper adopts the fuzzy set qualitative ratio method (Fs QCA) to explore the collaborative mechanism and formation path of the sustainable development of resource-based enterprises under digital transformation.

3.2. Data Sources

The existing research on the definition of resource-based enterprises mainly focuses on the following two perspectives: First, based on the perspective of factor input, resource-based enterprises that are different from labor, capital, technology and other manufacturing, technology and service-oriented enterprises take natural resources as their core advantages and have a high proportion of resource consumption costs. Second, based on the perspective of resource output, resource-based enterprises are enterprises that convert natural resources into raw materials for social production and meet social needs through the exploitation and refining of natural resources. Based on a more comprehensive research sample coverage, the first definition method is more suitable for this research objective. According to the "National Economic Industry Classification", resource-based enterprises are defined as enterprises engaged in natural resource extraction, washing and primary processing industries; the specific distribution is as follows, shown in Table 1:

Table 1. Industry classification of resource-based enterprises.

Industry	Code	Firm Name
Mining and washing industry	B06	Coal mining and washing industry
	B07	Oil and natural gas extraction industry
	B08	Black metal mining industry
	B09	Non-ferrous metal mining and beneficiation industry
	B10	Non-metallic ore mining and beneficiation industry
Primary processing industry	C25	Petroleum processing and coking industry
	C26	Chemical raw materials and chemical products manufacturing industry
	C30	Non-metallic mineral products industry
	C31	Black metal smelting and calendering industry
	C32	Non-ferrous metal smelting and rolling processing industry
	C33	Metal products industry
	D44	Power and heat production and supply industry

In 2015, the Chinese Government Work Report put forward the "Internet +" action plan for the first time to promote the integration of mobile internet, cloud computing, big data, Internet of Things, etc., with modern manufacturing and promote the coordinated development of Industrial Internet and Internet Finance (ITFIN). Therefore, this paper takes resource-based companies among the A-share listed companies in Shanghai and Shenzhen from 2016 to 2020 as research object and excludes ST companies, *ST companies, companies listed after 2015 and companies that have not applied for green patents within 5 years. After companies that have not undergone digital transformation and other incomplete financial data were removed, 46 companies were selected for analysis. At the same time, from December 2020 to December 2021, we visited and investigated a number of sample companies to obtain internal first-hand data, such as corporate management and employee levels. At the same time, we consulted and obtained micro-secondary data from CSMAR databases, prospectuses, annual reports, quarterly reports, announcements, project prospectuses and official websites.

3.3. Variable Measurements

3.3.1. Result Variable

Under the dual constraints of economic development and environmental protection, environmental efficiency can effectively embed green development goals into the development process of enterprises from a macro perspective, so as to fully measure the sustainable implementation effect of enterprises on energy conservation, emission reduction and pollution control. With reference to the existing studies on super-efficient DEA models [68–70], the non-parametric analysis method is used to take fixed assets, environmental protection expenditures and the number of employees as inputs and use the added value of the enterprise as the output to calculate environmental efficiency. This paper chooses to average environmental efficiency. The calculation result of the super-efficiency model is a relative value. The larger the value, the better the effect. The calculation formula is as follows:

$$\min\rho = \frac{1+\frac{1}{m}\sum_{i=1}^{m}\frac{S_i^-}{X_{ik}}}{1-\frac{1}{q_1+q_2}\sum_{r=1}^{q_1}\frac{S_r^+}{Y_{rk}}+\sum_{t=1}^{q_2}\frac{S_t^{b-}}{b_{tk}}}$$
$$\text{s.t.}\begin{cases}\sum\limits_{j=1,j\neq 1}^{n} X_{ij}\lambda_j - S_i^- \leq X_{ik} \\ \sum\limits_{j=1,j\neq 1}^{n} Y_{ij}\lambda_j + S_r^+ \geq Y_{rk} \\ \sum\limits_{j=1,j\neq 1}^{n} b_{tj}\lambda_j - S_t^{b-} \leq b_{tk} \\ 1-\frac{1}{q_1+q_2}\left(\sum\limits_{r=1}^{q_1}\frac{S_r^+}{Y_{rk}}+\sum\limits_{t=1}^{q_2}\frac{S_t^{b-}}{b_{tk}}\right) > 0\end{cases} \tag{1}$$

where:

$\lambda, s^-, s^+ \geq 0$; $i = 1, 2, \ldots, m$; $r = 1, 2, \ldots, q_1$; $t = 1, 2, \ldots, q_2$; $j = 1, 2, \ldots, n$ $(j \neq k)$;

ρ is the environmental efficiency value of resource-based enterprises, $\rho < 1$ is invalid, $\rho \geq 1$ is valid and the larger the value of ρ, the higher the environmental efficiency;

n is the number of decision-making units, which are composed of input m, expected output q_1 and non-expected output q_1;

S_i^-, S_i^+ are the relaxation variables of input and output;

X_{ik}, Y_{rk} and b_{tk} are the elements of the matrix of input, expected output and undesirable output;

λ is the weight vector.

3.3.2. Conditional Variable

Digital leadership is reflected in digital strategy and talent development. Its deep-level changes require the full support and promotion of managers to ensure the implementation of top-level design. This study refers to the existing study [71,72], using high-level talents as a proxy variable to measure the proportion of the number of employees with intermediate professional titles or above or the number of people with master's degree or above in the total number of employees. Referring on the structured feature word map of enterprises' digital capabilities [73], the text analysis function of Python software was used to count relevant keywords in enterprise annual reports, announcements and official websites, as shown in Table 2. The digital capability of an enterprise is calculated by the ratio of the frequency of disclosure (the product of the number of keywords and the frequency of occurrence) to the total number of words in the text.

Table 2. Structured feature word graph of enterprise digital capability.

Classifications	Digital Foundation	Digital Application
Artificial Intelligence Technology	Artificial Intelligence, Business Intelligence, Image Understanding, Investment Decision Assistance System, Intelligent Data Analysis, Intelligent Robot, Machine Learning, Deep Learning, Semantic Exploration, Biometrics Technology, Face Recognition, Speech Recognition, Identity Authentication, Autonomous Driving, Natural Language Processing	Industrial Internet, Industrial Internet, Internet Solutions, Internet Thinking, Internet Action, Internet Business, Internet Application, Internet Strategy, Internet Platform, Internet Model, Internet Ecology, Internet, Networking, Smart Energy, Intelligent Transportation, Intelligent Investment, Intelligent Environmental Protection, Smart Grid, Smart Factory, Smart Logistics, Intelligent Manufacturing, Intelligent Management, Intelligent Production, Intelligent Control, Information Integration, Information System, Automatic Control, Automatic Monitoring, Automatic Monitoring, Automatic Detection, Automatic Production Digital Control, Industrial Information, Industrial Communications, Future Factory, Unmanned Retail, Virtual Manufacturing, Integration
Big Data Technology	Big Data, Data Mining, Text Mining, Data Visualization, Heterogeneous Data, Credit Investigation, Augmented Reality, Mixed Reality, Virtual Reality	
Cloud Computing Technology	Cloud Computing, Stream Computing, Graph Computing, In-Memory Computing, Multi-Party Secure Computing, Brain-Like Computing, Green Computing, Cognitive Computing, Converged Architecture, Billion-Level Concurrency, Exabyte-Level Storage, Internet of Things, Cyber–Physical Systems	
Blockchain Technology	Blockchain, Digital Currency, Distributed Computing, Differential Privacy Technology, Smart Financial Contracts	

Digital policy support is measured by the number of policies related to the digital economy, digital development, industrial Internet, etc., promulgated by government departments in the city where the company is located. Drawing on the research in [74], the PITI index released by the Institute of Public Environment (IPE) and the Natural Resources Defense Council (NRDC) is used to measure the intensity of environmental regulation, which has high normative and data availability.

The number of green patent applications was used to measure green technology innovation, and the patent database of the State Intellectual Property Office of China (SIPO) was searched for the number of patents of sample companies by year [75]. It was matched with the International Patent Classification Green List (WIPO). The specific screening principles are as follows: patents containing keywords such as green, low-carbon, clean, circular, ecological, emission reduction, energy saving, environmental protection and sustainable can be regarded as green patents. This is the measure of green technology innovation. This paper refers to the project scoring measurement methods [76], which mainly include indicators such as environmental management, law and regulation, pollution control and sustainable development disclosure. Based on the classification criteria of this scoring item and the provisions of Article 19 of the Ministry of Environmental Protection's "Environmental Information Disclosure Measures (Trial)", the evaluation indicators for environmental information disclosure are constructed as shown in Table 3.

Table 3. Quality evaluation index of environmental information disclosure.

Number	Disclosure of Project Content
1	Enterprise environmental protection investment and environmental technology development
2	Environmental protection-related government appropriations, financial subsidies and tax breaks
3	Emission and emission reduction in pollutants from enterprises
4	ISO environment system certification-related information
5	Measures to improve the ecological environment
6	The impact of government environmental protection policies on enterprises
7	Loans related to environmental protection
8	Legal suits, compensation, fines and awards related to environmental protection
9	The concept and goal of enterprise environmental protection
10	Other environmentally related income and expenditure items

The disclosure quality of the enterprise is the sum of the scores, and the specific scoring rules are as follows: undisclosed is 0; general non-monetary information is 1; specific non-monetary information is 2; and monetary information is 3.

3.4. Data Calibration

Before configuration matching, all variables need to be calibrated by selecting appropriate anchor points. First of all, this paper selects the mean value of five-year data and calibrates the initial data using the direct calibration method. Then, the descriptive statistics of the comprehensive case are checked again, and the calibration points of complete affiliation, intersection and complete non-affiliation of the six condition variables and outcome variables are set as the upper quartile, the median and lower quartile of the sample data [77]; the measured raw data values were transformed and treated as 0, 0.33, 0.67 and 1. Finally, this paper uses the Fs QCA 3.0 software to assign membership to the data.

4. Results

4.1. Necessity Analysis

After the data calibration section, according to the analysis steps of QCA, this study needs to test the necessity of the condition variables. Among them, if there is a consistent result greater than 0.9, it is considered as a necessary condition for the result. According to the analysis results of the necessary conditions for high-level enterprise environmental efficiency in Table 4, the necessity of each single condition does not exceed 0.9, which means there are not necessary conditions and further configuration analysis can be performed.

Table 4. Analysis of the necessary conditions for high-level enterprise environmental efficiency.

Conditional Variable	Consistence	Coverage
Digital leadership	0.612	0.721
Digital capability	0.634	0.732
Environmental information disclosure	0.643	0.751
Green technology innovation	0.628	0.689
Digital policy support	0.671	0.703
Environmental regulation intensity	0.674	0.711

4.2. Conditional Configuration Analysis

Fs QCA3.0 software was used to analyze the configuration of the condition variables [9]. The configuration analysis of high-level enterprise environmental efficiency is shown in Table 5. Among them, "•" indicates that there is a core condition, and "○" indicates that there is an edge condition. Furthermore, the consistency threshold is set as 0.8, the frequency threshold is 2 and then the result of the operation is recorded. If the PRI consistency is >0.7, the corresponding result variable is 1; if the PRI consistency is <0.7, the corresponding result variable is 0, finally obtaining four combined paths. Table 3 shows the consistency, coverage and overall consistency and overall coverage of the four groups of condition variables.

Table 5. Configuration analysis of high-level enterprise environmental efficiency.

Condition Configuration	Configuration 1	Configuration 2	Configuration 3	Configuration 4
Digital leadership		●		
Digital capability	●	○	○	●
Environmental information disclosure	○		●	
Green technology innovation	●	●		○
Digital policy support		○		●
Environmental regulation intensity	○		●	○
Consistence	0.851	0.864	0.831	0.812
Coverage	0.261	0.294	0.314	0.123
Unique coverage	0.097	0.076	0.103	0.034
Concordance of solutions	0.832			
The coverage of the solution	0.625			

The consistency of the solution is 0.832, which indicates that 83.2% of the cases in all the configurations that satisfy the four sets of conditions have a high level of environmental efficiency. The coverage of the solution is 0.625, which indicates that four sets of conditional configurations can explain 62.5% of the cases of high-level enterprise environmental efficiency. The consistency of the solution and the coverage of the solution are both higher than the reference threshold, indicating that the configuration analysis results are more reliable.

Configuration 1 shows that enterprises with high digitization capability can quickly adapt to changes in the external environment. The characteristics of digital technology can not only realize the digitization of production factors for resource-based enterprises but also enhance ability to search and obtain information elements and improve the accuracy of corporate environmental information disclosure; at the same time, green technology innovation is an important way to promote the generation of new technologies, and green technology innovation empowered by digital technology can improve innovation efficiency, optimize green production processes and then reduce the cost of pollution control for resource-based enterprises. In addition, when faced with the pressure brought by governmental environmental regulations, these types of enterprises can strive for government approval through proactive environmental disclosure, calmly respond to changes in the external environment and achieve the purpose of energy saving and consumption reduction. In Configuration 1, digital technology has a guaranteeing role in the green sustainable development of resource-based enterprises, so this configuration is named "technical guarantee type". This configuration can explain 26.1% of high-level enterprise environmental efficiency cases, and about 9.7% of them can be explained by this configuration alone.

Configuration 2 shows that enterprises which focus on the cultivation of digital talents and the establishment of professional digital management teams will have solid R&D capabilities and governance levels. These types of resource-based enterprises can accurately grasp the evolution trend of digital transformation, realize better allocation of digital strategies and green innovation element inputs and lead the development direction of green innovation activities. At the same time, enterprises invest in green innovation elements to break innovation boundaries through digital technology, thereby improving product competitiveness and forming a virtuous circle. In addition, with the support of regional digital policies, enterprises can obtain digital innovation opportunities brought by the external environment and promote the production of high-level environmental efficiency. Resource-based enterprises in Configuration 2 quickly respond to the challenges brought about by changes in the internal and external environment by deploying digital strategies, so this configuration is named "strategy driven type". This path can explain 29.4% of high-level corporate environmental efficiency cases, and about 7.6% of them can only be explained by this configuration alone.

Configuration 3 shows that enterprises with high-quality environmental information disclosure can show their active commitment to environmental responsibility, establish their legal status and establish a good image. At the same time, active disclosure will better facilitate effective communication between enterprises and government regulators, reduce potential legal lawsuits and environmental losses and reduce the operational risks of enterprises. In addition, through the application of digital technology, these enterprises can establish an efficient and connected information network, which not only provides technical support for information disclosure but also helps to use the value network to obtain more innovative resources. In particular, reasonable environmental regulations may increase the production and operation costs of enterprises in the short term, but they will guide enterprises to conduct "green" behaviors such as disclosure of environmental information and green innovation and upgrade from end-to-end governance to source governance, thereby improving the environmental efficiency of enterprises. The pressure of environmental regulation in Configuration 3 enables resource-based enterprises to achieve sustainable development, so it is named "pressure lead type". This configuration can explain 31.4% of high-level corporate environmental efficiency cases, and about 10.3% of them can be explained by this configuration alone.

Configuration 4 shows that cities with better digital policies have developed regional economic conditions and abundant digital resources and provide enterprises with good technical resource support under the support of regional digital infrastructure. Resource-based enterprises can better carry out digital transformation, apply digital technology to quickly realize green technology innovation with lower input costs and offset the environmental regulation costs of enterprises through the "innovation compensation effect". In addition, digital technology can improve the sophistication and coordination efficiency of green innovation. Green manufacturing enabled by digital intelligence can achieve higher green value with less consumption and emissions, improve production efficiency and achieve energy saving and consumption reduction. In configuration 4, digital policy is an important boosting force to guide the green sustainable development of resource-based enterprises, so this configuration is named "policy pulled type". This configuration can explain 12.3% of high-level enterprise environmental efficiency cases, and about 3.4% of them can be explained by this configuration alone.

4.3. Robustness Aanalysis

By adjusting the value of the outcome variable "enterprise environmental efficiency", this paper explores the impact of the intersection value on the outcome variable to verify the robustness of the results. Specifically, the intersection value of the result variable is adjusted to the average value of complete membership and complete non-membership, and the conclusion is basically consistent with the previous analysis. The configuration analysis results show the same four configurations as the previous one; the consistency remains at 0.842, which is slightly improved compared with the above results. Additionally, the total coverage reaches 0.613, which can explain 61.3% of high-level enterprise environmental efficiency cases. Therefore, based on the above analysis, the conclusion of this paper is relatively robust.

5. Discussion

In order to provide more targeted green sustainable development pathways for enterprises with different digital resource endowments and organizational characteristics, this paper further discusses the formation mechanism based on the configuration analysis results of high-level environmental efficiency. According to the analysis of the strategic triangle research framework, the green sustainable development models of resource-based enterprises driven by digital technology can be divided into two models: "capability - oriented" and "environment-oriented", which can reflect digital technology application characteristics and green development strategies and respond to the business environment of resource-based enterprises, as shown in Figure 2.

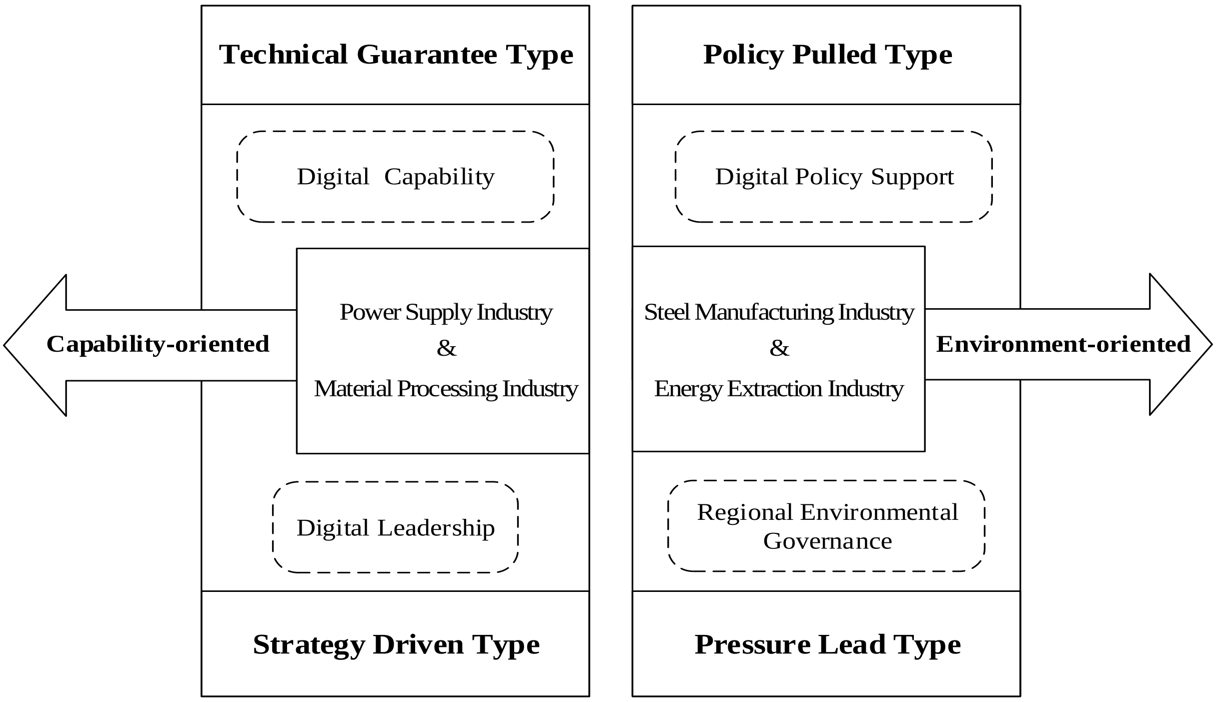

Figure 2. Differentiation types of high-level environmental efficiency of enterprises.

The "capability-oriented" model mainly corresponds to the technical guarantee and strategy-driven types. Resource-based enterprises create green value through digital capability and digital leadership and then actively capture and identify green development opportunities in the external environment. Among them, going back to the case found that the power supply industry represented by Tunghsu Blue Sky Co., Ltd. has built a digital intelligent operation and maintenance management platform, using big data analysis technology to realize the digitalization of assets and energy visualization, empowering green innovation through digital technology and realizing the comprehensive development of enterprises to "smart + ecological + environmental protection". The power supply industry has a relatively high proportion of technology research and development and is able to absorb the technological dividends brought by digital technology, use digital technology to optimize enterprise management processes, enhance information flow, reduce production costs and gradually move towards low-carbon, clean distributed green development and evolution to achieve the intelligent environmental protection goal of intelligent interaction. In addition, the material processing industry represented by Antai Technology Co., Ltd. pays attention to the development strategy of digital talents, has a post-doctoral scientific research station as a high-end R&D leader and maintains a high level of management foundation and scientific research capabilities. Develop intelligent manufacturing and increase green technology innovation to effectively reduce energy consumption and carbon emissions. The material processing industry needs the research and development of high-precision products. Driven by the digital development strategy, these resource-based enterprises quickly respond to changes to adapt to market development, actively carry out digital transformation, and rapidly change and carry out green technology innovation, so as to promote green production and transformation.

The "environment-oriented" model mainly corresponds to the pressure lead type and policy pulled type. Under the pressure of the external environment, resource-based enterprises respond to environmental shocks through the interactive response of organization and technology. At the same time, under the influence of digital policies, they will actively develop digital technologies to catch digital opportunities. The iron and steel manufacturing industry represented by Hangzhou Iron and Steel Group Co., Ltd., under the dual pressure of the national "carbon neutral" plan and urban environmental regulation, actively discloses corporate environmental information and social responsibility reports in response to urban environmental governance. Empowering the digital transformation of traditional industries with technological innovation has achieved process digitization and reduced energy consumption. The iron and steel manufacturing industry is facing development resistance such as high energy consumption and high pollution, and reasonable environmental regulations will force enterprises to carry out green reforms and compensate for environmental protection costs through innovation. Empower the digital transformation of traditional industries with technological innovation, improve economic benefits and carry out green development. Taking Shaanxi Coal and Chemical Industry Co., Ltd. as an example, with the support of regional policies such as “5G+ Industrial Internet” and “Industrial Digitalization”, develop core technology capabilities and expand technology industrialization capabilities, apply digital technology to promote “5G scene technology applications” and “5G+ smart mining areas”, and actively carry out research on ecological and environmental protection technologies to promote the green and intelligent development of the energy industry. The energy mining industry is characterized by high emissions and heavy assets, and its transformation is relatively difficult. Digital policies are an important booster to guide its green development. Under the promotion of government and regional digital policies, they actively carry out “digital + green” technological innovation research and promote the sustainable development of high-carbon industries.

6. Conclusions

6.1. Research Conclusion

With the intensification of digital transformation and the sudden changes in the external business environment, digital technology has become an effective way to enhance innovation efficiency, optimize resource allocation and improve the green environment in the process of green sustainable transformation of resource-based enterprises. Based on the theoretical and practical foundation of China, take the resource-based enterprises in Shanghai and Shenzhen A-share listed companies as a sample, use fs QCA to analyze the conditional configuration and explore the mechanism and realization pathway of resource-based enterprises’ green development through the strategic triangular model. Research results indicate:

(1) The high level of environmental efficiency of resource-based enterprises is the result of the synergistic effect of multiple factors; all factors are effectively combined to enhance the green effect of enterprises in the way of “same destination from different pathways”. Different types of enterprises can optimize the appropriate path of transformation with the help of digital technology technical characteristics and resource endowment, so as to activate the green vitality of enterprises and promote the sustainable development of green economy.

(2) The high-level environmental efficiency of resource-based enterprises needs to be composed of multi-dimensional condition variables collaboratively and concurrently. Through configuration matching, four pathways to achieve high-level environmental efficiency are explored, which mainly include the “technical guarantee type” composed of variables such as digital capabilities, green technology innovation, environmental information disclosure and environmental regulation intensity; “strategy driven type”, consisting of variables such as digital leadership, green technology innovation, digital capabilities and digital policy support; “pressure lead type”, consisting of variables such as the intensity of environmental regulation, environmental information disclosure and digital capabilities; and “policy pulled type”, consisting of variables such as digital policy support, digital capabilities, green technology innovation and environmental regulation intensity.

(3) In the process of green development, digital technology affects the interaction mode between resource-based enterprises and the environment, which can be divided into “capability-oriented” and “environment-oriented” models, which can clearly reflect the behavioral characteristics of resource-based enterprises using digital technology

to carry out green innovation and coping strategies for changes in the digital business environment. Among them, the green development of the power supply industry and the material processing industry is more in line with the "capacity-oriented" model, and the green development of the steel manufacturing industry and the energy extraction industry is more in line with the "environment-oriented" model.

6.2. Practical Contribution

The research in this paper can bring two practical implications for the green sustainable development of resource-based enterprises:

On the one hand, from the perspective of resource-based enterprise green management, enterprises should rationally use digital technology in combination with their own advantages and environmental factors and proceed from the "holism" to further optimize and improve the practical process mechanism of enterprise green sustainable transformation. First of all, resource-based enterprises should continuously improve the technological innovation system and operation mechanism, use digital technology to improve the efficiency of green technological innovation, improve and perfect the incentive mechanism for enterprise technological innovation and then promote the construction of high-quality talent teams. Secondly, resource-based enterprises should speed-up industrial transformation and upgrading and use digital technology to break down innovation barriers and reduce transaction costs, thereby improving the profitability of enterprises. Finally, resource-based enterprises must adhere to the sustainable development strategy, gradually reduce resource consumption and dependence on resources in the industrial chain with the support of digital technology, improve resource utilization efficiency and then extend the life cycle of the enterprise.

On the other hand, from the perspective of government policy formulation, the government should formulate applicable inclusive policies according to the differentiation of resource-based enterprises to provide a more complete innovation environment. First of all, activate the green incentive mechanism of resource-based enterprises by formulating various measures such as supporting policies, tax incentives and government subsidies, and enhance the information flow between governments and enterprises with the help of digital technology infrastructure. Secondly, establish and improve the human resources security system, introduce overseas R&D teams, learn and absorb international advanced technologies and improve the incentive mechanism for scientific and technological innovation so as to activate potential and release the "green value" of enterprise talents. Finally, build an innovation ecological group consisting of state key laboratories, national engineering technology research centers, engineering laboratories and various technology business incubators, strengthen the strategic innovation cooperation between digital technology enterprises and industrial enterprises and break geographical restrictions and information islands in order to accelerate the digital transformation of resource-based enterprises and promote the steady growth of the green economy.

6.3. Research Limitations and Prospects

This research has the following shortcomings: In terms of theoretical framework, this paper adopts the strategic triangle research framework of "operational capability–policy environment–value objective" and, although it covers many internal and external factors, it still has certain limitations. In the future, it can be considered from a deeper level and more diverse perspectives. In the research sample, considering the availability of data, this research selects resource-based enterprises, and in the future, heavily polluting industries can be selected as samples to make the results more universal. In terms of research methods, although the method of configuration analysis avoids the limitations of some traditional empirical analyses, it is necessary to combine the advantages of both methods in the future, which can further improve research on the optimization pathway of sustainable development in digital transformation.

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