International Journal of Business and Management; Vol. 18, No. 4; 2023
ISSN 1833-3850 E-ISSN 1833-8119
Published by Canadian Center of Science and Education

A Study on the Impact of Big Data Management on Business Agility—The Moderating Role of Corporate Strategy and Environmental Uncertainty

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Received: March 30, 2023 Accepted: April 28, 2023 Online Published: May 8, 2023

doi:10.5539/ijbm.v18n3p169 URL: https://doi.org/10.5539/ijbm.v18n3p169

Abstract

With the increasing uncertainty in the market environment and the integration of new IT technologies in business operations management, the use of big data management practices to increase operational agility has become a major concern for enterprises. Based on theories of dynamic capabilities and resource base, this paper analyses how big data management can contribute to the growth of enterprise agility and value, while incorporating the impact of environmental uncertainty and corporate strategy. The study found that:1.Big data infrastructure development, application management and human resource development better characterize enterprise big data management practices and effectively contribute to enterprise agility;2.Corporate strategy significantly moderates the relationship between big data management and agility, with big data application management and human resource development having a greater impact on the agility of forward-looking companies than defender strategies;3.External environmental uncertainty can effectively moderate the relationship between Big Data management and enterprise agility, as the environment becomes more dynamic, Big Data management can enhance enterprise agility, while the increase of environmental hostility will lead to Big Data management reducing enterprise agility. From the three aspects of big data infrastructure construction, big data application management and big data human resources training, it explores the impact of enterprise big data management on enterprise agility, but does not conduct an in-depth analysis of the interaction between the above three aspects; Although the sample size of this study meets the requirements of the structural equation model test, the sample size of the analytical strategy type of enterprises is relatively small, so the analytical strategy is not included in the moderating effect test. Further research can be carried out in depth from the above two aspects.

Keywords: big data management, enterprise agility, enterprise strategy, environmental uncertainty

1. Introduction

1.1 Introduce the Problem

With the accelerating pace of technological change and increasing competition between companies, the uncertainty of the business environment is increasing, which means that business agility poses a significant challenge. Business agility is the ability of a company to better address salient situations in the market environment and to derive opportunities and benefits from them (Ragazou, et al., 2022). It has been found that one of the key paths to improving business agility is the use of information technology (Buijs, 2014). The use of information technology can improve the efficiency of information exchange between collaborating firms and increase the speed of identifying market opportunities. At the same time, the interaction of IT resources with other complementary resources can strengthen cross-sectoral and cross-organizational partnerships, thus enhancing the ability of companies to respond to changes in the market environment promptly on time (Salam M A, 2017). In addition, the changing needs of consumers are increasing the level of agility required of companies. However, traditional information systems lack the ability to provide sustainable solutions to improve agility, are not designed with the highly decentralized control required for agile operations, and are not flexible enough to reallocate internal and external resources to handle highly complex, large volumes of multiple types of data in real time, It is difficult to process highly complex, large volumes of multiple types of data in real time (Che,

Safran, & Peng, 2013). As a result, companies are increasingly looking for new tools that can increase the flexibility of decision making and the speed of computing, and Big Data technologies have emerged. At the same time, the increasing digitization process has made it possible to access and analyses large amounts of structured and unstructured data, creating the conditions for the use of Big Data projects. As a result, a large number of companies have started to use big data management and improve their use of big data in order to be aware of market changes in real time, identify potential opportunities and improve their competitiveness. Big data management has been recognized as an important measure for companies to improve their competitive advantage, and their big data capabilities are one of the key competencies to improve their agility (Addo-Tenkorang & Helo, 2016). Based on this, this section examines the role of big data management in corporate agility from the perspective of resource-based theory and dynamic capabilities theory, and examines the moderating effects of strategic heterogeneity and environmental uncertainty.

2. Theoretical Analysis and Assumptions

2.1 Big Data Management and Enterprise Agility

The application of information technology in the dimensions of enterprise infrastructure building, management capabilities and human resources can improve enterprise agility (Gao & Li, 2017). This paper focuses on the impact of big data management practices on enterprise agility in terms of infrastructure development, application management and human resources. However, unlike previous information technologies, big data technologies are more effective in improving collaboration, information exchange and agility across the supply chain.

2.1.1 Big Data Infrastructure Development and Enterprise Agility

A solid IT infrastructure and well-structured can help businesses to have access to the most up-to-date information in the shortest possible time, thus enhancing their understanding of the internal and external environment. Efficient and high quality decisions help companies to respond to market changes as quickly as possible and meet the changing needs of consumers (Berger et al., 2019). Current big data facilities are better suited to the needs of the business environment and more effective in improving business agility than previous information infrastructures (Tiwari, Wee, & Daryanto, 2018). The connectivity based on big data infrastructure can help enterprises exchange and integrate information with other members of the supply chain in a timely manner, ensuring the speed and quality of information interaction; relational databases and real-time access logs can also incorporate data from daily operations into big data systems, facilitating enterprises to keep track of real-time dynamics such as customer orders and product inventories. Compatibility of big data infrastructure can break down barriers between enterprises and the external environment, remove organisational boundaries in accessing external information, and enhance collaboration between enterprises and other members of the supply chain, thus improving the ability of enterprises to respond to rapidly changing markets (Jeble, Dubey, & Childe et al., 2018); modularity can be achieved through the interoperability of system components Implementation. Modularity facilitates the development of new applications by enabling the interoperability of system components, thus enabling enterprises to adapt their application portfolios to changing business needs, thereby increasing their flexibility (Yu, Chavez, & Jacobs et al., 2018).

2.1.2 Big Data Application Management and Enterprise Agility

Resource-based theory suggests that valuable and scarce resources do not necessarily lead to competitive advantage, but rather the management and control of these superior resources (Barney & Ketchen et al., 2021). In other words, to realise the role of resources in enhancing competitive advantage, firms must use these resources effectively to maximise their value in four ways: planning, decision making, coordination and control. In terms of planning, a well-developed plan can help steadily advance the implementation of a company's projects and address any obstacles that may be encountered in the process, thereby increasing the synergy between the company and its supply chain partners. In terms of decision-making, companies make decisions on the use of big data from their own and external stakeholders' perspectives to maximise value across the supply chain, thereby enhancing collaboration and communication between supply chain members and improving their ability to adapt to changes in the environment (Govindan & Cheng et al., 2018). From a coordination perspective, strong coordination capabilities can facilitate communication and collaboration between the enterprise Big Data department and other departments and supply chain partners, thus successfully driving the analysis of enterprise Big Data applications and improving the visualisation of the enterprise supply chain for efficient decision-making (Maria Carmela Annosi & Federica Brunetta, 2021). In terms of control, the adaptation of Big Data management to business needs must rely on rigorous control capabilities.

2.1.3 Big Data Human Resource Training and Enterprise Agility

In addition to the hardware and software facilities of Big Data technology, Big Data talents, such as chief data officers, data engineers and analysts, are also essential components in the implementation of Big Data management in enterprises. Technical skills refer to the professional knowledge and skills of employees in Big Data, which is the important foundation for enterprises to smoothly promote the implementation of Big Data projects, deeply explore the business value of Big Data and ultimately achieve the improvement of enterprise agility; management skills refer to the management ability of enterprise Big Data personnel to reasonably plan the allocation and utilisation of Big Data resources, and strictly control the operation process of Big Data projects to avoid potential risks; business skills refer to the management ability of Big Data personnel to make a good use of the enterprise's Big Data resources. Business skills refer to the ability of Big Data personnel to grasp the strategic planning of the enterprise, gain timely insight into the external environment and make Big Data business decisions (Usama Awan, & Saqib Shamim et al., 2021). Strong business skills enable Big Data personnel to consider internal strategic deployment while taking into account external market opportunities and risks to help make optimal decisions for themselves and their supply chain partners; relationship skills refer to the ability of Big Data employees to communicate smoothly with other internal departments, external suppliers and service providers, and supply chain partners (Agostini, & Nosella, 2020). Strong relationship skills can facilitate more frequent communication and cooperation with internal and external actors, thus helping companies to access larger data resources and to plan and use them appropriately, and efficient communication and resource sharing among companies can ultimately enhance their ability to face market changes. Therefore, this paper proposes the following hypothesis: H1: Enterprise big data management helps to improve enterprise agility. H1a: Enterprise big data infrastructure development helps to enhance enterprise agility. H1b: Enterprise Big Data application management helps to improve enterprise agility. H1c: Enterprise Big Data human resource development contributes to enterprise agility.

2.2 The Moderating Role of Corporate Strategy

In terms of strategic characteristics, forward-looking firms tend to focus on offensive and exploratory innovation, with a preference for exploring potential customer needs, developing market-breaking products and services, and improving their responsiveness to the market; at the same time, forward-looking firms focus on whether they can use emerging technologies to identify market opportunities and risks before their competitors do, and then allocate resources to produce differentiated products. At the same time, forward-looking companies focus on the ability to use emerging technologies to identify market opportunities and risks before their competitors do, and then allocate resources to produce differentiated products. In contrast, defensive-minded companies tend to be more adaptive, preferring to meet the deterministic needs of their customers and focusing on adaptive capabilities in the face of a rapidly changing environment, i.e. companies with a defensive strategy place more emphasis on improving the process and productivity of existing products, focusing on providing relatively stable products and services in existing markets. As a disruptive technological change, big data technology aims to address the heterogeneous differentiation of customer needs through market segmentation, business model transformation, product and service upgrades, and to unlock the value of big data through automated algorithms that support or replace manual decision-making (Sun, Hall, & Casey et al., 2020). As a result, forward-thinking companies are more likely to focus on the use of big data management to improve their responsiveness to market changes. From a business agility perspective, the agility of a company to changes in its internal and external environment varies depending on its goals and strategies. On the one hand, in order to adapt to changes in the market, forward-looking players use new generations of information technology, such as big data technologies, the Internet of Things and cloud computing, to improve their agility. However, due to the IT investment paradox, defensive firms are less likely to choose disruptive technologies to improve agility (Anjar Priyono, & Fazli Idris, et al., 2020). On the other hand, the improvement of agility is also influenced by the collaboration of supply chain partners. In contrast, forward-looking companies prefer to use big data management to achieve synergies within the company and among supply chain companies in order to obtain the necessary core resources. In contrast, defensive companies tend to avoid risky activities in order to maintain their market position (Eivind Kristoffersen & Patrick Mikalef, et al., 2021). As a result, companies with a forward-looking strategy tend to enhance their big data management practices in order to improve their agility compared to companies with a defensive strategy. In terms of the impact of strategy type on business behaviour, business strategy has a significant impact on the way companies access and use external information. Forward-looking firms focus more on the latest technologies related to their product development when exploring potential market opportunities (Alexandre Pólvora, Susana Nascimento, & Joana S., et al., 2020), on accelerating the collaborative development of new products when establishing strategic alliances with suppliers, and on reshaping business processes by

increasing the level of integration within the firm and the supply chain. The defensive strategy emphasizes market orientation and focuses on gaining more information by focusing on competitors and target customers; optimizing its product development and production strategy in response to competitors' product upgrades and iterations, thus maintaining the company's existing market share and competitive advantage. Therefore, compared to forward-looking companies, defensive companies are more likely to react to changes in the market environment passively, and only a small number of companies use big data management to improve their agility. H2: Big data management is more likely to improve agility in forward-looking firms than in defensive firms. H2a: Forward-looking enterprise Big Data infrastructure is more likely to improve agility than defensive strategic enterprises. H2b: Forward-looking enterprise Big Data application management improves agility compared to defensive strategic enterprises. H2c: Big data human resource development for forward-looking enterprises increases agility compared to defensive strategic enterprises.

2.3 Moderating Effects of Environmental Uncertainty

In a market environment where enterprises face high uncertainty due to technological innovation, competitor behaviour and changes in customer demand, enterprises will gradually lose their original competitive advantages and need not only more comprehensive information resources, but also high-end IT technology to analyse such information (Patrick Mikalef, & Adamantia Pateli et al., 2021). Therefore, as an important technical tool for efficient access to and accurate analysis of data resources, the application of enterprise big data technology is of vital importance for enterprises to adapt to the needs of information processing in a dynamic environment. Given the high investment required to improve agility with big data management, the need to develop new IT competencies and acquire external knowledge is not as urgent in a relatively stable market. In a volatile market environment, however, the need to develop efficient IT capabilities to respond quickly to changes in the environment in order to quickly absorb heterogeneous knowledge, perceive external volatility and capture market opportunities is becoming increasingly important. The hostility of the external environment depends on the intensity of competition and the scarcity of resources (Chan & Lai, 2022). which can be measured in terms of marginal profitability and resource availability (Ling & López-Fernández, 2020). On the one hand, the hostility of the external environment has a negative impact on the development of new IT capabilities. In order to protect themselves against potential risks, make up for eroded profits and retain their existing market share, companies tend to focus more on product replacement, incremental product development and process technology refinement than on investing in IT applications, so a more hostile external environment may discourage the adoption of Big Data technologies. At the same time, a hostile external environment means more competition between firms, which increases the likelihood of speculative or illegal behaviour, leading to increased costs of information and knowledge exchange and reduced trust in business cooperation. Therefore, a hostile external environment may hinder the development of new IT capabilities and thus affect the agility of the firm. H3: Environmental uncertainty significantly moderates the relationship between big data management and enterprise agility H3a: Dynamism enhances the contribution of big data management to enterprise agility H3b: Hostility weakens the contribution of big data management to enterprise agility.

3. Study Design and Data Acquisition

3.1 Measurement of Variables

This study draws on well-established scales from existing studies and combines field research to design scales for enterprise big data management, enterprise agility, enterprise strategy and environmental uncertainty. The measures of enterprise big data management are based on the scales of Shuradze and Wagner (2016) and Wamba et al. (2017); enterprise agility is based on the scales of Liu et al. (1989), Sabherwal and Chan (2001); the measurement of environmental uncertainty was based on Auh and Menguc (2005). All questionnaire items were based on the Likert 5-point scale, and the questionnaire was revised through pre-research to form the official questionnaire. In addition, this paper is based on the strategic attribute analysis method proposed by Sabherwal and Chan (2001) to determine the strategic type of the sample companies. (1) Normalise the actual scores of the sample companies on the six attributes and use Mi to denote the actual score of the company on attribute i. (2) Assign a standard score of - 1, 0 and 1 to the low, medium and high attributes according to the standard attributes of the three strategy types as summarised by Sabherwal and Chan (2001), e.g. L If the defender's standard score on attribute i is denoted by L, DEF, then $L_{1, DEF} = 1$, $L_{2, DEF} = 1$, $L_{3, DEF} = 0$,

$L_{4, DEF} = -1$, $L_{5, DEF} = 0$, $L_{6, DEF} = 1$, and the standard scores of the other strategy types are derived accordingly; (3) The Euclidean distance is used to calculate the distance between the firm's actual score and the standard scores of the three strategy types. The distance between the actual score and the standard score of the three strategy types was calculated using Euclidean distance, e.g. the distance from the standard defender strategy type was

$\sum^{6}_{i=1}\{(M_i - L_{i,DEF})^2\}$; (4) the distance between the company and the three standard strategy types was compared and the company was included in the strategy type with the lowest distance.

3.2 Study Sample and Data

This study collected data by means of a questionnaire, and the respondents were middle and senior level employees, such as department heads or managers, who were using big data technology in their companies. A total of 600 questionnaires were distributed from mid-June to early September 2022, of which 255 questionnaires were returned, representing a valid return rate of 42.5%. The sample enterprises are wholly owned or controlled by Chinese enterprises, private enterprises and foreign-invested enterprises, accounting for 21.2%, 39.2% and 32.9% respectively; the number of employees in the sample enterprises is more than 100, accounting for 79.6%; the sample enterprises cover a wide range of industries, including manufacturing, wholesale and retail, logistics and express delivery, telecommunications services, IT technology and consulting, finance and e-commerce.

4. Empirical Analysis

4.1 Reliability and Validity Analysis

In this paper, Cronbach's coefficient, combined reliability and AVE were used to analyse the reliability of the scale, and SMART PLS 2.0 and SPSS19.0 software were used to calculate the above values of the latent variables of enterprise big data management and enterprise agility. The Cronbach's α coefficients for the key variables are above 0.6, the combined reliability CR is above 0.8 and the AVE values are above 0.5. Therefore, the reliability of the scale used in this study is good. In addition, the AVE square roots of the variables were compared with the correlation coefficients of the variables and other variables to verify the discriminant validity, and the results showed that the correlation coefficients of the variables were smaller than their respective AVE square roots, and the sample data had good discriminant validity.

Table 1. Results of the test of confidence validity

Variables	Cronbach's α	CR	AVE	Variables	Cronbach's α	CR	AVE
Connectivity	0.797	0.869	0.624	Technical competence	0.794	0.858	0.55
Compatibility	0.791	0.878	0.705	Technical management skills	0.814	0.877	0.642
Modularity	0.779	0.871	0.693	Business Competence	0.785	0.861	0.608
Plans	0.817	0.88	0.647	Relationship skills	0.804	0.872	0.631
Decision	0.815	0.878	0.643	Collaborative planning	0.851	0.894	0.628
Coordination	0.846	0.897	0.685	Process integration	0.827	0.879	0.592
Control	0.757	0.846	0.579	Visibility	0.830	0.881	0.596

4.2 Structural Equation Modeling

The PLS bootstrapping method was used to analyse the structural equation model, and the hypothesis testing results are shown in Figure 1. As shown in Figure 1, the standardized path coefficient of big data infrastructure construction on enterprise agility is 0.191, and the $p < 0.001$, so big data infrastructure construction can significantly improve enterprise agility, thus hypothesis H1a is verified. At the same time, the path coefficient of big data application management on enterprise agility is 0.230 with $P < 0.001$, so big data application management also significantly contributes to enterprise agility, and hypothesis H1b is verified. In addition, big data human resource development also positively affects enterprise agility (path coefficient = 0.487, $P < 0.001$), so hypothesis H1c can be verified. In summary, hypothesis H1 is verified.

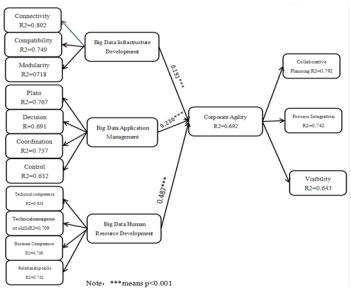

Figure 1. Results of the study hypothesis path analysis

4.3 Testing the Moderating Effect of Corporate Strategy

The sample was divided into two sub-samples of defenders and forward-thinkers according to their strategy types, and the moderating effects of different strategy types on the relationship between enterprise big data management and enterprise agility were analysed separately. The results of the analysis are shown in Table 2. The standardised path coefficients of Big Data infrastructure development, Big Data application management and Big Data human resource development on enterprise agility in the forward-looking enterprises were 0. 166, 0. 283 and 0. 470 respectively, and all were significant at the 1% level. In the defender companies, the standardised path coefficient of big data infrastructure development on enterprise agility is 0. 413 with $P < 0.001$, which is 0. 247 higher than the standardised path coefficient under the forward-looking strategy, therefore, hypothesis H2a is not passed. The standardised path coefficient of big data human resource development on enterprise agility is 0. 392 with $P < 0.001$, which is smaller than the coefficient of 0. 470 for the relationship between the two under the foresight strategy, and hypothesis H2c also passes.

Table 2. Analysis of the moderating effect of corporate strategy between enterprise big data management and corporate agility

Routes	Prospector		Defender	
	Path coefficient	T-value	Path coefficient	T-value
Big Data Infrastructure Development → Enterprise Agility	0.166***	2.111	0.413***	2.821
Big Data Application Management → Enterprise Agility	0.283***	3.432	0.053	0.363
Big Data HR Development → Enterprise Agility	0.470***	5.802	0.392***	3.907

4.4 Testing the Moderating Effect of Environmental Uncertainty

The general approach to testing the moderating effect is to check whether the regression coefficients of the independent variable (IV) × moderating variable (MOD) and the dependent variable (DV) are significant, or to check whether the change in R^2 of the regression equation before and after the inclusion of the crossover term is significant. Both methods are used to examine the moderating effect of environmental uncertainty. In addition, in order to reduce the effect of multicollinearity, the variables were first decentered and then averaged to obtain unique values for the variables of Big Data infrastructure development, Big Data application management, Big Data human resource development, environmental dynamics and environmental hostility, and finally the values of Big Data infrastructure development, Big Data application management and Big Data human resource development were averaged again to obtain the values of the variables of enterprise Big Data management. The results of the regression analysis are shown in Table 3. The results of the regression analysis are shown in Table 3.

The results of the regression analysis are shown in Table 3. As can be seen in Table 3, Model 1 contains only control variables, while Model 2 shows that Big Data management significantly improves enterprise agility. Model 3 incorporates two variables, hostility and dynamism of environmental uncertainty, and shows that Big Data management, dynamism and hostility significantly increase agility. In Model 4, the cross-sectional terms of the independent and moderating variables were considered and it was found that hostility negatively moderated the relationship between Big Data management and agility at $P < 0.01$, while environmental dynamics positively moderated the relationship between Big Data management and agility at $P < 0.05$. In the group regression model, R^2 and ΔR^2 both increased significantly, indicating that environmental dynamics and hostility had a significant effect on the relationship between Big Data management and agility. Hypothesis 3a and 3b were tested.

Table 3. Analysis of the moderating effect of environmental uncertainty between big data management and corporate agility

	Specific indicators	Model 1	Model 2	Model 3	Model 4
Control variables	Industry	0.046	-0.030	-0.003	-0.003
	Size of business	0.040	-0.002	0.029	0.023
	Years of operation	-0.064	-0.055	-0.066	-0.054
Independent variable	Big Data Management		0.824***	0.624***	0.608***
Adjustment variables	Hostility			0.279***	0.292***
	Dynamism			0.104***	0.105**
	Big Data Management × Hostility				-0.152**
	Big Data Management × Dynamism				0.115**
Statistical parameters	R^2	0.004	0.678	0.755	0.766
	ΔR^2	-0.007	0.673	0.749	0.759
	F-value	0.377	131.838***	127.364***	100.815***

Note. Dependent variable is supply chain agility; *** means P < 0. 001; **means P < 0. 01; *means P < 0. 05.

5. Conclusion

5.1 Research Findings

- Big data management can significantly improve enterprise agility. The empirical results show that big data infrastructure development, big data application management and big data human resource development can effectively contribute to enterprise agility (Lutfi & Al-Khasawneh, 2022).
- Enterprise strategy can regulate the relationship between big data management and enterprise agility. The moderating effect of corporate strategy can be seen in two main ways: firstly, forward-looking strategic companies are more likely to improve agility through big data application management and big data human resource development than defensive strategic companies; secondly, forward-looking strategic companies are less likely to improve agility through big data infrastructure development than defensive strategic companies. Therefore, in the process of investing in Big Data infrastructure, forward-looking strategic enterprises should pay more attention to improving connectivity, compatibility and modularity, and to matching and integrating with their business (Xie & Xu, 2022).
- Environmental uncertainty moderates the relationship between big data management and business agility. In a dynamic market environment, Big Data management can be more adaptive than in an adversarial market environment, which can improve business agility. However, companies should not ignore the inhibiting effect of hostile environments on the relationship between Big Data management and agility, and should improve their ability to adapt to different market environments in order to make Big Data management import decisions.

5.2 Management Insights

Use big data management to help improve enterprise agility. Firstly, in the process of building big data infrastructure, attention should be paid to improving the connectivity, compatibility and modularity of enterprise big data infrastructure construction, so as to speed up the transfer of internal and external information, strengthen the collaborative planning capability of supply chain partners and improve the flexibility of enterprises to respond to market changes. Secondly, in the process of managing Big Data applications, enterprises should take into full consideration the actual business situation and formulate a reasonable Big Data application project plan; they should improve their Big Data management decision-making capabilities and promote information flow and resource sharing within the enterprise and among supply chain members through good coordination and control. Third, according to their own business situation, enterprises can implement a categorised and tiered talent training and incentive mechanism for the required big data talents, and focus on the comprehensive capacity training of big data talents.

The company's strategy should be matched with its big data management. On the one hand, in the process of big data application practice, a comprehensive problem-oriented plan should be formulated, focusing on the urgency

of the application area of big data and the detectability of the application value, and adjusting the deployment of enterprise big data applications in a timely manner in accordance with the internal and external conditions; on the other hand, in the process of big data infrastructure construction, attention should be paid to the degree of matching between the construction of big data projects and enterprise strategies; the benchmark should be the satisfaction of enterprise needs, rather than blindly seeking new and complete solutions. On the other hand, in the process of building big data infrastructure, attention should be paid to the extent to which the construction of big data projects matches the enterprise's strategy.

Improve the adaptability of enterprise big data management to the external environment. On the one hand, in a dynamic environment, enterprises should identify potential opportunities and threats in a timely manner through investing in big data projects, focus on grasping external heterogeneous opportunities, and be bold in opening up new market segments, while at the same time enhance the comprehensive capacity of big data management to deal with potential threats and summarise relevant experiences in a timely manner. On the other hand, in a hostile environment where resources are scarce and competition is fierce, enterprises should prioritise their Big Data investments, prioritising those that can improve their short-term performance to maintain their market share.

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