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# How and When Does Big Data Analytics Capability Boost Innovation Performance?

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**Abstract:** The diffusion of big data in recent years has stimulated many companies to develop big data analytics capability (BDAC) to boost innovation performance. However, research regarding how and when BDAC can increase innovation performance is still scant. This study aims to test how (i.e., the mediating role of strategic flexibility and strategic innovation) and when (i.e., the moderating role of environmental uncertainty) BDAC can boost a firm's innovation performance drawing on resource-based theory. Through a survey of 421 Chinese managers and employees who are engaged in the field of big data analytics, this study reveals that (1) BDAC has a positive effect on innovation performance, (2) strategic flexibility and strategic innovation play a significant serial mediating role in this relationship, and (3) the positive effect of BDAC on innovation performance is more significant under high (vs. low) environmental uncertainty conditions. This study contributes to the extant literature by verifying how BDAC can increase a firm's innovation performance through the serial mediating role of strategic flexibility and strategic innovation. It also confirms a contingent factor (i.e., environmental uncertainty) regarding the positive effect of BDAC on innovation performance.

**Keywords:** big data analytics capability; strategic flexibility; strategic innovation; innovation performance; environmental uncertainty; resource-based theory; dynamic capability theory

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## 1. Introduction

The current business world is full of increasing uncertainties and challenges. In particular, the COVID-19 pandemic has brought unprecedented challenges to global supply chains [1], marketing channels [2], consumer behaviors [3], etc. Many firms are pursuing innovative business models to deal with these challenges [4,5]. In particular, many firms are increasingly investing in big data analytics capability (BDAC) to enhance their innovation and competitive advantages [6–9]. BDAC is defined as the capacity of a firm to capture, manage, process and analyze big data to generate valuable insights for business value creation [8,10]. It is generally recognized that traditional enterprises failing to introduce BDAC are difficult to obtain the latest data and real-time information. It is easier for them to face operating risks. On the contrary, firms with BDAC can efficiently seize valuable opportunities to realize business innovation. Innovation involves the usage of new insights to develop, accept, and implement new ideas [11]. Indeed, BDAC is considered "the big issue in innovation" [12] and "the next frontier for innovation, competition, and productivity" [13].

Although it is significant for researchers to map out how to benefit from BDAC, there are limited endeavors examining the linkages between BDAC and innovation performance [14]. On the one hand, some literature is still theoretical or, at most qualitative [15,16]. On the other hand, quantitative research on BDAC and innovation performance relationship is still in its infancy. For instance, some statistical evidence shows that BDAC

can directly improve innovation performance [17,18]. Some empirical evidence indicates that BDAC can indirectly enhance innovation performance through the mediators of business model innovation [19], learning capability [7], marketing affordances [20], dynamic capability [21], firm agility [9], etc. Moreover, some scholars empirically verified that the effect of BDAC on innovation performance is contingent on the fit between big data and BDAC [17], firms' investment in IT-specific skills [18], etc. Accordingly, despite prior studies proposing some insightful findings, research regarding the effect of BDAC on innovation performance is still in its infancy. In particular, prior studies have neglected to explore how and when BDAC boosts a firm's innovation performance from the perspective of strategic management [22].

This study follows resource-based theory [23,24] and integrates BDAC, strategic flexibility, strategic innovation, innovation performance and environmental uncertainty into a conceptual model to investigate the possible mediating role of strategic flexibility and strategic innovation and the moderating role of environmental uncertainty between BDAC and innovation performance to fill these gaps. This study is significant for enterprises to improve their innovative performance levels amid fierce competition. Specifically, this study explores the following three questions: (a) whether BDAC boosts a firm's innovation performance; (b) whether BDAC increases a firm's strategic flexibility and strategic innovation, thereby contributing to its innovation performance; and (c) whether the effect of BDAC on innovation performance is contingent on environmental uncertainty.

Strategic flexibility refers to a firm's ability to reallocate and reconfigure its existing resources, processes and strategies to adapt to the changing environment [25,26]. Rialti et al. [27] suggested that BDAC can contribute to a firm's strategic flexibility through the mediating role of firm ambidexterity. It seems that BDAC can be an antecedent variable of strategic flexibility. A firm with high strategic flexibility may result in new competencies, creative technologies and novel business models [28,29], thereby helping it obtain superior strategic innovation [30]. Strategic innovation involves the reconceptualization of the business model and reshaping existing markets by breaking the rules and changing the nature of competition to obtain a significant value improvement for customers and growth for firms [31]. Probably, strategic flexibility can be an antecedent variable of strategic innovation. Furthermore, strategic innovation could turn into a firm's innovation performance [32]. Innovation performance specifically refers to the outputs, effect and speed of a firm's innovations [33]. Accordingly, strategic flexibility and strategic innovation may play serial mediating roles between a firm's BDAC and its innovation performance. Additionally, BDAC is one type of dynamic capability [4,5,34], and the effect of dynamic capability on performance was theorized as contingent on the external environment [35]. Nevertheless, few prior studies have shed light on the mediating role of strategic flexibility and strategic innovation and the moderating role of the external environment (e.g., environmental uncertainty) on the relationship between BDAC and performance.

Through a survey of 421 subjects in China, this study confirms the positive effect of BDAC on innovation performance and the "BDAC → strategic flexibility → strategic innovation → innovation performance" serial mediation link. This study also affirms that the positive effect of BDAC on innovation performance is more obvious under a high (vs. low) environmental uncertainty condition. This study contributes to the extant literature by providing novel empirical evidence regarding the positive effect of BDAC on a firm's innovation performance and how BDAC can boost innovation performance through the mediating role of strategic flexibility and strategic innovation. Moreover, this study confirms a contingent condition (i.e., environmental uncertainty) regarding the positive effect of BDAC on innovation performance.

In the remainder of this paper, we introduce the theoretical background and hypotheses, methodology, and results. This paper ends with a general discussion.

## 2. Literature Review and Hypothesis Development

### *2.1. Resource-Based Theory (RBT)*

Resource-based theory (RBT) is based on two main assumptions about organizational resources to interpret why some organizations gain better performance than other rivals. First, companies operating in the same industry can own a diverse mixture of resources, which means resources in a certain company are heterogeneous [36]. Second, these unique resources are difficult to exchange across companies, which means resources in a certain enterprise are also immobile [37]. On the basis of the two core assumptions, the logic of RBT embraces the VRIO framework, which clearly points out that organizational performance relies on the extent to which an organization is able to possess concurrently valuable (V), rare (R), imperfectly imitable (I) resources which are properly organized (O) [23]. Firms are regarded as owning strategic resources at hand, which, if they are VRIO, will contribute to sustainable competitive advantage.

RBT is a significant paradigm for studying the relationship between BDAC and organizational performance. Specifically, on the one hand, RBT is valuable for scholars to identify the scope of resources that will contribute to building up BDAC [38]. Firms own a collection of tangible and intangible resources, which can be a radical foundation for conceptualizing the dimensions of BDAC. On the other hand, BDAC is recognized as a category of capability that, concurrently possessing VRIO characteristics, may creatively provide competitive advantage and excellent performance to organizations [39]. RBT is useful for demonstrating a clear connection between capabilities as antecedent variables and firm performance as the dependent variable. Thereby, this paper regards RBT as a convincing framework for integrating distinguishing BDAC dimensions, their synergistic effects on innovation performance and the contingency of strategic flexibility and strategic innovation associated with this entire capability-performance relationship.

### *2.2. BDAC Based on RBT*

Resource-based theory (RBT) suggests that resources featuring valuable (V), rare (R) and inimitable (I) traits that are properly organized (O) could result in a firm's competitive advantage and superior performance [24]. BDAC consists of the following three components [34]. First, BDA infrastructure's flexibility capability involves the flexibility of a firm's data system; a data system with high flexibility can ensure that data analysts promptly collect, analyze and deploy a firm's data resources, and it specifically includes BDA connectivity, compatibility and modularity. Second, BDA talent capability, which involves the competence of data scientists (the person with data analytics expertise) to efficiently execute organizational tasks in the context of big data, specifically includes BDA technology management knowledge, technical knowledge, business knowledge and relational knowledge. Third, BDA management capability includes BDA planning, investment, coordination and control. Following the logic of RBT, the BDAC has the attributes valuable (V), rare (R), and inimitable (I); if properly organized (O), it provides a firm with necessary new knowledge and insights, thus contributing to the firm's incremental and radical innovations and then innovation performance [34,40,41].

### *2.3. BDAC, Strategic Flexibility and Innovation Performance*

#### 2.3.1. BDAC and Innovation Performance

Sun et al. [33] suggested that innovation performance is related to the outputs, effect and speed of innovations. Innovation performance is defined from the aspects of efficiency and effectiveness. BDAC can contribute to a firm's innovation performance in the following ways. First, BDAC brings unprecedented innovation opportunities to firms through a better understanding of customer needs [42]. For instance, depending on online customer records, Amazon generates "you might also need" prompts for every product bought or visited, which creatively increases sales of new products and services [43]. Second, compared to competitors, firms with BDAC can process different types of data

information to discover implicit insights, thus making better decisions that, in turn, improve a firm's capability to continuously enhance its product innovation processes [44]. Tesla Motors Inc., for example, purchases survey data of "reviews of new energy vehicles" from Chinese survey platforms to determine which kind of new projects should be invested in, thereby bringing sustainable innovation benefits to the company [45]. Finally, BDAC helps firms improve their learning abilities and enhance their new knowledge and idea generation [46], which in turn increases firms' new product and service innovation and innovation performance.

Some extant literature has identified a positive link between organizational BDCA and innovation results, which can provide some support for our research. Using matched-pair survey data from the Pakistan Electronic Media Regulatory Authority (PEMRA), Muhammad et al. [47] recognized a direct positive relationship between BDAC and innovation performance. Similarly, exploiting survey data from 2706 manufacturing and service companies in Germany, Niebel et al. [18] identified that BDCA is closely connected with a higher propensity to innovate and a higher innovation intensity, which brings direct positive effects on the sales share of new products and services. Furthermore, on the basis of survey data from Iran's 185 chief information officers (CIOs), ZareRavasan [9] found that BDCA supports companies in being more creative in terms of checking new ideas in a virtual environment ahead to introducing them in reality, which provides both positively direct and indirect effects on innovation performance.

Thus, we propose the following hypothesis:

**Hypothesis 1 (H1).** *BDAC is positively related to innovation performance.*

#### 2.3.2. BDAC and Strategic Flexibility

Strategic flexibility refers to a firm's capability to reallocate and reconfigure its existing resources, processes and strategies to adapt to the changing environment [25,26]. It particularly involves the effective management of potential risk and uncertainty by immediately responding to environmental changes in a proactive or reactive way [48,49]. A firm's BDAC could be a vital antecedent of strategic flexibility. First, firms with BDAC can collect, analyze and reconfigure various pieces of information, which is valuable for identifying emerging environmental changes [50]. Accordingly, firms are able to flexibly adjust their strategies and promptly respond to threats and opportunities in the external environment [42,51]. In addition, BDAC provides firms with various data resources that could enhance internal resource allocation and restructuring, thereby improving their strategic flexibility [52]. Additionally, through the development of BDAC, a firm can build an efficient communication system. Convenient internal and external communications can also increase a firm's strategic flexibility [53].

Some extant studies have verified that organizational BDCA is positively related to strategic flexibility, providing some evidence for our paper. On the basis of 215 survey data collected from managers of European companies, Rialti et al. [27] found that BDAC is an important antecedent of a company's strategic flexibility, while the relationship is mediated by knowledge management capabilities and ambidexterity. Similarly, exploring six Finnish growth organizations, Matalamaki and Joensuu-Salo [54] noted that the digitalization process and strategic flexibility are intertwined, which means the development of digitalization in the big data era improves organizational strategic flexibility; concurrently, strategic flexibility promotes the application of new technology.

Thus, we propose the following hypothesis:

**Hypothesis 2 (H2).** *BDAC is positively related to strategic flexibility.*

#### 2.3.3. Strategic Flexibility and Innovation Performance

Furthermore, strategic flexibility can improve a firm's innovation performance comprehensively. First, strategic flexibility makes it possible for a firm to allocate its resources

flexibly and, consequently, keep its innovation portfolios up to date [55]. Innovative products and services can better fulfill customer needs and increase companies' sales [30]. Second, companies that are strategically flexible are also well situated to forecast market uncertainty and risks and react by developing creative processes and activities, which in turn reduces economic losses [56]. Third, Brozovic [57] proposed that distinctive forms of strategic flexibility may result in new product innovations that are hard for competitors to imitate, which may bring distinct competitive advantages and excellent performance to a firm.

In the extant literature, scholars have established that strategic flexibility can positively influence innovation performance. Using a sample composed of 201 European enterprises, Kekale et al. [58] found that the improvement of strategic flexibility in the process of new product development can directly enhance sustainable innovation performance. Similarly, based on a database of 69 firms from Turkey, Cingöz and Akdoğan [59] found some empirical support for the positive relationship between strategic flexibility and innovation performance.

Accordingly, we propose the following hypothesis:

**Hypothesis 3 (H3).** *Strategic flexibility is positively related to innovation performance.*

Combining the arguments of H1 (BDAC → innovation performance), H2 (BDAC → strategic flexibility), and H3 (strategic flexibility → innovation performance), we further expect the following hypothesis:

**Hypothesis 4 (H4).** *Strategic flexibility mediates the relationship between BDAC and innovation performance.*

### *2.4. BDAC, Strategic Innovation and Innovation Performance*

#### 2.4.1. BDAC and Strategic Innovation

Strategic innovation refers to the reconceptualization of the business model and reshaping of existing markets by breaking the rules and changing the nature of competition to obtain a significant value improvement for customers and growth for firms [31]. A firm's BDAC can be an antecedent of strategic innovation. First, BDAC can facilitate firms' accurate prediction of customer needs, thereby promoting innovations to their business models and better fulfilling customers' needs [41]. Inherently, BDAC-driven strategic innovation lies in the possibility of rationalizing management's intuitions and creativity through the prompt and continuous availability of real-time information [60]. Furthermore, through the utilization of big data analytics, firms are able to enhance customer segmentation, optimize pricing strategies and establish new delivery and communication channels to renew their strategies [61]. Additionally, with the development of BDAC, the techniques of digital simulation, virtual reality (VR) and augmented reality (AR) are concurrently developing. Thereby, companies can accurately simulate various parameters of new products and services and the prototype visual mode to consumers, ultimately providing customers with innovative products and services that better meet their needs. Thus, the development of BDAC contributes to a firm's strategic innovation.

Indeed, according to a sample of 253 UK firms, Ciampi et al. [41] demonstrated that BDAC positively impacts firms' competence for business model innovation directly or indirectly through the mediator of entrepreneurial orientation. Similarly, based on the case study of three manufacturing firms in China, Cheah and Wang [60] also found a positive connection between BDAC and business model innovation. Business model innovation is a vital component of strategic innovation [31,62], which provides statistical evidence for our research.

Accordingly, we propose the following hypothesis:

**Hypothesis 5 (H5).** *BDAC is positively related to strategic innovation.*

2.4.2. Strategic Innovation and Innovation Performance

Having a differentiated (and difficult-to-imitate) but concurrently effective and efficient structure for an enterprise's innovative business strategy is extremely significant to the establishment of competitive advantage and the improvement of innovation outcomes [63]. Strategic innovation allows firms to commercialize their ideas, strategies and resources in new ways, which consequently increases the diversity of products and services portfolios and better fulfills market demands (increasing their short-term innovation performance). Apart from this, to some extent, risk and uncertainty can be mitigated, and more benefits can be obtained through redesigning its business models and corporate strategies [64]. Measuring risk and uncertainty makes great contributions to the improvement of long-term innovation performance [65].

Although few papers verify the positive influence of strategic innovation on innovation performance, existing statistical evidence for the relationship between business model innovation and innovation performance can support our hypothesis. On the basis of the data from Swedish firms, Tavassoli and Bengtsson [66] identified that companies creatively reformulate their business models, which are associated with complementary innovations in processes, marketing and organization, and can present better innovation performance. Analogously, Gronum et al. [67] utilize a sample of 331 Australian firms to verify that business model innovation matters to innovation performance but only if firms concentrate their business model design efforts more closely on coherently entrenching innovation and efficiency within their activity and process architecture. As has been mentioned above, business model innovation is a significant component of strategic innovation, which provides empirical evidence for our study.

Accordingly, the following hypothesis is proposed:

**Hypothesis 6 (H6).** *Strategic innovation is positively related to innovation performance.*

Combining the arguments of H1 (BDCA → innovation performance), H5 (BDCA → strategic innovation) and H6 (strategic innovation → innovation performance), we further expect the following hypothesis:

**Hypothesis 7 (H7).** *Strategic innovation mediates the relationship between BDAC and innovation performance*.

*2.5. Strategic Flexibility and STRATEGIC innovation*

Strategic flexibility is a significant antecedent of strategic innovation. Based on a strategic management perspective, firms with strategic flexibility become more sensitive to new competencies, creative technologies and novel business models that are needed in strategic innovation [28]. In essence, on the basis of the resource-based view, strategic flexibility enables firms to combine, allocate and coordinate their resources of internal and external stakeholders [68], which promotes enterprises to satisfy new demands through new resource portfolios and strategic reforms. As Herhausen et al. [32] suggested, strategic organizational flexibility provides a new window of opportunities in the strategy formulation process, enhancing the new value propositions and strategic patterns.

Some existing literature has identified the positive relationship between strategic flexibility and strategic innovation. Utilizing survey data from 303 Chinese manufacturing, Han and Gao [69] verified that strategic flexibility improves management innovation through the mediator of strategic innovation. Han and Gao [69] also proved that employee orientation positively influences strategic flexibility and strategic innovation orderly, which, in turn, improves original innovation. Furthermore, there is also some statistical evidence identifying that strategic flexibility is a promoter of business model innovation [28,70], which is a vital category of strategic innovation that has been explained above. Thus, we propose the following hypothesis:

**Hypothesis 8 (H8).** *Strategic flexibility is positively related to strategic innovation.*

Combining the arguments regarding H1 (BDAC → innovation performance), H2 (BDCA → strategic flexibility), H8 (strategic flexibility → strategic innovation), and H6 (strategic innovation → innovation performance), we further expect the following hypothesis:

**Hypothesis 9 (H9).** *The relationship between BDAC and innovation performance is mediated by strategic flexibility and strategic innovation in an orderly manner.*

### *2.6. The Moderating Effect of Environmental Uncertainty*

Environmental uncertainty is the unpredictability of the external environment, the inability to forecast the impact of environmental change and the difficulty in predicting the consequences of a response choice [71]. It also refers to the lack of information or knowledge in terms of environmental factors [72]. Accordingly, this paper regards environmental uncertainty as the inability to predict the external environment changes due to the lack of adequate information.

The conditions under which dynamic capabilities are able to increase value have been a debatable topic and have always been theorized to be mainly contingent on aspects of external environments [35]. As Wilden and Gudergan [73] proposed, dynamic capabilities play a smaller role in a stable environment, where changes do not occur frequently and tend to be predictable. On the contrary, dynamic capabilities play an extremely vital role in a relatively dynamic and uncertain environment, where changes always occur at a fast-paced speed and in unpredictable ways. BDAC is a kind of dynamic capability. One of the most important functions of BDAC is prediction and analysis [74]. Such predictive and analytical competency can help firms keep sustainably competitive advantages in a complex and dynamic environment. Contrarily, when the environment is relatively stable, firms without these predictive abilities can still maintain their survival and development as usual [8]. As such, we hypothesize the following:

**Hypothesis 10 (H10).** *Environmental uncertainty positively moderates the relationship between BDAC and innovation performance.*

The overall conceptual framework is depicted in Figure 1.

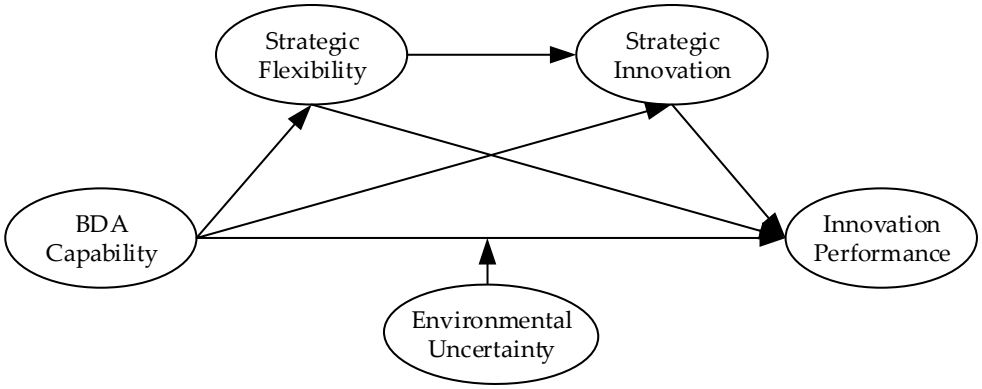


**Figure 1.** Conceptual Framework.

## 3. Methodology

### *3.1. Sample*

The survey data were collected via the sample service of a leading survey platform (wjx.cn) in China. The service has a database containing information from more than 2.6

million Chinese managers and staff. The data were collected between 4 and 6 June 2021. In addition to the service fee for the platform, we paid each valid response 3 yuan. We deleted invalid responses before the formal analysis. The deletion criteria included the following: subjects (a) were not engaged in the field of big data analytics; (b) chose the same option for the majority of the items; (c) did not finish the survey; and (d) completed the survey in less than 5 min (the minimum time revealed by a pretest). Finally, we obtained 421 valid responses, 48.7% of which were male. Most of them have worked with their companies for more than 10 years. Table 1 shows the specific characteristics of the sample.

**Table 1.** Characteristics of the Sample.

| Control Variable | | n | % |
|---|---|---|---|
| Gender | Male | 205 | 48.7 |
| | Female | 216 | 51.3 |
| Age | 18–30 years | 45 | 10.7 |
| | 31–35 years | 39 | 9.3 |
| | 36–40 years | 254 | 60.3 |
| | 41–45 years | 42 | 10.0 |
| | 46 years or older | 41 | 9.7 |
| Education | Junior qualifications | 39 | 9.3 |
| | Secondary qualifications | 50 | 11.9 |
| | Junior college | 250 | 59.4 |
| | Bachelor | 37 | 8.8 |
| | Master's or above | 45 | 10.7 |
| Job position level | Junior | 64 | 15.2 |
| | Intermediate | 74 | 17.6 |
| | Senior | 283 | 67.2 |
| Firm tenure | Less than 5 years | 83 | 19.7 |
| | 5–9 years | 55 | 13.1 |
| | More than 10 years | 283 | 67.2 |
| Number of employees in the firm (Firm size) | Less than 10 | 50 | 11.9 |
| | 10–99 | 44 | 10.5 |
| | 100–999 | 263 | 62.5 |
| | More than 1000 | 64 | 15.2 |

*3.2. Measures*

All measurements were adapted from the literature (see Appendix A). Subjects responded to these items using a five-point scale ranging from 1 = strongly disagree to 5 = strongly agree. We measured BDAC through the three first-order dimensions of Wamba et al. [34], i.e., BDA infrastructure flexibility (12 items), BDA management capabilities (19 items) and BDA personnel expertise (17 items). However, referring to prior studies [20,44], we averaged the three first-order dimensions to generate a second-order construct (i.e., BDAC) in the empirical analyses. Innovation performance (5 items) was measured with reference to [33]. Strategic flexibility (10 items) was operationalized using the approach of Li et al. [75]. Strategic innovation (4 items) was operationalized with reference to Han and Gao [69]. Environmental uncertainty (9 items) was measured based on Chen et al. [76]. Given the high internal consistency of these constructs ($\alpha > 0.8$, see Appendix A), subjects' responses to corresponding items were averaged to generate the innovation performance, strategic flexibility, strategic innovation, and environmental uncertainty constructs. Additionally, to eliminate possible interference from demographic variables, gender, age,

education, job position level, firm tenure and firm size were also included in the questionnaire.

### *3.3. Statistical Procedure*

We employed IBM SPSS 23.0, AMOS 25 and the SPSS PROCESS macro (v.2.16) developed by Hayes [77] to analyze the data. First, confirmatory factor analysis (CFA) based on AMOS 25 was conducted to verify the convergent and discriminant validity. Table 2 indicates that the factor loadings of all items were over 0.6; thus, we kept all of the items. The average variance extracted (AVE) of all constructs was above 0.5, and the composite reliability (CR) of the constructs was greater than 0.842, indicating acceptable convergent validity. Second, Table 3 shows that all of the square roots of the AVEs of the constructs were larger than the correlations among constructs, thus confirming the discriminant validity [78]. Third, Cronbach's $\alpha$ of all constructs was assessed (see Appendix A), and all $\alpha$ values were greater than 0.8, indicating high internal consistency. A correlation analysis, a bootstrap analysis with a serial mediation model and a moderation model were employed to test the hypotheses.

**Table 2.** Assessment of validity and reliability.

| Constructs | Items | Loadings | CR | AVE | Constructs | Items | Loadings | CR | AVE |
|---|---|---|---|---|---|---|---|---|---|
| BDA Connectivity (BDACN) | BDACN1 | 0.933 | 0.590 | 0.850 | BDA Business Knowledge (BDABK) | BDABK1 | 0.906 | 0.620 | 0.866 |
| | BDACN2 | 0.688 | | | | BDABK2 | 0.724 | | |
| | BDACN3 | 0.711 | | | | BDABK3 | 0.767 | | |
| | BDACN4 | 0.714 | | | | BDABK4 | 0.739 | | |
| BDA Compatibility (BDACM) | BDACM1 | 0.887 | 0.618 | 0.865 | BDA Relational Knowledge (BDARK) | BDARK1 | 0.930 | 0.617 | 0.864 |
| | BDACM2 | 0.753 | | | | BDARK2 | 0.728 | | |
| | BDACM3 | 0.748 | | | | BDARK3 | 0.732 | | |
| | BDACM4 | 0.746 | | | | BDARK4 | 0.733 | | |
| BDA Modularity (BDAMD) | BDAMD1 | 0.920 | 0.633 | 0.872 | Resource Flexibility (RF) | RF1 | 0.912 | 0.587 | 0.849 |
| | BDAMD2 | 0.744 | | | | RF2 | 0.731 | | |
| | BDAMD3 | 0.782 | | | | RF3 | 0.715 | | |
| | BDAMD4 | 0.720 | | | | RF4 | 0.686 | | |
| BDA Planning (BDAPL) | BDAPL1 | 0.935 | 0.591 | 0.850 | Coordination Flexibility (CF) | CF1 | 0.932 | 0.568 | 0.886 |
| | BDAPL2 | 0.694 | | | | CF2 | 0.700 | | |
| | BDAPL3 | 0.752 | | | | CF3 | 0.734 | | |
| | BDAPL4 | 0.665 | | | | CF4 | 0.706 | | |
| BDA Investment (BDAIN) | BDAIN1 | 0.917 | 0.608 | 0.885 | | CF5 | 0.721 | | |
| | BDAIN2 | 0.743 | | | | CF6 | 0.701 | | |
| | BDAIN3 | 0.741 | | | Strategic Innovation (SI) | SI1 | 0.951 | 0.597 | 0.853 |
| | BDAIN4 | 0.728 | | | | SI2 | 0.715 | | |
| | BDAIN5 | 0.753 | | | | SI3 | 0.693 | | |
| BDA Coordination (BDACO) | BDACO1 | 0.938 | 0.626 | 0.869 | | SI4 | 0.702 | | |
| | BDACO2 | 0.724 | | | Technology Uncertainty (TU) | TU1 | 0.927 | 0.595 | 0.853 |
| | BDACO3 | 0.737 | | | | TU2 | 0.729 | | |
| | BDACO4 | 0.747 | | | | TU3 | 0.696 | | |
| BDA Control (BDACT) | BDACT1 | 0.940 | 0.589 | 0.895 | | TU4 | 0.710 | | |
| | BDACT2 | 0.742 | | | Marketing Uncertainty (MU) | MU1 | 0.948 | 0.633 | 0.895 |
| | BDACT3 | 0.744 | | | | MU2 | 0.736 | | |
| | BDACT4 | 0.707 | | | | MU3 | 0.728 | | |
| | BDACT5 | 0.728 | | | | MU4 | 0.765 | | |
| | BDACT6 | 0.717 | | | | MU5 | 0.781 | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| BDA Technical Knowledge (BDATK) | BDATK1 | 0.924 | 0.575 | 0.870 | Innovation Performance (IP) | IP1 | 0.929 | 0.572 | 0.868 |
| | BDATK2 | 0.670 | | | | IP2 | 0.706 | | |
| | BDATK3 | 0.721 | | | | IP3 | 0.721 | | |
| | BDATK4 | 0.702 | | | | IP4 | 0.690 | | |
| | BDATK5 | 0.750 | | | | IP5 | 0.709 | | |
| BDA Technological Management Knowledge (BDATM) | BDATM1 | 0.942 | 0.577 | 0.842 | | | | | |
| | BDATM2 | 0.663 | | | | | | | |
| | BDATM3 | 0.711 | | | | | | | |
| | BDATM4 | 0.689 | | | | | | | |

**Table 3.** Correlation Analysis.

| Variables | Mean | SD | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| BDAC | 2.954 | 0.475 | 0.789 | | | | |
| Strategic Flexibility | 3.034 | 0.738 | 0.417 *** | 0.759 | | | |
| Strategic Innovation | 3.028 | 0.969 | 0.341 *** | 0.323 *** | 0.773 | | |
| Environmental Uncertainty | 3.014 | 0.756 | 0.427 *** | 0.385 *** | 0.299 *** | 0.785 | |
| Innovation Performance | 2.980 | 0.885 | 0.416 *** | 0.459 *** | 0.508 *** | 0.355 *** | 0.756 |

Bold values on the diagonal are the square roots of AVE. *** represents that it is significant at 1% level.

## 4. Results

### *4.1. Correlation Analysis*

Table 3 shows that there were significant correlations (Pearson coefficients) among the major constructs. All of the correlations among the constructs were less than 0.5, implying that multicollinearity is not a problem in this study [79].

### *4.2. Hypothesis Testing*

The SPSS PROCESS macro (v.2.16) was used, and the procedure suggested by Hayes and his colleagues was followed to assess the proposed hypotheses [74]. This research used the bootstrapping test (boot = 5000) and computed 95% bias-corrected lower-level confidence intervals (LLCIs) and upper-level confidence intervals (ULCIs) around the estimates of the indirect effects to conduct a serial multiple mediation analysis of strategic flexibility and strategic innovation (Model 6 of PROCESS) and of the moderation analysis of environmental uncertainty (Model 1 of PROCESS),.

The bootstrap results of the mediation effects are shown in Table 4 and Figure 2. In support of H1, the results showed that BDAC had a positive effect on innovation performance ($\beta = 0.766$; $p < 0.001$). As we hypothesized (H2), BDAC had a positive effect on strategic flexibility ($\beta = 0.639$; $p < 0.001$). The results also illustrated that both BDAC ($\beta = 0.501$, $p < 0.001$) and strategic flexibility ($\beta = 0.416$, $p < 0.001$) were positively related to innovation performance, thus supporting H3. Accordingly, BDAC had a direct positive effect on innovation performance, and it also indirectly increased innovation performance through the mediating effect of strategic flexibility, which supports H4.

**Table 4.** Serial Multiple Mediation Regression Results.

| | Coefficient | SE | t Value | *p* Value | LLCI (95%) | ULCI (95%) |
|---|---|---|---|---|---|---|
| Dependent variable: Innovation performance ($R^2 = 0.289$, F = 20.985) | | | | | | |
| BDAC | 0.766 | 0.082 | 9.293 | 0.000 | 0.604 | 0.928 |
| Mediation of Strategic Flexibility | | | | | | |
| Dependent variable: Strategic flexibility ($R^2 = 0.198$, F = 14.548) | | | | | | |
| BDAC | 0.639 | 0.069 | 9.312 | 0.000 | 0.504 | 0.773 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Dependent variable: Innovation performance ($R^2$ = 0.289, F = 20.985) | | | | | | |
| BDAC | 0.501 | 0.085 | 5.878 | 0.000 | 0.333 | 0.668 |
| Strategic flexibility | 0.416 | 0.056 | 7.477 | 0.000 | 0.306 | 0.525 |
| Mediation of Strategic Innovation | | | | | | |
| Dependent variable: Strategic innovation ($R^2$ = 0.127, F = 8.604) | | | | | | |
| BDAC | 0.692 | 0.094 | 7.364 | 0.000 | 0.507 | 0.876 |
| Dependent variable: Innovation performance ($R^2$ = 0.341, F = 26.617) | | | | | | |
| BDAC | 0.506 | 0.079 | 6.380 | 0.000 | 0.350 | 0.662 |
| Strategic innovation | 0.376 | 0.039 | 9.615 | 0.000 | 0.299 | 0.453 |
| Serial Multiple Mediation of Strategic Flexibility and Strategic Innovation | | | | | | |
| Dependent variable: Strategic flexibility ($R^2$ = 0.198; F = 14.548) | | | | | | |
| BDAC | 0.639 | 0.069 | 9.312 | 0.000 | 0.504 | 0.773 |
| Dependent variable: Strategic innovation ($R^2$ = 0.166; F = 10.280) | | | | | | |
| BDAC | 0.506 | 0.101 | 5.010 | 0.000 | 0.308 | 0.705 |
| Strategic flexibility | 0.290 | 0.066 | 4.397 | 0.000 | 0.160 | 0.420 |
| Dependent variable: Innovation performance ($R^2$ = 0.396; F = 29.902) | | | | | | |
| BDAC | 0.336 | 0.081 | 4.142 | 0.000 | 0.176 | 0.495 |
| Strategic flexibility | 0.321 | 0.053 | 6.114 | 0.000 | 0.218 | 0.424 |
| Strategic innovation | 0.326 | 0.038 | 8.509 | 0.000 | 0.251 | 0.402 |

Constant and control variables are omitted for parsimony. SE represents Standard Error. LLCI and ULCI are the lowest and highest confidence intervals, respectively. They are generally 95% confidence intervals.

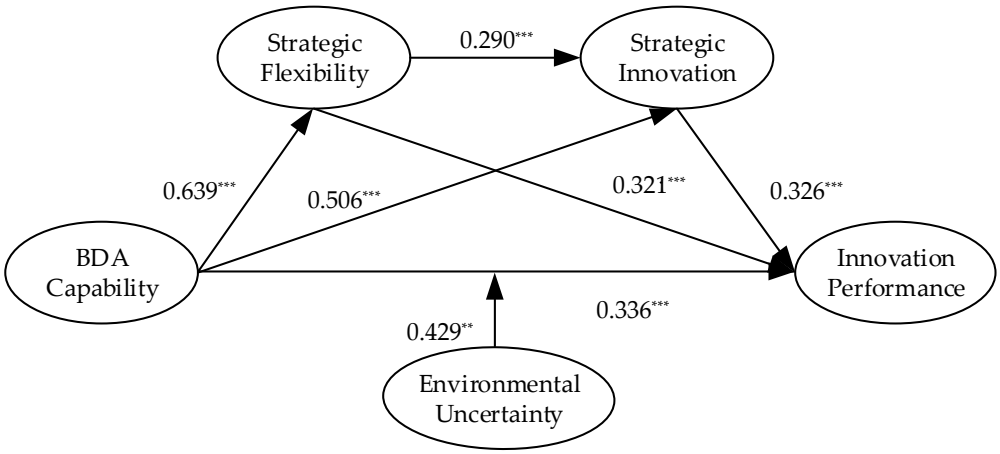


**Figure 2.** Verified Model. *** represents that it is significant at 1% level, **represents that it is significant at 5% level.

Furthermore, the results in Table 4 demonstrate that BDAC has a positive effect on strategic innovation (β = 0.692; $p < 0.001$), thus confirming H5. Both BDAC (β = 0.506, $p < 0.001$) and strategic innovation (β = 0.376, $p < 0.001$) had a significant effect on innovation performance, which supports H6. These results also affirmed that BDAC could increase innovation performance through the mediating effect of strategic flexibility, thus supporting H7. Additionally, BDAC (β = 0.336, $p < 0.001$), strategic flexibility (β = 0.321, $p < 0.001$), and strategic innovation (β = 0.326, $p < 0.001$) were positively related to innovation performance, thus affirming H8. Consequently, we can conclude that strategic flexibility and strategic innovation can mediate the relationship between BDAC and innovation performance in an orderly manner, which supports H9.

The direct and indirect effect sizes of the mediation effects are illustrated in Table 5. The mediation effects of strategic flexibility (Indirect1 in Table 5) and strategic innovation

(Indirect3 in Table 5) and the serial mediation effects of strategic flexibility and strategic innovation (Indirect2 in Table 5) were estimated as 0.205, 0.060 and 0.165, respectively (with a 95% confidence interval). The total indirect effects were 0.431 with a 95% confidence interval ([CI] = [0.348, 0.516]), and the direct effects of BDAC were 0.336 with a 95% confidence interval ([CI] = [0.176, 0.495]), indicating that the serial multiple mediation effects were partial mediation. The indirect effects accounted for 56.27% of the total effects.

**Table 5.** Direct and indirect effect results.

| Effect | Coefficient | SE | LLCI (95%) | ULCI (95%) |
|---|---|---|---|---|
| Total Effect | 0.766 | 0.082 | 0.604 | 0.928 |
| Total Direct Effect | 0.336 | 0.081 | 0.176 | 0.495 |
| Total Indirect Effect | 0.431 | 0.043 | 0.348 | 0.516 |
| Indirect 1: BDAC → Strategic flexibility → Innovation performance | 0.205 | 0.034 | 0.143 | 0.272 |
| Indirect 2: BDAC → Strategic flexibility → Strategic innovation → Innovation performance | 0.165 | 0.032 | 0.105 | 0.231 |
| Indirect 3: BDAC → Strategic innovation → Innovation performance | 0.060 | 0.017 | 0.030 | 0.098 |

SE represents Standard Error. LLCI and ULCI are the lowest and highest confidence intervals, respectively. They are generally 95% confidence intervals.

The bootstrap results of the moderation effects are shown in Table 6 and Figure 2. Both BDAC ($\beta = 0.475$, $p < 0.001$) and environmental uncertainty ($\beta = 0.113$, $p < 0.001$) were positively related to innovation performance. The coefficient of the interaction term "BDAC × environmental uncertainty" was also significant, $\beta = 0.429$, $p < 0.001$. These results support H10, indicating that the positive effect of BDAC on innovation performance was more significant under high (vs. low) environmental uncertainty conditions.

The verified model with path coefficients is shown in Figure 2.

**Table 6.** Moderation Regression Results.

| | Coefficient | SE | t Value | *p* Value | LLCI (95%) | ULCI (95%) |
|---|---|---|---|---|---|---|
| Moderation of Environmental Uncertainty | | | | | | |
| Dependent Variable: Innovation performance ($R^2 = 0.253$; F = 15.435) | | | | | | |
| BDAC | 0.475 | 0.393 | −4.814 | 0.001 | 0.111 | 2.568 |
| Environmental uncertainty | 0.113 | 0.322 | −2.173 | 0.000 | 0.038 | 1.073 |
| BDAC × Environmental uncertainty | 0.429 | 0.122 | 3.510 | 0.001 | 0.189 | 0.669 |

Constant and control variables are omitted for parsimony. SE represents Standard Error. LLCI and ULCI are the lowest and highest confidence intervals, respectively. They are generally 95% confidence intervals.

## 5. Discussion

### *5.1. Discussion of the Empirical Results*

The results of the research provide various insights into the relationship between BDAC and a firm's innovation performance. Given the diffusion of big data, the productivity paradox of BDAC has gradually attracted extensive attention from scholars. A majority of scholars identify that BDAC can positively influence a firm's performance, especially innovation performance [17,18,21]. Nevertheless, a minority of scholars raise that the impact of BDAC on a firm's performance is uncertain because big data systems are expensive to establish, which may bring unpredictable risks [7,80]. Our research proposed a conceptual model, conducted a questionnaire survey and utilized the bootstrap method to analyze the survey data and clarify the relationship between BDAC and firm innovation performance. First, the results identified that BDAC is positively related to firm innovation performance ($\beta = 0.336$, $p < 0.001$), which means that the hypothesis of the main effect is supported, and a firm owning BDAC can enhance its innovation performance

effectively and efficiently. Furthermore, we compared our main effect test results with the extant literature. On the basis of a survey from the US and China, Hao et al. [17] confirmed that BDAC had a significantly positive relationship ($\beta = 5.853$, $p < 0.010$), whereas $BDAC^2$ had a significant negative relationship with innovation performance ($\beta = -0.700$, $p < 0.100$) in the US sample; BDAC had a significantly positive relationship ($\beta = 6.473$, $p < 0.010$) whereas $BDAC^2$ had a negative but not significant relationship with innovation performance ($\beta = -0.087$, $p > 0.100$) in the Chinese sample. It indicated that BDAC had an inverted U-shaped relationship with innovation performance in the US sample and a positive relationship with innovation performance in the Chinese sample. Based on the survey of German firms, Niebel et al. [18] verified that BDAC is positively related to innovation performance ($\beta = 0.067$, $p < 0.001$), which is consistent with our research results. Second, based on a strategic management perspective, this research provides a deeper understanding of mechanisms of how organizations can use BDAC to improve innovation performance through the multiple serial mediators of strategic flexibility and strategic innovation. Specifically, BDAC is positively related to strategic flexibility ($\beta = 0.639$, $p < 0.001$), strategic flexibility is positively related to strategic innovation ($\beta = 0.290$, $p < 0.001$), and strategic innovation is positively related to innovation performance ($\beta = 0.326$, $p < 0.001$). It indicated that the mediating effect hypotheses are supported, and strategic flexibility and strategic innovation play a significantly serial mediating role in this relationship between BDAC and innovation performance. Third, this study also affirms the positive effect of BDAC on innovation performance is more significant under a high (vs. low) environmental uncertainty condition ($\beta = 0.429$, $p < 0.005$). The proposed moderating effect hypothesis is supported.

### *5.2. Theoretical Contributions*

This study contributes to the extant literature in the following ways. First, given the inconsistent findings of the relationship between BDAC and innovation performance [7,15–17], this study provides novel empirical evidence that supports the positive relationship between BDAC and innovation performance.

Second, our findings provide deeper knowledge regarding how firms can use BDAC to improve innovation performance through the multiple serial mediators of strategic flexibility and strategic innovation. Several prior studies have confirmed the mediating role of firms' dynamic capacities [8], agility [9] and big data marketing affordances [17]. Based on the strategic management perspective, this study demonstrates the serial mediation roles of strategic flexibility and strategic innovation between BDAC and innovation performance, thus providing complements for the mediation path revealed in prior studies.

Finally, this study confirms the positive moderation effect of environmental uncertainty on the relationship between BDAC and innovation performance. Several prior studies have documented contingent factors, such as the fit between big data and BDAC [15], firms' investment in IT-specific skills [16] and environmental dynamism [8]. This study provides a new contingent factor, i.e., environmental uncertainty, regarding the effect of BDAC on innovation performance.

### *5.3. Managerial Implications*

Our findings have practical implications for firm managers. First, given the positive effect of BDAC on firms' innovation performance, managers should realize that developing BDAC can contribute to a firm's superior innovation and performance. Thus, they should attempt to develop their BDAC. Since BDAC consists of BDA infrastructure flexibility, BDA management capabilities and BDA personnel expertise, enterprises are advised to develop their BDAC in the following aspects: (a) investing more in big data analytics infrastructure to increase the availability and flexibility of datasets; (b) improving their big data analytics management capability to facilitate intelligent business awareness in managerial decisions; and (c) cultivating or recruiting professional talent who are

proficient in big data analytics techniques, thus building a firm's capacities in database management, analysis tool utilization, intelligent decision making and cross-functional collaboration.

Second, our findings confirm that BDAC can boost innovation performance through the mediating roles of strategic flexibility and strategic innovation. Strategic flexibility mainly involves the ability to adapt to the current changing environment. Strategic innovation emphasizes the ability to seize external opportunities to obtain competitive advantages in the future. Based on the empirical results, BDAC is an efficient way to improve a firm's abilities to adapt to the current environment (i.e., strategic flexibility) and capacities to seize future opportunities (i.e., strategic innovation), which, in turn, improves a firm's innovation performance. Firms are advised to focus on the flexible application of BDAC to obtain real-time information. The information can be transferred to business insights to strengthen a firm's adaptive and innovative capabilities.

Finally, since the positive effect of BDAC on innovation performance is more obvious in a high-uncertainty environment, the development of BDAC is more important in a high-uncertainty environment business world. The high-uncertainty environment consists of technology uncertainty and market uncertainty. When a firm is faced with high technology uncertainty and market uncertainty, the firm is encouraged to take advantage of BDAC to maintain sustainable innovation performance. Given that the COVID-19 pandemic has imposed a great level of uncertainty on the current business world, the development of BDAC, strategic flexibility and strategic innovation could be particularly important for firms pursuing competitive advantages and superior performance.

### *5.4. Limitations and Future Research Directions*

This study still has limitations. As in most survey-method-based research, the reports about the firm's innovation performance were inferred from the staff's personal responses. Moreover, we only used sample data from China. Future studies could collect samples from other cultures to test the external validity of our findings. Additionally, it may be valuable to explore the antecedents of BDAC and some other factors that may matter in the relationship among BDAC, strategic flexibility, strategic innovation and innovation performance.

## 6. Conclusions

There is an increasing number of studies focusing on the research of BDAC. It is of significance for enterprises to explore how and when BDAC can increase innovation performance. Based on a survey of 421 Chinese managers and employees, this study found that BDAC is positively related to innovation performance; strategic flexibility and strategic innovation play significantly serial mediating roles in this relationship on BDAC influencing innovation performance; the positive effects of BDAC on innovation performance are more significant under high (vs. low) environmental uncertainty conditions. In theory, this study is one of the first to test how (i.e., the mediating role of strategic flexibility and strategic innovation) and when (i.e., the moderating role of environmental uncertainty) BDAC can boost a firm's innovation performance. In practice, based on the empirical results, first, it is suggested that firm managers invest more in big data analytics infrastructure to increase the availability and flexibility of datasets; second, they are encouraged to improve their big data analytics management capability to facilitate intelligent business awareness in managerial decisions; third, they are advised to cultivate and recruit professional talent who are proficient in big data analytics techniques, to improve a firm's capacities in database management, analysis tool utilization, intelligent decision making and cross-functional collaboration. In addition, with the development of BDAC, it is recommended that firms improve their abilities to adapt to the environment and the ability to seize external opportunities to obtain competitive advantages in the future.

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## Appendix A

**Table A1.** Measurements.

| Constructs | Items |
|---|---|
| BDA infrastructure flexibility | BDA Connectivity ($\alpha$ = 0.842) |
| | Compared with the competitors in your industry, your firm owns more advanced analytics systems. |
| | The branch offices of your company are closely connected to the central office of your firm for sharing analytics insights. |
| | Open system network mechanisms are used in your firm to support analytics connectivity. |
| | Apparent communications bottlenecks do not exist within your firm when sharing analytics insights. |
| | BDA Compatibility ($\alpha$ = 0.860) |
| | The software applications in your firm can be easily applied on multiple analytics platforms. |
| | The user interfaces in your company offer transparent access to all platforms and applications. |
| | Your firm can seamlessly share analytics-driven information internally, regardless of location. |
| | The multiple analytics interfaces or entry points are provided in your firm for external end-users. |
| | BDA Modularity ($\alpha$ = 0.865) |
| | Your firm widely utilizes reusable software modules in the new system development. |
| | Object-oriented technologies are available for end users to create their own applications. |
| | Object-oriented tools are available for analytics personnel to shorten the development time of new applications. |
| | The applications in your firm can be adapted to fulfill various requirements when carrying out analysis tasks. |
| BDA management capabilities | BDA Planning ($\alpha$ = 0.840) |
| | Your firm constantly seeks innovative opportunities for the strategic utilization of BDA. |
| | Your firm introduces and develops numerous plans for the strategic use of BDA. |
| | Your firm executes BDA planning processes in systematic ways. |
| | Your firm adjusts BDA plans frequently according to the changing environment. |
| | BDA Investment ($\alpha$ = 0.880) |
| | When your firm makes BDA investment decisions, it always considers and forecasts the effects they will have on employee productivity. |
| | When your firm makes BDA investment decisions, it usually thinks about and projects how much these actions can support end users in making quicker decisions. |

| | |
|---|---|
| | When your firm makes BDA investment decisions, it always considers and estimates whether it will consolidate or eliminate some jobs.<br>When your firm makes BDA investment decisions, it usually considers and forecasts the cost of training end-users.<br>When your firm makes BDA investment decisions, it always thinks about and forecasts the time that managers may spend overseeing the change. |
| | BDA Coordination ($\alpha$ = 0.862)<br>The business analysts and line people in your firm meet regularly to discuss significant firm issues in both formal and informal ways.<br>The business analysts and line people from various departments of your firm regularly attend cross-functional meetings.<br>The business analysts and line people in your firm harmoniously coordinate their efforts with each other.<br>The business analysts and line people regularly share various information to ensure that decision-makers and operators have access to all necessary and available know-how. |
| | BDA Control ($\alpha$ = 0.892)<br>The responsibility for BDA development in your firm is clearly allocated.<br>The BDA department in your firm is clear about the criteria of their performance.<br>Compared with rivals, your firm is better at connecting parties (i.e., communicating and information sharing) within the business processes.<br>Compared with rivals, your firm is better at controlling costs within business processes.<br>Compared with rivals, your firm is better at introducing complex analytical methods into business processes.<br>Compared with rivals, your firm is better at introducing detailed information into business processes. |
| BDA personnel expertise | BDA Technical knowledge ($\alpha$ = 0.865)<br>The analytics personnel at your firm are quite capable in terms of programming skills.<br>The analytics personnel at your firm are quite capable in terms of managing project life cycles.<br>The analytics personnel at your firm are quite capable in the areas of data management and maintenance.<br>The analytics personnel at your firm are quite capable in the area of distributed computing.<br>The analytics personnel at your firm are quite capable in data analytics decision systems. |
| | BDA Technological management knowledge ($\alpha$ = 0.832)<br>The analytics personnel at your firm are quite capable of understanding technological trends.<br>The analytics personnel at your firm are quite capable of learning new technologies.<br>The analytics personnel at your firm are quite capable of understanding the critical factors for the success of the firm.<br>The analytics personnel at your firm are quite capable of understanding the role of business analytics as a means, not an end. |
| | BDA Business knowledge ($\alpha$ = 0.861)<br>The analytics personnel at your firm have a good understanding of your firm's policies and plans.<br>The analytics personnel at your firm are quite capable of dealing with business problems and thinking of appropriate solutions.<br>The analytics personnel at your firm understand your business functions at a high level.<br>The analytics personnel at your firm understand your business environment at a high level. |
| | BDA Relational knowledge ($\alpha$ = 0.857)<br>The analytics personnel at your firm are quite capable in terms of managing projects.<br>The analytics personnel at your firm are quite capable in terms of executing work in a collective environment.<br>The analytics personnel at your firm are quite capable in terms of teaching others. |

| | |
|---|---|
| | The analytics personnel at your firm are quite capable of keeping close relationships with your firm's customers. |
| Resource flexibility | Resource flexibility ($\alpha$ = 0.843)<br>The difficulty in switching the utilization of core resources to another way within your firm is quite low.<br>The time to switch the utilization of core resources to another way within your firm is quite short.<br>The cost to switch the utilization of core resources to another way within your firm is quite low.<br>The extent that the same resources are alternatively used in developing, producing, and selling different products within your firm is quite high. |
| Coordination flexibility | Coordination flexibility ($\alpha$ = 0.885)<br>Your firm can reach a high degree of consensus in the utilization of resources in different departments.<br>Your firm can reach a high sharing degree in the utilization of resources in different departments.<br>Your firm can discover some new resources or combinations of resources inside the firm.<br>Your firm can discover some new resources or combinations of resources outside the firm.<br>Your firm enhances agility by fostering capabilities.<br>Your firm enhances adaptability by fostering capabilities. |
| Strategic innovation | Strategic innovation ($\alpha$ = 0.848)<br>Your firm has a unique business model.<br>Your firm's strategy is different from others in the industry.<br>Your firm strives to have an unusual strategy.<br>Your firm's competitive strategy has great potential value. |
| Technology uncertainty | Technology uncertainty ($\alpha$ = 0.847)<br>The degree of technological change within your industry is great.<br>The availability of technology is higher in your enterprise.<br>The speed of technology updates in your industry is very fast.<br>Technological innovation has great influence on product development at your firm. |
| Market uncertainty | Market uncertainty ($\alpha$ = 0.893)<br>Customer needs and product preferences change quickly.<br>The customers' demand for new products is high.<br>New customers have high demand for our products.<br>New customers are constantly entering the market.<br>The product demand from new and old customers is completely different. |
| Innovation performance | Innovation performance ($\alpha$ = 0.866)<br>Compared with your rivals, your firm usually launches new products or services earlier.<br>Compared with your rivals, your firm's products usually have more advanced technologies.<br>Compared with your rivals, the market responses to your firm's new products are better.<br>Compared with your rivals, the development speed of products in your firm is faster.<br>Compared with your rivals, the input-output rate of new products in your firm is higher. |

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