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ORIGINAL PAPER

BIG DATA CAPABILITY AND SUPPLY CHAIN PERFORMANCE: THE MEDIATING EFFECT OF SUPPLY CHAIN RESILIENCE AND THE MODERATING EFFECT OF ENVIRONMENTAL UNCERTAINTY

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ABSTRACT. Background: This paper aims to investigate the relationship between big data capability (BDC) and supply chain performance (SCP), and to examine the mediating role of supply chain resilience (SCR) and the moderating role of environmental uncertainty (EU) on the relationship between BDC and SCP. Drawing on the dynamic capability view and contingency theory, the study developed and tested a conceptual model with empirical data, clarifying the effects of BDA on SCP, the mediating effects of SCR and the moderating effects of EU.

Methods: The primary survey data of 232 responses were collected from supply chain managers of manufacturers in China. The data were analyzed by employing SPSS and AMOS, and hierarchical regression was used to test the hypothesis.

Results: The study found that BDC and its three dimensions have a significant impact on SCP, with a partial mediating role for SCR. Additionally, environmental uncertainty significantly moderates the relationships between BDC and SCR and between SCR and SCP.

Conclusions: The results indicate the growing role of big data in supply chain resilience and performance, especially for small and medium-sized firms. Manufacturing companies should accelerate the development of supply chain resilience management systems and enhance their ability to cope with environmental changes. Managers should also be alert to the risks of changes in the external environment and allocate appropriate resources to mitigate environmental uncertainty and adapt to environmental changes. Limitations and further research directions are also provided in the paper.

Keywords: Big data capability; Supply chain resilience; Supply chain performance; Environmental uncertainty.

INTRODUCTION

Big data plays a critical role in solving problems in operations, and the term does not simply mean a huge amount of data (Wamba et al. 2015). Insights can be extracted from data to enhance decision-making capabilities (Chen, Chiang, and Storeyet 2012; McAfee and Brynjolfsson 2012). Existing studies mainly focus on the level of individual firms, discussing the important impact of big data capability (BDC) on business model innovation (Mikalef et al. 2020; Ciampi et al. 2021), strategic decision-making (Kache and Seuring 2017; Ghasemaghaei and Calic 2019), firm performance (Akter et al. 2016; Wamba et al. 2017), and competitive advantage (Dubey et al. 2018). Moreover, organizations are becoming increasingly digital, and a large volume of data is being generated in their supply chains (Wang et al. 2016). Firms cannot formulate a supply chain management strategy without the support of BDC. Specifically, BDC reduces uncertainty by enhancing access to information and generating knowledge (Chen et al., 2015; Gnizy 2019). BDC contributes to supply chain management, providing a better understanding of customer behavior, higher visibility and transparency of the supply chain (Baryannis et al. 2018), and improved operational efficiency while eliminating supply risks (Kache and Seuring

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2017) and improving the performance level of the supply chain (Li et al. 2016). While many firms enhance BDC to extract new insights and create new forms of value, other firms have yet to leverage big data to transform their supply chain operations (Sanders 2016). The authors argue that there is a need for more empirical research explicating the mechanisms through which BDC effects are diffused to improve SCP.

Supply chain resilience remains a key managerial challenge affecting the performance of organizations (Brandon-Jones et al. 2014). Since the outbreak of COVID-19, along with the changes in the global supply and demand relationship, the vulnerability of the supply chain has been gradually exposed, supply chain disruptions have occurred frequently, and the global industrial supply chain has nearly collapsed. The havoc the pandemic created challenged the way that firms manage their supply chain processes. It has been proven that without maintaining a stable supply chain in the face of unprecedented changes, firms cannot maintain normal production and operational activities. The more resilient the supply chain, the less the impact of the pandemic (EI Baz and Ruel 2020). Therefore, building supply chain resilience (SCR) is increasingly recognized as an effective strategy to address supply chain challenges, risks, and disruptions (Chunsheng et al. 2019; Zhou et al. 2022). In the post-COVID-19 era, to cope with the impact of environmental uncertainties and supply chain disruption, SCR has become the core capability of firms to survive and compete in the changing landscape (Jüttner and Maklan 2011). There is a consensus among industrial firms that it is necessary to improve SCR (Brusset and Teller 2017). The current challenge faced by firms is how to build up a more resilient supply chain to manage and minimize risks. The existing literature shows that emerging information technologies such as BDC (Singh and Singh 2019), artificial intelligence (Belhadi et al. 2021; Gupta et al. 2021), and blockchain technology (Min 2019) have great potential in supply chain risk analysis (Ivanov, Dolgui, and Sokolov 2018), which can reduce the difficulty of information processing and improve the recovery efficiency of supply chain breakage by strengthening information processing capability. At the same time, the supply chain visualization facilitated by information technology helps firms to identify the potential supply chain fracture risk (Rajagopal 2016), thus improving the resilience of the supply chain (Xu et al. 2020). Firms with an extensive utilization of digital technologies can operate with more resilience due to improved visibility and coordination (Ivanov, Blackhurst, and Das 2021; Alvarenga et al. 2023). BDC is playing an increasingly important role in enhancing the resilience of supply chains, strengthening digital adoption, and addressing operational crises (Bag et al. 2021; Bahrami and Shokouhyar 2021; Gupta et al. 2022). However, although some research has affirmed these direct effects, little is known about the mechanisms that act in the relationship between the BDC, resilience, and performance. Against this backdrop, the current study attempts to answer the following questions:

RQ1. Does big data capability have a positive impact on supply chain resilience?

RQ2. Does SCR play a mediating role in the relationship between BDC and supply chain performance?

RQ3. How does environmental uncertainty moderate the relationship between BDC, SCR, and supply chain performance?

In addressing and answering these research questions, this study makes both theoretical and practical contributions. Firstly, it develops and enriches the research on the mechanisms through which BDC affects supply chain performance, and at the same time provides theoretical insights into the value creation of BDC at the organizational level. Secondly, it extends the theoretical framework of the antecedents and consequences of SCR, explaining how BDC affects supply chain performance through resilience. Thirdly, it helps to clarify the boundary conditions for the role of BDC and SCR by examining the moderating role of environmental uncertainty in the relationship between BDC, SCR, and supply chain performance. In general, the study provides insights and a decision-making basis for company managers to enhance BDC, cope with supply chain risks, and improve firm supply chain management capability by analyzing the relationships between BDC, SCR, and supply chain performance and the associated boundary conditions.

THEORETICAL BACKGROUND

Dynamic capability view (DCV)

The fundamental tenet of the resource-based view (RBV) is to investigate a firm's value creation and value capture processes from a static vantage point, ignoring the influence of market turbulence. Teece et al. (1997) extend the RBV and believe that firms need to constantly integrate and reconstruct their resources and capabilities, as they have to cope with changes in the external market environment and technological environment and avoid losing their competitive advantage due to these changes. This ability to integrate and configure a firm's resources to adapt to environmental changes is a dynamic capability which can help firms to maintain a competitive advantage in an ever-changing environment.

Dynamic capability theory is the primary theoretical perspective used to develop a conceptual model in this study. The application of BDC in the field of supply chains can enhance the dynamic information processing capability of firms, provide decision-makers with knowledge, and generate better resource allocation, thus creating competitive advantages (Côrte-Real, Oliveira, and Ruivo 2017; Matthias et al. 2017). More specifically, BDC can reduce uncertainty by stimulating insight (Mikalef et al. 2019b) and knowledge creation, and it enhances an organization's strategic decision-making capability, which is more valuable in a dynamic environment with a high degree of uncertainty (Chen, Chiang, and Storey 2012; Chen, Preston, and Swink 2015). From this point of view, dynamic capability theory is particularly useful to explain the influence of big data capability. At the same time, in the field of supply chain research, the resource-based view (RBV) focuses on the internal resources of firms and does not go beyond the level of firms (Kraaijenbrink, Spender, and Groen 2010). However, SCR is a system-level phenomenon, which occurs at the supply chain level rather than at the level of individual firms, and it involves the linkages between firms (Duong and Chong 2020).

In addition, the resource-based view (RBV) assumes that the future value of resources is determined in a predictable environment, but SCR is precisely nonlinear, dynamic, and unpredictable. SCR is intended to solve the problem of supply interruption caused by environmental turbulence, while the dynamic capability view (DCV) emphasizes the ability to constantly reconstruct a 'dynamic' that is consistent with the changing environment. Nevertheless, there is a natural relationship between the two. Many studies have explored SCR and its formation mechanism based on dynamic capability theory (Brusset and Teller 2017; Li et al. 2017), and many researchers regard SCR itself as a dynamic capability (Lee and Rha 2016; Chowdhury and Quaddus 2017). Therefore, the dynamic capability view (DCV) provides a theoretical basis for related research on SCR and the logical framework of this paper.

Contingency theory

Contingency theory is a management theory developed from western empiricism in the 1960s. It is based on the contingency idea of a concrete analysis of specific problems in western organizational management (Fiedler 1964). The basic idea of contingency theory is that the methods and measures that each organization needs to take are determined by its internal requirements and external environment, and there are no universal principles and methods applicable to any situation. Organizations are required to adapt to the development and changes in their internal conditions and external environment (Wong, Boon-itt, and Wong 2011).

In the empirical study of contingency theory, environmental uncertainty is the most widely studied environmental variable (Wong, Boon-itt, and Wong 2011; Mikalef and Krogstie 2018). Especially in the study of supply chain management, environmental uncertainty is an important contingency factor that needs to be considered when evaluating the antecedents and outcomes of SCR (Grötsch, Blome, and Schleper 2013). On the one hand, the firm's internal resource capacity needs to match the environmental risk level (Mikalef et al. 2019a). The supply chain's dynamic environment has a beneficial effect on developing organizational capabilities (Mikalef et al. 2019; Belhadi et al. 2021) when organizational decision-makers are facing substantial environmental uncertainty. Factors such as rapid changes in customer demand and unpredictable market trends can make firms fall into the dilemma of information asymmetry constraints. Therefore, it is necessary to strengthen information capture to obtain valuable information to help firms respond quickly, and BDC becomes crucial. In other words, when the environment is highly uncertain, organizations are increasingly reliant on BDC to help them cope with environmental change (Mikalef et al. 2018; Dubey et al. 2019). On the other hand, SCR also needs to match the level of environmental uncertainty (Shashi et al. 2019). Environmental uncertainty increases the possibility of supply chain disruption due to the impact of the external environment (Lee and Rha 2016; Ambulkar, Blackhurst, and Grawe 2015), which requires firms in the supply chain to actively use resilience to help them cope with the risk of disruption (Um and Han 2020), prepare in advance, respond in time, and recover faster. In other words, the higher the degree of environmental uncertainty, the more significant the impact of resilience on supply chain performance (Wong et al. 2020).

HYPOTHESIS DEVELOPMENT AND RESEARCH MODEL

BDC and supply chain performance

BDC is an extension of the concept of information technology capability (Hopkins 2011). The existing literature mainly defines BDC from two different perspectives: the resource-based view and the dynamic capability view. Based on the RBV, BDC includes human resources and infrastructure related to big data applications (Akter et al. 2016). Enterprises can gather, integrate and deploy resources related to big data, and utilize big data resources to improve performance (Gupta and George 2016) and competitiveness. Based on the DCV, BDC puts more emphasis on the response to the external environment (Mikalef et al. 2019a). This is regarded as the utilization of big data resources by firms to gain valuable insights and make effective decisions so as to improve the dynamic ability of firms to cope with changes in the external environment (Chen, Preston, and Swink 2015). This study argues that BDC is a dynamic capability for firms to realize deep data mining and real-time data analysis by integrating data resources, big data talent, technologies, and other resources related to big data. Therefore, this study divides BDC into three dimensions: resource integration capability (RIC), depth analysis capability (DAC) and real-time insight, and predictive capability (RTIPC). RIC refers to a firm's ability to gather and integrate internal and external big data resources. DAC refers to the ability of firms to analyze the integrated data resources, deeply mine them, and extract valuable information to meet the business needs of firms. RTIPC refers to the ability of firms to achieve real-time insight into market opportunities and accurate prediction of market changes through the analysis of valuable information.

Resources are the key to developing capabilities (Kitchens et al. 2018). RIC can maximize productivity, enhance collaboration, reduce costs, and improve operational efficiency by gathering and integrating internal and external big data resources, and then have a better chance to improve supply chain performance (Schoenherr and Speier-Pero 2015). By analyzing integrated data resources, DAC can deeply mine and extract valuable information to meet the business needs of firms and promote big data technology to play a role in assisting with decision-making in business analysis, which helps to improve supply chain performance (Ghasemaghaei and Calic 2019; Gunasekaran et al. 2017). RTIPC enables real-time insight into market opportunities and accurate prediction of market changes and positively impacts supply chain performance by stimulating insight and knowledge creation to reduce uncertainty (Arunachalam, Kumar, and Kawalek 2018; Belhadi et al. 2019). Technological advantages help firms perceive environmental changes in advance, enhance the predictability of the external environment, maximize data value, and further help manage the supply chain by reducing intervention and improving decision-making (Kache and Seuring 2017). Thus, we propose the following hypotheses:

H1. BDC has a significant positive impact on supply chain performance.

H1a. RIC has a significant positive impact on supply chain performance.

H1b. DAC has a significant positive impact on supply chain performance.

H1c. RTIPC has a significant positive impact on supply chain performance.

SCR and Supply chain performance

With an uncertain external operating environment and unpredictable risks, traditional risk management thinking is shifted from a strategy of response to interruptions to a more active strategy, that is, establishing SCR to reduce the negative impact of the interruption (Xu et al. 2020; Scholten, Stevenson, and van Donk 2019). Initially, SCR was conceived as the ability of an organization to respond to unexpected events and resume normal operations (Rice and Caniato 2003), as a passive recovery ability which enables the supply chain to recover as soon as possible after a disruption (Christopher and Peck 2004; Sheffi 2005). Resilience provides the supply chain with the ability to prepare for disruption, reduce the impact of disruption and recover quickly from disruption (Tukamuhabwa et al. 2015; Birkie, 2016), thus entering a better state than before the interruption. Based on previous scholars' definition of resilience, this study regards SCR as a dynamic ability to cope with supply chain interruption which can keep the supply chain highly alert to the environment and allow it to respond quickly after the interruption, thus maintaining the continuity of supply chain operations.

Supply chain resilience is an important factor affecting supply chain performance. As an active strategy of risk management, the impact of SCR on supply chain performance has been confirmed in various ways (Jüttner and Maklan 2011). A supply chain with good resilience has low interruption probability, low losses, and fast recovery. Compared with less resilient supply chains, it is more competitive and leads to better performance (Jain et al. 2017). Based on the RBV, Birkie et al. (2017) described SCR as an irreplaceable resource for firms to improve performance under supply chain fracture. Especially for highly complex supply chains, resilience plays a more prominent role in promoting performance as a resource. Based on the DCV, Chowdhury et al. (2019) and Dubey et al. (2019) believe that SCR can mitigate risks through supply chain dynamics and play a central role in mitigating emergencies or maintaining previous supply chain performance levels. Hasani and Khosrojerdi (2016) found that SCR improves the performance of core firms, and ensures product availability throughout the whole supply chain and the timely satisfaction of end customer demand, which leads to the improvement of the overall efficiency of the supply chain. Thus, we propose the following hypothesis:

H2. SCR has a significant positive impact on supply chain performance.

BDC and supply chain resilience

The environment faced by supply chain management is undergoing profound and complex changes, requiring firms to show foresight about the future environment when building a resilient supply chain system. BDC is considered an important way to improve the visibility and transparency of supply chains (Baryannis et al. 2018; Shan et al. 2018). As firms increasingly use BDC, scholars emphasize the necessity to better understand how BDC has become a valuable resource for firms to build supply chain risk resilience (Côrte-Real, Oliveira, and Ruivo 2017; Gupta et al. 2022). RIC can help firms integrate and reconstruct internal and external resources to quickly respond to supply chain disruption and maintain sustainable operations in an uncertain environment (Brusset and Teller 2017). DAC can deeply analyze supply chain data, process real-time data to monitor processes and events, and extract valuable insights from data analysis, while managers can make efficient decisions and reduce supply chain risks (Dubey et al. 2019). RTIPC can change the previous dependence on historical data, expert advice, and market information, analyze demand data in real-time with the help of more available information sources in the big data era, and enhance the visibility and forecasting accuracy of the supply chain (Hofmann 2017). The source of supply chain disruption can be determined by predictive analysis, and the probability of disruption risk can even be predicted based on historical data to enhance SCR (Choi et al. 2018). Thus, we propose the following hypotheses:

H3. BDC has a significant positive impact on SCR.

H3a. RIC has a significant positive impact on SCR.

H3b. DAC has a significant positive impact on SCR.

H3c. RTIPC has a significant positive impact on SCR.

Mediating role of SCR

The value of BDC has attracted considerable attention from scholars in supply chain management. They believe that strong BDC can help firms establish competitive advantages and improve the performance of the supply chain. However, it does not have a direct influence but one mediated by dynamic capability (Mikalef et al. 2020; Wamba et al. 2020). Wamba et al. (2017) verified how BDC has a positive impact on firm performance through dynamic capability. Lee and Rha (2016) demonstrated that the process of building dynamic capability is also a process of improving the resilience of the supply chain. Dubey et al. (2019) demonstrated that BDC can provide competitive advantages to organizations through SCR, moderated by organizational flexibility. Laguir et al. (2022) found that organizational analytical ability affects operational performance through SCR. Other scholars have verified the mediating role of SCR in the positive impact of advanced information processing technologies such as the use of information technology (Gu et al. 2020) and artificial intelligence (Belhadi et al. 2021) on SCP. High and lasting SCP depends to a large extent on the ability of firms to use their information processing capabilities to operate in a dynamic supply chain and to build resilience against destructive and unexpected events. Thus, we propose the following hypothesis:

H4. SCR mediates the relationship between BDC and supply chain performance.

Moderating role of environmental uncertainty

An environment with higher uncertainty will have a greater impact on the firm, and it is more necessary for the firm to have the resources and capabilities to cope with the highly uncertain environment. When the business environment exhibits low uncertainty, the supply chain environment faced by a firm is relatively stable, and the market demand and supply change is predictable, so the firm lacks motivation to actively enhance its BDC to improve SCR. Therefore, the influence of BDC on SCR is not significant (Rajesh 2017). When the supply chain environment is highly uncertain, the volatile environment will weaken the confidence of key organizational decision-makers in making strategic and operational decisions, and the ability to obtain information will be more valuable (Srinivasan and Swink 2017). Therefore, the more turbulent the environment, the more significant the impact of BDC on SCR.

Improving the resilience of the supply chain inevitably entails input costs, so SCR also needs to match the level of environmental risk (Yuan and Li 2022). When the environment is less dynamic, the probability of supply chain disruption is lower, and maintaining a high SCR at this time is likely to erode corporate profits. When the environment becomes more dynamic, the possibility of supply chain interruption due to external environmental shocks also increases. Under these circumstances, a lack of SCR can cause firms to suffer major interruption losses. The higher the level of environmental dynamics, the higher the positive effect of dynamic capabilities on the organization (Chowdhury et al. 2019). Thus, we propose the following hypotheses:

H5. Environmental uncertainty significantly moderates the relationship between BDC and SCR.

H6. Environmental uncertainty significantly moderates the relationship between SCR and supply chain performance.

Based on the above theoretical analysis and research hypotheses, on the one hand, BDC indirectly affects supply chain performance through the mediating effect of SCR. On the other hand, environmental uncertainty positively moderates the relationship between BDC and SCR, and also positively moderates the relationship between SCR and supply chain performance. Combining these two aspects, it is logical to conclude that high environmental uncertainty also strengthens the mediating role of SCR in the influencing process of 'big data capability → supply chain resilience → supply chain performance', namely, there is a moderated mediating effect. Thus, we propose the following hypothesis:

H7. Environmental uncertainty positively moderates the mediating relationship between BDC and supply chain performance.

Based on the previous literature, this paper constructs a hypothetical model of the effect mechanism of BDC on supply chain performance, as shown in Fig. 1.

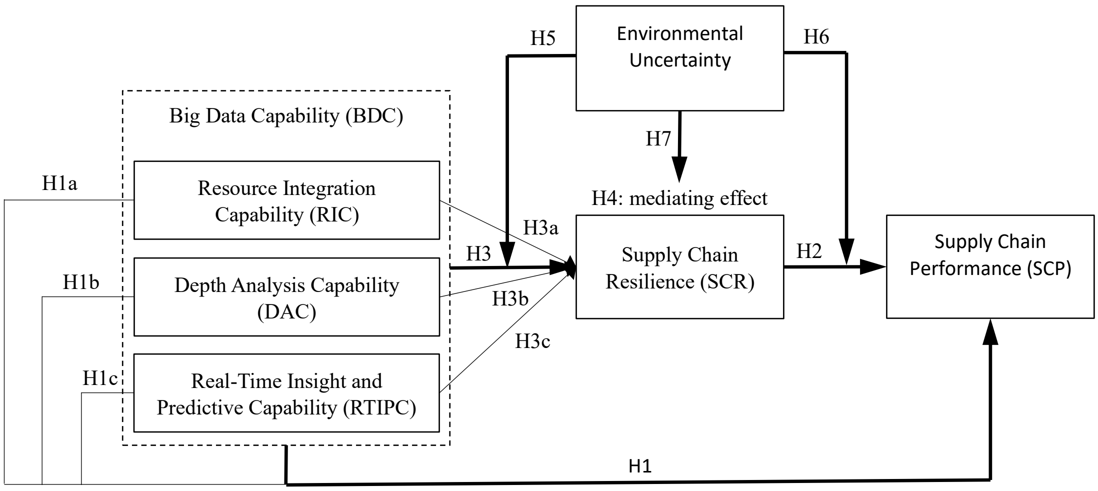

Fig. 1. Conceptual framework
Source: Own study based on theoretical assumptions.

MATERIALS AND METHODS

Measurement

To ensure the effective measurement of the research model, the maturity scale widely used by well-known scholars was selected for this study. The literature demonstrates that the BDC scale consists of three dimensions: RIC, DAC, and RTIPC. It can be measured by fifteen items (Xie, Liu, and Wang 2016). SCR can be measured by six items (Gölgeci and Ponomarov 2014) and SCP can be measured by seven items (Huo, Zhao, and Zhou 2013; Gu, Yang, and Huo 2020). The environmental uncertainty scale consists of two dimensions: demand uncertainty and supply uncertainty. Six items were adapted for its measurement (Zhao et al. 2018). Based on previous research, we selected a few items as control variables, e.g., firm age, annual operating income, and firm size. We asked respondents to indicate the extent to which they agreed with the following statements on a five-point Likert scale ('1 – strongly disagree' to '5 – strongly agree'). Given that most of the measurement items were extracted from English literature while the respondents were Chinese, we followed the translation and back-translation method to translate the English scale and ensure the translated Chinese scale truly and accurately reflected the meaning of the original English scale. To further refine the measurement, the questionnaire was pre-tested with a small sample. Based on the feedback, the questionnaire was modified and improved for large-scale distribution. The final constructs and items are presented in the Appendix.

Sampling and data collection

A structured questionnaire was used for data collection with manufacturing firms in China. As a manufacturing power in the world, China has become the supply chain hub of the world's manufacturing industry, and manufacturing is the main pillar of China's national economy. It was also the area most affected by the COVID-19 pandemic. Therefore, it is more representative to use survey data from Chinese manufacturing firms to study supply chain resilience. This study targeted managers and more senior staff in Chinese manufacturing firms who understand supply chain management well. The reason for targeting these respondents is that they are more aware of their firms' operations and have a better understanding of the supply chain. Their answers can effectively improve the response's reliability and validity.

The data collection took place from April to August of 2022. The data were mainly collected in two ways: one was using the sample service of the 'Credamo' survey platform to distribute questionnaires to sample groups; the other was entrusting data collection to consulting companies. A total of 400 questionnaires were distributed, including 84 paper questionnaires and 316 online questionnaires, and a total of 301 responses were received. After screening out invalid questionnaires that obviously violated rules or had inconsistent or incomplete answers, a total of 232 valid responses were used for data analysis, with an effective rate of 77.08%. Table 1 presents the profiles of the respondents.

Non-response bias and common method bias

It is essential to check for the issue of non-response bias and common method bias (CMB) in the case of a survey-based study. It was decided to compare the early responders with the late responders to verify the existence of serious problems of non-response bias (Armstrong and Overton 1977). This paper employed the independent t-test for the evaluation of non-response bias, The results of the t-test suggested that there were no significant differences between the early and late responses, indicating that there was no non-response bias in this study.

To mitigate the effect of common method bias (CMB), we took several steps. Firstly, the English reference items were translated by back translation to ensure that the scale truly and accurately reflected the meaning of the original English scale. Secondly, the survey samples involved firms from different regions, with different owners, and of different sizes to ensure the fair distribution of samples. Finally, we ran Harman's single-factor test to ascertain the absence of common method bias. The test results showed that seven factors emerged, out of which the first factor accounted for 30.484% of the variance, indicating that the data were not influenced by CMB.

Reliability and validity

Cronbach's alpha coefficient was the main basis for testing the consistency of the scale items. Table 2 presents Cronbach's alpha for all the constructs. It was more than 0.7 in each case, indicating good construct reliability (Nunnally and Bernstein 1994). CFA was conducted to estimate construct validity, and the measurement model results indicate a good model fit: χ^2/df 1.076, RMSEA 0.018, IFI 0.990, TLI 0.988, CFI 0.990. These values indicate that the fit meets acceptable criteria. The standardized factor loadings for all conformations were above 0.5 and significant. The CR ranges from 0.838 to 0.879, meeting the standard of 0.70. The estimates of average variance extracted range from 0.505 to 0.704, which is higher than the commonly recommended level of 0.5. This proves that the model has good convergent validity.

Table 3 presents the value of the square root of each variable. AVE was greater than the correlation coefficients between variables, indicating that the constructs of this study have high discriminant validity (Fornell and Larcker 1981). In addition, the correlation analysis results show that there is a significant correlation between the main variables, and the results of the analysis are consistent with the relationships predicted by the theory, which provides preliminary evidence for subsequent verification of the hypotheses.

RESULTS

Main effect hypotheses testing

Hierarchical regression with SPSS 26 was used to test the hypotheses proposed in the theoretical framework (see Fig 1). Several models (M) were developed in SPSS starting with the control variables and the main effects, and Table 4 reports the results of the hypothesis testing. Firstly, we verified the impact of BDC and its dimensions on supply chain performance. Model 1 examines the impact of the control variables on supply chain performance. Model 2 tests the impact of BDC with control variables on SCP to validate H1 ($\beta = 0.559$, $p < 0.001$) and demonstrates that H1 is supported. Model 3 validates H1a ($\beta = 0.442$, $p < 0.001$), Model 4 validate H1b ($\beta = 0.447$, $p < 0.001$), and Model 5 validates H1c ($\beta = 0.457$, $p < 0.001$). In general, BDC and its dimensions have a positive impact on supply chain performance. Secondly, Model 6 tests the impact of SCR with control variables on supply chain performance, thus validating H2 ($\beta = 0.466$, $p < 0.001$), demonstrating that H2 is supported. Lastly, we verified the impact of BDC on SCR. Model 7 examines the impact of control variables on SCR. Model 8 tests the impact of BDC with control variables on SCR to validate H3 ($\beta = 0.498$, $p < 0.001$), hence, H3 is supported. Model 9 validates H3a ($\beta = 0.380$, $p < 0.001$), Model 10 validates H3b ($\beta = 0.418$, $p < 0.001$), and Model 11 validates H3c ($\beta = 0.398$, $p < 0.001$). To sum up, BDC and its dimensions have a positive impact on SCR.

Mediation effect hypotheses testing

To evaluate the mediating role of SCR on the relationship between big data capability and supply chain performance, the study tested for the significance of the indirect effect using Hayes' process macro for SPSS. For parsimony's sake, a single indicant variable was used for the BDC construct given that the dimensions are conceptually reinforcing and that the statistical results suggest that they are significantly positively correlated. We controlled for firm ownership, firm age, annual sales, and firm size on both the mediator and the outcome variables. We measured the significance of indirect effects by setting the number of sampling iterations (n) equal to 5,000. The confidence interval was set to 95%, Model serial number 4 was selected, and the result after executing the program is presented in Table 5. The results reveal that SCR significantly and positively mediates the effect of BDC on supply chain performance, given that the bootstrap confidence interval did not include zero. This lends sufficient support to H4.

Moderation effect hypotheses test

Testing the moderating effect of environmental uncertainty on the relationship between BDC and SCP

Moderator variables were added to Model 8 to build Model 12, and the interaction term of BDC and environmental uncertainty was added to model 12 to build model 13. The regression results are shown in Table 6. The results show that the regression coefficient of the interaction term on SCR is 0.203 ($p<0.001$). The significant change in R^2 indicates that environmental uncertainty has a significant positive moderating effect on the relationship between BDC and SCR. Hypothesis H5 is thus verified. We plotted the interaction effect of environmental uncertainty between BDC and SCR (see Fig. 2).

Testing the moderating effect of environmental uncertainty on the relationship between SCR and SCP

Moderator variables were added to model 6 to build Model 14. Furthermore, on the basis of model 14, the interaction term of SCR and environmental uncertainty were added to construct model 15, and the regression results are presented in Table 6. The data results show that the regression coefficient of the interaction term on supply chain performance is 0.232 ($p<0.001$). The significant change in R^2 indicates that environmental uncertainty has a significant positive moderating effect on the relationship between SCR and supply chain performance. Hypothesis H6 is therefore verified. In addition, we plotted the interaction effect of environmental uncertainty for SCR and SCP (see Fig.3).

Fig. 2. Moderating effect of environmental uncertainty on BDC and SCR.
Source: Own study based on research results.

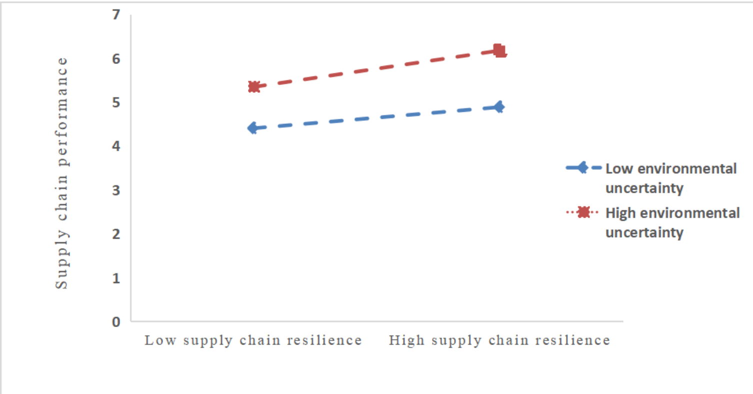

Fig. 3. Moderating Effect of Environmental Uncertainty on SCR and SCP.
Source: Own study based on research results.

Testing the Moderated mediating effect

Based on existing analyses and referring to the research of Preacher, Rucker, and Hayes (2007) and Hayes (2015), this study used Hayes' process macro for SPSS to further test whether there is a moderated mediation effect in the theoretical model. After entering the independent variable, dependent variable, and intermediary variable, the sample size was set to 5,000, the confidence interval was set to 95%, and the Model serial number 58 was selected. The test results are presented in Table 7. The data results show that the indirect effect value is 0.028 when environmental uncertainty is low, and the 95% confidence interval [-0.029, 0.106] contains zero, indicating that the intermediary effect of SCR is not significant. For medium and high environmental uncertainties, the 95% confidence intervals are [0.048, 0.213] and [0.162, 0.420], respectively, excluding zero, indicating that the mediating effect of SCR is significant. At the same time, the indirect effect value of high environmental uncertainty is larger than that of medium environmental uncertainty, indicating that the higher the level of environmental uncertainty, the stronger the mediating effect of SCR, and thus hypothesis H7 is verified.

DISCUSSION AND CONCLUSIONS

Discussion and conclusions for researchers

The supply chain management literature has witnessed a growing interest in developing a better understanding of how BDC can add value to the organizational supply chain. Within this context, based on dynamic capability theory and contingency theory, this study integrated BDC, SCR, and supply chain performance into the same research framework, and examined the mediating effect of supply chain elasticity on the relationship between big data capability and supply chain performance, and the moderating effect of environmental uncertainty. The validity of the theoretical model is verified by survey data from manufacturing firms in China.

First, the study finds that BDC and its dimensions contribute to supply chain performance. Based on the summary of previous research on the relationship between BDC and supply chain performance, this study proposed four hypotheses, H1, H1a, H1b, and H1c. These four hypotheses are supported by the results of the empirical tests reported in the study. This conclusion is consistent with the research results of Chen, Preston, and Swink (2015) and Gunasekaran et al. (2017), who also investigated the relationship between BDC and supply chain performance. Big data analysis can transform data into insights and intelligence, which helps to improve supply chain performance.

Second, SCR has a significant positive impact on supply chain performance. Based on the summary of previous studies on the relationship between SCR and supply chain performance, this study proposed hypothesis H2. The empirical study results show that SCR has a significant positive impact on supply chain performance. This view has been widely recognized by scholars, because SCR is related to the ability of a firm's supply chain operations to recover from unforeseen disruptions. Firms lacking in resilience cannot cope with environmental changes, which leads to frequent chain breaks and has a serious negative impact on performance.

Third, BDC and its dimensions also have a significant positive impact on SCR. Based on the summary of previous research on the relationship between BDC and SCR, this study proposed four hypotheses, H3, H3a, H3b, and H3c. These four hypotheses were supported by the empirical data. This conclusion is consistent with the research conclusions of Williams et al. (2013) and Hofmann (2015). Insights generated by big data analytics can potentially reduce uncertainty in terms of demand, capacity, and supply availability. The greater the visibility and processing power of information, the more responsive the supply chain, and the more significant the impact on resilience.

In addition, SCR plays a mediating role in the relationship between DAC and supply chain performance. Through multiple linear regression analysis and bootstrap double testing, this study examined the mediating role of SCR in the relationship between BDC and supply chain performance. The empirical analysis results show that the mediating role of SCR in the relationship between BDC and SCP is significant, and H4 is verified, which is consistent with the research of Bahrami and Shokouhyar (2021). This empirical result shows that firms can significantly improve the performance of the supply chain either by training BDC or by building an SCR management system. More importantly, SCR mediates the effect of BDC on supply chain performance.

Finally, the study finds that environmental uncertainty significantly moderates the relationship between BDC and SCR and the relationship between SCR and SCP; further, it also positively moderates the mediating relationship between BDC and supply chain performance. That is, the greater the environmental uncertainty, the stronger the mediating role of supply chain elasticity on the relationship between BDC and supply chain performance. These findings are in line with those of studies conducted by Wamba et al. (2019), Dubey et al. (2019), and Yuan and Li (2022). The supply chain's dynamic environment has a beneficial effect on the development of organizational capabilities. The use of BDC at the organizational level affects organizational value creation, but these effects also depend on the dynamic level of the environment.

Discussion and conclusions for managers

The current paper has some implications for managers seeking to enhance the practice of supply chain management at a firm level.

Firstly, the role of big data should be taken seriously, especially for small and medium-sized firms with poor anti-risk ability. Data is an important means of production in the post-pandemic era, and giving full play to technological advantages will help firms to perceive changes in the environment in advance, that is, to maximize the value of data. Nowadays, personal data has been fully mined by the consumer internet, but data in the supply chain is far from being fully exploited. Therefore, firms need to attach importance to the role of data and strengthen the application of BDC in supply chain management. By applying big data to every stage of supply chain management, information flow within or between firms can be enhanced so as to strengthen the pre-risk prediction capability of the supply chain and deal with risks discovered after the event in a timely manner. In this way, firms can be guided to make efficient decisions to mitigate risks, take corresponding measures to avoid risks, and improve risk management capability in the supply chain.

Secondly, manufacturing firms should accelerate the development of the SCR management system and enhance its capability to cope with environmental changes. The Covid-19 pandemic has shown that without a safe and stable supply chain, firms cannot maintain normal production and business activities, and the more resilient the supply chain, the less it was affected by the pandemic. Especially for manufacturing firms, the role of resilience is more prominent. The supply chain of the manufacturing industry is longer, and it is more prone to supply chain interruption. This view is supported by a UBS report in the China CFO Evidence Lab Research Report, which shows that the strongest impact of the pandemic was on China's major industry: the manufacturing sector. In the post-pandemic era, manufacturing firms will face a dynamic uncertain environment for a long time, and the risk of supply chain disruption will be more frequent. Therefore, it is urgent to accelerate the development of SCR among manufacturing firms.

Thirdly, practitioners should be alert to the risks of changes in the external environment and allocate appropriate resources. The COVID-19 pandemic will continue to have an impact on the global manufacturing system, and this impact will continue in the post-pandemic era. In this new normal, firms are prompted to replace the past principle of efficiency first with the principle of efficiency and safety, and rebuild the industrial supply chain. To be specific, manufacturing firms need to balance two important modes, namely, the competition mode under normal order and the mode that can be continued when hit (normal system and recovery system). Therefore, this study further advocates the consideration of the effects of uncertain external environmental factors on the supply chain to develop working practices.

Limitations and further research directions

There are a few limitations of this study, which may provide directions for future research. Firstly, the study used a cross-sectional data set to test the proposed hypotheses, which is limited in its ability to infer causality despite the examination of data quality. Future studies could further verify the hypothesized causal relationship by collecting longitudinal data to obtain more convincing conclusions. Secondly, to avoid confusion between the sub-dimensions of SCR and its antecedents, the study regards SCR as a single dimension. However, SCR is a multi-dimensional and multi-level structure. In the future, it will be necessary to describe the connotations of SCR more systematically, choose an appropriate dimension division method, and adopt a more objective approach to measure SCR. Finally, although this study discusses the impact of big data capability and its three dimensions on supply chain resilience, the analysis is not sufficiently detailed. In a follow-up study, we will explore the specific stages of the impact of enterprise big data capabilities on resilience (beforehand, during and after the event), to further clarify the relationship between the two.

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