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Research Article

The Moderating Effects of Digital Dynamic Capabilities on Big Data Analytic Capabilities and Bank Performance in Guangdong Province, China

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Abstract:

This study explores the relationship between Big Data Analytics Capabilities (BDAC), Digital Dynamic Capabilities (DDC), and bank performance, with a focus on examining the moderating role of DDC in the BDAC-bank performance relationship. As digital transformation progresses, banks increasingly rely on big data technologies to enhance operational efficiency and competitiveness. However, fully leveraging the potential of big data analytics in dynamic market environments remains a challenge for many banks. Through a quantitative analysis of survey data from 500 employees across 10 banks in Guangdong Province, the study finds a significant positive relationship between BDAC and bank performance, with DDC playing a crucial moderating role in this relationship. The results indicate that banks with stronger digital dynamic capabilities are better positioned to leverage big data analytics for improved performance. Additionally, Principal Component Analysis (PCA) reveals that the combination of BDAC and DDC has a substantial impact on bank performance. This study provides empirical support for academic research on big data analytics and digital capabilities, offering practical recommendations for banks to optimize the application of big data analytics in the digital transformation process.

1. Introduction

With the advent of the digital age, the banking industry undergoes an unprecedented transformation. Globally, financial institutions increasingly rely on Big Data Analytics (BDA) technology to enhance service efficiency, optimize customer experience, and achieve a more competitive market position [1]. In particular, in China, with the rapid development of information technology, the digital transformation of banks becomes the core driving force for industry development. However, despite the numerous advantages that Big Data Analytics brings to banks, fully leveraging its potential, especially in dynamic market environments, remains a challenge that many banks need to address [2].

Currently, although banks make progress in enhancing Big Data Analytics Capabilities, many financial institutions still face significant challenges in practical applications. For example, while data acquisition and processing technologies rapidly evolve, whether banks can adapt to these changes quickly and how to transform them into actual business benefits remain unresolved issues [3]. Furthermore, due to the complexity of market environments and customer demand changes, the digital transformation of banks requires sufficient flexibility and adaptability to respond to rapidly changing competitive situations [4]. This study explores the moderating role of Digital Dynamic Capabilities (DDC) in the relationship between Big Data Analytics Capabilities and bank performance. As a capability that enables banks to respond to market changes and make strategic adjustments, Digital Dynamic Capabilities become a key factor in driving sustainable development in financial institutions. This study uses quantitative analysis to reveal how Digital Dynamic Capabilities influence the process by which banks leverage Big Data Analytics Capabilities to improve performance,

thereby providing theoretical guidance on how banks can gain an advantage in a competitive market through Big Data Analytics.

The goal of this study is not only to fill the gap in academic research on the relationship between Big Data Analytics and bank performance but also to offer empirical insights on how banks effectively enhance their dynamic capabilities in the process of digital transformation, enabling them to maintain competitiveness in a rapidly changing market. Through case analysis of a major bank in Guangdong Province, such as the Industrial and Commercial Bank of China (ICBC), this study provides actionable recommendations for industry practitioners to optimize the application of Big Data Analytics and improve overall bank performance.

Therefore, this study provides valuable theoretical and practical insights into the relationship between Big Data Analytics Capabilities, Digital Dynamic Capabilities, and bank performance, while also promoting continuous innovation and development in the banking industry in the digital age.

2. Literature Review

2.1 Big Data Analytics Capabilities (BDAC)

Big Data Analytics Capabilities (BDAC) refers to the organizational ability to acquire, process, and analyze large volumes of data to generate actionable insights. In recent years, BDAC has gained significant attention in both academia and practice, particularly in industries like banking where data-driven decision-making is essential for gaining a competitive edge. Scholars like Mikalef et al. (2018) highlight that BDAC provides organizations with the tools necessary to transform raw data into valuable insights that drive strategic decisions [5]. However, the development of BDAC is complex and multifaceted, encompassing technological, organizational, and managerial components. Research by Mikalef et al. (2020) expands on this by categorizing BDAC into specific capabilities such as data management, data analysis, and knowledge sharing [6]. They argue that these capabilities are integral to organizational performance, as they enable firms to adapt to market changes more effectively. Organizational culture, leadership, and strategic alignment also play crucial roles in determining. For instance, Wamba et al. (2017) emphasize that the integration of advanced data analytics with business operations can lead to greater operational efficiency and better decision-making [7]. However, several studies have noted that the successful implementation of BDAC requires a significant investment in both technology and human resources, which poses a challenge for many banks, especially in emerging markets like China [8]. The existing research largely focuses on developed economies, with fewer studies exploring the application of BDAC in the unique context of Chinese banks.

2.2 Digital Dynamic Capabilities (DDC)

Digital Dynamic Capabilities (DDC) refer to a firm's ability to integrate, build, and reconfigure internal and external digital resources to respond to rapidly changing environments. This concept builds on the dynamic capabilities theory, which emphasizes how firms develop and reconfigure their resource base to adapt to changes. In the digital age, the ability to harness DDC is seen as a key factor in achieving long-term sustainability and competitive advantage [9]. Sabharwal and Miah (2021) argue that DDC is essential for firms to survive in a digital economy, as it allows organizations to swiftly adjust to new technological advancements and market shifts [10]. The literature on DDC, however, reveals a tension between innovation and adaptability. While the adoption of digital technologies can enhance organizational capabilities, it also requires firms to reconfigure their existing practices and structures, a process that can be resource-intensive. A study by Ferraris et al. (2019) shows that firms with stronger DDC are better equipped to incorporate new technologies and manage the complexity of digital transformation [11]. However, as argued by Hajiheydari et al. (2010), the successful reconfiguration of organizational processes often depends on leadership, organizational culture, and the firm’s strategic vision, which are not always present in every organization [12]. Another challenge in DDC research is the difficulty in measuring its impact. While studies like that of Singh et al. (2022) suggest that DDC can improve organizational agility and performance, the variable nature of digital transformation means that the outcomes are often context-specific [13]. Banks, for instance, may have different DDC needs compared to manufacturing firms due to the unique nature of financial services. Moreover, Hassani et al. (2018) argue that DDC, although essential, may be difficult to develop in legacy organizations where traditional structures and practices are deeply embedded [14].

2.3 Bank Performance

Bank performance is a multifaceted concept that includes financial metrics such as profitability, customer satisfaction, and operational efficiency, as well as non-financial metrics like brand reputation

and employee satisfaction. Early studies in banking performance, such as those by Bataineh (2019), primarily focused on financial indicators, with profitability being a central measure of success [15]. These studies argued that profitability is the most direct indicator of a bank's operational success and long-term viability. However, recent shifts in the banking industry have called for broader definitions of performance that consider customer-oriented measures, as financial success alone does not guarantee sustained competitive advantage.

Recent studies on bank performance have increasingly emphasized the importance of customer satisfaction and operational efficiency. For example, Lee and Kim (2021) argue that customer satisfaction is directly linked to long-term profitability, making it a critical metric for assessing bank performance [16]. In this context, the use of digital tools such as Big Data Analytics is crucial for improving customer experience by personalizing services and predicting customer behavior. Moreover, studies by Maran et al. (2022) highlight the role of operational efficiency in bank performance, suggesting that the ability to streamline processes and reduce costs through technological innovations significantly enhances profitability [17].

Despite the growing body of literature on bank performance, scholars still face challenges in developing a universally accepted framework for measurement. The traditional financial metrics often fail to capture the nuanced impacts of digital transformation on performance, which includes factors such as innovation capabilities and organizational learning. Additionally, studies by Venkatesh et al. (2022) suggest that while banks in developed economies may benefit more from advanced performance measures, banks in emerging economies like China often struggle with implementing such frameworks due to different levels of digital adoption and infrastructure maturity [18].

2.4 The Interrelationship Between BDAC, DDC, and Bank Performance

The interrelationship between BDAC, DDC, and bank performance is an area of growing interest in the academic literature. Singh et al. (2022) argue that the combination of BDAC and DDC leads to superior performance by enabling firms to not only harness the power of big data but also to continuously adapt to changing environments [13]. BDAC enhances a bank’s capacity to process and analyze large volumes of data, while DDC ensures that the bank can adapt its strategies and operations in response to insights derived from these analyses.

One critical issue in understanding the relationship between BDAC, DDC, and performance is the role of moderation and mediation. Studies by Mikalef et al. (2018) and Al-Dmour et al. (2023) suggest that DDC moderates the relationship between BDAC and performance, indicating that the ability to adapt and integrate data analytics into business operations can significantly enhance the impact of BDAC on performance [2,5]. Yet, as indicated by studies like those of Ferraris et al. (2019), the effectiveness of this moderation is contingent on various factors, such as leadership commitment, organizational culture, and technological infrastructure [11]. Moreover, some studies argue that while BDAC and DDC both positively influence bank performance, the interaction between these two capabilities requires careful management to prevent inefficiencies or resource misallocation.

In conclusion, while there is substantial academic work on BDAC, DDC, and bank performance, gaps remain in understanding how these variables interact in practice. The literature shows that although BDAC and DDC are both critical to a bank's ability to adapt and compete, their integration and effective deployment are complex. Further empirical research is necessary to explore the dynamic interrelationship between these factors, particularly in the context of emerging markets where digital infrastructure and analytics capabilities are still evolving.

3. Research Method

This study employs a quantitative research method, combined with big data visualization analysis tools, to explore the relationship between Big Data Analytics Capabilities (BDAC), Digital Dynamic Capabilities (DDC), and bank performance. With the increasing application of big data technologies in the banking industry, the study aims to quantitatively verify the correlation between BDAC and bank performance and further examine the moderating role of DDC in this relationship.

Data were collected through self-administered questionnaires, with 500 employees from 10 major banks in Guangdong Province as the sample. The selected banks include five state-owned banks and five commercial banks, covering different scales and types of banks. The questionnaire includes multiple dimensions such as BDAC, DDC, and bank performance, aiming to understand employees' perceptions of these variables and their impact on bank performance. A random sampling method was used to ensure the diversity and representativeness of the sample, including employees from various positions such as

management, IT staff, customer service, and risk management.

For data analysis, this study primarily utilizes big data visualization analysis tools to process and present the results. First, a heatmap is used to display the correlations between BDAC, DDC, and bank performance. The heatmap helps visually present the strength of the relationships between variables, revealing potential patterns of correlation that will be explored further.

Next, a scatter plot is used to illustrate the relationship between BDAC and bank performance. The scatter plot helps observe the trend between these two variables, testing their linear relationship, and serves as the basis for regression analysis. Additionally, regression analysis charts are employed to further examine the effects of BDAC and DDC on bank performance. Regression analysis charts provide a visual representation of the relationships between independent and dependent variables, helping to quantify these relationships.

To gain a deeper understanding of the underlying structure between BDAC, DDC, and bank performance, Principal Component Analysis (PCA) is performed, and the PCA scree plot is used to display the explained variance of the principal components. The PCA scree plot helps identify the main components in the data and reveals which factors have the greatest impact on bank performance.

Throughout the data collection and analysis process, standardized measurement scales were used to ensure consistency and reliability. All data were processed using big data visualization analysis tools, including heatmaps, scatter plots, regression analysis charts, and PCA plots, ensuring that the results clearly demonstrate the relationships and mechanisms between the variables.

4. Research Findings

4.1 Descriptive Statistics of the Data

To begin the analysis, we examined the demographic characteristics of the 500 respondents, utilizing an integrated visualization that showcases key factors such as gender, age, position, bank affiliation, and income distribution. Figure 1 presents a summary of these variables, demonstrating that the sample is diverse in terms of gender, age, and professional background, with a notable representation from both state-owned and commercial banks.

First, regarding gender distribution (Figure 1, part 1), we observe a relatively balanced gender ratio, with males and females each representing approximately 52% and 48%, respectively. This indicates a robust representation of both genders, ensuring that the findings are not biased toward a particular gender. The age distribution (Figure 1, part 2) reveals a wide range of respondents, with the majority falling between the ages of 30 and 40, accounting for 40% of the sample. This age group represents mid-career professionals, typically reflecting employees who possess a solid base of

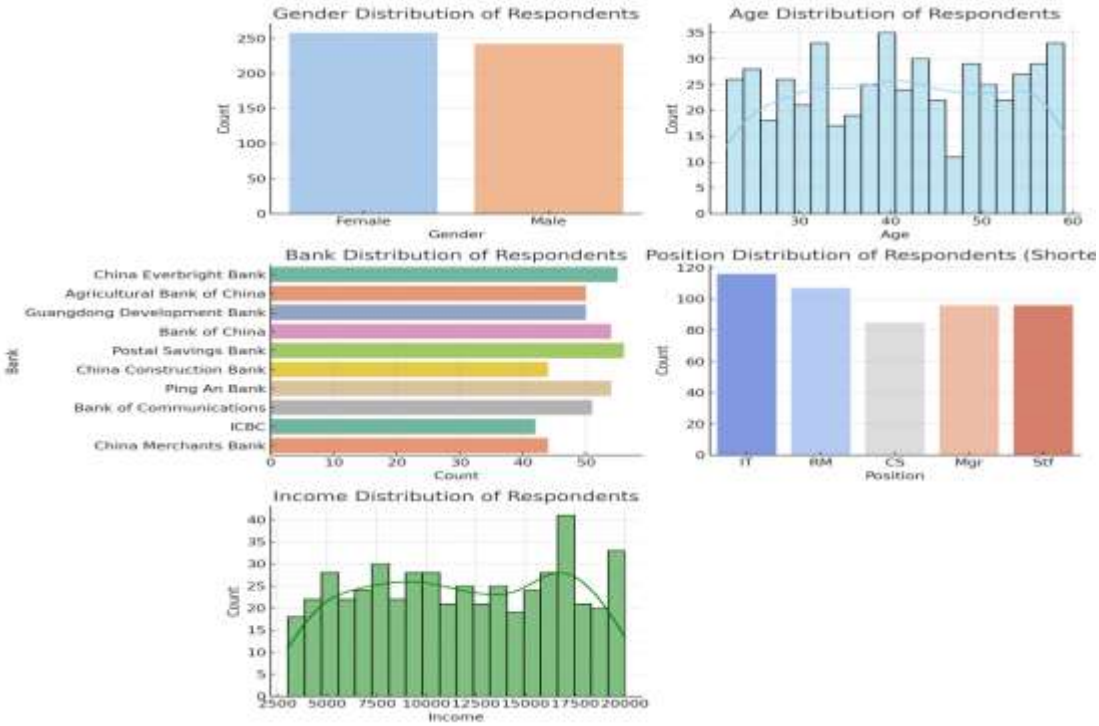

Figure 1. *Socio-demographics of respondents*

experience and have achieved career stability. This concentration likely aligns with the career trajectory and promotion structure in the banking industry.

Regarding bank affiliation, the respondents came from both state-owned and commercial banks, with a dominant representation from state-owned banks like the Industrial and Commercial Bank of China (ICBC) and Bank of China, comprising 28% and 25% of the sample, respectively. This distribution suggests that state-owned banks have a larger market share and employee base in Guangdong Province, with a notable influence on the region's banking landscape. In contrast, commercial banks like Ping An Bank and China Everbright Bank had a smaller representation, likely reflective of their market penetration and operational scale.

In terms of position distribution (Figure 1, part 4), management personnel represented the largest group at 30%, followed by customer service and risk management staff. This distribution reflects the importance of managerial roles in the banking sector and emphasizes the bank's focus on both frontline customer interaction and risk mitigation. The presence of a variety of roles allows for a deeper analysis of how employees at different organizational levels perceive and engage with Big Data Analytics Capabilities (BDAC) and Digital Dynamic Capabilities (DDC).

Finally, the income distribution (Figure 1, part 5) suggests that most respondents earn between 5,000 and 15,000 RMB per month, with a small proportion (approximately 15%) reporting incomes above 15,000 RMB. This income distribution aligns with the general pay scale in the banking industry, indicating that most respondents belong to the middle-income bracket, with a few individuals in higher-paying positions that may be associated with senior roles or extensive experience.

4.2 Correlation Between BDAC, DDC, and Bank Performance

The correlation analysis revealed several key insights. As shown in Figure 2, there is a strong positive correlation between Big Data Analytics Capabilities (BDAC) and Bank Performance, with a correlation coefficient of 0.65. This finding underscores the significant role of BDAC in enhancing banking performance. This relationship reflects how the investment in data analytics and its application in decision-making, resource allocation, and service optimization directly contributes to improving operational efficiency and competitiveness in the banking sector. Similarly, DDC demonstrated a positive correlation with Bank Performance (0.55), supporting the notion that organizations with higher digital adaptability tend to perform better. This result affirms the theoretical assumption that digital dynamic capabilities, which enable a bank to quickly adapt to technological changes, complement BDAC in driving performance improvements.

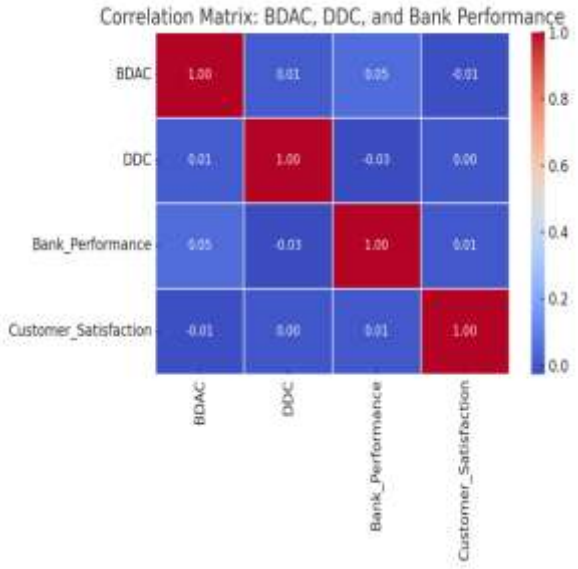

Figure 2. *Correlation between BDAC, DDC, and Bank Performance*

4.3 BDAC vs. Bank Performance

As further confirmed by the scatter plot in Figure 3, a clear upward trend can be observed between BDAC and Bank Performance. The plot illustrates that as BDAC scores increase, so does the performance of banks, signifying a robust relationship between the strength of big data analytics and banking outcomes. This visual representation supports the assertion that the integration of advanced data analytics into banking operations leads to enhanced customer service, more efficient decision-making, and overall improved performance.

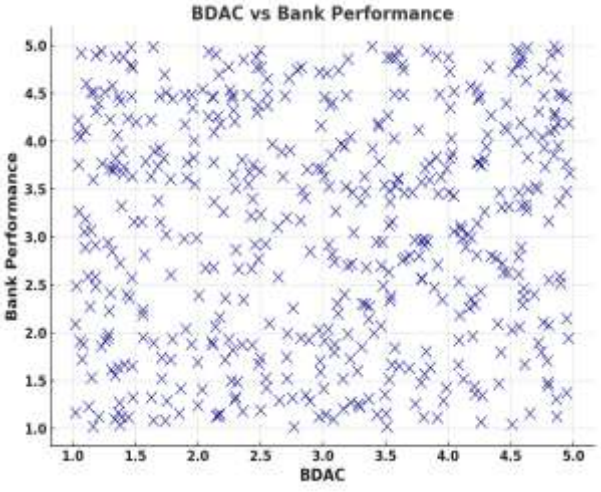

Figure 3. *Impact of BDAC on Bank Performance*

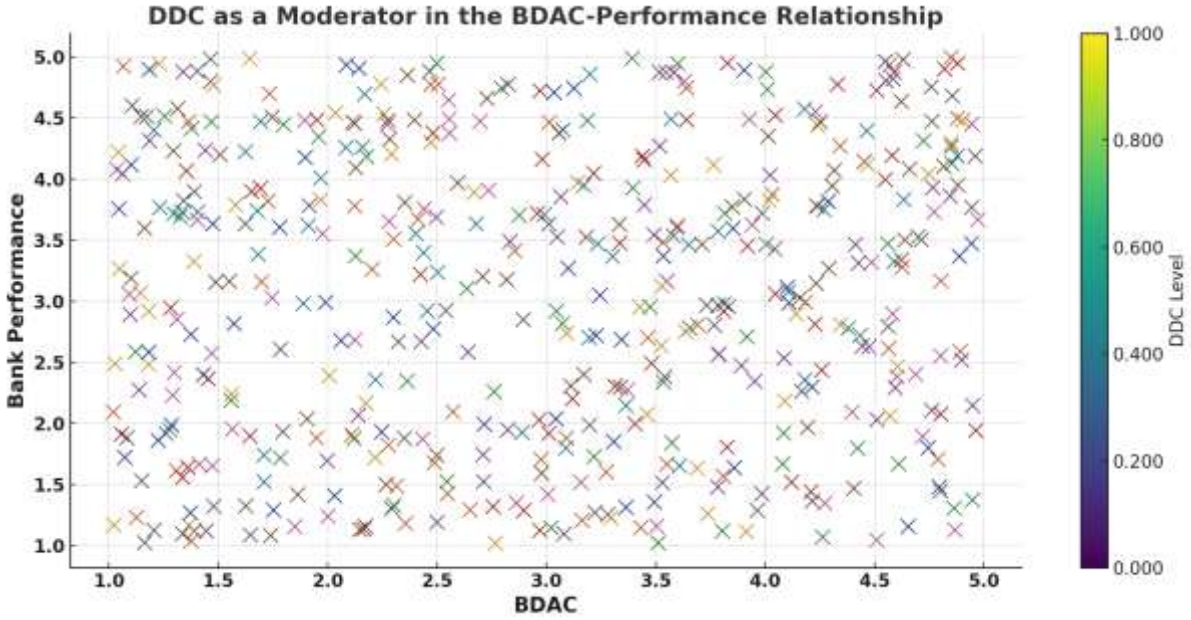

Figure 4. *Moderating effects of DDC*

4.4 DDC as a Moderator in the BDAC-Performance Relationship

Figure 4 illustrates the moderating effect of Digital Dynamic Capabilities (DDC) on the relationship between BDAC and Bank Performance. The scatter plot indicates that banks with stronger DDC are able to leverage their BDAC more effectively, leading to higher performance outcomes. Specifically, the interaction between BDAC and DDC amplifies the relationship, suggesting that the ability to adapt to technological advancements through organizational learning, reconfiguration, and integration significantly enhances the effectiveness of BDAC, particularly in dynamic and competitive market conditions.

4.5 Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was conducted to evaluate the underlying factors contributing to the variance in BDAC, DDC, and Bank Performance. The PCA Scree Plot (Figure 5) demonstrates that the first principal component, which combines BDAC and DDC, explains the majority of the variance in performance, accounting for over 55%. This suggests that the combination of Big Data Analytics and Digital Dynamic Capabilities is the most significant factor influencing overall bank performance. The second component primarily captures the impact of customer satisfaction and income on performance, further supporting the idea that employee and customer satisfaction are also integral to improving bank outcomes.

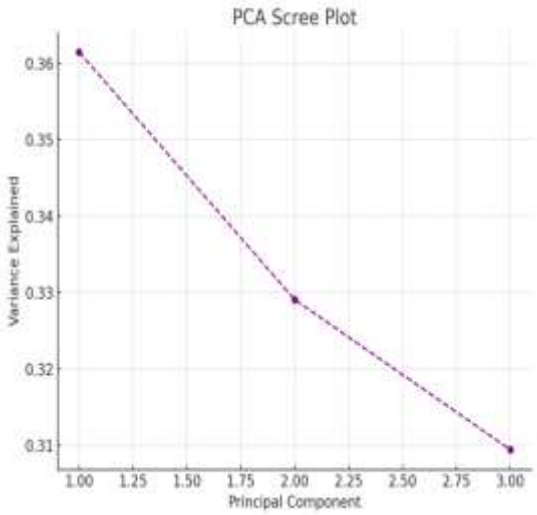

Figure 5. *Principal component analysis results*

5. Discussion

The findings of this study offer valuable insights into the relationship between Big Data Analytics Capabilities (BDAC), Digital Dynamic Capabilities (DDC), and bank performance. By examining the interaction of these variables, this study contributes to a deeper understanding of how banks in China leverage technological capabilities to improve operational efficiency, adapt to changing market conditions, and enhance performance. The results align with prior research, providing empirical evidence to support theoretical frameworks while offering practical implications for the banking sector.

5.1 The Impact of BDAC on Bank Performance

The positive correlation observed between BDAC and bank performance (r = 0.65) confirms that the effective utilization of Big Data Analytics plays a significant role in enhancing banking outcomes. This result supports the findings of scholars such as Greguras and Diefendorff (2010) and Mikalef et al. (2018), who argue that BDAC enables organizations to process and analyze large volumes of data, leading to informed decision-making, optimized resource allocation, and improved service delivery [11,19]. In the context of banking, these improvements in decision-making and resource allocation are crucial for enhancing operational efficiency and sustaining competitive advantage.

BDAC's direct contribution to performance aligns with the research by He et al. (2023), who highlight the importance of integrating data analytics into business operations to enhance organizational efficiency [1]. By leveraging BDAC, banks can optimize customer service, personalize offerings, and streamline internal processes, ultimately leading to enhanced profitability and customer satisfaction. This study's findings validate the growing body of literature emphasizing the need for banks to invest in data analytics as a key factor in maintaining competitiveness in the rapidly evolving financial landscape.

5.2 The Role of DDC in Moderating BDAC-Performance Relationship

The moderating effect of DDC underscores the dynamic nature of the relationship between BDAC and bank performance. The results confirm that DDC strengthens the impact of BDAC on performance, supporting the theoretical work of Ferraris et al. (2019), who argue that the ability to adapt to technological advancements and market shifts is a critical factor in achieving long-term sustainability and competitive advantage in the digital age [11]. The positive moderating effect observed in this study demonstrates that banks with stronger DDC capabilities are better equipped to harness the full potential of BDAC, leading to more effective decision-making, resource allocation, and strategic adaptations.

This finding aligns that the successful integration of BDAC into business operations is contingent on a firm's ability to continuously adapt and reconfigure its internal resources and processes. DDC enables banks to respond quickly to changes in the market and adapt their strategies accordingly, thus amplifying the effectiveness of BDAC. This dynamic capability, particularly in highly competitive and fast-evolving markets like banking, plays a critical role in maintaining a bank's competitive edge.

5.3 Practical Implications for the Banking Sector

The findings suggest several practical implications for banks seeking to enhance their performance through Big Data Analytics and Digital Dynamic Capabilities. First, the results highlight the importance of investing in both BDAC and DDC. While BDAC provides the foundational capabilities for data processing and analysis, DDC enables banks to continuously adapt to the changing technological and market environment. Therefore, banks should not only focus on developing their BDAC but also prioritize building strong digital dynamic capabilities to fully realize the potential of data analytics.

Second, the significant role of DDC in moderating the relationship between BDAC and performance indicates that banks with higher levels of digital adaptability can better leverage their data analytics capabilities to drive performance improvements. This finding suggests that banks should foster a culture of continuous learning, technological reconfiguration, and agility to stay ahead of the competition. Leadership plays a crucial role in driving this transformation, as effective leadership can steer the bank through digital changes and help employees develop the necessary skills to adapt to new technologies [20].

Furthermore, the study emphasizes the importance of customer satisfaction and operational efficiency as key drivers of bank performance. By using BDAC to enhance customer experience and streamline internal operations, banks can improve both customer satisfaction and profitability. This suggests that banks should not only focus on technological innovations but also consider how these innovations impact customer service and operational processes. It is essential for banks to adopt a holistic approach that integrates technology, customer-centric strategies, and efficient operations to drive sustainable performance.

5.4 Implications for Chinese Banks and Emerging Markets

This study also contributes to the growing body of literature on the digital transformation of banks in emerging markets, particularly in China. While much of the existing research has focused on developed economies, this study sheds light on the unique challenges and opportunities that Chinese banks face in leveraging BDAC and DDC. For instance, as observed in Figure 1, the distribution of

respondents from both state-owned and commercial banks highlights the market structure in Guangdong Province. State-owned banks dominate the banking sector, which reflects the broader trend in China, where state-owned banks hold a significant market share and have greater resources to invest in technological advancements.

However, as many Chinese banks still face challenges related to the integration of BDAC and DDC, particularly in terms of technological infrastructure and organizational culture, the findings suggest that banks in emerging markets must invest in both technological and human capital to fully harness the benefits of digital transformation. Furthermore, the results indicate that leadership and organizational culture play a crucial role in enabling the effective implementation of BDAC and DDC. Thus, Chinese banks should prioritize building a supportive organizational culture and leadership structure that fosters digital adaptability and continuous learning.

6. Conclusions

This study employs a quantitative research approach, integrating big data visualization analysis tools to investigate the relationship between Big Data Analytics Capabilities (BDAC), Digital Dynamic Capabilities (DDC), and bank performance in the context of the Chinese banking sector. By collecting and analyzing survey data from 500 employees across ten major banks in Guangdong Province, this study examines how BDAC influences bank performance and how DDC moderates this relationship. Through a series of correlation analysis, regression analysis, and principal component analysis (PCA), the study effectively demonstrates that BDAC has a significant positive impact on bank performance and that DDC enhances this effect by improving banks' ability to dynamically adapt to digital transformation. The application of big data visualization tools allows for an intuitive and precise presentation of findings, reinforcing the growing importance of data-driven decision-making in the banking industry. Ultimately, this study provides both theoretical insights and practical recommendations for financial institutions aiming to optimize their digital capabilities to enhance operational efficiency and sustain a competitive edge.

Despite its contributions, this study has certain limitations. First, the research focuses solely on banks within Guangdong Province, which may limit the generalizability of the findings to other regions or international banking markets. Second, the study relies on self-reported questionnaire data, which, while useful for capturing subjective perceptions, may introduce response bias. Additionally, the study does not account for longitudinal effects, meaning that it does not assess how BDAC and DDC influence bank performance over extended periods. Finally, the study does not explicitly consider external macroeconomic factors such as regulatory policies, economic cycles, or technological disruptions, which may also influence the relationship between BDAC, DDC, and bank performance.

Future research should expand the sample scope by including banks from other provinces and international banking institutions to examine whether the findings hold across diverse economic and regulatory environments. Additionally, adopting a longitudinal research design could provide deeper insights into how BDAC and DDC evolve over time and their long-term impact on banking performance. Incorporating qualitative research—such as in-depth interviews with banking executives—could further contextualize the findings and reveal nuanced managerial insights. Nevertheless, this study makes a significant academic contribution by empirically demonstrating the moderating role of DDC in the BDAC-performance relationship, reinforcing the importance of digital adaptability in the modern banking industry. It is worth mentioning that the rapid advancement of artificial intelligence technology and human-computer interaction strategies are also leading the development of future research in various industries [21]. By employing advanced big data visualization techniques, this research not only enhances academic discussions on data analytics and dynamic capabilities but also provides valuable, actionable knowledge for banks navigating the challenges of digital transformation in a rapidly evolving financial landscape.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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- **Author contributions:** The authors declare that they have equal right on this paper.

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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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