Does Big Data Applications and Financial Innovation Lead to Enhance Banking Performance? Evidence from the United Kingdom

Abstract

Big data and financial innovations are vital to enhancing the performance of banking institutions. However, limited evidence exists on the effects of big data applications and financial innovation on bank performance. This study addresses this gap by constructing a theoretical framework linking big data applications and financial innovations to bank performance. The framework was empirically tested using questionnaire data from 150 branches of UK banking institutions between January and June 2023. Adopting hierarchical regression modelling, results show that both big data applications and financial innovations positively enhance customer satisfaction as well as financial and market performance within the banking sector. Moreover, big data applications positively impact financial innovations within banks. The study contributes to a deeper understanding of big data applications and provides valuable insights for promoting financial innovations within the banking industry.

Keywords: Financial innovation, big data, Market performance, banking performance, UK.

1. Introduction

Big data, characterised by its volume, velocity, variety, veracity, and value, allows organisations to analyse vast amounts of structured and unstructured data with specific characteristics (Mikalef et al., 2019b, Ghasemaghaei and Calic, 2020, Al-Dmour et al., 2023). Evidence indicates that the world market for big data is expected to surge from US$193.14 billion in 2019 to US$492.92 billion in 2030 (Olabode et al., 2022). This projected growth highlights the increasing standing of big data across various industries, driven by advancements in technologies. With an estimated 2.5 quintillion bytes of data generated daily and 90% of the globe's data created in the last two decades, big data represents a significant driver of innovation (Manyika et al., 2011).

Globally, firms have embraced big data as a critical tool for gaining a competitive advantage by extracting valuable customer insights, improving operational efficiency, and driving new business strategies (Bughin, 2016; Chaudhary et al., 2015). Evidence also suggests that many companies are leveraging big data applications (BDA) to develop new products and services (Cheng and Shiu, 2023b, Ciampi et al., 2021). To date, previous studies have extensively examined the relationships between BDA and firm performance (Mikalef et al., 2019a, Gupta and George, 2016, Wamba, 2022, Wamba et al., 2017, Awan et al., 2022, Chatterjee et al.,

2023), as well as its contribution to innovation or product development (Johnson et al., 2017, Lehrer et al., 2018, Mikalef et al., 2020a). However, the majority of these studies have predominantly focused on industries such as information technology, hospitality, retail, and manufacturing (Jain et al, 2024, Morimura and Sakagawa, 2023).

Meanwhile, the banking industry has been undergoing significant transformations, driven by strategic initiatives aimed at enhancing profitability, enhancing customer satisfaction, and embracing technological advancements. A key enabler of this transformation is BDA, which utilizes machine learning, data mining, predictive analytics, and artificial intelligence to analyze real-time customer and market data, enabling banks to develop targeted marketing strategies, optimize customer service, and predict market trends (Hashem et al., 2015). According to Kiron et al (2014), BDA provides a competitive advantage in banking by predicting future consumer behaviors. Evidence suggests that banks have been transforming from traditional data processing to a data-driven culture, utilizing BDA for real-time fraud detection, credit risk assessment, and regulatory compliance to ensure financial system trust and stability (Sun et al., 2018). More recently, IBS Intelligence highlighted that BDA has significantly transformed the banking sector by enabling real-time data processing and providing crucial insights for decision-making (Sharma, 2024). However, challenges such as data privacy, regulatory compliance, and quality persist, posing obstacles to its sustainable and ethical application (Manyika et al., 2011). Hence, banks are under increasing pressure to adapt and innovate within an increasingly dynamic banking environment to improve performance and gain a competitive advantage.

In addition to BDA, financial innovations (FI) are transforming traditional banking models with digital banking, blockchain technology, mobile payments, and Fintech, improving service delivery, transaction security, transparency, and customer experience (Philippon, 2016, Tapscott and Tapscott, 2016, Thakor, 2020). FI is revolutionizing banking practices by enhancing financial performance, strengthening customer engagement, and expanding access to financial services across diverse populations (Nazir et al., 2021). In particular, the development and application of new technologies, products, and processes are driving the efficiency, accessibility, and security of the banking industry (Frame and White, 2004). These FI technologies entail transforming existing financial products and services, promoting innovative solutions to meet consumer needs, and improving operational efficiency (Frame and White, 2004, Qamruzzaman et al., 2021). The widespread adoption of digital banking services is a key factor in these changes, allowing customers to have more seamless and personalized interactions. However, the evolution of FI involves risks including cybersecurity threats, regulatory compliance challenges, and increased operational complexity, which banks must address to fully realize its potential benefits (Gomber et al., 2018).

To date, the existing literature on the impact of FI on bank performance has yielded mixed results (Chen & Peng, 2020, Nejad, 2022, Manasseh et al. 2023). While some studies show positive relationships between FI and banks' performance (Atalay et al., 2013, Cherotich et al., 2015, Gunday et al., 2011), others report negative relationships (Pooja and Singh, 2011, Corbet et al, 2023, Zhao et al, 2022). The integration of BDA and FI has been shown to enhance banking performance by improving financial performance (FP), customer satisfaction (CS), and competitive market position. However, despite the widespread implementation of digital banking and FI such as contactless payments, asset management services, online investment banking, and data management applications, the role of BDA in driving FI and improving bank performance remains underexplored (Villeroy de Galhau, 2016; Phan et al., 2020). Banks are increasingly focusing on enhancing CS through digital banking services, advanced customer relationship management systems, and the adoption of innovative financial products. Evidence suggests that CS can be enhanced by providing tailored, data-driven services that cater to individual needs, leading to increased retention rates and brand loyalty (Chen et al., 2023, Khan et al., 2022). Additionally, in terms of market performance (MP), banks that effectively utilize big data and FI are better equipped to capture market share and gain a competitive edge in the rapidly evolving financial landscape (Olabode et al., 2022).

Although BDA improves decision-making and fosters innovation by enabling banks to anticipate customer needs and deliver personalized, real-time solutions (Hub, 2023), the existing literature primarily focuses on developing and emerging markets (Corbet et al 2023, Phan et al., 2020, Zouari-Hadiji 2021, Nyamekye et al, 2023, Manasseh et al. 2023, Abbas et al, 2024), leaving the impact of FI on banking performance in developed countries, particularly in the UK, underexplored. Moreover, there is a lack of a theoretical framework to address the ethical, legal, and operational challenges involved in developing strategic models for banks to enhance performance and meet the demands of digital transformation. These gaps present a compelling opportunity to investigate how BDA and FI can advance banking performance, particularly in the United Kingdom, with a focus on CS, MP, and FP. Hence, this study aims to address these issues through the following key research questions: 1. Does big data application support financial innovations? 2. Does big data application and financial innovation improve bank performance? 3. To what extent do big data applications and FI improve bank performance? 4. Will big data applications and FI enhance customer satisfaction?

This paper examines UK banks as a natural setting to explore the research questions outlined above. Since 2019, the UK banking sector has contributed £132 billion to the economy and is the leading Fintech hub in Europe, accounting for 6.9% of overall operations (Gavin Powell and Johnny Mayo, 2021). While the integration of BDA represents the next frontier in transforming the UK banking sector, its full potential in real-time decision-making, predictive

analytics, and personalized banking services remains underutilized (Cutter, 2023). This is mainly because UK banks' adoption of BDA is hindered by issues like predictive analytics' lack of explainability, data integration issues, privacy concerns, and high implementation costs of advanced FI (The Fintech Times, 2023).

To investigate these dynamics, we analyzed the relationships among 150 UK banking institutions using hierarchical regression modeling and multi-theoretical frameworks, including the dynamic capability view, the resource-based view, stakeholder theory, diffusion innovation theory, and agency theory. Results suggest that BDA positively impacts FI and banks' CS, MP, and FP. Moreover, we show that FI significantly and positively affects CS, MP, and FP in the banking sector. Notably, we reveal that BDA and FI positively impact the FP of banks aged 1-10 years, 11-39 years, and over 40 years, with matured financial resources affecting banks over 40 years. Moreover, our results reveal that BDA and FI in mature and older banks significantly enhance CS and MP. Finally, our post-ad hoc analysis shows that there is a direct connection between BDA and profitability, risk-adjusted return on assets, and financial expenses as a proportion of net sales.

Our findings contribute to the existing literature from multiple perspectives. First, we contribute to inconclusive findings and limited empirical evidence on BDA's effects on bank performance in developed markets especially in the UK (Park et al., 2019, Chatterjee et al., 2023, Jain et al., 2024, Morimura and Sakagawa, 2023, Chatterjee et al, 2023). We are the first to discover this nexus empirically using the United Kingdom banking sector. Second, the literature lacks comprehensive research on how BDA contributes to a bank's FI (Sivarajah et al, 2024, Zheng et al., 2022, Korayim et al., 2024, Forough et al., 2024). We highlight the vital role of FI in BDA within banking institutions, leading to improved performance and sustainability. Thirdly, the study is the first to investigate FI's influence on customer satisfaction and banks' FP and MP in developed markets by focusing on UK banking institutions, filling observed gaps in the existing literature. In addition, we utilized validated and self-developed survey questionnaires to measure bank-level variables, focusing on managers' BDA levels to understand FI and bank performance, including customer satisfaction and financial and marketing performance (Corbet et al., 2023, Zouari-Hadiji., 2021, Nyamekye et al., 2023, Abbas et al, 2024, Wang et al., 2022; Wang & Cao, 2022). Therefore, we provide insights to understand that adopting FI can transform banks' strategic capabilities and operational efficiencies, thereby enhancing customer satisfaction, financial outcomes, and marketing performance. Finally, we used a multi-theoretical framework, including RBV, DCV, DIT, ST, and AT, to examine how UK banks can leverage big data applications to develop FI that enhance customer satisfaction, financial performance, and market performance. We advance these theories by demonstrating how BDA integrates with innovation development and performance metrics to drive sustainable

banking practices. By linking BDA-driven FI with enhanced customer and organizational outcomes, the study bridges a gap in the finance literature, presenting a novel, actionable framework for achieving sustainability in the digital age.

The rest of the paper is organized as follows. Section 2 provides a comprehensive theoretical background; section 3 discusses the literature review and hypothesis development. Section 4 introduces the research methodology. We used section 5 to present results in testing the hypothesis followed by robustness, and additional tests. Second 6 discusses the research results, their theoretical and practical relevance, limitations, and recommendations for future studies. Our final section presents conclusions.

2. Theoretical Background

Despite the growing interest in BDA, FI, and firm performance in academia and firms, a multi-theoretical framework for explaining banking reasons for engaging in it has not yet been developed. Existing studies often draw on the resource-based view (RBV), dynamic capability view (DCV), diffusion innovation theory (DIT), agency theory (AT), and stakeholders theory (ST) (He et al., 2020, Mikalef et al., 2020b, Chatterjee et al., 2024, Zhang et al., 2024, Oroud and Alumany, 2024). While DCV and RBV offer a management framework for leveraging adaptation and technological resources to create competitive advantages in dynamic business environments, they do not explicitly account for BDA as a specific resource. Moreover, they overlook how BDA synergizes with FI to influence banking-specific performance metrics, such as customer satisfaction and market performance (Mikalef et al., 2019a).

The DIT offers insights into market dynamics but does not fully address how banks can balance innovation with maintaining stable financial performance. Meanwhile, the AT suggests that BDA can reduce agency costs through transparent decision-making. However, further research is needed to understand how data governance can mitigate conflicts of interest in banking. Finally, the ST overlooks the critical role of BDA in meeting stakeholder expectations, necessitating further exploration of how big data BDA supports banks in balancing financial performance and customer satisfaction. As discussed above, there is an apparent weakness in each theoretical insight's ability to explain BDA, FI, and banking performance.

Considering banks' motivations for technological innovations, we argue that a multi-theoretical framework is suitable to simultaneously capture the relationships between BDA, FI, and banking performance within the banking sector for both researchers and banking professionals, potentially guiding future innovations in banking technology and data strategy. In such context, DCV suggests that firms can adapt to dynamic environments by continuously

integrating, developing, and recognizing resources, while also pursuing innovative performance strategies considering route dependences and market positioning.

Literature has adopted the DCV to explain how organizations build competitive advantages and performance in a changing environment, considering the rapid advancement of technology and the changing needs of customers (Cenamor et al., 2019, Chuang, 2020). Utilizing Fintech innovations such as BDA, artificial intelligence, blockchain, and FI, Firms can tackle the dynamic business environment and enhance their internal and external capabilities to gain a competitive advantage (Fosso Wamba and Mishra, 2017, Wamba et al., 2020) and improve operational efficiency within organizations (Chen et al., 2016). According to (Haarhaus and Liening, 2020) and Teece et al. (1997), a firm's management and operational procedures are integrated with the exploitation of dynamic capabilities, allowing for the quick and efficient reconfiguration of resources in response to market conditions. Banks must effectively utilize big data in decision-making, innovate financial services and products, and adapt to market dynamics to achieve superior performance. Therefore, BDA and FI act as dynamic capabilities in the banking market, identifying opportunities and responding to threats, focusing on large dataset analysis and innovative product development.

Second, RBV suggests that firms' competitive advantage stems from firms' resources that are rare, valuable, inimitable, and non-substitutable (Barney, 1991). In banking, data analytics and technological capabilities are strategic resources that can differentiate institutions. Within this study, BDA and FI can be viewed as unique organizational resources that enhance banking performance by enabling insights into customer needs, optimizing operations, and fostering innovative financial products. Third, DIT suggests that certain innovations fundamentally change the competitive landscape by introducing new ways of meeting customer needs (Christensen, 1997). In the banking sector, big data-driven FI can disrupt traditional banking processes, providing more personalized customer experiences and enabling banks to compete with Fintech firms. Fourth, AT suggests that conflicts arise between owners and managers due to misaligned interests. In the context of FI, BDA offers transparency and accountability, potentially reducing agency costs by enabling data-driven decision-making. The study utilizes AT to investigate how BDA can mitigate information asymmetry and enhance shareholder value through enhanced banking performance. Finally, ST highlights the importance of considering the interests of all stakeholders, including customers, employees, investors, and regulatory bodies (Freeman, 1984). BDA allows banks to gather and analyze data to improve customer experience, compliance, and internal processes, which aligns with stakeholder expectations. The understanding of BDA, FI, and BP concepts is crucial to enhancing the framework, and vital to improve operational efficiency and strategic decision-making in the banking sector.

3. Related Literature and Hypothesis Development

The deployment of big data analytics has emerged as a transformative force in the banking sector, greatly influencing decision-making, enhancing operational efficiency, and improving customer experience (He et al., 2023). Big data is characterized by its enormous volume, diverse variety, high veracity, significant value, and rapid velocity, residing in various databases (Owolabi et al., 2024, Sivarajah et al., 2024, Taherdoost, 2024). BDA involves managing and analyzing large, complex data to gain market advantage and improve decision-making (Anwar et al., 2024, Wang et al., 2016, Al-Khatib, 2023), enabling organizations to transform raw, unstructured data into valuable knowledge resources, driving strategic management processes (Gao and Sarwar, 2024). By leveraging BDA, firms can uncover actionable insights from large volumes of data, leading to operational transformation and enhanced competitive advantage (Mikalef et al., 2019b, Anwar et al., 2024). Lamba and Singh (2017) suggest that BDA is a critical tool for analyzing vast amounts of functional data, empowering firms to derive meaningful insights that inform business decisions. In banking, BDA involves the collection, storage, and analysis of large datasets to generate actionable insights. Banks utilize BDA for customer segmentation, fraud detection, credit scoring, and predictive analytics, enabling personalized services, anticipating customer needs, and swift market response (Sivarajah et al., 2017, Kumar et al., 2023). BDA offers real-time customer behavior insights, enabling banks to make data-driven decisions for personalized financial products and services, improving performance and customer retention (Adeniran et al., 2024).

Financial innovation is vital for banks to drive growth and maintain a competitive edge in a rapidly digitizing market, amidst technological advancements and evolving consumer expectations (Gunday et al., 2011, Zouari-Hadiji, 2023). FI is crucial in transforming existing financial products and services, fostering innovative solutions that meet consumer needs, and enhancing operational efficiency (Frame and White, 2004, Qamruzzaman et al., 2021). FI drives value creation by improving productivity, reducing costs, and enhancing access to financial services (Bhardwaj et al., 2023, Costanzo et al., 2003). Technological advancements such as blockchain, digital payment systems, and peer-to-peer lending have revolutionized banking services, reducing transaction costs and expanding customer interactions (Garcia & Wang, 2022; Singh et al., 2023). These innovations have significantly improved access to financial services through platforms like mobile banking, e-wallets, and robo-advisory services, thereby enhancing customer satisfaction and operational efficiency (Chen et al., 2022). Particularly, innovations are crucial in reducing financial constraints, addressing inefficiencies in traditional banking systems, and promoting better risk management and corporate governance practices for stability and trust (Nazir et al., 2021, Shahwan and Habib, 2020).

These advancements reshape existing banking services and strengthen the relationship between financial development and economic growth by enhancing the allocation of financial resources and fostering technological progress (Yusheng et al., 2021). Broadly, FI aims to alleviate financial constraints, utilising technology-based digital financial products and systems to enhance economic welfare (Johnson and Kwak, 2012). Economies with well-developed financial systems tend to exhibit higher levels of innovation, leading to improved financial inclusion and economic performance (Qamruzzaman et al., 2021, Ali et al., 2021). Thus, FI significantly contributes to economic and social development by creating new opportunities and ensuring the stability of the broader financial framework.

Fintech advancements like BDA, AI, and blockchain are revolutionizing banking by improving service delivery, security, and customer trust, thereby boosting market positions (Yin et al., 2023, Tchidi and Zhang, Ahmad et al., 2025). For instance, blockchain enhances transparency and security, while AI-powered chatbots improve customer service by providing real-time responses, streamlining operations, and extending services to underserved populations (Zhou et al., 2024). Furthermore, BDA and AI are enabling banks to offer personalized FI products and services to meet the unique needs of individual customers (Chen et al., 2022). These innovations in banking institutions enhance operational efficiency, and financial inclusion, and serve diverse customers by integrating FI, big data, and technological advancements (Bhardwaj et al., 2023). Additionally, FI reduces entry barriers for Fintech firms, intensifies competition, and accelerates technology adoption, prompting traditional banks to rethink service delivery models and adopt sustainable practices (Nazir et al., 2021). Nejad (2022) emphasizes that FI involves creating new products, services, processes, or organizational forms to improve performance, reduce costs, and better meet customer needs. FI significantly contributes to socioeconomic goals, economic resilience, and poverty reduction (Qamruzzaman et al., 2021) by creating new financial instruments, technologies, and markets (Bara and Mudzingiri, 2016, Dabrowski, 2017, Adekoya et al., 2024). Advanced technologies and FI are revolutionizing banking practices, enhancing financial performance, customer engagement, and accessibility to financial services across diverse populations (Nazir et al., 2021).

The literature indicates that global findings on BDA, innovation development, and firm performance are influenced by various research methods, data, and theoretical foundations (See Table A). Notably, most of these studies established positive relationships between BDA and firm performance and innovation impact on firm performance. More specifically, the review showed that BDA is positively related to firm performance (Brock and Khan, 2017, Park et al., 2019, Chatterjee et al., 2023). For instance, Jain et al (2024) found that BDA has positive effects on supply chain performance in India. (Morimura and Sakagawa, 2023) discovered

that BDA has a positive impact on the performance of Japanese retail firms. Moreover, the literature supports the positive promotion of innovation or product development by BDA (Ardito et al., 2019, Mishra et al., 2019, Ghasemaghaei and Calic, 2020, Mikalef et al., 2020a, Cheng and Shiu, 2023a). Sivarajah et al (2024) highlight BDA's pivotal role in driving innovation in Indian Industries. Similarly, Korayim et al. (2024) identify BDA's potential to advance organizational innovation in Indian healthcare firms, and Forough et al. (2024) illustrate how BDA capabilities accelerate both the quality and speed of innovation in manufacturing. However, the literature highlights a significant gap in understanding how the BDA specifically supports financial innovation within the banking sector. Notably, previous studies mainly focus on manufacturing, healthcare, and SMEs, leaving limited empirical evidence on how BDA drives performance and innovation in banking. The banking sector's reliance on data-driven strategies is a concern due to its need to navigate complex regulatory environments and evolving customer demands.

[Insert Table A Here]

Finally, despite the studies of FI toward economic growth (Bara and Mudzingiri, 2016, Nazir et al., 2021, Qamruzzaman and Wei, 2018, Bara et al., 2016, Taddese Bekele and Abebaw Degu, 2023, Mtar and Belazreg, 2023), studies on FI enhance banking performance remain limited in finance and innovation literature. The integration of BDA and FI offers a promising pathway to enhance banking performance comprehensively. Big data insights provide valuable information that can strengthen the effectiveness of financial innovations such as customer-centric product development and predictive service offerings. This synergy can improve FP, CS, and competitive positioning within the industry. Studies indicate that BDA allows banks to streamline operations and reduce costs, while FI adds value through personalized offerings, driving customer satisfaction and loyalty (Joshi, 2023, Lin et al., 2022). Table B provides a comprehensive overview of research on BDA, innovation, and firm performance, highlighting its theoretical foundation. Table B highlights significant research opportunities in FI research after reviewing its significant contributions to economic growth and firm performance.

[Insert Table B Here]

First, the literature on FI indicates a research gap in developed countries as studies focused on developing and emerging countries' banking institutions. For instance, Corbet et al (2023) examined the effect of Fintech innovation on Chinese banks' performance and found a negative effect of Fintech innovation and the profitability of banks. Moreover, Phan et al (2020) examine whether Fintech technology impacts banks' performance in the Indonesian market. Zouari-Hadiji (2021) examined seven privately owned Tunisian banks and found that they

respond positively to technological developments and banking products to manage risks and improve performance. Nyamekye et al, (2023) found that FI significantly impacted bank performance in Ghana from 2007 to 2015. Abbas et al, (2024) utilized data from 90 Pakistani companies from 2014 to 2020 and revealed that financial innovation does not fully reflect a company's performance. From the proceedings, limited studies exist on the correlation between FI and bank performance in developed countries, particularly the United Kingdom. This highlights the need for increased scholarship on financial innovation in developed nations. Second, the literature indicates that FI significantly impacts firm performance and economic growth within an economy. Yet, research on the causality and extent of FI impact on bank performance, focusing on firm-level surveys is still limited (Beck et al., 2016, Wang and Cao, 2022, Wang et al., 2022). The literature primarily utilized secondary firm data to gauge financial innovation and bank performance. Furthermore, apart from the impact of FI on financial sector development and economic growth, the micro-level question remains concerning the extent to which FI affects bank performance. Finally, literature on FI's impact on bank performance has yielded mixed results (Chen & Peng, 2020, Nejad, 2022, Manasseh et al. 2023). Studies show positive relationships between FI and banks' performance (Atalay et al., 2013, Cherotich et al., 2015, Gunday et al., 2011), while others argue that FI negatively impacts banking performance (Pooja and Singh, 2011, Corbet et al, 2023, Zhao et al, 2022). These mixed results call for more investigations needed even within the context of a developed economy.

3.1. Big data applications and financial innovation

Big data is a method that efficiently analyses large volumes of structured and unstructured data, offering valuable insights and providing comprehensive customer perspectives (Erevelles et al., 2016; Ghasemaghaei and Calic, 2020). BDA is gaining recognition as a crucial organisational ability that enhances innovation, operational efficiency, and competitiveness by effectively utilising big data technologies and tools (Ransbotham and Kiron, 2017). In this regard, innovation is conceptualized as the addition of new products, processes, and managerial activities involved in service or product provision. Niebel et al. (2019) suggest that BDA can significantly boost product innovation by improving decision-making opportunities. FI involving online banking, green deposits, fast payments, asset management services, and financial service devices can significantly improve performance in the banking sector, economic processes, and markets. By integrating data from multiple sources, banks can generate unmatched insights to drive financial innovation. Innovating in the digital era relies on a firm's ability to utilise diverse data sources, both traditional and non-traditional. DCV suggests that firms can develop and refine capabilities by processing novel data to build more precise models for strategic decisions. Consequently, BDA facilitates FI by

enabling banks to efficiently organize and deploy capabilities through carefully honed data insights (Erevelles et al., 2016). Research indicates that BDA positively influences innovation, particularly in manufacturing, IT, healthcare, and SME settings (Ardito et al., 2019, Mishra et al., 2019, Ghasemaghaei and Calic, 2020, Sivarajah et al., 2024, Korayim et al., 2024, Foroughi et al., 2024). The literature on the impact of BDA on a bank's FI development, especially in the UK remains limited. Consequently, this study aims to close the gaps by proposing the following hypothesis.

H1: Big data applications positively influence financial innovations.

3.2. Big Data Applications and Bank Performance

Big data refers to a substantial amount of structured and unstructured data, characterised by the 5Vs (Ghasemaghaei and Calic, 2020; Wamba et al, 2017). Ghose (2015) asserts that big data aids organisations in making swift, efficient business decisions, addressing challenges, technical advancements, economic factors, and productivity, thereby enhancing performance (Suoniemi et al., 2020; Elia et al., 2020). The RBV suggests that big data is a valuable, rare, and inimitable resource that offers firms a sustainable competitive advantage. Leveraging BDA through various tools and methods supports firms to improve product quality, corporate productivity, and customer satisfaction, thereby increasing the overall firm value. (Ghasemaghaei and Calic, 2020; Thekkoote, 2022). Banks' vast consumer demographic, behavioural, and transactional data repositories have been proven to significantly enhance their performance through BDA (Hung et al., 2020). (Al-Dmour et al., 2023) discovered that BDA has a positive influence on banks' performance. Firms with dynamic capabilities can efficiently utilise and manage large data volumes to fully leverage big data for enhanced performance. DCV highlights the importance of firms' DCs to adapt, integrate, and reconfigure internal and external competencies in response to dynamic environments for superior performance (Teece, 1997). Yet, the literature on the relationship between BDA and firm performance is still inconclusive (Zhong et al., 2016). While some studies have suggested that BDA leads to positive improvements in firm performance by enhancing sales growth and profitability (Gupta et al., 2019; Wamba et al., 2017; Mikalef and Krogstie, 2020; Lehrer et al., 2018; Raguseo and Vitari, 2018), others found that BDA negatively enhanced firm performance (Ghasemaghaei et al., 2017, Kretzer et al., 2014). The DIT suggests that the integration of disruptive technologies like BDA can revolutionise traditional business models and offer competitive advantages in rapidly changing markets. The fragmented findings in existing literature indicate the need for further research into the BDA-performance relationships. Moreover, most BDA-firm performance relationships focused on manufacturing, information technology, and the hospitality industry (Aydiner et al., 2019; Yadegaridehkordi et

al., 2020), leaving a significant research gap in the banking sector. Despite the UK's unique operating environment and the potential to leverage BDA for competitive advantage, the effects of BDA on banks' financial performance remain limited. Therefore, we propose that a bank's capability in organizing and adopting BDA plays a distinguishing role in improving financial performance, creating competitive advantage, and fostering long-term value creation.

H2a: Big data application has a positive effect on financial performance.

Firms are leveraging BDA to enhance customer satisfaction and gain a competitive edge by providing actionable insights and tailoring offerings (Giebe et al., 2019). RBV asserts that BDA is a valuable and inimitable resource that allows firms to develop distinctive capabilities, ensuring sustained competitive advantage (Barney, 1992). BDA provides companies with tools to evaluate consumer feedback from social media, online reviews, and customer support interactions, thereby ensuring customer satisfaction and organisational success. In the banking sector, BDA facilitates the rapid adoption of innovations, enabling banks to meet evolving customer needs effectively. The DCV emphasises the importance of firms adapting and integrating resources like BDA to adapt to environmental changes and maintain competitiveness.

By leveraging BDA, banks can enhance their capability to meet customer expectations, thereby building trust and fostering long-term relationships. Banks increasingly enhance their customer service operations by integrating data from diverse sources, including ATM transactions, social media feedback, internet searches, and customer complaints (Barton and Court, 2012). Moreover, BDA empowers banks to deliver personalised services, anticipate customer needs, and proactively address challenges, resulting in enhanced customer interactions and satisfaction. While prior research demonstrates a positive relationship between BDA and firm performance, we recognised a lack of empirical studies specifically exploring how BDA impacts customer satisfaction in the banking sector. Consequently, we contribute to the banking literature by investigating the relationship between BDA and customer satisfaction leading to the following hypothesis:

H2b: Big data application is positively related to customer satisfaction.

Wamba et al (2017) argued that firms can enhance market performance by utilising big data, as it provides a fresh perspective on the market. Currently, companies have access to advanced data, enabling them to develop fresh insights from various sources to better meet customer demands (Olabode et al., 2022). Therefore, banks' ability to efficiently analyse large amounts of data can significantly enhance their competitive position. DCV allows companies

to utilise BDA as a dynamic capability to navigate complex environments and gain a competitive edge. By providing transparent and actionable insights, BDA ensures that decisions are made in alignment with the interests of both internal and external stakeholders. AT suggests that BDA can address information asymmetries between management and key stakeholders, such as shareholders and customers. Furthermore, ST suggests that banks can enhance their market reputation and performance by effectively utilising big data to balance and prioritise stakeholder interests. BDA is vital for marketing decision-making and achieving favourable market performance outcomes, aligning with the RBV, and highlighting the value of rare and difficult-to-replicate capabilities (Gupta et al., 2019). Research showed positive relationships between BDA and market performance outcomes (Akter et al., 2021, Olabode et al., 2022, Yasmin et al., 2020). By providing firms with the ability to identify new opportunities ahead of competitors, big data ensures that firms can address both existing and emerging customer needs, leading to more stable income streams (Mikalef et al., 2020b). However, literature remains scanty on the effect of BDA on market performance especially in banking. Therefore, our study addresses this gap by hypothesising that banks' capability to leverage BDA can lead to enhancing their market performance.

H2c: Big data applications have a positive influence on banks' market performance.

3.3. Financial Innovation and Bank Performance

FI significantly influences the banking industry, leading to the creation of new products and services to gain a competitive edge in the market (Xie et al, 2023, Tufano, 2003). Banks face unstable environments and must adapt to technological innovations. Successful application of contemporary information technologies can achieve most financial inclusion. Mabrouk and Mamoghli (2010) posited that the first bank to introduce new products or implement innovative delivery methods will likely earn more than its rivals. Previous studies have shown positive relationships between FI and banks' performance (Amore et al., 2013, Beck et al., 2016, Duygun et al., 2013, Le and Ngo, 2020b). (Wang et al., 2022) indicate that FI can significantly improve a bank's financial performance. Aayale (2017) and Cherotich et al. (2015) showed that FI has been proven to enhance the financial performance of banks. Therefore, banks that excel in FI can enhance their financial performance by incorporating novel technologies. These findings suggest that banks leveraging advanced financial innovations can achieve higher profitability and return on investment by aligning their business strategies with novel technological capabilities. Drawing on the DCV, we argue that superior financial performance in the banking sector arises from the ability to dynamically reconfigure resources and processes to incorporate FI (Berger, 2003). Despite extensive research, the FI-FP nexus

remains limited in scope, particularly in the UK context. Moreover, empirical investigations exploring the effect of FI on FP in UK banks are scarce. Thus, we hypothesize that:

H3a: Financial innovation has a positive impact on financial performance.

Organizations continuously innovate to attract customers and enhance their satisfaction levels (Nemati et al., 2010). Moreover, managers are open to innovation investment when they acknowledge that their current products are not fully meeting customer demands (Simon and Honore Petnji Yaya, 2012). FI involves banks creating innovative products to improve customer satisfaction, share, and meet needs, while also distinguishing themselves from competitors. Studies have consistently shown a positive correlation between technological advancements and increased customer satisfaction (Ameme and Wireko, 2016, YuSheng and Ibrahim, 2019). Technological innovations improve bank productivity, reduce customer transaction costs, and conserve costs for both banks and customers (Musara and Fatoki, 2010, Angko, 2013). The capability of banks to meet customer needs depends on their ability to generate, utilise, and implement FI activities effectively. From the DCV perspective, FI represents dynamic capabilities that add value for both firms and customers, ultimately fostering competitive advantage (Teece, 1997). Furthermore, ST suggests that FI enables banks to address the expectations of key stakeholders, particularly customers, by delivering innovative and tailored financial products and services. Despite these theoretical insights, limited studies exist examining the relationship between FI and customer satisfaction in banking institutions. Hence, we hypothesise

H3b: FI has a positive influence on customer satisfaction.

Innovation is widely recognised as a driver of enhanced corporate performance. For instance, Liao and Rice (2010) demonstrated that innovation contributes to firm performance, longevity, and sustainability. Similarly, Zapata-Cantu et al. (2016) confirmed that innovation positively influences market performance. Market performance is often measured by market share and penetration, and firms often innovate to improve their market position, often through financial product and service innovations (White et al., 2009). Evangelista and Vezzani (2010) found that product innovation leads to competitive advantage through technology-driven superiority, while service innovations enhance quality and design, allowing firms to capture more market share. From a DCV perspective, FI represents banks' ability to adapt their dynamic capabilities to capitalise on market opportunities and enhance performance. Moreover, AT highlights that innovations can reduce information asymmetries, enabling banks to align their strategies with stakeholder expectations and enhance market trust.

FI allows banks to utilise advanced tools and platforms to improve operations, enhance security, and increase transparency. For instance, digital payment systems and mobile banking applications provide personalised customer solutions, promoting loyalty and engagement, thereby attracting and retaining customers. Banks can attract and retain high-value customers by introducing personalised financial products and utilising data analytics for targeted marketing strategies. FI can enable banks to expand into new markets, improve customer experiences, and enhance their market share and competitiveness. However, the empirical link between FI and market performance in the banking sector remains unexplored leading to our below hypothesis

H3c: FI is positively related to market performance.

Notably, this study is the first to examine the impact of FI on bank performance, considering the dynamics among bank performance, customer satisfaction, and market performance. Figure 1 presents our conceptual model, mapping the research hypothesized relationships.

[Insert Figure 1 here]

4. Methodology

4.1. Research Context and Design

We focus on the banking industry in the United Kingdom for three reasons. First, the UK, a global leader in Fintech and innovation, saw a 6% increase in operational activity in the banking sector, contributing £132.5 billion in revenue in 2024-2025 (IBISWord, 2024). Second, the UK recognized for its advanced financial infrastructure is Europe's Fintech powerhouse, boasting over 3,200 firms and attracting £11.6 billion in investments in 2021 (Deloitte, 2022). These advancements highlight the UK's banking institutions as frontrunners in integrating BDA to revolutionize FI, enhance decision-making, and achieve superior performance. Thirdly, UK banks are utilizing big data in various areas, including online banking and real-time data-driven asset management, to drive innovation and gain a competitive edge. As the industry evolves, the seamless adoption of BDA has enabled banks to offer customer-centric solutions while optimizing operational efficiency. Amid the rapidly changing landscape, understanding how BDA and FI drive customer satisfaction, and financial and market performance is vital. By situating this research in one of the world's most vibrant financial markets, we provide valuable insights for policymakers, Fintech innovators, and banking leaders, shedding light on how big data and FI can redefine the future of banking performance.

We adopt a quantitative research design based on a survey-based approach to collect data from UK banking institutions including both traditional and digital-first banks. The survey captured data on BDA adoption, FI, and performance metrics including customer satisfaction, market competitiveness, and financial outcomes. The selection of a survey method was guided by the need to gather diverse perspectives on the adoption and impact of BDA and FI within the banking sector. To ensure representativeness, the sample includes institutions varying in size, digital maturity, and market focus. The survey period was set between January and June 2023, aligning with recent developments in big data technologies and Fintech innovation.

4.2. Data Collection Procedure

As part of the data collection procedure, we conducted in-depth interviews with seven respondents such as senior managers, finance, and marketing managers of banks in the UK. The interviews provided a comprehensive explanation of the conceptual domain of constructs, thereby enhancing the development and improvement of the research conceptual framework. The interviews, lasting thirty to forty-five minutes, were semi-structured to allow informants to share their thoughts and understandings based on the research questions. Mainly, we inquired from the informants about the conceptual framework of BDA and FI, focusing on how their implementation in banking drives performance gains.

Building on insights from the interviews, we employed the quantitative approach utilizing a cross-sectional survey, widely recognized in business research for its effectiveness in drawing robust conclusions from large samples to empirically test our conceptual framework (Olabode et al., 2022). Since constructs are objective realities that manifest as causal linkages, our research approach enables their empirical measurement through reliable and appropriate data collection instruments. Therefore, we address the research questions by capturing the objective and social realities of the constructs through survey-based data from banking managers in the UK.

The questionnaire was designed with thirty questions for the constructs along with respondents and firm profiles. Construct questions were composed based on a 7-point Likert-type scale for all constructs from (1=Strongly Disagree, 7=Strongly Agree). The questionnaire was pre-tested with experts who reviewed it in our presence and raised queries about certain wordings. This process allowed us to address minor issues and refine the questionnaire, resulting in a final survey structured into three sections. The first section examined respondents and their firm's profiles, while the remaining sections assessed the research constructs, including BDA, FI, FP, customer satisfaction, and market performance.

After the pre-test, we conducted a pilot test with 10 managers to gain insights into respondents' understanding and suitability for answering the questions of the questionnaire. Notably, the pilot testing indicates the feasibility of the research survey, smooth implementation of the study, and quality of research design and procedures. Noticeably, the survey data was not adjusted post-pilot testing and was not included in the final research analysis.

We used an online platform through email to distribute the final survey to bank managers over eight months (June 2022 to February 2023). Managers were targeted considering their broad insights into the bank's technological innovations and in-depth understanding of the study constructs. We have attached a cover letter to the questionnaire, outlining the study purpose, survey background, and confidentiality assurance, considering the research context and previous studies.

4.3. Variables' Measurement

This study measured constructs utilizing multi-items with a seven-point Likert scale. Notably, some constructs were measured based on the knowledge of existing tested scales from the literature and others were self-developed through the initial interviews.

4.3.1. Dependent Variables

To measure bank performance, this study used financial performance, market performance, and customer satisfaction. Financial performance is the measure of a bank's overall financial health and performance over a given period. In particular, we utilized risk-adjusted return on assets-*RAROA* (which measures the profitability of financial institutions relative to risk), net sales of financial expenses *(*a specific category of expenses deducted from the total sales revenue to calculate the net sales), and profitability (which measure firms profit relative to its expenses) as measurements for banks performance. The utilization of RAROA and FES as new indicators was derived from the initial interviews conducted with managers on their firms' applications of big data and FI developments in banking. Meanwhile, profitability is a widely considered dimension in empirical banking literature used to measure bank financial performance (Saghi-Zedek, 2016, Scott et al., 2017, Ky et al., 2019). Overall, we developed nine items for financial performance (Risk-adjusted return on assets-RAROA (four items), shares on financial expenses in Net sales (FES) (three items), and profitability (two items).

Customer satisfaction determines how happy customers are with firm products and services. Hence, we developed four customer satisfaction measures based on initial interviews and existing literature, tailored to the study's context. Market performance refers to the alignment of marketing strategy goals with actual results, measured by key performance indicators like

return on investment, cost per sale, and customer conversion rate. Accordingly, we developed four items to measure banks' market performance adopted from (Gupta et al., 2019).

4.3.2. Independent Variables

We measured big data application (BDA) with 12 items adapted from (Johnson et al., 2017) Based on data volume, data variety, and data velocity. Particularly, we adopted four items for big data volume, four items for big data variety, and four questions for data velocity. For financial innovation, we developed seven measurement items based on initial interviews and existing literature, tailored to the study context. Notably, it was categorized into products innovation measured with three items, and services innovations measured with four items respectively. Table 1 shows the variable descriptions

[Insert Table 1]

4.3.3. Control Variables

Our models incorporate control variables to isolate the impact of other firm-level variables on the relationship under study. Firm size has been used in previous studies of financial performance and technological innovation. Larger firms normally benefit from economies of scale, greater access to financial resources, and increased market power, which can enhance profitability (Shahrour et al., 2024). To control for firms' size, the natural logarithm of total full-time bank employees and the number of years since bank operation are employed. Firm age has been a significant control variable in numerous studies on financial performance and technological decision-making. Banks with a longer history of establishment often have better performance advantages and more time to build and solidify their reputation compared to newer institutions. To control for firms' age, the natural logarithm of several years since bank operation is employed (Gupta and Batra, 2016). Finally, to control the role of competition implications of investing in BDA and FI developments, industry competition is employed. We measured on a scale ranked (1= highly competitive to 7 Strongly competitive) following the work of (Zhou et al., 2016). The research controlled for industry competition since the United Kingdom is among the top 10 most competitive countries in the world and the fourth most competitive economy in Europe (Schwab, 2018).

4.4. Data Analysis and Model Specification

To test our hypotheses, we used multiple hierarchical regression modeling through the SPSS. The method permits to put different variables into the regression model hierarchically, which not only clearly shows which variables have the most explanatory power, but also helps to avoid multiple contribution linearity problems. Therefore, we constructed analytical models to

test the hypotheses with variables including BDA, FI, financial performance, customer satisfaction, and market performance. Particularly, control variables were added including firm age, firm size, and industry competition. Model 1 tests the effects of BDA on FI. Model 2 explores the effect of BDA and FI on FP. Model 3 tests the impacts of BDA and FI on customer satisfaction and model 4 tests the effects of BDA and FI on market performance. In the model, *"*FI*"* denotes financial innovation, *"*BDA*"* is big data applications "FP denotes financial performance, "CS denotes customer satisfaction, and "MP" denotes market performance. Betaβ_0 denotes the regression coeicients and $\varepsilon_{i,t}$ is the disturbance term.

$$\mathrm{FI_{it}} = \beta_0 + \beta_1(\mathrm{BDA})_{\mathrm{it}} + \beta_2(\mathrm{LnSize})_{\mathrm{it}} + \beta_3(\mathrm{Lnage})_{\mathrm{it}} + \beta_4(\mathrm{CI})_{\mathrm{it}} + \varepsilon_{it} \quad (1)$$

$$\mathrm{FP_{it}} = \beta_0 + \beta_1(\mathrm{BDA})_{\mathrm{it}} + \beta_2(\mathrm{FI})_{\mathrm{it}} + \beta_3(\mathrm{LnSize})_{\mathrm{it}} + \beta_4(\mathrm{Lnage})_{\mathrm{it}} + \beta_5(\mathrm{CI})_{\mathrm{it}} + \varepsilon_{\mathrm{it}} \quad (2)$$

$$\mathrm{CS_{it}} = \beta_0 + \beta_1(\mathrm{BDA})_{\mathrm{it}} + \beta_2(\mathrm{FI})_{\mathrm{it}} + \beta_3(\mathrm{LnSize})_{\mathrm{it}} + \beta_4(\mathrm{Lnage})_{\mathrm{it}} + \beta_5(\mathrm{CI})_{\mathrm{it}} + \varepsilon_{\mathrm{it}} \quad (3)$$

$$\mathrm{MP_{it}} = \beta_0 + \beta_1(\mathrm{BDA})_{\mathrm{it}} + \beta_2(\mathrm{FI})_{\mathrm{it}} + \beta_3(\mathrm{LnSize})_{\mathrm{it}} + \beta_4(\mathrm{Lnage})_{\mathrm{it}} + \beta_5(\mathrm{CI})_{\mathrm{it}} + \varepsilon_{\mathrm{it}} \quad (4)$$

5. Results

With 300 questionnaires distributed among UK bank managers, we received 150 completed responses, representing 50%, after several reminders via email urging banks to participate in and promote the survey. The online survey's nature and data collection resulted in a data set without missing values, as respondents could not proceed with the next question without answering a specific question. Table 2 shows the respondents' characteristics. Out of the 150 managers, 50.7% were top managers, 35.3% were middle managers, and 21% were senior managers. Regarding education, 41% are post-graduates and 33% declared to hold a bachelor's degree. Considering age, 38% declared to be between 36-45 years, 23.3% belonged to the 26-35 years, 22% belonged to 20-25 years, and 16.7% to 45 and above. Male respondents were higher than females (100, 66.7% vs.50, 33.3%).

[Insert Table 2 Here]

5.1. Common Method Bias

Our paper, based on self-reported data, has been validated due to potential common method bias issues with all data originating from one instrument. (Podsakoff et al., 2012). First, we included a lengthy introduction to the questionnaire to explain BDA, FI, and BP, which benefited respondents in providing correct responses. Second, our questionnaire's measurement items were randomised to prevent participants from recognising causal relationships concerning constructs. Additionally, we ensured the privacy and confidentiality of respondents regarding the information gathered. Third, the Harman single-factor method was applied to the data, revealing a 26.7% accuracy level, one factor lower than the 50%

benchmark (Fuller et al., 2016). Fourth, we utilised a marker variable method to assess the impact of CMB on the validity and reliability of data analysis. (Lindell and Whitney, 2001). Hence, the study model used gender as a marker variable, a theoretically irrelevant construct, with a non-significant connection between gender and FI. Additionally, the correlation coefficient between variables was tested to detect common method bias, and the maximum value was found to be 0.587, significantly below the threshold of 0.9 (See Table 4). Lastly, the regression model's collinearity was tested using the variance inflation factor (VIF) and tolerance values, revealing no multicollinearity issues with values less than 5 or 10 (Hair Jr et al., 2017). Overall, the results indicate that there is no significant common method bias in the sample.

5.2. Validity and Reliability Estimates

The fitness test was used to assess the reliability and validity of a measurement model, ensuring its accurate match with the actual situation. (Wang et al., 2021). We utilise properties including Cronbach's alpha (CA), Factor Loadings (FL), Composite Reliability (CR), and Average Variance Extracted (AVE) to achieve this goal. Table 3 provides the results. Before estimating the validity and convergent tests, we assessed the survey sample adequacy and fitness of the data by adopting the Kaiser Meyer Olkin (KMO) index and Bartlett's chi-square. We found 0.83 of 1% significance, greater than the standard 0.6 benchmark for sample adequacy and suitability for analysis (Hair et al., 2010). Factor loadings of items for constructs exceeded the 0.5 minimum level. The reliability of a construct is typically tested using a CA value exceeding 0.7, which is within the standard range. From the results, CA exceeded the 0.7 threshold (BDA=0.789, FI=0.771, FP=0.753, CS=0.748, MP=0.712) (Gliner et al., 2001). CR coefficients for variables exceeded the benchmark of 0.7 (Bonsu et al., 2024). Further, the results of the AVE values exceeded 0.5 thresholds, indicating that the variations reported by the questionnaire items were significantly larger than the changes driven by measurement errors. (Raykov, 2012). Therefore, convergent validity is recognised for the research sample.

[Insert Table 3 Here]

Moreover, we assessed model validity using the square root of average variance estimates (Fornell-Larcker standard) and the Heterotrait-Monotrait ratio (HTMT) standards for discriminant validity, assessing unrelated indicators (Henseler et al., 2015). Tables 6 display the inter-construct correlation values and the diagonal square root of AVEs. Results show the square root of AVE values outperforms all construct correlations that meet the Fornell-Larcker criterion standards. (Fornell and Larcker, 1981). We conducted a heterograft-monotrait (HTMT) analysis to improve discriminant validity due to insufficient criterion metrics, following.

(Henseler et al., 2015) Recommendation. The results from the HTMT testing fell below the upper cut-off of 0.85 (see Table 5). Thus, we confirmed the discriminant validity of the study.

[Insert Table 4 Here]

[Insert Table 5 here]

5.3. Empirical Findings

Table 6 presents regression analysis results to test the study hypotheses. H1 anticipated the positive effect of BDA on financial innovation. As expected, model 1 shows a positive and significant effect of big data applications on financial innovation at a 1% significance level ($\beta=0.61$, $p<0.001$), indicating that big data applications will significantly improve financial innovations of banks at about 61%. Therefore, the applications of big data by banks can lead to improved financial innovations. Model 2 shows that BDA has a positive effect on financial performance, suggesting that 5% of big data applications can potentially improve the financial performance of banks in the UK at about 13%. The result supports H2a. Similarly, model 2 evidence positive and significant effects of FI on the financial performance of banks ($\beta=0.55$, $p<0.001$), supporting H3a. Model 3 shows that big data application has a positive influence on customer satisfaction at a 5% significance level, indicating that, big data applications by banks can lead to achieving customer satisfaction. The results support H2b confirming that banks' applications of big data increase coordination permitting them to respond to customer needs. Similarly, model 3 evidences significant and positive effects of FI on market performance, suggesting that banks FIs support banks' market performance supporting H3c. In model 4, we expected that both BDA and FI would positively enhance banks' market performance. Indeed, our result shows the positive and significant impact of both on banks' market performance. Particularly, BDA showed positive and 5% significance level effects on banks' market performance and support H2c, implying that, banks' accessibility of large datasets is utilized to develop novel insights from diverse data sources to understand customers which improves market performance. Regarding FI, results evidence significant and positive effects on MP, suggesting that, banks' FIs support banks' marketing performance which supports H3c. Notably, the constructs' predictive relevance is assessed using R^2 consistent with Cohen's (1988) requirement of R^2 being over 0.26 for substantial predictive power (Cohen, 1988). From Table 6, FI accounts for 57.4% of the total variance in big data applications, financial performance, customer satisfaction, and market performance accounted for 57.4%, 53%, and 54% of the total variance in BDA and financial innovation.

[Insert Table 6]

5.4. Robustness check

We conducted three additional tests to validate robustness, First, the paper used Partial Least Squares-Structural Equation (PLS) Modelling to test and estimate our hypotheses, considering its effectiveness in analyzing structural relationships (Hair et al., 2012). In recent years, the Partial Least Squares-Path Modelling method has become a prominent estimating tool in business and finance research (Ghasemaghaei, 2021, Chatterjee et al., 2023). The results from PLS-SEM are presented in Figure 2. From Figure 2, BDA positively impacts FI, validating H1, suggesting that BDA provides banks with valuable insights by analyzing vast amounts of structured and unstructured data, enabling innovative financial products and services tailored to customer needs. Similarly, the result supported the positive effects of BDA on FP, CS, and MP, which validates H2a, H2b, and H2c, respectively. This suggests that big data applications enhance profitability and operational efficiency, improve customer experience and loyalty, and strengthen market competitiveness and positioning. Finally, the results evidence the positive effects of FI on FP, CS, and MP, validating H3a, H3b, and H3c (see Figure 2). This means that FI drives profitability and growth, enhances customer experiences and loyalty, and boosts competitive positioning and market success. Therefore, our findings are robust considering the consistent results of the study models.

[Insert Figure 2 Here]

Second, we utilized a split sample analysis, focusing on firm age as a theoretical variable, with three groups of respondents (1- 10 years, N=41), FP (11- 39 years, N=71) FP (> 40 years, N=32*)*. Considering the works of (Dietrich and Wanzenried, 2011, and Corbet et al., 2023), such characteristics can drive the nexus amid big data, FI, and bank performance. Banks with longer establishment periods tend to have better performance benefits and a longer period to develop their reputation compared to newer banks (Dietrich and Wanzenried, 2011). According to the results (Table 7), BDA has a positive impact on financial performance for banks established between the ages of 1-10, 11-39, and >40. Interestingly, the effects of BDA on FP for banks above 40 years is larger, because banks above 40 years are mature and might have the financial muscles to analyze and develop better analytics-driven insights, which in turn, support banks' use of digitalized transaction data to increase financial performance. Similarly, we find a positive effect of FI on the financial performance of banks for groups (1-10, 11-39, and >40). However, firms that existed for more than 40 years had the largest effects, indicating that banks with long existence will be efficient in applying big data to provide insights leading to an upsurge in the financial performance. However, the effects of BDA on the financial performance of banks that existed between 1-10 years are positive but nonsignificant, which accounted for numerous reasons. The most significant one might be that those banks'

level of big data applications is not optimal. The exploitation and applications of BDA tools come with distinct types of analytical applications consideration, thus, those banks need to first understand big data environments (Osei-Assibey Bonsu et al., 2023). Similarly, the results find a positive effect of BDA and FI on CS for the dimensions of banks' existence. However, their effects are significant, indicating that mature and older firms' applications of big data and FI can lead to improved customer satisfaction. Finally, results indicate a positive effect of BDA and FI on MP for all firm existence dimensions, indicating that, irrespective of bank age, BDA and FIs have the capabilities to improve MP. Overall, the results remained unchanged on firm age, and thus the findings remain consistent and robust.

[Insert Table 7 Here]

Finally, we examine whether to examine (1) whether FI is how BDA influences bank performance (FP, CS, MP) and (2) whether BDA is how FI influences bank performance (FP, CS, MP). We estimate the mediation at a 95% confidence interval by adopting the bootstrapping method model 4 PROCESS. (Preacher et al., 2007). From Table 8, results show a positive effect of BDA on FI ($\beta = 0.038$, $p < 0.05$), CS ($\beta = 0.36$, $p < 0.01$), and MP ($\beta = 0.26$, $p < 0.01$), validating our hypothesis. Importantly, we estimated the significance of FI's indirect effect on BDA via FP, CS, and MP. As evidenced in Table 8, there is a significant indirect effect of FI on FP (effect=0.18, LLCI=0.04, ULCI=0.345), CS (effect=0.21, LLCI=0.05, ULCI=0.36), and on MP (effect=0.51, LLCI=0.26, ULCI=0.74). We conclude that FI mediates the BDA effects on banks FP, CS, and MP, which suggests that FI indirect effect can support banks FP and both CS and MP. Finally, we find the positive indirect effect of BDA on FI and FP, CS and MP relationships with BDA on FP (Effect=0.29, LLCI=0.15, ULCI=0.45), CS (Effect=0.04, LLCI=0.06, ULCI=0.14) and MP (Effect=0.38, LLCI=0.57, ULCI=0.80) (See Table 8). The results suggest that, through BDA, the banking industry may scale up strategic planning while also transforming and processing data to provide necessary insights guaranteeing banks improved performance. The mediation results validate the resources and capabilities of BDA and FI, enhancing banks FP, CS, and MP, thus confirming the robustness of our study findings.

[Insert Table 8 Here]

5.5. Additional Analysis

We conducted additional analysis using the proxies of financial performance (RAROA, FES, and Profitability) due to their multi-dimensional nature. Specifically, we estimated the effects of BDA and FI on each proxy including the control variables. Table 9 reports the results of the regression analysis.

The study indicates that BDA can significantly improve RAROA by optimising returns and risk management, thereby enhancing the overall performance of the bank. By leveraging advanced algorithms and predictive models, BDA enables banks to identify, assess, and mitigate various risks, including credit, market, and fraud. This proactive approach provides valuable insights into potential threats, allowing banks to implement effective measures to minimise their impact. However, BDA has a positive effect on banks' FES, indicating that BDA can enhance firm performance by improving net sales of financial expenses by 30.5%. BDA enables banks to analyse customer trends and patterns, supporting critical predictions that drive business performance. By identifying customer loyalty, banks can leverage BDA investments to increase sales and optimise financial outcomes. Finally, we observe the positive effect of BDA on the profitability (PT) of banks, suggesting that BDA leads to improved banks' profitability, aligning with the existing literature (Akter et al., 2016, Jayanand et al., 2015).

For FI, the study shows that FI has a positive and significant effect on RAROA, suggesting that FI is a valuable tool for banks to improve their performance by adjusting risk, leading to risk management. Innovations are linked to various risks, including market, credit, and operational risks, which can lead to bank fragility. Therefore, FI investments reinforce financial risk management, which is effective for bank performance (Beck et al., 2016). For the bank's FES, results show a positive and significant effect of FI on FES, indicating that FI is likely to enhance bank financial performance through net sales (FES), leading to bank efficiency. Likewise, there is an indication of the positive and significant impact of FI on profitability, suggesting that FI can lead to enhanced bank profitability. Mabrouk and Mamoghli (2010) discovered that the main force behind innovations in products, processes, and services increases banks' profitability.

Overall, the results show comparatively lower effects, indicating that while BDA and FI enhance bank performance, their impact on individual metrics may be influenced by contextual factors and market dynamics. For instance, RAROA and FES's lower impact may be due to their unique nature, which may be influenced by external factors including market volatility, regulatory constraints, and asset management strategies. Meanwhile, implementation costs from these innovations could potentially outweigh their immediate benefits for PT. Therefore,

banks should adopt targeted strategies to maximise the impact of BDA and FI on specific FP dimensions. For example, leveraging advanced analytics can potentially enhance the efficiency of resource allocation and credit risk management in RAROA. FIs that cater to customer needs, such as personalised products and enhanced digital banking services, can boost customer retention and satisfaction, thus improving FES. To advance profitability, banks can improve implementation processes and efficiently scale innovations to decrease costs. The study emphasises the importance of aligning BDA and FI strategies with specific performance objectives within the banking sector. In this regard, the study recommends further research on the influence of technological maturity, organisational agility, and market characteristics on the impact of innovations on different financial performance dimensions.

[Insert Table 9 Here]

5.6. Post hoc Analysis

Post hoc analysis refers to a statistical analysis conducted after research has been conducted and data collected (Zhang et al., 2019). A post-hoc test is done to identify which groups differ from each other. Therefore, we performed post-hoc tests using Partial Least Squares of Structural Equation Modelling version 4 to gain a better comprehension of big data's impact on the kinds of financial innovation (product and service) and financial performance categories.

Figure 3 provides evidence that BDA has a direct positive and significant effect on FI in the product (β=0.266, pv<0.01) and service innovations (β=0.345, pv=<0.01), suggesting that 1% of BDA supports banks generate new financial products and services by 61% of BDA coefficients. Hence, we suggest that BDA enhances financial products and services as defined in this research. Next, we estimated the effects of financial innovation kinds (service and product innovation) on bank FP measurements. The impact of FI on bank performance is fascinating. The effect of product innovations on profitability is positive and significant (β=0.142, p-value <0.01), RAROA (β=0.027, p-value <0.05) and FES (β=0.038, p-value <0.05), suggesting that substantial generation of financial product innovations by banks leads to improving the profitability and ensuring effective risk management and efficiency at 20.7% of banks in the UK. Notably, product innovation effects on RAROA and FES were insignificant but positive, implying that a decrease in financial innovation products would not ensure risk management and efficiency of banks. Regarding the effects of service innovations, there are positive effects of service financial innovations on bank profitability, RAROA, and FES. However, their effects are significant at a 1% significance level, suggesting that banks'

generation of financial service innovations improves banks' profitability, risk management, and efficiency. The effects of BDA on FP categories evidence a positive effect of BDA on profitability (β=0.159, pv=<0.01), RAROA (β=0.305, pv=<0.01), and FES (β=0.145, pv=<0.01), confirming that BDA has a large direct effect on profitability, RAROA and FES of banks. The results confirm the importance of the BDA for banks' financial innovations, hence building firm dynamic capability which validates the DCV for competitive advantage (Teece et al, 1992). Particularly, BDA has a larger effect on RAROA, suggesting that banks collecting and analysing relevant data helps to recognize potential risks and design and implement risk mitigation strategies. The post-ad hoc analysis shows that there is a direct nexus between BDA and profitability, RAROA and FES.

[Insert Figure 3 Here]

6. Discussion

The study proposes seven relationships, all of which have been supported. First, the study suggests that BDA positively impacts financial innovation, suggesting that banks leverage big data applications to efficiently analyze large data volumes, identify trends, enhance decision-making, improve customer experiences, and develop innovative financial products and services. The result matches previous studies that discovered that BDA impacts innovation development, but these studies were limited to the banking industry (Mikalef et al., 2020, Mikalef and Krogstie, 2020, Sivarajah et al., 2024, Zheng et al., 2022, Korayim et al., 2024). For instance, Foroughi et al., (2024) indicated that BDA capabilities positively influence both innovation quality and speed of the manufacturing industry. Our results suggest that BDA can significantly enhance the financial innovation market by fostering a more harmonious relationship between customer preferences and product characteristics. (Johnson et al., 2017). By integrating BDA into operational and strategic processes, banks can enhance their ability to offer personalized financial solutions tailored to the evolving needs of their customers. This capability enhances customer relationships and fosters long-term loyalty, a crucial aspect in the competitive financial sector. Moreover, BDA is vital in establishing FI policies and enhancing a bank’s dynamic capabilities, leading to performance enhancements influenced by new ideas and insights (Teece, 1997). Banks can enhance their financial innovation capabilities by sensing opportunities, seizing them, and reconfiguring resources dynamically. More specifically, BDA supports the creation of financial products and services through predictive analytics, aiding in identifying market demands and predicting risks. For example, banks are using advanced machine learning algorithms and real-time data analysis to create personalized loan schemes, risk-adjusted investment portfolios, and innovative payment

solutions. The innovations enhance financial performance and demonstrate how BDA enhances organizational agility, a vital aspect of the DCV.

Second, the study shows that BDA positively impacts financial performance, customer satisfaction, and marketing performance, signifying that banks analyzing large datasets enhance their performance. The study confirms previous research highlighting the significant role of BDA in modern business performance (Akter et al., 2016, Fosso Wamba and Mishra, 2017, Mikalef et al., 2020b, Suoniemi et al., 2020, Itani et al., 2024, Chatterjee et al., 2023, Olabode et al., 2022). The findings align with ST, which highlights valuing stakeholder interests and generating long-term value from a theoretical perspective. The use of BDA insights enables banks to enhance customer service, increase stakeholder engagement, and foster trust. Research indicates that companies using BDA improve customer satisfaction, stakeholder engagement, and marketing capabilities (Raguseo and Vitari., 2018, Erevelles et al., 2016, Suoniemi et al., 2020). Banks utilize BDA to identify opportunities, exploit them through targeted strategies, and reconfigure resources to maintain a competitive edge in dynamic markets supporting DCV. BDA enhances organizational agility and responsiveness by enabling the ability to anticipate customer preferences and adapt marketing strategies. The study underscores the strategic significance of BDA in decision-making and forecasting processes, ultimately leading to enhanced firm performance. Moreover, AT explains BDA's role in reducing information asymmetry, promoting transparency, aligning managerial actions with organizational goals, enhancing governance, and enhancing responsiveness and competitiveness. By addressing fragmented findings between BDA and firm performance and previous studies focused more on industries such as manufacturing, IT, and hospitality, our analysis bridges the gap in understanding the banking sector in the UK. The RBV highlights the strategic importance of BDA as a unique capability that offers firms a sustained competitive advantage through actionable insights and improved operational efficiency. Furthermore, the analysis is groundbreaking in linking BDA to banking-specific marketing performance, a topic with limited empirical research. By contributing to the understanding of how BDA transforms CS and marketing performance, this study enriches the literature and emphasizes the strategic importance for banks to integrate BDA into their operational and strategic frameworks.

Finally, the results show that FI positively affects financial performance, customer satisfaction, and marketing performance, indicating that FI enables companies to develop innovative products, streamline services, and enhance operational efficiencies, ultimately improving customer experiences and market competitiveness. The study confirms and expands on previous research indicating a positive correlation between FI and bank performance. For example, some scholars demonstrated the significant impact of FI on financial performance,

emphasizing its potential to drive profitability (Amore et al., 2013, Beck et al., 2016, Duygun et al., 2013, Le and Ngo, 2020a). Similarly, (Ameme and Wireko, 2016) and (YuSheng and Ibrahim, 2019) highlight the effectiveness of technological innovations in enhancing customer satisfaction and creating superior service experiences. Additionally, Zapata-Cantu et al. (2016) highlighted the significant role of FI in enhancing marketing performance through enhanced customer segmentation, personalized offerings, and innovative outreach strategies. Through FI, banks can enhance customer satisfaction by providing personalized and tailored solutions to meet evolving customer needs. By fostering such advancements, banks can not only retain existing customers but also attract new ones, thereby reinforcing customer loyalty and satisfaction. FI improves financial performance by optimizing resource allocation, reducing costs, and generating new revenue streams, thereby enhancing the profitability and sustainability of financial institutions. Moreover, FI enhances marketing performance by enabling firms to create targeted, data-driven strategies, improve customer engagement, and enhance their competitive market positioning. Innovative financial solutions enable banks to thrive in a globalized economy by addressing market demands, technological advancements, and customer expectations, ensuring long-term growth and stability. Overall, our study reveals that FI positively impacts bank performance, extending existing literature and providing the first exploration of FI's impact on customer satisfaction, and financial and market performance in the UK.

6.1. Theoretical implications

Theoretically, the research significantly contributes to the existing literature. First, BDA and firm performance literature cover various industries, enhancing overall performance. However, limited research explores BDA's impact on customer satisfaction and financial performance in banks, highlighting its potential for improved performance, but requires a suitable lens for rationale. However, most of the studies of BDA's impact on firms' performance focused on manufacturing, SMEs, information technology, and construction, with limited focus on the banking sector (Park et al., 2019, Chatterjee et al., 2023, Jain et al., 2024, Morimura and Sakagawa, 2023, Chatterjee et al, 2023). We highlight the significance of BDA in enhancing banks' performance. Hence, we shed insight on the underlying mechanisms in which BDA enhances banking performance through customer satisfaction and the financial and marketing performance of United Kingdom banking institutions.

Second, literature on the impact of FI on bank performance has yielded mixed results (Chen and Peng, 2020, Nejad, 2022, Manasseh et al., 2024, Corbet et al., 2023, Zhao et al., 2022). Owing to mixed results found in the literature, more investigations are needed (even within the context of a developed economy). Moreover, studies on FI reveal that research on banking

institutions is skewed towards developing and emerging countries creating a research gap yet to be filled in the context of developed countries (Corbet et al., 2023, Phan et al., 2020, Zouari-Hadiji, 2023, Nyamekye et al., 2023). However, limited studies exist on the relationships between FI and bank performance in developed countries, especially the United Kingdom. This suggests an important call to increase scholarship on financial innovation in developed countries. Therefore, we highlight the significant positive impact of FI on the bank performance of UK banking institutions, filling observed gaps in the existing literature.

Third, the study reveals that both BDA and FI can significantly improve customer satisfaction, financial performance, and marketing performance in banks. Consequently, BDA and FI are vital for banks' CS, and financial and marketing performance, as they require advanced data-driven insights, innovative product development, and strategic adaptability to market demands. FI and BDA enable banks to create customized financial products, streamline operations, and accurately anticipate customer needs. However, literature remains scanty on the effects of BDA and FI on CS, and the financial and marketing performance of banking institutions. Therefore, we improve the understanding that adopting BDA and promoting FI can transform banks' strategic capabilities and operational efficiencies, thereby enhancing customer satisfaction, financial outcomes, and marketing performance. Notably, our study is the first to investigate the influence of BDA and FI on CS, financial outcomes, and marketing performance of banks in developed markets, particularly the UK. Finally, we contribute to the enhancement of RBV, DCV, DIT, AT, and ST in the finance and banking literature by demonstrating the roles of BDA and FI in improving banks' customer satisfaction, and financial and marketing performance. The RBV posits that organizations gain competitive advantages by leveraging unique, valuable, and inimitable resources. Our findings reveal that BDA and FI are strategic assets that enhance service delivery, operational efficiency, and customer satisfaction, promoting adaptability and long-term growth. Moreover, our findings support the DCV, stating that BDA and FI enable banks to identify market opportunities and adjust their internal resources to meet evolving market demands. Banks can effectively navigate the complexities of modern financial environments, delivering innovative, customer-focused solutions due to these capabilities. From DIT insights, the study highlights the role of BDA and FI in creating innovative solutions that challenge traditional banking paradigms, enabling personalized financial products and streamlined processes. We further extend AT suggesting that transparency and alignment of managerial decisions with organizational goals, while FI enhances trust and accountability by promoting strategic alignment between shareholder interests and operational objectives. Finally, our findings align with ST, revealing that BDA and FI enhance stakeholder engagement, resulting in enhanced customer satisfaction, loyalty, and long-term organizational sustainability, fostering relationships with customers, investors, and

regulators. The study enhances the application of these theoretical frameworks in the banking sector, demonstrating how BDA and FI can foster innovation, adaptability, and sustainable growth. By linking these theories to our findings, we enhance the literature on financial innovation and big data transformation in the banking sector.

6.2. Managerial and Policy Implications

We highlight valuable practical implications along with interesting theoretical implications. First, managers need to comprehend the significant impact of BDA capability on banking operations, thereby aiding in the identification of performance opportunities. For example, BDA has demonstrated its potential by enabling firms to monitor market dynamics, identify customer opportunities, and support the development of financial services and products. Second, the study highlights the pivotal role of FI capability in driving banks' FP, CS, and MP. Managers should acknowledge that investing in innovative financial products and services is not just a strategic decision but a necessity for gaining a sustained competitive advantage. Banks can enhance customer satisfaction and market positioning by fostering an innovative culture and allocating resources to research and develop personalized financial solutions. Moreover, the study indicates that FI enhances operational efficiency, improves customer engagement, and facilitates data-driven decision-making. To maximize the benefits of FI, banking institutions should prioritize integrating technological advancements and cross-functional collaboration. Managers are encouraged to utilize agile frameworks for continuous product and service iteration, ensuring alignment with market demands and customer expectations. Finally, considering that BDA and FI serve as powerful levers to enhance banks' performance, bank top management must adopt a holistic perspective that extends beyond mere cost efficiency. Managers can enhance operations, value creation, customer engagement, and market competitiveness by fostering a culture of financial innovation within banking institutions. This involves creating a culture that promotes creativity, experimentation, and the integration of innovative technologies into business operations. Management should prioritize financial innovation and big data applications over cost efficiency to achieve long-term growth, customer loyalty, and a sustainable competitive advantage.

Besides, we provide two vital implications to policymakers. (1) Policymakers should prioritize creating tailored financing policies to improve customer satisfaction, financial performance, and marketing performance. Policies should be tailored to meet the evolving needs of the banking sector and foster a conducive environment for innovation-driven growth. (2) Policymakers should provide comprehensive support to banking institutions to effectively manage and optimize their performance. The initiative promotes investment in the dynamic

capabilities of BDA and FI. Banks can improve customer satisfaction, financial performance, and marketing by investing in critical capabilities to navigate competitive environments and adapt to market demands.

6.3. Limitations and future research agenda.

We present four main limitations for further investigation. First, we utilize cross-sectional data from banking institutions, allowing for the potential expansion of the investigation to include a larger sample using the analytical model. Second, we used the RBV, DCV, stakeholders, agency theories, and DIT to support our hypotheses and conceptual model. Further studies can expand our research using more models for estimating big data analytics, FI, and bank performance. Third, the findings may have been influenced by a sample from emerging nations, as we examined our research from a developed country. Finally, the study focuses on the direct relationships between BDA, FI and banks performance. Competition and government regulations are significant factors influencing financial innovations developments and technological innovations. Therefore, we are calling for further research to investigate the mediating effects of competition and government regulations on the effect of FI on banks' performance.

7. Conclusion

The study investigated the impact of big data applications and FI on UK bank's performance. We employ multi-theoretical frameworks like DCV, RBV, DIT, AT, and ST to analyze the impact of BDA and FI on banks' customer satisfaction and financial performance. The proposed links were empirically validated using data from 150 banking institutions in the UK, with the results analyzed with multiple hierarchical regression modeling. The findings demonstrated that BDA has a positive effect on FI, suggesting that, BDA supports FI developments of banks. Moreover, BDA positively increases banks' customer satisfaction and financial and market performance. Finally, the study showed that FI has a positive impact on customer satisfaction, financial performance, and market performance. The study strongly supports that BDA and financial innovation are instrumental in enhancing customer satisfaction, financial performance, and market performance in banks. Overall, we highlight the vital role of BDA in enhancing financial performance, customer satisfaction, and market performance in banking institutions.

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