Does fintech innovation improve the efficiency of Jordanian banking system

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Abstract

The digital transformation in financial services industry has stimulated most banks to include technologically enabled techniques in their banking operations in an attempt to improve their efficiencies. Therefore, the term "fintech" has garnered a significant attention in both practice and academia, especially since the 2008–9 Financial Crisis. However, due to the shortcomings in available literature regarding the role of digital transformation in the efficiency of Jordanian banking sector, this research purpose is to investigate whether the adoption of financial technology influences the efficiency of Jordanian listed banks during the period 2015-2024. For this causal research, the study employed the Fixed effect and Random effect approaches to analyze a panel data set form the listed banks that implemented emerging technologies. The findings indicate that fintech investment (INR and ING) considerably improves bank efficiency, whereas bank age moderates this effect negatively due to slow technology adoption. Established banks, on the other hand, continue to be more efficient in general, owing to their expertise and reputation. It is concluded that the bank fintech negates bank efficiency as well as the investments of banks in technological innovation are confirmed to be ineffective.

Keywords: Banks efficiency, DEA, Emerging technologies, Fintech innovation, Fintech startups, SFA.

1. Introduction

Fintech is a relatively new idea that has gained the interest of many researchers conducting research on it in recent years. Various definitions of fintech have been put forth, indicating a range of perspectives and methods for comprehending

this area of study. According to research on the development of fintech by Alt, et al. [1] fintech and technological innovation in the finance sector are closely related, demonstrating how the sector is utilizing technology to enhance performance. As a result, the fintech sector came into being. According to opinions on fintech presented by Alt and Puschmann [2]; Breidbach, et al. [3] and Thakor [4] there are two ways to understand it. First, fintech describes how financial institutions are utilizing innovative technology. Second, the term "fintech" describes non-intermediate businesses that use technological innovation to provide sophisticated financial products in an effort to improve customer satisfaction and the efficiency of the banking system [5, 6]. In our paper, we focused on the first perspective, which examines the fundamental elements and background of fintech development [7]. Commercial banks are at the frontline of the adoption of technological innovation, with fintech being developed and formulated within financial institutions. Our study uses the term "bank fintech," which is similar to the terms used by Cheng and Qu [8] and Li, et al. [9] to describe fintech in banks. Past quantitative research has demonstrated that bank fintech variable measurements vary. For example, utilizing a text mining technique, they created the bank fintech index to measure the technological innovation of Chinese commercial banks. According to Singh, et al. [10] the bank fintech variable is a set of dummy variables that are linked to the emerging technologies that commercial banks are implementing, such as blockchain, artificial intelligence, robotic process automation, cloud computing, and payment technology. For the purpose of creating the bank fintech index, Li, et al. [9] acquired the fintech innovation news from every commercial bank. These studies demonstrated the relationship between emerging technologies and bank fintech measurement, which is linked to bank investment in technological innovation. Based on the financial statement, it can be approximated by hardware, software, and other pertinent information technologies [11].

According to our knowledge, the publications that are currently available appear to have overlooked the bank fintech measurement protocol that links to the financial statement. We therefore regarded it as a research gap. Studies including Ho and Mallick [12] and Bhatia and Aggarwal [13] claimed that intangible assets on financial statements have been utilized as a proxy to measure bank fintech variable. After the financial crises of 2008, like every other country Jordan is also focusing on innovation. Furthermore, Ali [14] found that while Jordanian investors were risk-takers prior to the crisis, they turned more rationale during that time. Sixty-eight percent of financial institutions in the Jordanian market are fully investing their budgets and resources to transform to a digital economy. While non-bank institutions have invested the majority of their members in this process, banks have committed the largest portion of their budget to digitalization. According to Ismail, et al. [15] in Jordan, thirty percent of financial institutions believe that there is sufficient technology available for the local market to become digital, twenty-six percent believe that the technology available is insufficient, and forty-four percent of financial institutions in Jordan have no opinion about the services provided by technology firms. They came to the conclusion that the fintech companies' services would improve with greater cooperation between the financial and technology sectors. Fintech industry transformation has become deeply embedded in the financial sector. In Jordan, as in many other nations, fintech is expanding. Fintech startups and digital banking are growing daily. According to an analysis of Bank's 2015 and 2024 annual reports many commercial banks have been using emerging technologies to restructure and improve their performance and competitiveness.

This suggests that by providing their customers with innovative financial products, these banks are prepared to take on fintech firms. Banks now have the chance to provide their customer and themselves with innovative products and advantages. Artificial intelligence (AI) and machine learning are examples of advanced technologies that are increasingly being used to handle customer requirements. This helps banks save money on operations while also saving time for customers. Additionally, banks can increase the range of banking services and products they offer and open up new market niches by utilizing electronic banking accounts. Due to the fintech's significant impact on the banking sector, billions of dollars are anticipated to be invested in this field over the next several years in order to meet consumers' growing needs. However, a number of studies highlighted a problem that was stated in the following way:

1.1. People In Jordan Are Not Very Knowledgeable About Fintech, So for Jordanian Banks to Compete in the Global Market, They Need to Understand How Fintech Adoption Can Impact Their Efficiency
As a result, the following research question has arisen:
Q: Does fintech Innovation effects the efficiency of Jordanian listed Banks?

Accordingly, on the basis of the above-mentioned question, the primary objective of this empirical study is *to examine the impact of fintech adoption in the efficiency of Jordanian banks, which are listed in Amman Stock Exchange.*

The two primary approaches to measuring efficiency are parametric and nonparametric. Stochastic frontier analysis (SFA) usually embodies the parametric approach, whereas data envelope analysis (DEA) represents the nonparametric approach. There is a current scholarly discussion regarding the most effective way to measure the efficiency of DEA vs SFA. SFA and DEA have both been used by numerous publications to evaluate bank efficiency. For example, Beccalli [16]; Doan, et al. [17] and Luo, et al. [18] and others have used SFA, while Owusu Kwateng, et al. [19] and Paradi and Zhu [20] have used DEA. Essential conditions for the SFA method are appropriate functional form and factors. Since there aren't many studies on what influences Jordanian bank efficiency, the SFA method's proxies for assessing efficiency aren't very good. Since its original proposal by Charnes, et al. [21]. DEA has gained recognition and been used extensively in a variety of academic and practical contexts. To calculate the efficiency, mathematical programming is used in it. According to Staub, et al. [22]. DEA is the most widely used technique and is simple to use when handling multiple factors. As a result, we measured Jordan's bank efficiency using the DEA methodology. Our study sheds light on the impact of fintech on bank efficiency in Jordan, a developing nation where banks are making significant investments to keep up with the industry's rapid growth.

The structure of the paper is as follows. We provide a thorough literature review in Section 2. In Section 3, the variables, data, and suggested methodology are defined. Results are explained in Section 4 along with a discussion of the analysis. Section 5 concludes with research findings, recommendations for the future, and future directions.

2. The Review of Literature

2.1. The Role of Fintech innovation in Banking Activities

The term "bank fintech," as previously stated, describes the technological innovation and digitization of the banking industry. Banks are under pressure to change and stay competitive in light of the rise of fintech startups, so they are investing in technology and working with fintech firms. Technology has had a significant impact on the financial industry, but fintech has far-reaching effects beyond the financial industry. Traditional financial firms are facing challenges from emerging fintech companies. Due to differences in fintech regulations and technology, many shadow banks have expanded and prospered [23]. The majority of researchers have only looked at fintech's impact on the financial sector. According to Fuster, et al. [24] fintech accelerated the processing of loan applications by roughly 20% as opposed to increasing the default rate. Fintech-enabled loan lenders can also collect market data, better manage demand shocks, and lessen financing barriers for companies. According to Haddad and Hornuf [25] many well-known companies have incorporated fintech start-ups and/or their products and services into their own business models, indicating that they believe these businesses are superior.

Research has shown that the goal of bank technology innovation is to enhance bank performance through the integration of emerging technologies like blockchain, cloud computing, and artificial intelligence (AI) into bank operations [5, 8]. Discovered that the implementation of emerging technologies by banks resulted in enhanced customer satisfaction and operational efficiency. He proposed that bank fintech could lower risk-taking by enhancing control and operational effectiveness. Furthermore, bank fintech was found to be a significant factor in lowering credit risk and enhancing bank performance by Cheng and Qu [8]. Research on the history of fintech [1, 4, 26] has confirmed that banks have prioritized technological innovation in order to address a variety of operational issues and offer customers the best banking experience possible. In order to fully reap the benefits of AI, Sami Ali, et al. [27] emphasized the necessity for financial institutions to make investments in the technology and create a strategic plan for its application. According to the study, artificial intelligence, block chain, and robo advisor technologies are all assisting Jordan's banking system in going digital.

According to Fang, et al. [28] big data and machine learning facilitate easier financial access for businesses while lowering risk. Fintech, a technological advancement in the financial sector, is a tool used by new businesses to take on established ones. Scholars have examined the effects of fintech outside of the financial industry. The impact of fintech on internationalization was studied by Puthusserry, et al. [29] while Zhang, et al. [30] examined its effects on urbanization, and Berman, et al. [31] examined its relationship with innovation and niche technologies. Chen, et al. [32] determined the relevant efficiency scores for Chinese banks with different ownership structures using a stochastic Meta frontier approach. The results show that state-owned commercial banks have the lowest cost efficiency and employ inferior technology. In assessing the influence of fintech advancements, it is crucial to acknowledge that fintech breakthroughs enhance banks' operational efficiency while simultaneously advancing the technology they utilize.

Liao [33] used both parametric and non-parametric analysis to examine the impact of fintech on Taiwanese banks' efficiency. He discovered that fintech increases bank productivity. Neobank LINC is a new digital bank that Cairo Amman Bank built in 2022. Numerous banks have begun collaborating with fintech firms. For example, Arab Bank established two partnerships: AB iHub and AB Accelerator. These results lead to the conclusion that improving bank performance is the goal of technological innovation in banks. The Financial Stability Board claims that technological innovation in banks has a big impact on them in a lot of ways, like enhancing operations, growing efficiency, and opening up new business models. A bank's ability to compete in the banking industry is increased when it takes the lead in technological innovation. Banks can improve productivity, lower operating costs, and strengthen their management skills by investing in technological innovation [34]. Numerous academics have discovered that digital innovation improves bank performance and liquidity [35]. Research has demonstrated that technological innovation in banks can expedite customer digitalization via online banking and improve bank performance through lower operating costs, better customer service management, and more efficient processes [36]. According to Appiahene, et al. [37] bank technology innovation is a vital weapon for competing in the finance sector. Planning and credit risk management software technological innovation has been found to positively influence organizational systems and bank competencies while negatively correlated with leverage, leading to increased bank profitability in 17 European countries Campanella, et al. [38].

Ali, et al. [39] found that AI-based systems play a crucial role in enhancing effective risk management, creating convenience, reducing costs, and improving clients' trust towards banking services. They examined the Jordanian banking system using primary data, incorporating banking employees and clients. Furthermore, they suggested that in order for the banking sectors in developing nations like Jordan to contribute more positively to their economies, they should embrace and integrate AI-based systems into their banking operations and services. Disruptive technologies enhance bank performance and financial stability in the EU28, according to Del Gaudio, et al. [40]. Additionally, technology innovation modifies conventional business models, enhances efficiency in the finance sector, and offers consumers the best possible banking transaction experience [41, 42].

Furthermore, bank technology innovation lowers credit risk, which promotes better bank performance, according to Cheng and Qu [8]. Disruptive technologies are used by banks to gather information and create credit scores. New technologies help banks manage their credit risk and become more diversified, which boosts bank profits. Innovation in bank technology enhances internal process management and business model performance [43]. According to Campanella,

et al. [38] banks can use bank fintech to grow their business models and improve overall performance. According to Dorfleitner, et al. [44] technological innovation aids banks in gathering and evaluating consumer data on transaction history and demographics, increasing bank efficacy and reducing expenses. As previously stated, it is evident from reviewing the annual reports of the majority of Jordanian banks that the primary objective of bank technology innovation embodied in the bank fintech concept—is performance enhancement, with an emphasis on efficiency. Thus, the current study postulates that technological innovation, as represented by bank fintech, will have a significant impact in banks' efficiency. Therefore, the following principal hypothesis is formulated:

H_1: *The Fintech adoption is significantly impacting the efficiency of Jordanian listed bank.*

3. Methodology

3.1. Research Design

In this study, we examined the impact of fintech adoption on the efficiency of Jordan's listed banks. Thus, it is causal research. Jordanian banks that are listed on the Amman Stock Exchange are used as the study's sample for this reason. We have decided to examine the period from 2015 to 2024.

3.2. Model Specification

In order to investigate the impact of fintech adoption on the efficiency of Jordanian Listed Bank, we have chosen the panel model and applied the methodology of Pham, et al. [5] & Beccalli [16]. The estimation is done using the model that follows:

$$BEF_{it} = \propto + \beta fintechAD_{it} + \gamma BChar_{it} + \mu_i + \delta_{it} \qquad (1)$$

Where, the term BEF_{it} refers to bank efficiency, $\beta fintechAD_{it}$ relates to fintech adoption, and the $BChar_{it}$ stands for the characteristics variables of bank in time $_t$. However, the $\propto$ symbol is the constant, β and γ are the coefficient of independent variables, μ_i is the unobservable effect specific to each individual, and the δ_{it} represents the remainder disturbance.

3.3. Variables Definitions and Measurements

3.3.1. Dependent Variable: Bank efficiency (BEF)

The bank efficiency in this research is determined using the DEA approach. Since its first introduction by Charnes, et al. [21]. DEA has gained popularity as a technique in both academic and practical areas. DEA leads to a decision-making unit's (DMU) increased efficiency.

$$h_j = \frac{\sum_{r=1}^{s} u_{rj} y_{rj}}{\sum_{i=1}^{m} v_{ij} x_{ij}} \qquad (2)$$

Subject to u_r & $v_i \geq 0$, Max $h_j \leq 1$, j = 1… n; r = 1… s; i = 1, …, m

y_j & x_j = output and input of the j-th DMU.

u_r = weight of the r-th output

v_i = weight of the i-th input.

h_j = efficiency score of the j-th DMU.

A DMU is efficient if h_j = 1, and if less than 1, it is inefficient. Other methods need certain assumptions in order to calculate efficiency values; DEA does not. Given that all input and output weights are equal, there isn't a particular DEA model. However, if there are a lot of important input variables in the measurement, the efficiency value could be skewed and high. As a result, in order to reduce the risk involved with the DEA method, the number of inputs should be restricted Contreras [45] and [46]. There has been debate over which inputs and outputs should be chosen when measuring bank efficiency variables in the finance sector using the DEA [47]. For example, Henriques, et al. [48] used total loans as the output and three components for input variables: fixed assets, total deposits, and personnel expenses. Total assets and deposits were the inputs used by Tamatam, et al. [49] and the outputs were interest income, total income, and operating profit.

Eyceyurt Batir, et al. [50] computed the efficiency of two types of banks i.e. participation banks and conventional banks in Turkey using loans, off-balance sheet items, labor, capital, and funds. While Zhu, et al. [51] measured bank efficiency in Pakistan using interest, non-interest expense, interest income, and non-interest income, Kamarudin, et al. [52] assessed the efficiency of Malaysian banks using the value of their deposits, loans, and incomes. Our study's calculation of the bank efficiency variable followed the pure DEA model of Charnes, et al. [21] and Seiford and Zhu [53] with labor and capital serving as inputs and revenue as the output.

3.3.2. Independent Variables

The independent variables of this research are including the following:

3.4. Fintech

Numerous approaches to evaluating bank fintech—bank technology innovation—have been put forth in earlier research studies. Pierri and Timmer [54] used the percentage of personal computers per employee and the IT budget to assess the adoption of technology by banks in the United States. Pham, et al. [5] employed intangible assets as a proxy for the variable of bank technology innovation in Pakistan and Vietnam. Firm technology innovation was measured by Bagna, et al. [55] and Chen, et al. [32] using accounting figures on financial statements related to intangible assets. According to

Demmou, et al. [56] intangible assets are crucial to a company's performance. In India, Widnyana, et al. [57] discovered a strong correlation between firm technology innovation and firm performance, as evidenced by the substantial impact of intangible assets on firm performance.

As a result, one important aspect of the fintech sector is that intangible bank assets can be used as proxy for bank fintech measurement. Additionally, Reilly [58] and Gumbau-Albert and Maudos [11] contend that technological innovation in the areas of software, hardware, and patents is a key component that significantly influences banks' intangible assets. For this reason, it is very valuable to measure the bank fintech variable with intangible assets. Thus, taking into account the aforementioned arguments, we used the intangible assets listed on financial statements to calculate the bank fintech variable in our study. Specifically, we looked at the growth rate of intangible assets (ING) and the ratio of intangible assets to fixed assets (INR).

3.5. Bank Characteristic Variables

Two important aspects of bank operations are reputation and experience, which are reflected in the age of the bank [59, 60]. People are generally more comfortable doing business with older banks than with those that are more recent. It is anticipated that bank age will have a positive impact on efficiency because this benefit enhances bank competitiveness and lowers operating costs. We used the methodology of Pham, et al. [5] and Chiu and Chen [59] in our research. The logarithm of the years from the initial launch to time t is used to determine bank age.

3.6. Data Collection

As per the 2019 Cisco Global Digital Readiness Index, the majority of Jordanian banks have focused more on utilizing emerging technologies to enhance their operational efficiency. Nine banks—Jordan Islamic Bank, Jordan Kuwait Bank, The Housing Bank for Trade and Finance, Arab Jordan Investment Bank, Cairo Amman Bank, Safwa Islamic Bank, Arab Bank, Jordan Ahli Bank, and Bank of Jordan—were essentially utilizing emerging technologies to restructure and improve performance and competitiveness, according to a review of the bank's annual reports for the thirteen listed banks on the Amman stock exchange for the years 2015-2024. And it is greatly appreciated that three of them—the Arab Bank, Jordan Ahli Bank, and Bank of Jordan—meet the criteria of the definition of a bank fintech. Bank-level data were taken from the annual reports and audited financial statements of three listed banks from 2015 to 2024, based on the data collection capabilities and data available. These documents are provided by the Amman Stock Exchange.

3.7. Data Analysis

In accordance with Wooldridge [61] we use a variety of techniques, including fixed-effect (FE), and random effect (RE) approaches, to estimate the impact of bank fintech on bank efficiency based on the panel data of three banks from 2015 to 2024. Among the dependent and independent variables within a bank, FE is interested in examining the effects of variables that change over time. There are features unique to each bank that may or may not affect the predictor variable. Analyzing how variations among entities affect the dependent variable is of interest to RE. Since RE makes the assumption that the entity's error term does not correlate with the predictors, time-invariant variables are permitted to function as explanatory variables.

4. Findings Discussion

4.1. Descriptive Statistics and correlation

Table 1 displays the results of the descriptive statistics. Each variable has thirty observations for the three listed banks that have fully embraced fintech.

Table 1.
Descriptive statistics.

Variables	Symbols	Obs.	Mean	Sts. Dev.	Minimum	Maximum
Bank	BEF	30	0.5489	0.1893	0.0121	1
Fintech	INR	30	0.4886	0.1879	0.0214	0.9945
	ING	30	0.2879	1.0057	-0.9954	11.5231
Char. Var.	AGE	30	3.9273	0.5273	1.0836	5.1120
	Age (years)	30	63.6700	5.5638	52	82

With a BEF_{mean} is 0.5489 the bank is slightly above average in terms of efficiency. It indicates that the efficiency of Jordan's banks is mediocre. There is a significant difference between the highest and lowest efficiency, as shown by $BEF_{max} = 1$ and $BEF_{min} = 0.0121$, In light of our findings, the bank's operational scale and strategy may provide an explanation. Large banks, like BOJ, still primarily rely on interest income, but small banks place more of an emphasis on investing in technological innovation to improve bank performance, particularly with regard to service income from unconventional products. Rather than investing in technology innovation to increase income from services, large banks typically expand their credit scales to increase revenue. In addition, market power and bank competition within the Jordanian banking sector may account for the notable variations in bank efficiency. INR and ING stand for the bank fintech variable. Between intangible and tangible assets, there is an equal capital allocation, with the average INR being close to 50% ($INR_{mean} = 0.4886$). We can conclude that the bank's interest in financial innovations and technologies is a positive

indication. Nonetheless, a significant disparity exists between INR_{max}= 0.9945 and INR_{min}= 0.0214, suggesting that one bank devotes a greater portion of its capital to technological innovation investments, while another bank does not.

ING is approximately 27.96% on average annually (ING_{mean} = 0.2879). These findings suggest that bank managers' perceptions of the importance of technological innovation may be shifting. With an average age of 64 (AGE_{mean}= 63.670), the majority of banks have relevant experience in the banking sector. In 2015, BOJ was the youngest at 62 (Age_{min}= 52). The newest bank in the sample, BOJ, was founded in 1960. At 82 years old, Arab Bank is the oldest bank (Age_{max}= 82).

Table 2.
Correlation test.

Variables	BEF	INR	ING	AGE
BEF	1.0000			
INR	-0.1892	1.0000		
ING	-0.0621	0.0799	1.0000	
AGE	0.4225	0.1522	0.0799	1.0000

The results in Table 2 displays that there is a negative correlation between bank fintech variables (INR and ING) and bank efficiency (BEF), with $r_{INR-BEF}$= -0.1892 and $r_{ING-BEF}$= -0.0621. This suggests that as banks increase their use of innovative technology, their efficiency declines. Mature banks are more efficient than young banks, according to the positive correlation values ($r_{AGE-BEF}$= 0.4225), between bank characteristics and efficiency.

4.2. Model Estimations

In order to gain insight into the relationship between bank efficiency and fintech, the proposed model is modified in accordance with the findings of the correlation test and descriptive statistics. Below are four modified models that have particular variables.

First, the effect of bank characteristics (AGE) on the bank efficiency is estimated in the following model 1:
$$BEF_{it} = \propto + \gamma AGE_{it} + \mu_i + \delta_{it} \qquad (3)$$
Second, the bank fintech variables are added in the following model 2:
$$BEF_{it} = \propto + \beta_1 INR_{it} + \beta_2 ING_{it} + \gamma AGE_{it} + \mu_i + \delta_{it} \qquad (4)$$
Third, there is also an addition to the interaction between bank characteristics and bank fintech variables, in the following model 3 and model 4 respectively.
$$BEF_{it} = \propto + \beta_1 INR_{it} + \beta_2 ING_{it} + \gamma AGE_{it} + \theta_1 INR_{it} \times AGE_{it} + \mu_i + \delta_{it} \qquad (5)$$
$$BEF_{it} = \propto + \beta_1 INR_{it} + \beta_2 ING_{it} + \gamma AGE_{it} + \theta_2 ING_{it} \times AGE_{it} + \mu_i + \delta_{it} \qquad (6)$$
While the statistical values of θ are used to identify the influence of bank characteristics on the bank fintech and bank efficiency's relationship, the statistical values of β show how bank fintech affects bank efficiency.

Table 3.
Estimation Results by FE and RE.

Variables	Model 1		Model 2	
	FE	RE	FE	RE
Constant	-2.1538***	-1.7725***	-2.1629***	-1.7638***
	(-10.68)	(-10.10)	(-10.79)	(-10.01)
INR	-	-	0.0887	0.0409
			(1.50)	(0.81)
ING	-	-	-0.0001	0.0002
			(-0.01)	(0.02)
AGE	0.1252**	0.0572	0.1276*	0.0477
	(1.89)	(1.21)	(1.98)	(1.07)
INR*AGE	-	-	-	-
Observations	30	30	30	30
R-sqr	0.5488	0.5451	0.5526	0.5980
Statistical Value	60.98***	243.71***	40.97***	242.11***
Hausman test	16.89***	-	32.69***	-
Wald test	178.55***	-	172.49***	-
Wooldridge test	42.528***	-	43.158***	-
	Model 3		Model 4	
Variables	FE	RE	FE	RE
Constant	-2.9479***	-2.5243***	-2.2197***	-1.8044***
	(-11.35)	(10.41)	(-11.02)	(-10.14)
INR	2.1753***	2.0623***	0.1184*	0.0544
	(4.55)	(4.61)	(1.68)	(1.05)
ING	-0.0036	-0.0041	0.2145**	0.2064**
	(-0.64)	(-0.60)	(2.03)	(2.06)

AGE	0.3748***	0.2937***	0.1615**	0.065824
	(4.60)	(4.12)	(2.29)	(1.55)
INR*AGE	-0.6787***	-0.6495***	-0.0742**	-0.0721**
	(-4.48)	(-4.22)	(-2.21)	(-2.07)
Observations	30	30	30	30
R-sqr	0.5256	0.5766	0.5521	0.5544
Statistical Value	42.10***	284.01***	38.11***	252.11***
Hausman test	31.44**	-	32.09***	-
Wald test	203.98***	-	164.92***	-
Wooldridge test	49.896***	-	55.057***	-

Note: *, **, and *** are significant levels at 10%, 5%, and 1%, respectively.

The findings in Table 3 show that every statistical value row indicates that the model is at a significance level of 1%, meaning that the variation in bank efficiency can be explained by at least one independent variable in the model. Additionally, the R-square rows of the FE and RE columns demonstrate that the model's independent variables account for approximately 54%–59% of the variation in bank efficiency ($R-sqr_{min}$= 0.5526 and $R-sqr_{max}$= 0.5980), other variables not included in the model account for the remaining variation. According to the authors, these R-squares are very valuable for assessing how bank fintech affects bank efficiency. It was found that the AGE variable's coefficients were positive at the 10%–1% significance level. This suggests that established banks are more efficient than newly established ones. Studies like [59, 60, 62] affirm the benefits of experience and reputation in the banking sector, which can be used to explain this observation. we suggest that a key factor in increasing bank efficiency is the ease with which well-known, long-standing banks are able to win over consumers' trust.

While other models incorporate bank fintech variables, Model 1 does not take into account how bank fintech affects bank efficiency. There is inconsistency in the estimation results of the effect on BEF between models. While the remaining models are not significant, the coefficients of INR in models 3 and a part of model 4 exhibit significant positive results at levels of 1%–10%. The estimation findings of other models show that the null hypothesis—that there is no meaningful relationship between ING and BEF—cannot be rejected, with the exception of the ING coefficients in model 4, which are only significant at a 5% level. It is clear from the substantial positive correlation between INR, ING, and BEF that the productivity paradox does not exist in the sample. In particular, this result lends credence to the idea that higher bank innovation spending can boost efficiency. The P-value and the coefficients of INR*AGE and ING*AGE demonstrate the influence of bank characteristics on the relationship between bank fintech and bank efficiency. According to the estimation, bank age is negatively affecting the relationship between bank fintech and bank efficiency. In particular, the slow adoption of technological innovations by banks may account for the detrimental significance levels of 1% and 5% for the coefficients of INR*AGE and ING*AGE, respectively. It could have anything to do with human resources at banks. Based on our observations, employees at mature (older) banks are not young and have a difficult time adopting new bank technology because of their lengthy history. Heteroscedasticity and autocorrelation problems could be present in the model estimation results produced by FE and RE. The Hausman test, with values of 16.89, 32.69, 31.44, and 32.09 for models 1, 2, 3, and 4, respectively, demonstrates that the null hypothesis of the preferred estimation result by RE is rejected at a significant level of 1%. This shows that rather than using RE's estimation results, FE's are more appropriate to explain how bank fintech affects bank efficiency.

If the FE estimation is more appropriate than the RE estimation, the modified Wald and Wooldridge tests will be used to test for heteroskedasticity and autocorrelation problems. These tests will specifically be conducted on models 1, 2, 3, and 4. The null hypothesis of homoskedasticity is rejected because the Wald test row shows that models 1, 2, 3, and 4 have heteroskedasticity issues, with statistical values of 178.55, 172.49, 203.98, and 164.92, respectively. Thus, at the 1% significance level, it can be said that all estimation results of the four models by FE or RE exhibit heteroskedasticity. Based on the statistical values of the Wooldridge test row, which are 42.528, 43.158, 49.896, and 55.057 for models 1, 2, 3, and 4, respectively, the null hypothesis that no serial correlation exists in the four models is rejected. This data suggests that, at the 1% significance level, autocorrelation problems are present in the models.

5. Conclusion

In both practice and academia, the term "fintech" has garnered significant attention since the 2008–2009 Global Financial Crisis. The term "fintech" describes the use of emerging technologies to improve financial products and boost providers' market-share performance. The adoption of advanced technology by established financial institutions (referred to as "bank fintech") and non-intermediation companies are two ways to conceptualize the fintech idea. Most banks in Jordan, a developing nation, have recently placed an increased emphasis on innovative banking technology to increase their efficiency. This study focuses on the fintech bank perspective and looks at how it affects Jordanian banks' efficiency. We created a panel model for estimation based on our ability to collect data and a review of the literature in order to carry out our research. And used FE and RE techniques to analyze panel data from three banks that implemented emerging technologies between 2015 and 2024 in order to find empirical Evidence of the impact of bank fintech on bank efficiency. While our study yielded a mixed result, most of them confirm the idea that bank fintech negatively affect the bank efficiency, indicating that bank investments in technological innovation are ineffective. Chen, et al. [32] also found the similar results. Low levels of financial literacy and the slow adoption of new technologies by banks and their customers are

two possible reasons of this. Banks should actively invest in fintech to increase efficiency, while more traditional institutions need to priorities digital transformation and employee's competitive adaption.

5.1. Limitations and Suggestion for Future Research

Scientific research procedures have limitations and by their very nature imperfect. Recognizing these limitations can help direct future investigations and stop readers from exaggerating or undervaluing the results in relation to the study's overall context. The DEA method was employed in this study to evaluate Jordanian bank efficiency. Although this method is highly valued, other techniques, like stochastic and non-stochastic frontier analyses, have also been demonstrated to be effective in assessing the efficiency of a firm [63]. In order to improve our comprehension of the connection between bank fintech and bank efficiency in the Jordanian context, it is advised that future research take into account these additional techniques for evaluating bank efficiency. Additionally, the bank fintech variables in this study were computed using financial measurements. But there are other important ways to measure bank technology innovation as well, like non-financial measurements and text mining techniques. Cheng and Qu [8] for instance, created the bank fintech index by applying a text mining technique, illustrating how Chinese commercial banks are utilizing technological innovation. The volume of transactions through digital banking channels, the number of employees working in science and technology, or surveys can be used as proxies for nonfinancial measurements [64]. Future researchers are advised to take these extra methods into account in order to present a comprehensive picture of how bank fintech affects bank performance.

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