

Luo, Heng; Kamarudin, Fakarudin; Nor, Normaziah Mohd

Article

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*Corresponding author: Heng Luo,
School of Business & Economics,
Universiti Putra Malaysia, Serdang,
Malaysia
E-mail: barryluoheng@foxmail.com

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David McMillan, University of Stirling,
UK

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BANKING & FINANCE | RESEARCH ARTICLE

ICT and the dual banking efficiency nexus: A cross-country analysis with country governance moderation in GCC countries

Heng Luo^{1*}, Fakarudin Kamarudin¹ and Normaziah Mohd Nor¹

Abstract: Our study investigates the influence of information and communication technology (ICT) applications at the national level on the efficiency of Islamic banks (IBs) and conventional banks (CBs) operating in Gulf Cooperation Council (GCC) countries. We analyze data collected from both CBs and IBs in GCC countries over the period spanning from 2006 to 2021. Specifically, ICT in this context refers to the extent to which ICT is applied on a national scale, encompassing activities both within and outside the banking sector. In our basic regression, we observe that ICT negatively impacts both types of bank efficiency, with the effect varying depending on the type of bank. Notably, the coefficient of IBs is slightly higher than that of CBs. Country governance (GC) moderates the negative effect of ICT on both types of bank efficiency. Additional robustness tests indicate that ICT is negatively related to both types of bank efficiency.

Subjects: Corporate Finance; Banking

Keywords: ICT; DEA; conventional banks; Islamic banks; country governance

1. Introduction

The world economy grew by 5.9% in 2021 as a result of the widespread use of vaccinations. Due to several COVID-19 policy support measures, the worldwide Islamic Financial Services Industry (IFSI) demonstrated resilience despite a resurgence of the pandemic in 2021, supported economies, and maintained its growth rate. By the end of 2021, Islamic finance attained a growth rate of 11.3%. GCC countries as an economic block maintain a prominent position in the international Islamic financial market, holding the highest share of Islamic banking assets according to the Islamic Financial Services Stability Report 2021. Additionally, the region's banking sector has witnessed significant changes as a result of financial deregulation and innovation (Ariss, 2010). In light of these factors, we select CBs and IBs in GCC countries as our research sample.

ICT has recently dominated international economic operations. In addition to poverty reduction, its contributions to the economic development of underdeveloped regions and the reduction of inequality have been substantial. Although the social and economic conditions of GCC countries vary only slightly, it is crucial to acknowledge that the levels of ICT may differ significantly. A higher ICT level can foster technological advancements in the banking sector, leading to improved operational processes, faster transactions, and streamlined services, ultimately boosting bank efficiency. However, this may also bring about more stringent regulatory requirements related to



data privacy and security, imposing additional compliance burdens on banks. Furthermore, advanced technology may accelerate competition, potentially resulting in a decrease in bank efficiency. While there is an ongoing argument about whether ICT can truly enhance bank efficiency, we believe it is vital to gain a clearer understanding of whether ICT has indeed contributed to the improvement of bank efficiency in GCC countries while the debate on this topic continues.

To investigate the nexus between ICT and two types of bank efficiency, we choose the data from World Development Indicators to construct our ICT index. The ICT-bank efficiency nexus has been investigated in a few studies (Appiahene et al., 2019; Arora & Arora, 2013; Berger & DeYoung, 2006; Le et al., 2022; Martín-Oliver & Salas-Fumás, 2008; Scott et al., 2017). Based on bank-level panel data of six countries over the period spanning from 2006 and 2021, we conclude that ICT decreases bank efficiency in our basic regression model, but the coefficient differs between IBs and CBs. Additionally, the moderating effect of country governance on the ICT and the bank efficiency nexus is positive in terms of most indexes of country governance. The negative influence of ICT on bank efficiency will be weakened in countries where the level of political stability, government effectiveness, regulatory quality, rule of law, and control of corruption is high. The negative influence of ICT on bank efficiency will be amplified in countries where the levels of voice and accountability are high. Additional robustness tests reveal results similar to the basic regression model.

Our study has two key novelties compared to the previous literature. First, this research contributes to the banking system literature. To the best of our knowledge, this study enriches the extant literature surrounding bank efficiency by investigating the influence of ICT on the efficiency of CBs and IBs in GCC countries. In the preceding studies, the influence of ICT over the dual banking system was not the central point of the analysis. Instead, scholars focused their attention on CBs in Ghana (Appiahene et al., 2019), India (Arora & Arora, 2013), and Europe (Simper et al., 2019). Therefore, the lessons learned from previous studies in other countries may not be applicable to GCC countries. Additionally, this study enriches the extant literature by analyzing the role of country governance in moderating the nexus between ICT and the efficiency of CBs and IBs. Prior studies have not examined how country governance influences the relationship between ICT and bank efficiency.

Second, this study contributes to the literature that explores the determinants of the efficiency of CBs and IBs. Numerous studies have investigated various factors to uncover the determinants of the efficiency of CBs and IBs, such as country governance (Kamarudin et al., 2022), Shari'ah supervision (Mollah & Zaman, 2015), and globalization (W Jubilee et al., 2022). Our study reveals that ICT is another important macro determinant. First, we examine the different efficiency levels between CBs and IBs. Subsequently, we find that ICT is negatively correlated with both types of bank efficiency using multiple panel regression analysis (MPRA) in our basic regression, and that the absolute value of the coefficient of IBs is greater than that of CBs.

The remainder of the study is delineated in the following sections. Section 2 presents the literature review. Section 3 describes the data and associated methodology. Section 4 reports the empirical results. Section 5, the final section, highlights key conclusions and implications for policymakers.

2. Literature review

2.1. The relationship between ICT and banks

Empirical evidence examining the role that ICT plays in the efficiency of banks remains limited. Many studies have focused on the impact of ICT on poverty, inequality, economic growth, and the environment. ICT has a positive and considerable influence on inclusive growth in Africa (Nchake & Shuaibu, 2022). Additionally, ICT continues to offer significant benefits in poverty reduction within the Southern Africa Development Community, and it is considered a tool for accelerating economic

growth (Olamide et al., 2022). ICT can also promote information sharing and business networking, while also enhancing the effectiveness of inbound open innovation (Ofori et al., 2022). All of the above can contribute to inclusive growth. ICT impairs the environment because of the excessive energy consumption from the use of numerous inefficient ICT devices and the shortened life cycles and e-waste brought about by ICT (Danish et al., 2018). The popularity of ICT contributes to a deterioration in environmental quality, which can be attributed to associated inefficient energy consumption and heavy reliance on fossil fuels for power (Avom et al., 2020).

The existing literature currently focuses primarily on the impact of ICT on banks (Appiahene et al., 2019; Arora & Arora, 2013; Berger & DeYoung, 2006; Le et al., 2022; Martín-Oliver & Salas-Fumás, 2008; Scott et al., 2017; Simper et al., 2019), but the results are mixed. Some scholars contend that ICT is positively related to bank performance. ICT increases the profits of banks by reducing costs and increasing demand, and the impact is slight and negative within the first few years of the adoption of ICT (Scott et al., 2017). The positive impact of ICT on bank performance was documented by Appiahene et al. (2019) based on the data of 444 Ghanaian bank branches. Significant ICT spending by Indian banks has been proven worthy and has truly increased revenues (Arora & Arora, 2013). Given the integration of advanced ICT, banks have enhanced their capacity to identify problematic loans, mitigating the impact of poor management techniques in Europe (Simper et al., 2019). Agency expenses have been reduced thanks to the popularity of ICT in the banking industry (Berger & DeYoung, 2006). ICT developments may also enhance bank efficiency in 27 Vietnamese commercial banks (Le et al., 2022). However, some scholars hold different views. For instance, there is no evidence that investing in IT capital boosts demand for loans or deposits in Spain (Martín-Oliver & Salas-Fumás, 2008). The impact of IT varies depending on the bank, resulting in worse profitability performance for the banking industry as a whole (Beccalli, 2007). The advantages of technology could be passed on to consumers and other production-related elements rather than the organizations themselves (Berger, 2003). The popularity of ICT can undermine banks' profits by encouraging clients to migrate to FinTech services and introduce the entry of new rivals, namely, FinTech businesses that offer similar high-quality services (Del Gaudio et al., 2021).

There is still ongoing debate regarding the impact of ICT on bank efficiency. To gain more comprehensive insights, it is essential to include additional empirical data, especially from dual banking system countries, such as the GCC countries. Building on the above discussion, we propose the following hypothesis:

Hypothesis 1. ICT has a negative effect on both types of bank efficiency in GCC countries.

2.2. The impact of country governance on the relationship between ICT and the efficiency of two types of banks

The extant literature is scant in addressing the moderating effect of country governance on the impact of ICT on the efficiency of banks. However, some of this literature confirms that country governance can influence the efficiency of banks. Some country governance dimensions, such as voice and accountability, are positively correlated with the efficiency of both types of banks, while some indexes, such as regulatory quality and the rule of law, have a significant impact on CBs (Kamarudin et al., 2022). The effectiveness of a country's institutions can improve the function of bank risk governance (Nguyen & Dang, 2023a).

Hypothesis 2. Country governance can moderate the relationship between ICT and both types of bank efficiency in select countries.

3. Data and methodology

To analyze the influence of ICT on the efficiency of conventional and Islamic banks, we gather data from a variety of sources. First, we extract the information about the bank from BankFocus for the period spanning from 2006 to 2021 in GCC countries. The reason why we choose these countries is because the assets of Islamic banks in GCC countries occupy a large proportion of global Islamic banking assets. All of the data is supplemented using a linear interpolation method.

Second, the ICT index is extracted from three indexes, including mobile cellular subscriptions (per 100 people), fixed telephone subscriptions (per 100 people), and fixed broadband subscriptions (per 100 people). These three indexes are gathered from World Development Indicators (WDI).

Third, the country-level control data, such as inflation and GDP growth, are gathered from WDI.

Fourth, the governance indicators are gathered from the Worldwide Governance Indicators (WGI). A higher value indicates a better level of governance.

3.1. Dependent variable: Data Envelopment Analysis (DEA) score as a proxy for bank efficiency

We choose the following variables for the DEA model due to the availability of data. Banks act as a significant component in surplus units and deficit units. Therefore, we use (i) deposits and short-term funding and (ii) fixed assets as inputs to generate (a) loans and (b) total financial assets, including securities, following the established methodology (Alexakis et al., 2019; Barth et al., 2013; Haque & Brown, 2017; Mirzaei et al., 2022; Shahwan & Habib, 2023; W Jubilee et al., 2021). The details of inputs and outputs are revealed in Table 1.

3.2. Independent variable: ICT

The components of the ICT index are available at the World Development Indicators (WDI). Following previous studies (Albiman & Sulong, 2017; Appiah-Otoo & Song, 2021; Njangang et al., 2022), this study chooses fixed telephone subscriptions (per 100 people), fixed broadband subscriptions (per 100 people), and mobile cellular subscriptions (per 100 people) as proxies for ICT. We construct an ICT index similar to Appiah-Otoo and Song (2021) using principal component analysis (PCA), which suits this study because it maximizes the variance, rather than minimizing the least square distance.

3.3. Moderating variable: Country Governance (CG)

The WGI project reports this index for many countries. This index includes six dimensions of governance: voice and accountability (vae), political stability and absence of violence/terrorism (pve), government effectiveness (gee), regulatory quality (rqe), rule of law (rle), and control of corruption (cce).

3.4. Control variable

We consider three bank-level variables, including bank size, credit risk, and capitalization, to avoid missing variables that may impact the efficiency of the bank.

Table 1. DEA inputs and outputs

	Variables	Definitions
	Inputs	
X1	Deposits	Deposits & short-term funding
X2	Physical capital	Fixed Assets
	Outputs	
Y1	Loan	Gross loans
Y2	Investment	Total financial assets: securities

First, we define the size of the bank as the natural logarithm of total assets following the methods of Nguyen (2021, 2022). Size is expected to be positively related to a bank's efficiency, because big banks may enjoy the welfare brought about by economies of scale. However, a negative correlation can also be observed because small banks operate in a local protective environment, where they gain high profits but realize high costs (Mamatzakis et al., 2008).

Second, we control for credit risk by using the ratio of loan loss reserves to gross loans. This ratio can also represent the quality of the loan. Credit risk is anticipated to exhibit a negative correlation with a bank's efficiency.

Third, we control for the level of capitalization. This index is gauged by the equity over total assets. Capitalization is expected to be positively related to a bank's efficiency, because a high proportion of equity in the capital structure will lead to a low probability of bankruptcy. However, due to the substitution of loans with less risky assets, such as treasury bonds, the overemphasis on capitalization may lead to reduced efficiency (VanHoose, 2007).

In terms of country-level variables, we consider GDP growth (annual %) as the proxy for the economic development of different countries. Higher GDP growth (annual %) may indicate a more financially inclusive economy, where individuals and businesses have better access to banking services. With more customers, the efficiency of the banking sector can be enhanced.

We also choose inflation as the country-level control variable. We use CPI as the proxy for inflation. Due to asymmetric information and variances in the accuracy of CPI expectations, banks adjust the interest rates and gain revenue in the prediction (W Jubilee et al., 2022). Based on the above, we can expect inflation to be positively correlated with bank efficiency.

All the details about our variables are shown in Table 2.

3.5. Assessing a bank's technical efficiency using DEA

Farrell (1957) holds the opinion that the main reason for people's efforts to solve the problem of the production efficiency measurement was the failure to find a measurement standard that could solve multiple inputs and outputs, and the DEA method is the solution to this problem. Following the studies of previous scholars such as W Jubilee et al. (2021, 2022) and Kamarudin (2015), this study employs estimates of efficiency levels under the assumption of variable returns to scale (VRS).

DEA can be input- or output-oriented. Under the output-oriented method, the DEA can attain the optimal output while the input is constant. In the input-oriented method, the situation is similar.

The DMUs were supposed to be $(k = 1, \dots, K)$ with the vector of input indicated as $x = (x_1, \dots, x_N) \in \mathbb{R}^{N+}$ and the vector of output represented as $y = (y_1, \dots, y_M) \in \mathbb{R}^{M+}$. The efficiency of the DMUs can be calculated using Equation (1):

$$TE_K = \frac{\alpha_1 y_{1k} + \alpha_2 y_{2k} + \dots + \alpha_M y_{Mk}}{\beta_1 x_{1k} + \beta_2 x_{2k} + \dots + \beta_N x_{Nk}} = \frac{\sum_{m=1}^M \alpha_m y_{mk}}{\sum_{n=1}^N \beta_n x_{nk}}$$

Where:

TE_K = the technical efficiency score given to the K-th DMU;

α = output weights;

β = input weights.

Table 2. Variable explanations

	Variable	Symbol	Description	Source
Dependent variable	Efficiency score	Inte	Measure the efficiency of the bank(log).	Calculated by the author
Independent variable	information and communication technology	ICT	Measure the level of ICT	Generated by Principal Component Analysis (PCA)
Bank-level control variables	Size	InAsset	Bank's total assets (log).	BankFocus
	Credit risk	quality	Loan Loss Res./ Gross Loans	BankFocus
	Capitalization	capital	Equity/Total assets	BankFocus
Country-level variables	GDP	GDPGR	GDP growth (annual %)	World Bank World Development Indicators
	CPI	CPI	Consumer price index (2010 = 100) (log).	World Bank World Development Indicators
Moderating variable	Country Governance	CG		World Banks Governance Indicators(http://info.worldbank.org/governance/wgi/#reports)
	Voice and Accountability, Estimate	vae	The level of participation of citizens in the government affairs	
	Political Stability and Absence of Violence/Terrorism, Estimate	pve	The level of political stability	
	Government Effectiveness, Estimate	gee	The level of commitments of government to their policies	
	Regulatory Quality, Estimate	rqe	The level of implementing policies	
	Rule of Law, Estimate	rle	The level of contract enforcement, judiciary system	
	Control of Corruption, Estimate	cce	The level of eliminating corruption	

3.6. Second-stage analysis

After calculating the TE, this study uses parametric (t-test) and nonparametric (Mann-Whitney (Wilcoxon) and Kruskal—Wallis) tests to investigate the differences in the efficiency scores of Islamic and conventional banks in selected countries and regions.

The next step of this study is to determine the protentional factors that might impact the efficiency of banks by MPRA, including the ordinary least squares (OLS) and generalized least squares (GLS) methodologies. The Breusch Pagan and Lagrangian Multiplier (BP and LM) test is the foremost step, because this test can detect whether pooled or panel data is optimal. If the

p-value of the BP test and the Chi-square of the LM test are significant at a 5% level, then we choose panel data. Both the fixed effects model (FEM) and random effects model (REM), based on the GLS model, are employed in this study to address the panel data. The Hausman test is used to choose which model is suitable for this research based on a null hypothesis. The FEM will be chosen to analyze the data if the null hypothesis is rejected (at 1% to 5% significance levels only); otherwise, the REM is used (Kamarudin et al., 2022).

3.7. Econometric model

Following previous scholars (Banker & Natarajan, 2008; Kamarudin, 2015), this study utilizes the OLS regression method to examine the relationship between macroprudential policies and the efficiency of both types of banks. We propose the following empirical equation:

$$Inte_{it} = \alpha_0 + \alpha_1 ICT_{jt} + \sum_{a=1}^3 \beta_a BC_{it} + \sum_{b=1}^2 \delta_b CC_{jt} + \varepsilon_{ijt}$$

$$Inte_{it} = \alpha_0 + \alpha_1 ICT_{jt} + \alpha_2 CG_{jt} + \sum_{a=1}^3 \beta_a BC_{it} + \sum_{b=1}^2 \delta_b CC_{jt} + \alpha_3 ICT_{jt} * CG_{jt} + \varepsilon_{ijt}$$

where:

$Inte_{it}$ = TE of bank i at time t (log).

ICT_{jt} = ICT index of country j at time t

CG_{jt} = country governance of country j at time t

BC_{it} = bank-level control variable of bank i at time t

CC_{jt} = country-level control variable of country j at time t

ε_{ijt} = the error term

4. Empirical results

4.1. Univariate test

We conduct the univariate test for our sample. In Table 3, three different tests can be seen in panels A, B, and C. The t-test results indicate that the efficiency of CBs is higher than that of IBs ($0.529 > 0.459$), and this result is significant at the 1% level. Additionally, the results from the non-parametric Mann-Whitney (Wilcoxon) and Kruskal-Wallis tests yield similar, significant conclusions. This documents that CBs are more efficient than IBs.

4.2. PCA

The PCA method essentially reduces a group of variables to a smaller composite index. Many previous studies have used this method to construct a composite ICT index. We decomposed fixed telephone subscriptions (per 100 people), fixed broadband subscriptions (per 100 people), and mobile cellular subscriptions (per 100 people) as a weighted average called the ICT index.

4.3. Descriptive statistics

Table 4 presents the descriptive statistics of variables of all banks in the sample.

For the main variable, the mean value of the efficiency is -0.898 (in log terms) with a standard deviation of 0.791 . The mean value of the ICT is 0 with a standard deviation of 1.058 . Significant fluctuations around the sample mean it can be observed for other control variables.

Table 3. Univariate test of efficiency on Islamic vs. conventional banks

Region	Panel A: t-test		Panel B: M-W		Panel C: K-W	
			Wilcoxon Rank-Sum test		Equality of Populations test	
	t (Prb > t)		z(Prb>z)		χ^2 (Prb > χ^2)	
	Mean	t	Mean Rank	z	Mean Rank	χ^2
Te						
CB	0.529	4.06***	587.16	-4.684***	587.16	21.94***
IB	0.459		492.44		492.44	

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4. Descriptive statistics for all banks

variable	N	mean	p25	p75	sd	min	max
Inte	1108	-0.898	-1.266	-0.376	0.791	-6.121	0
Inasset	1108	16.02	15.07	17.11	1.484	11.89	19.52
quality	1101	5.894	2.333	6.042	9.729	-8.201	101.7
Capital	1108	18.02	11.44	17.34	14.37	-7.27	96.32
GDPGR	1108	3.185	1.287	5.228	4.556	-8.855	26.17
CPI	1108	4.667	4.605	4.747	0.115	4.335	4.896
ICT	1108	0	-0.609	0.708	1.058	-2.253	2.365
vae	1108	-1.136	-1.318	-0.907	0.346	-1.907	-0.485
pve	1108	0.178	-0.493	0.76	0.699	-1.335	1.224
gee	1108	0.58	0.19	0.961	0.51	-0.309	1.505
rqe	1108	0.51	0.258	0.716	0.345	-0.177	1.107
rle	1108	0.47	0.312	0.625	0.246	-0.001	0.996
cce	1108	0.487	0.079	1.069	0.507	-0.336	1.559

Our correlation matrix in Table 5 confirms that there is no multicollinearity issue in the regression estimation.

4.4. Basic results

In Table 6, we include bank-level and country-level determinant variables, namely, size of bank (lnAsset), credit risk (quality), capitalization levels (capital), GDP growth (GDPGR), and inflation (CPI). We also include ICT in the model. In the preliminary stage, the results from Table 6 show that the fixed effects model is most suitable for use in this study because the p value of the BP test and the Chi-square of the LM test are significant at the 1% level or lower, and the p value of the Hausman test is significant at the 1% level or lower.

The fixed effects model in Table 6 shows that ICT has a significant and negative effect on the efficiency of CBs and IBs, and the absolute value of the coefficient of IBs is greater than CBs. The following two factors may be used to explain why both types of banks have negative signs. On the one hand, as ICT becomes popular in the banking industry, there may be more rivalry as banks work to offer innovative services and improve consumer experiences. Consequently, banks may encounter challenges in maintaining their previous cost levels due to intensified competition. On the other hand, with the implementation of ICT, banks must handle large volumes of customer data, raising concerns about data privacy and regulatory compliance. The proliferation of ICT

Table 5. Correlation matrix for the explanatory variable

	Inte	Inasset	quality	Capital	GDPGR	CPI	ICT	vae	pve	gee	rqe	rle	cce
Inte	1												
Inasset	0.039	1											
quality	-0.328***	-0.310***	1										
Capital	-0.014	-0.602***	0.347***	1									
GDPGR	-0.082***	-0.073**	-0.152***	-0.011	1								
CPI	-0.163***	0.144***	0.177***	0.055*	-0.390***	1							
ICT	-0.127***	0.021	0.127***	0.054*	-0.129***	0.412***	1						
vae	-0.036	-0.110***	0.071**	-0.098***	0.002	-0.192***	-0.179***	1					
pve	0.148***	0.036	-0.082***	-0.142***	0.158***	-0.238***	-0.023	0.524***	1				
gee	0.087***	-0.055*	0.012	0.012	0.075**	-0.028	0.667***	0.090***	0.516***	1			
rqe	0.075**	-0.153***	0.060**	0.004	0.073**	-0.043	0.615***	0.050*	0.298***	0.834***	1		
rle	0.116***	-0.059**	0.029	-0.064**	0.077**	0.054*	0.421***	0.264***	0.558***	0.723***	0.761***	1	
cce	0.143***	-0.018	-0.078***	-0.016	0.184***	-0.174***	0.459***	0.185***	0.710***	0.915***	0.683***	0.709***	1

*p < 0.1, ** p < 0.05, *** p < 0.01

Table 6. Basic regression results

	CB			IB		
	ols	fe	re	ols	fe	re
Constant	5.009***	3.035**	3.768***	2.246	0.988	1.025
	(1.14)	(1.40)	(1.19)	(2.03)	(2.11)	(2.01)
Inasset	0.001	-0.179**	-0.019	-0.071*	-0.150	-0.098
	(0.02)	(0.09)	(0.03)	(0.04)	(0.13)	(0.07)
quality	-0.001	0.013***	0.008**	-0.047***	-0.027***	-0.036***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Capitalization	0.002	-0.005	0.000	0.006**	-0.004	0.004
	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)
GDPGR	-0.034***	-0.038***	-0.036***	-0.035***	-0.041***	-0.040***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
CPI	-1.233***	-0.168	-0.896***	-0.409	0.140	-0.062
	(0.25)	(0.34)	(0.27)	(0.44)	(0.54)	(0.44)
ICT	-0.033	-0.186***	-0.114***	-0.139***	-0.384***	-0.287***
	(0.02)	(0.04)	(0.03)	(0.05)	(0.05)	(0.05)
N	719	719	719	382	382	382
r2	0.074	0.165		0.356	0.300	
r2_a	0.067	0.098		0.346	0.236	
F	9.548***	21.876***		34.610***	24.960***	
BP LM	chibar2(01) =103.28***			chibar2(01) =97.10***		
chi2			95.129***			155.130***
Hausman		chi2(6) = 44.91***			chi2(6) =34.50***	

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

involves extensive data exchanges. In the banking sector, this amplifies concerns surrounding data security (Del Gaudio et al., 2021). Ensuring compliance with data protection laws can be demanding and can also result in penalties if not managed properly. In order to address growing concerns about data security, banks may incur additional, continuous expenses to deal with hackers and cybercriminals (Le et al., 2022). Concerning the larger absolute value of the coefficient of IBs, this can be explained by the different sizes of banks. Barth et al. (2013) contend that big banks enjoy economies of scale. In general, CBs are larger in size compared to IBs. In addressing the costs incurred by ICT development, it will be easier for CBs to absorb these costs, but these costs have a greater impact on relatively smaller IBs. Moreover, smaller banks will find it more challenging to survive under the intense competition brought about by the widespread adoption of ICT.

In terms of control variables, the impact of bank size is significantly negative at a 5% level for CBs. This can be explained by greater effort that must be applied to address diverse businesses (De Young, 1995). Similar negative relationships between bank size and efficiency can be concluded from existing research (Isik & Hassan, 2003; Staub et al., 2010). In terms of the significant positive (negative) relationship between the quality of the loan and CBs (IBs), this phenomenon arises from differing loan management philosophies. It implies that higher credit risk leads to increased efficiency levels in CBs and lower efficiency in IBs. CBs may have decided to have lower expenses in the short run by limiting the costs that are allocated to underwriting and monitoring loans in order to maximize long-term earnings, whereas IBs tend to have higher costs in the short time. In the long run, loan performance will be worse for CBs, and existing research documents a similar phenomenon (Kamarudin et al., 2016, 2022). Turning to the GDP growth rate, this variable is

negatively correlated with the efficiency of CBs and IBs, and the results are statistically significant. During periods of strong economic growth, central banks might raise interest rates to control inflation. Higher interest rates can increase borrowing costs for businesses and consumers, leading to reduced loan demand for banks and potentially impacting their productivity. When GDP growth rate is high, there might be greater demand for loans. The unmatched level of risk management leads to lower quality bank loans, which in turn negatively affects their efficiency. Meanwhile, banks may cut expenses in areas such as credit screening and monitoring (Kamarudin et al., 2017; W Jubilee et al., 2022), leading to an increased percentage of bad loans that lower a bank's profitability level. Similar results can be seen in the extant research (Kamarudin et al., 2016; W Jubilee et al., 2022). Surprisingly, the coefficient of capitalization and CPI is insignificant in terms of the two types of banks.

4.5. Moderating effect of country governance

Country governance is one of the important elements that affect bank efficiency, along with GDP, CPI, and other macro indexes. This element comprises the traditions and institutions by which authority in a country is exercised. The regulatory environment of a country is widely acknowledged to play a crucial role in shaping the functioning of financial institutions, and governance practices exhibit significant variations across nations. Kamarudin et al. (2016) find that a high level of country governance can influence the efficiency of banks. For example, country governance promotes democracy, eradicates poverty, and develops and executes strong rules and regulations to establish a harmonious environment for units. Kamarudin et al. (2022) note that good governance will uphold the rule of law and maintain its efficacy, which will benefit banks since it will make launching a business less unpredictable and risky. Strong country governance can also alleviate information asymmetry and benefit banks (Bolton & Freixas, 2006).

We choose country governance as the moderating variable to examine the moderating effect of country governance on bank efficiency. Tables 7 and 8 show the regression results with the country governance interaction term to examine the role of governance in the relationship between ICT and efficiency in terms of CBs and IBs. We can conclude that political stability, government effectiveness, regulatory quality, rule of law, and control of corruption positively and significantly moderate the relationship between ICT and the efficiency of both types of banks. However, voice and accountability weaken the ICT-efficiency nexus. Interestingly, the interaction is not significant in terms of CBs but is significant in terms of IBs. The positive moderating effect of political stability may be explained by the fact that leaders actively utilize their authority to advance societal welfare rather than their own personal interests. Political stability may lead to greater government support for data security in the banking sector and reduce the cost that banks incur. It may also improve the efficiency of banks by lowering transaction costs and alleviating the outcome of asymmetric information (Kamarudin et al., 2016).

Government effectiveness weakens the negative effect of ICT on the efficiency of banks. A government that is efficient and proactive in supporting ICT initiatives can create a conducive regulatory environment for banks. Clear and supportive regulations can facilitate the smooth adoption and integration of ICT solutions, reducing potential hurdles and negative impacts on bank efficiency.

A high level of regulatory quality ensures that regulations related to ICT adoption in the banking sector are clear, supportive, and well-designed. Such regulations can facilitate the smooth integration of ICT solutions into bank operations, thus improving the efficiency of banks. Additionally, excellent regulatory quality can foster more effective efforts to address bureaucracy and greater responsibility among government personnel (Kamarudin et al., 2016).

It can also be observed from Tables 7 and 8 that the rule of law and the control of corruption play a positive moderating role. A strong rule of law ensures a stable and predictable regulatory environment for banks. When laws related to ICT adoption are well-defined and consistently applied, banks can navigate the regulatory landscape with ease, minimizing disruptions and negative impacts on efficiency.

Table 7. Moderating effect of governance in CB

	Model 1			Model 2			Model 3		
	ols	fe	re	ols	fe	re	ols	fe	re
Constant	4.944*** (1.15)	3.204** (1.40)	3.735*** (1.20)	3.994*** (1.14)	4.420*** (1.43)	3.610*** (1.20)	0.261 (1.27)	-0.887 (1.39)	0.032 (1.28)
Inasset	0.002 (0.02)	-0.166* (0.09)	-0.011 (0.03)	-0.006 (0.02)	-0.268*** (0.09)	-0.031 (0.03)	0.016 (0.02)	-0.239*** (0.09)	-0.018 (0.03)
quality	-0.001 (0.00)	0.016*** (0.00)	0.008** (0.00)	-0.002 (0.00)	0.008* (0.00)	0.005 (0.00)	-0.003 (0.00)	0.004 (0.00)	0.002 (0.00)
Capitalization	0.002 (0.00)	-0.004 (0.01)	0.002 (0.00)	0.003 (0.00)	-0.005 (0.01)	0.002 (0.00)	0.006* (0.00)	-0.002 (0.01)	0.004 (0.00)
GDPGR	-0.033*** (0.01)	-0.040*** (0.01)	-0.036*** (0.01)	-0.028*** (0.01)	-0.035*** (0.01)	-0.033*** (0.01)	-0.029*** (0.01)	-0.033*** (0.01)	-0.031*** (0.01)
CPI	-1.207*** (0.25)	-0.122 (0.34)	-0.891*** (0.27)	-1.007*** (0.25)	-0.151 (0.34)	-0.834*** (0.27)	-0.353 (0.27)	0.904*** (0.35)	-0.167 (0.28)
ICT	0.117 (0.13)	-0.343** (0.13)	-0.138 (0.13)	-0.170*** (0.03)	-0.251*** (0.04)	-0.204*** (0.03)	-0.488*** (0.06)	-0.682*** (0.07)	-0.553*** (0.06)
vae	0.066 (0.09)	0.551** (0.22)	0.130 (0.13)						
ICT*vae	0.135 (0.11)	-0.169 (0.11)	-0.028 (0.11)						
pve				0.127*** (0.04)	-0.027 (0.14)	0.133** (0.06)			
ICT*pve				0.260*** (0.04)	0.221*** (0.05)	0.228*** (0.04)			

(Continued)

Table 7. (Continued)

	Model 1			Model 2			Model 3		
	ols	fe	re	ols	fe	re	ols	fe	re
gee							0.332*** (0.07)	-0.485*** (0.13)	0.194** (0.09)
ICT*gee							0.328*** (0.05)	0.496*** (0.05)	0.372*** (0.05)
N	719	719	719	719	719	719	719	719	719
r2	0.076	0.179		0.140	0.193		0.155	0.266	
r2_a	0.066	0.111		0.131	0.126		0.145	0.205	
F	7.337***	18.098***		14.480***	19.786***		16.232***	30.062***	
BP LM	chibar2(01) =97.12***			chibar2(01) =90.93***			chibar2(01) =103.17***		
chi2			95.847***			137.575***			161.322***
Hausman			chi2(8) =58.01***			chi2(8) = 33.75***			chi2(8) =84.57***
	Model 4			Model 5			Model 6		
	ols	fe	re	ols	fe	re	ols	fe	re
Constant	0.303 (1.30)	-1.859 (1.46)	-0.981 (1.34)	0.764 (1.16)	-1.255 (1.40)	-0.648 (1.21)	0.727 (1.24)	1.114 (1.41)	0.417 (1.27)
Inasset	0.015 (0.02)	-0.277*** (0.09)	-0.028 (0.03)	0.013 (0.02)	-0.252*** (0.09)	-0.015 (0.03)	0.013 (0.02)	-0.256*** (0.09)	-0.008 (0.03)
quality	-0.005 (0.00)	0.005 (0.00)	0.003 (0.00)	-0.004 (0.00)	0.002 (0.00)	0.001 (0.00)	-0.002 (0.00)	0.005 (0.00)	0.003 (0.00)
Capital	0.007** (0.00)	-0.004 (0.01)	0.003 (0.00)	0.006* (0.00)	-0.003 (0.01)	0.004 (0.00)	0.005 (0.00)	-0.003 (0.01)	0.004 (0.00)
GDPGR	-0.026*** (0.01)	-0.030*** (0.01)	-0.028*** (0.01)	-0.021*** (0.01)	-0.026*** (0.01)	-0.023*** (0.01)	-0.029*** (0.01)	-0.033*** (0.01)	-0.031*** (0.01)

(Continued)

Table 7. (Continued)

	Model 4			Model 5			Model 6		
	ols	fe	re	ols	fe	re	ols	fe	re
CPI	-0.368 (0.27)	1.165*** (0.37)	0.079 (0.29)	-0.463* (0.25)	0.907*** (0.34)	-0.058 (0.27)	-0.429 (0.27)	0.487 (0.35)	-0.283 (0.28)
ICT	-0.598*** (0.08)	-0.874*** (0.09)	-0.723*** (0.08)	-0.719*** (0.08)	-0.846*** (0.08)	-0.795*** (0.08)	-0.422*** (0.06)	-0.534*** (0.07)	-0.478*** (0.06)
rqe	0.426*** (0.10)	0.153 (0.14)	0.282** (0.12)						
ICT*rqe	0.593*** (0.09)	0.768*** (0.09)	0.663*** (0.09)						
rle				0.521*** (0.10)	0.705*** (0.16)	0.542*** (0.13)			
ICT*rle				0.928*** (0.11)	0.837*** (0.11)	0.906*** (0.11)			
cce							0.328*** (0.06)	0.006 (0.12)	0.307*** (0.08)
ICT*cce							0.349*** (0.06)	0.389*** (0.06)	0.370*** (0.06)
N	719	719	719	719	719	719	719	719	719
r2	0.142	0.249	0.191	0.191	0.268	0.150	0.150	0.215	0.215
r2_a	0.132	0.187	0.181	0.181	0.207	0.141	0.141	0.150	0.150
F	14.652***	27.481***	20.897***	20.897***	30.309***	15.678***	15.678***	22.665***	22.665***
BP LM		chibar2(01) =114.47***		chibar2(01) =107.49***		chibar2(01) =97.79***			
chi2		166.449***		205.339***		145.563***			
Hausman		chi2(8) =58.68***		chi2(8) =49.57***		chi2(8) =61.04***			

Standard errors in parentheses

*p < 0.1, ** p < 0.05, *** p < 0.01

Table 8. Moderating effect of governance in IB

	Model 1			Model 2			Model 3		
	ols	fe	re	ols	fe	re	ols	fe	re
Constant	2.932 (2.06)	-0.421 (2.19)	0.843 (2.08)	2.303 (2.02)	2.008 (2.19)	2.008 (2.04)	-2.167 (2.15)	-1.137 (2.15)	-1.867 (2.08)
Inasset	-0.079* (0.04)	-0.187 (0.13)	-0.102 (0.07)	-0.107** (0.04)	-0.142 (0.13)	-0.116* (0.07)	-0.098** (0.04)	-0.097 (0.13)	-0.122* (0.07)
quality	-0.046*** (0.00)	-0.027*** (0.00)	-0.034*** (0.00)	-0.049*** (0.00)	-0.029*** (0.00)	-0.038*** (0.00)	-0.048*** (0.00)	-0.029*** (0.00)	-0.037*** (0.00)
Capitalization	0.006* (0.00)	-0.005 (0.01)	0.004 (0.00)	0.006* (0.00)	-0.002 (0.01)	0.004 (0.00)	0.005* (0.00)	-0.001 (0.01)	0.004 (0.00)
GDPGR	-0.036*** (0.01)	-0.043*** (0.01)	-0.041*** (0.01)	-0.030*** (0.01)	-0.039*** (0.01)	-0.037*** (0.01)	-0.032*** (0.01)	-0.036*** (0.01)	-0.035*** (0.01)
CPI	-0.541 (0.44)	0.612 (0.58)	-0.062 (0.46)	-0.295 (0.44)	-0.108 (0.56)	-0.208 (0.46)	0.563 (0.47)	0.414 (0.55)	0.587 (0.46)
ICT	0.085 (0.20)	-0.779** (0.20)	-0.428** (0.20)	-0.175*** (0.05)	-0.369*** (0.06)	-0.281*** (0.05)	-0.449*** (0.09)	-0.676*** (0.09)	-0.590*** (0.09)
vae	-0.071 (0.15)	0.196 (0.29)	-0.212 (0.20)						
ICT*vae	0.213 (0.17)	-0.336** (0.16)	-0.105 (0.16)						
pve				0.074 (0.06)	-0.005 (0.21)	0.070 (0.10)			
ICT*pve				0.224*** (0.07)	0.146* (0.07)	0.193*** (0.07)			

(Continued)

Table 8. (Continued)

	Model 1			Model 2			Model 3		
	ols	fe	re	ols	fe	re	ols	fe	re
gee							0.530*** (0.12)	-0.298 (0.23)	0.329** (0.16)
ICT*gee							0.158* (0.09)	0.395*** (0.09)	0.285*** (0.09)
N	382	382	382	382	382	382	382	382	382
r2	0.363	0.311		0.384	0.309		0.400	0.339	
r2_a	0.350	0.244		0.371	0.242		0.387	0.274	
F	26.600***	19.595***		29.092***	19.427***		31.076***	22.205***	
BP LM	chibar2(01) =88.27***			chibar2(01) =89.26***			chibar2(01) =79.17***		
chi2	155.580***			169.429***			180.117***		
Hausman	chi2(8) =36.58***			chi2(8) = 28.34***			chi2(8) =36.07***		
	Model 4			Model 5			Model 6		
	ols	fe	re	ols	fe	re	ols	fe	re
Constant	-4.139* (2.27)	-3.241 (2.33)	-4.157* (2.22)	-0.591 (2.00)	-1.010 (2.10)	-1.256 (1.98)	-1.682 (2.12)	-0.744 (2.21)	-1.663 (2.09)
Inasset	-0.032 (0.04)	-0.177 (0.13)	-0.083 (0.06)	-0.092** (0.04)	-0.164 (0.13)	-0.106 (0.07)	-0.124*** (0.04)	-0.168 (0.13)	-0.144** (0.07)
quality	-0.046*** (0.00)	-0.031*** (0.00)	-0.037*** (0.00)	-0.049*** (0.00)	-0.031*** (0.00)	-0.038*** (0.00)	-0.049*** (0.00)	-0.030*** (0.00)	-0.038*** (0.00)
Capitalization	0.007** (0.00)	-0.001 (0.01)	0.005 (0.00)	0.006** (0.00)	0.001 (0.01)	0.006 (0.00)	0.004 (0.00)	-0.002 (0.01)	0.003 (0.00)
GDPGR	-0.030*** (0.01)	-0.033*** (0.01)	-0.031*** (0.01)	-0.030*** (0.01)	-0.034*** (0.01)	-0.032*** (0.01)	-0.032*** (0.01)	-0.036*** (0.01)	-0.035*** (0.01)

(Continued)

Table 8. (Continued)

	Model 4			Model 5			Model 6		
	ols	fe	re	ols	fe	re	ols	fe	re
CPI	0.701 (0.48)	1.054* (0.58)	0.888* (0.48)	0.176 (0.43)	0.517 (0.54)	0.360 (0.43)	0.577 (0.47)	0.530 (0.57)	0.629 (0.47)
ICT	-0.574*** (0.13)	-0.781*** (0.13)	-0.672*** (0.12)	-0.612*** (0.12)	-0.733*** (0.12)	-0.707*** (0.12)	-0.408*** (0.08)	-0.623*** (0.08)	-0.563*** (0.08)
rqe	0.967*** (0.16)	0.482* (0.25)	0.834*** (0.19)						
ICT*rqe	0.294* (0.15)	0.459*** (0.17)	0.340*** (0.15)						
rle				0.835*** (0.18)	0.736*** (0.24)	0.819*** (0.21)			
ICT*rle				0.667*** (0.19)	0.571*** (0.20)	0.631*** (0.19)			
cce							0.412*** (0.10)	0.275 (0.19)	0.395*** (0.14)
ICT*cce							0.246** (0.10)	0.360*** (0.09)	0.340*** (0.09)
N	382	382	382	382	382	382	382	382	382
r2	0.415	0.331	0.414	0.414	0.343	0.399	0.399	0.332	0.382
r2_a	0.402	0.266	0.402	0.402	0.279	0.386	0.386	0.267	0.382
F	33.055***	21.487***	32.991***	32.991***	22.651***	30.948***	30.948***	21.575***	30.948***
BP LM	chibar2(01) = 86.13***			chibar2(01) = 93.43***			chibar2(01) = 92.05***		
chi2	190.398***			198.013***			185.753***		
Hausman	chi2(8) = 27.23***			chi2(8) = 24.58***			chi2(8) = 27.60***		

Standard errors in parentheses

*p < 0.1, ** p < 0.05, *** p < 0.01

Table 9. Robustness test

	CB			IB		
	ols	fe	re	ols	fe	re
Constant	2.669*	-0.258	0.129	4.261	0.564	2.023
	(1.52)	(2.11)	(1.68)	(2.99)	(3.69)	(3.22)
Inasset	-0.001	-0.086	-0.010	-0.065	-0.089	-0.090
	(0.02)	(0.10)	(0.03)	(0.04)	(0.14)	(0.07)
quality	-0.000	0.012***	0.009**	-0.046***	-0.028***	-0.037***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Capitalization	0.002	0.002	0.003	0.005*	-0.004	0.003
	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)
GDPGR	-0.036***	-0.045***	-0.042***	-0.038***	-0.056***	-0.050***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
CPI	-0.651*	0.367	-0.004	-0.849	0.230	-0.184
	(0.36)	(0.42)	(0.39)	(0.71)	(0.81)	(0.76)
Internet	-0.005***	-0.011***	-0.009***	-0.000	-0.011**	-0.006
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
N	719	719	719	382	382	382
r2	0.081	0.157		0.341	0.213	
r2_a	0.073	0.089		0.330	0.140	
F	10.492***	20.594***		32.292***	15.703***	
BP LM	chibar2(01) =112.45***			chibar2(01) =61.87***		
chi2			105.314***			119.168***
Hausman		chi2(6) = 22.96***			chi2(6) =23.07***	

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Effective legal systems have reduced uncertainty and risk in undertaking business (Kamarudin et al., 2016). The lack of regulatory oversight in addressing corruption can lead to rent-seeking behavior (Clarke, 2016). When corruption is effectively managed, there is more transparency in government actions and decision-making (Ball, 2009). Banks can trust that ICT initiatives will not be influenced by corrupt practices, contributing to a more conducive environment for efficiency-enhancing technology adoption.

Finally, in terms of the negative moderating effect of voice and accountability, this can be explained by the role that citizens and state institutions play in daily life (Kamarudin et al., 2022). With a high level of voice and accountability, there might be increased scrutiny and pressure on banks to be transparent and responsive to customers and stakeholders during the ICT adoption process. This heightened scrutiny may create additional challenges and delays in implementing ICT solutions, negatively impacting bank efficiency.

4.6. Robustness test

Following the study of Zheng et al. (2023), we choose individuals using the Internet (% of population) as another proxy for ICT. We report the regression in Table 9. The coefficient of Internet is negatively related to the efficiency of both types of banks, which indicates that the result is robust, confirming our basic regression result.

5. Conclusion

ICT is commonly believed to enhance bank efficiency, but this study presents contrasting findings. In this study, we build upon the methodologies used in previous research (Kamarudin et al., 2022; Le et al., 2022;

Phung et al., 2022; W Jubilee et al., 2022; Wasiaturrehma et al., 2020), employing DEA to evaluate bank efficiency. Subsequently, we conduct a second-stage regression analysis to investigate the impact of environmental factors, including ICT and country governance, on this efficiency. However, few studies have examined the moderating effect of country governance on the impact of ICT on efficiency.

We investigate the relationship between ICT and efficiency by analyzing data from conventional banks (CBs) and Islamic banks (IBs) in GCC countries for the period spanning from 2006 to 2021. Univariate tests reveal that the efficiency of CBs exceeds that of IBs. Our basic regression results show a negative correlation between ICT and the efficiency of both types of banks. This phenomenon can be explained by increased competition due to the popularity of ICT in the banking industry and the additional expenses required to address data security concerns arising from handling large customer data volumes. Regarding the larger absolute value of IBs, this can be attributed to the smaller cost brought about by the economies of scale. This finding contradicts existing research (Appiahene et al., 2019; Arora & Arora, 2013; Le et al., 2022; Scott et al., 2017; Simper et al., 2019), which contends that ICT developments can enhance bank efficiency. For other control variables, we observed a positive (negative) relationship between the quality of the loan and the efficiency of CBs (IBs), and this phenomenon arises from differing loan management philosophies. Additionally, GDP growth rate is negatively correlated with the efficiency of CBs and IBs. This can be explained by increased bad loans. Additionally, bank size is negatively correlated with the efficiency of CBs. This can be explained by the need to devote greater effort to address diverse businesses.

In terms of the moderating effect, we observe that all subindexes of country governance positively moderate the relationship between ICT and bank efficiency, with the exception of voice and accountability. The negative moderating effect observed in both types of banks may stem from heightened scrutiny and pressure on banks to prioritize transparency and responsiveness to customers and stakeholders during the ICT adoption process.

The results of our study have important policy implications. First, it is of the utmost importance to emphasize the role of improved country governance in enhancing bank efficiency and mitigating the negative impact of ICT, drawing upon successful government policies. The government should find the mechanism through which ICT impairs the efficiency of banks and devise appropriate policies to address this situation. Furthermore, bank managers should accord greater attention to the quality of loans and FinTech development (Nguyen & Dang, 2023b).

Although this study greatly expands upon the extant knowledge on the topic, it also has several drawbacks. GCC countries are considered high-income countries, and the generalizability of ICT's impact on bank efficiency to other low- or middle-income countries deserves additional investigation. Furthermore, the ICT index is derived from three ICT-related subindexes, potentially limiting its ability to comprehensively capture all relevant factors. Moreover, the impact of ICT on banks could be explored in other countries with dual banking systems.

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Author details

Heng Luo¹

E-mail: barryluoheng@foxmail.com

ORCID ID: <http://orcid.org/0009-0003-7362-5917>

Fakarudin Kamarudin¹

ORCID ID: <http://orcid.org/0000-0001-8180-1173>

Normaziah Mohd Nor¹

¹ School of Business & Economics, Universiti Putra Malaysia, Serdang, Malaysia.

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Correction

This article has been corrected with minor changes. These changes do not impact the academic content of the article.

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