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# Measuring the Effect of COVID-19 on Bank Cost Efficiency in Indonesia Using Stochastic Frontier Analysis: Conventional vs Islamic Evidence

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**Abstract:** This study focuses on finding the impact of the Covid-19 pandemic on the cost efficiency of banks using Stochastic Frontier Analysis (SFA). Building on intermediation and risk-return theories, we contend that credit risk, profitability, capital buffers and liquidity management have different impacts on costs in crisis and normal regimes. Using SFA, we estimate a translog cost frontier and Battese-Coelli (1995) inefficiency-effects model on a balanced panel of the quarterly data of Indonesian banks over the period 2015-2024. Inefficiency is modeled using Non-Performing Loan (NPL), Return on Asset (ROA), Capital Adequacy Ratio (CAR), Loan-to-Deposit Ratio (LDR), a dummy of the Covid period (2020-2022) and interaction terms of structural change. Results show that average cost efficiency is high but significantly lower during the lives of the Covid compared to outside the pandemic and conventional banks are seen to be more efficient than Islamic counterparts, Muamalat being the least efficient. Crucially, determinant effects are state-dependent: before the pandemic NPL, ROA, and CAR are associated with less inefficiency and LDR with more inefficiency, whereas during the pandemic such associations become weaker or become opposite and LDR/FDR becomes efficiency-improving. Theoretically, we provide proof of a regime shift mechanism in efficiency drivers under disruption, which means that models of performance should take crisis interactions into account when testing banking efficiency and cross-model heterogeneity.

**Keywords:** Cost Efficiency; SFA; Covid-19; Banking

## 1. Introduction

The Covid-19 crisis had placed tremendous pressure on the banking sector, Islamic and conventional, in terms of impacting the quality of credit/financing, quality of credit/financing distribution, growth of asset and also liquidity and profitability (Seto, 2021; Sulton et al., 2021). These conditions make the assessment of the extent to which the pandemic shock affected the operational efficiency of banks and risk in credit, because these are the most important channels of transmission of the effect of crises on the performance of banks and the more urgent. This study considers the cost efficiency of banks and tests if bank costs were changed by the effects of the Credit risk, profitability, capital, and liquidity.

In terms of operational efficiency, Operating Expenses to Operating Income ratio (BOPO) is taken as a simple indicator of a bank's capacity to determine and control costs in relation to the operating income. However, BOPO is a reduced form indicator and it cannot distinguish managerial inefficiency from random shocks. Cross-country evidence shows that the pandemic created higher efficiency pressures and banks responded by adjusting cost strategies and digitalizing processes and tightening risk controls, with possibly different impacts for Islamic versus conventional banks (Ghouse et al., 2022).

From the credit quality picture Non-Performing Loan/Financing ratio (NPL/NPF) shows the soundness of the credit/financing portfolio under economic stress. Relative stability of credit risk in Islamic financing is often associated with contract structures related to underlying assets/real activity and risk-sharing mechanisms, although results also depend on the composition of portfolios, the quality of mitigation and restructuring policies. Cross-country evidence indicates that credit expansion slowed down in the first

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phase of the Covid-19 period in both systems and that the expansion of credit in conventional banks was more severely impacted and the resilience of Islamic banks relatively higher (Boubakri et al., 2023). These results indicate that the relationships between efficiency and credit risks may change during a crisis and outside of a crisis.

Also, in the literature, there is a focus on how Islamic banking is not necessarily more efficient, citing that this depends on operating models, governance and constraints and that Islamic banks did not necessarily outperform conventional banks during the pandemic (Ashraf et al., 2023). At the same time, stability-oriented studies put emphasis on factors that may support the resistance of Islamic banks during crisis, among them governance of risk management, funding structure and digital financial inclusiveness (Banna et al., 2017). Interpreting resilience through NPL/NPF alone has to be done with caution because restructuring policies and regulatory forbearance may temporarily suppress NPL increases. Therefore, a combination of efficiency measures and credit risk and prudential indicators (liquidity, profitability, capitalization) give a more holistic view as illustrated in Indonesian comparative studies (Febrianto, 2024; Hidayah et al., 2021).

Methodologically, the Stochastic Frontier Analysis (SFA) can be readily employed for assessing efficiency in the pandemic era as it removes inefficiency by separating it from random shocks beyond managerial control. A dummy for Covid-19 helps to strengthen inference because it allows comparisons across regimes. This is relevant against conflicting previous results where sometimes DEA studies found Islamic banks not as stable/less efficient (Ferari & Sudarsono, 2011), and sometimes Islamic banks to be more efficient/more resilient to global shocks (Novandra, 2014; Ramly & Hakim, 2017), and SFA studies provide mixed evidence across periods and samples (Jannah & Oktaviana, 2022; Mohamad et al., 2008).

Existing studies tend to compare Islamic and conventional banks based on average performance or single indicators, and not clearly test the relationship to determine whether there is a reconfiguration of cost inefficiency during crisis conditions. Mixed results in DEA and SFA further indicate the need for a crisis-aware cost frontier that ties efficiency to credit risk and prudential conditions and permits different impacts during the Covid-19. In the Indonesian context, resilience may also be framed outside from financial outcome through Sharia/maqashid compliance dimension (Hanafi & Rohman, 2022). This wider perspective is useful to interpret the heterogeneity in crisis response between banking models.

This study aims to (1) estimate bank cost efficiency using SFA translog cost frontier, (2) test whether the cost efficiency between the Covid (2020-2022) and normal times, (3) test whether the relationship between NPL/NPF, ROA, CAR and LDR/FDR and inefficiency, and (4) test whether this relationship change during Covid-19, clarifying the Islamic conventional differences in Indonesia.

## 2. Materials and Methods

SFA classifies shocks that are external to the phenomenon under being observed as random that with the noise associated with the system as inefficient cost. This secondary the phenomenon of unobserved shocks and measurement errors and allows SFA to construct interrelation of measurement of a dependent to measurement of independent and other financial values to be measured in the study as incommensurable. SFA as a measure of statiscal approximation is appropriate on the framework of this study Coelli et.al (2005).

According to intermediation approach, banks are perceived as financial intermediaries that mobilize funds and change them into income-generating assets (C. W. Sealey & Lindley, 1977). Total cost (TC) is the total expenditure of the banks, outputs (Y1-Y2) are the major income-generating assets like loans/financing and other relevant loans, and input prices (P1–P3) are proxies of prices of funds, labor, and capital/operating resources. The cost frontier has been specified in a translog form to cater for non-linearities and interactions between outputs and input prices. Following the intermediation approach, the selection of outputs and input prices is guided by the objective of representing the core banking production process, transforming mobilized funds into earning assets, using

variables that are comparable across conventional and Islamic banks. Accordingly, $Y_1$ is defined as loans/financing (the primary intermediation output) and $Y_2$ as other earning assets to capture differences in asset composition beyond credit/financing. On the input side, $P_1$ proxies the price of funds, $P_2$ proxies the price of labor, and $P_3$ proxies the price of capital/operating resources, so that the frontier explains total cost as a function of output volumes and unit input costs. This structure is widely used in banking cost-frontier studies because it preserves economic meaning (unit cost x quantity) while remaining feasible under quarterly financial-statement reporting.

$$ln(TC_{i,t}) = f(lnY1_{i,t}, lnY2_{i,t}, lnP1_{i,t}, lnP2_{i,t}, lnP3_{i,t}; \beta) + v_{i,t} + u_{i,t} \quad (1)$$

$$v_{i,t} \sim N(0, \sigma_v^2), \; u_{i,t} \geq 0 \quad (2)$$

$$CE_{i,t} = exp(-u_{i,t}) \quad (3)$$

$$u_{i,t} = \delta_0 + \delta_1 NPL_{i,t} + \delta_2 ROA_{i,t} + \delta_3 CAR_{i,t} + \delta_4 LDR_{i,t} + \delta_5 Covid_{i,t} + \delta_6 (NPL_{i,t} \times Covid_{i,t}) + \delta_7 (ROA_{i,t} \times Covid_{i,t}) + \delta_8 (CAR_{i,t} \times Covid_{i,t}) + \delta_9 (LDR_{i,t} \times Covid_{i,t}) + w_{i,t} \quad (4)$$

In The symmetrical error component, v, is one of the variables in this composite cost frontier, and deals with the shocks of external factors that managers have no control over. Also, in this composite cost frontier, the term, u, which is non-negative, deals with the bank's "excess cost" in relation to the minimum cost frontier with respect to the same outputs and input prices. Cost inefficiency is defined as CE = exp(-u) and is costed with the range of values from 0 to 1, with values closer to 1 displaying more cost efficiency.

The inefficiency specification follows Battese & Coelli (1995), and explains the NPL, ROA, CAR, and LDR baseline (preCOVID) variations in inefficiency, with NPL, ROA, CAR, LDR, and the COVID 19 dummy (coded 1 for 2020-2022) which captures and shifts to a different level in the during of pandemic. For data processing purposes, quarterly financial statement items are harmonized across banks and periods to ensure consistent definitions for total cost, outputs and input-price proxies. Monetary variables used in the frontier are transformed with the help of natural logarithm and the dummy for the Covid is coded as 1 for 2020-2022 and 0 for others to define the pandemic regime. The complete model is given in Eq.(1)-(4) consistently: Eq. (1) defines the translog stochastic cost frontier, Eq. (2) defines the two components of the error, Eq. (3) defines cost efficiency as a function of the inefficiency term, and Eq. (4) models inefficiency based on bank fundamentals and their interaction with Covid, and All computations, estimation and generation of figures/tables are implemented using R Studio software with SFA routine in favor of translog frontiers and Battese-Coelli inefficiency-effects specifications. Interaction terms allow each of the determinants to have a different marginal effect during in COVID, for example, the effect of NPL in the pandemic is $\delta_1 + \delta_6$. With respect to cost frontier specifications, ineffDecrease = FALSE and positive δ increases u (which means that there is a higher state of inefficiency) and thus it results in a lower CE. A negative δ instead increases cost efficiency by lowering u.

To deal with the issues that may arise with regard to representativeness and potential selection bias, the current study considers the sample of four banks as representing a purposeful, theory-based, comparative design rather than a statistical representation of the Indonesian banking industry as a whole. The choice of BCA and BRI represents large banks with systemic significance and good continuity of quarterly data, whereas BSI and Muamalat represent contrasting Islamic banking profiles (dominant post-merger Islamic bank vs. long-standing standalone Islamic bank). This composition allows an informative Islamic-conventional comparison under consistent quarterly reporting over a period from 2015 to 2024. Considering the small number of banks, the findings are interpreted as evidence on the within-sample dynamics and should not be generalized mechanically to the whole of Indonesian banking sector.

## 3. Results and Discussion

This section reports the measurement results of banking cost efficiency and discusses their implications in the context of the COVID-19 pandemic. The discussion focuses on

comparing the efficiency performance of conventional versus Islamic banks and on how risk indicators and bank characteristics may amplify or dampen the pandemic's effect.

**Table 1.** Descriptive statistics of Cost Efficiency (CE) scores

| T | Obs | Mean | Median | SD | Min | Max |
|---|---|---|---|---|---|---|
| Total | 160 | 0,950585 | 1,000000 | 0,070300 | 0,716000 | 1,000000 |
| Pra-COVID | 112 | 0,958712 | 1,000000 | 0,078800 | 0,716000 | 1,000000 |
| COVID | 48 | 0,931623 | 0,932000 | 0,039000 | 0,841000 | 1,000000 |
| BCA | 40 | 0,974650 | 1,000000 | 0,043800 | 0,880000 | 1,000000 |
| BRI | 40 | 0,986300 | 1,000000 | 0,023800 | 0,920000 | 1,000000 |
| BSI | 40 | 0,964700 | 1,000000 | 0,059700 | 0,762000 | 1,000000 |
| Mua | 40 | 0,876650 | 0,889000 | 0,080000 | 0,716000 | 1,000000 |

Table 1 shows that, across 160 observations, the average Cost Efficiency (CE) score is 0.9506 with a median of 1.0000, indicating that most observations are highly efficient, although some variation remains (SD 0.0703), with a minimum of 0.7160 and a maximum of 1.0000. When compared by period, mean CE in the pre-COVID period (0.9587) is higher than during COVID (0.9316), and the median declines from 1.0000 to 0.9320, suggesting a weakening of cost efficiency during the pandemic. By bank, BRI records the highest mean CE (0.9863), followed by BCA (0.9747) and BSI (0.9647), while Muamalat has the lowest mean CE (0.8767) with a median of 0.8890 and relatively larger dispersion (SD 0.0800). To capture long-run dynamics and detect potential pattern shifts during COVID-19, Figure 1 presents the bank-level CE trend over 2015Q1–2024Q3.

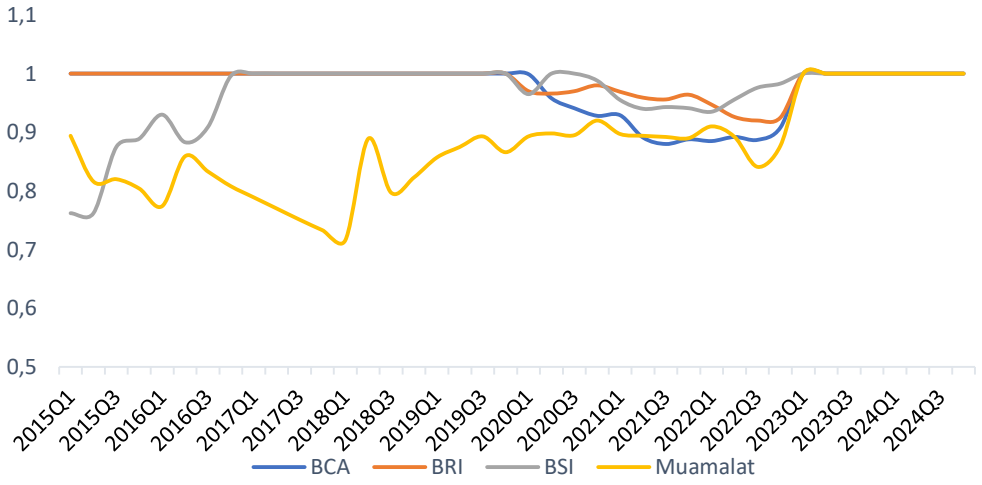


**Figure 3.** Bank-level Cost Efficiency (CE) trend (2015Q1–2024Q3)

The trends surrounding COVID-19 represented an era of efficiency pressure as intermediation was weakened during the pandemic. However, while there was governance of credit demand and there was restructuring of the other intermediation, the pandemic increased risk and costs related to intermediation (such as administrative losses, provisioning, and problem- loans). Thus, there was a greater tendency of banks being pushed away from the minimum-cost frontier, hence the Centre of Efficiency (CE) sinks. This trend aligns with the hypothesis of market perceptions and bank funding being the weakest at the beginning of the pandemic and with banks at a higher credit risk. This trend during the pandemic aligns with the theory of more 'plumable' (or more credit worthy) banks and less 'plumable' (or less credit worthy) banks as presented during the stabilizing phase of the pandemic (Aldasoro et al., 2020). The results associated with the declining bank efficiencies during the COVID-19 period in Indonesia and the risk and performance indicators capture the understanding of the overall studies surrounding the

COVID period in general (Ikhwan & Riani, 2022). This heterogeneity in the degree of decline in the speed of recovery efficiency can be used to explain discrepancies in the system losses and the available funding (or liquidity).

Stochastic Frontier Analysis (SFA) splits the closest shift of the frontier (difference in the 'minimum costs' needed) from the entity's inefficiency (a bank's distance from the frontier). The study examining the impact of COVID on the efficiency of Islamic versus conventional banks in the channeling of credit risk, profitability, capital, and liquidity as the literature posits: amplified pressure during the pandemic was directed towards higher risk banks hence the rise of strong profitability and adequate balance sheet performance (Aldasoro et al., 2020). Comparative evidence also suggests that during the pandemic Islamic banks were more liquid (had stronger buffers) and with better quality of assets, hence, possibly pointing to a more efficient operational response than conventional banks (Butt & Chamberlain, 2025). Therefore, the difference in response efficiency to the performance of risk variables (multi-factor interaction with COVID) is also as a result of the studies that see the impact of COVID 19 as a mostly shock to the quality of assets, and hence the shift in the profit-risk-liquidity response (Aldasoro et al., 2020; Ikhwan & Riani, 2022).

**Table 2.** Stochastic Frontier Analysis (SFA) estimation results

| Variabel | Koef | SE | pvalue | Sig |
|---|---|---|---|---|
| (Intercept) | 5.215120 | 1.362313 | 0.000129117 | *** |
| lnY1 | -1.497059 | 0.301989 | 7.14667e-07 | *** |
| lnY2 | 2.187832 | 0.342959 | 1.77918e-10 | *** |
| lnP1 | 0.384443 | 0.634421 | 0.544532 | |
| lnP2 | 0.290714 | 0.541330 | 0.591243 | |
| lnP3 | 0.346501 | 0.183227 | 0.0586105 | . |
| I (0.5*lnY1^2) | 0.249706 | 0.017684 | 0 | *** |
| I (0.5*lnY2^2) | 0.020775 | 0.024341 | 0.393399 | |
| I (0.5*lnP1^2) | 0.348920 | 0.137148 | 0.0109554 | * |
| I (0.5*lnP2^2) | 0.277064 | 0.089851 | 0.0020452 | ** |
| I (0.5*lnP3^2) | -0.080164 | 0.021812 | 0.000237561 | *** |
| I (lnY1* lnY2) | -0.128174 | 0.015992 | 1.11022e-15 | *** |
| I (lnP1*lnP2) | -0.275702 | 0.099132 | 0.00541652 | ** |
| I (lnP1*lnP3) | 0.038690 | 0.036612 | 0.290623 | |
| I (lnP2*lnP3) | 0.022699 | 0.030910 | 0.462727 | |
| I (lnY1*lnP1) | 0.027253 | 0.026263 | 0.299407 | |
| I (lnY1*lnP2) | 0.012753 | 0.019082 | 0.503918 | |
| I (lnY1*lnP3) | -0.028831 | 0.014010 | 0.0396013 | * |
| I (lnY2*lnP1) | 0.003857 | 0.041230 | 0.925468 | |
| I (lnY2*lnP2) | -0.018700 | 0.031370 | 0.551106 | |
| I (lnY2*lnP3) | 0.038623 | 0.015673 | 0.0137246 | * |
| Z(Intercept) | 0.525675 | 0.155970 | 0.000750687 | *** |
| NPL | -0.028383 | 0.001426 | 0 | *** |
| ROA | -0.019442 | 0.009017 | 0.03107 | * |
| CAR | -0.046236 | 0.007825 | 3.45054e-09 | *** |
| LDR | 0.004291 | 0.001831 | 0.0191235 | * |
| covid | -0.241368 | 0.182693 | 0.186445 | |
| NPLxcovid | 0.073034 | 0.016373 | 8.16578e-06 | *** |

| | | | | |
|---|---|---|---|---|
| ROAxcovid | 0.049233 | 0.015053 | 0.00107321 | ** |
| CARxcovid | 0.044901 | 0.008140 | 3.46185e-08 | *** |
| LDRxcovid | -0.009421 | 0.002067 | 5.15801e-06 | *** |
| sigmaSq | 0.003974 | 0.000364 | 0 | *** |
| gamma | 0.000064 | 0.000000 | 0 | *** |

Table 2 shows that changes in cost efficiency are largely accounted for by the explanatory variables in the inefficiency (Z) equation rather than by the fact that the dummy for the pandemic may have a pure level effect, suggesting that changes in cost due to the pandemic operate primarily through changes in the relationship between bank fundamentals and inefficiency. This interpretation is consistent with the view that the effect of the impact of the Covid-19 is evolving due to the asset quality, profitability, capitalization, and liquidity of banks during crisis conditions(Couaillier et al., 2022; Haris et al., 2024).

In the pre-COVID period, the negative and significant coefficients on NPL, ROA and CAR indicate that better management of assets quality, better profitability, and higher capital buffers are related to lower inefficiency u and consequently to higher cost efficiency CE, while the positive and significantly LDR coefficient indicates that more aggressive intermediation is related to higher inefficiency and therefore consistent with higher monitoring and risk-related costs. During the time of the Covid, the determinant structure is altered: the positive and significant NPLxCOVID and ROAxCOVID interactions undo the pre-COvid effects of NPL and ROA, thereby in the Covid pandemic regime their net impacts are efficiency-increasing which is consistent with increases in the costs of provisioning, restructuring and risk management under stress. The positive CARxCOVID interaction severely neutralizes CAR's efficiency-enhancing effect in the pre-COVID context, while the negative LDRxCOVID interaction turns LDR into an efficiency-enhancing factor suggesting that a controlled way to preserve intermediation can be helpful to reduce average costs during the pandemic.

Overall, these results reinforce that the efficiency pressure in the context of the pandemic between conventional vs Islamic are not about "bank type" but what are the fundamental (NPL, CAR, LDR, ROA) response to the pandemic shock under different business models (Elnahass et al., 2021; Ikhwan & Riani, 2022). Accordingly, Figure 2 compares average CE in the pre/non-COVID and the COVID periods by bank type, and Figure 3 shows the same comparison at the individual-bank level to show up heterogeneity which may be obscured by group averages.

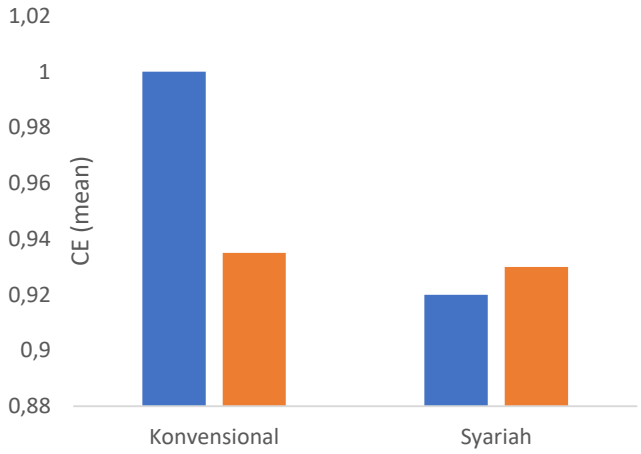


**Figure 2.** Average CE before/non-COVID (blue) vs during COVID (orange) by bank type

The Analysis shows COVID-19 is associated with changes in cost efficiency with differences in magnitude and Islamic versus conventional banks. This is in accordance

with the argument that the changes introduced by the pandemic are "translated" through fundamentals (asset quality, liquidity, and capital resilience) that are in different configuration in different models of banking. According to the 2023 IFSB, Islamic banks in different jurisdictions have been reported to have entered the crisis with relatively better liquidity and capital, though still being exposed to the real sector downturns. In Indonesia, there is also empirical evidence of differences in the performance/risk resilience exposed by Islamic versus conventional banks in the pandemic, which might account for the fact that the average CE pre- and non-COVID and during COVID may not show the same pattern of movement across bank categories (Hidayah et al., 2021).

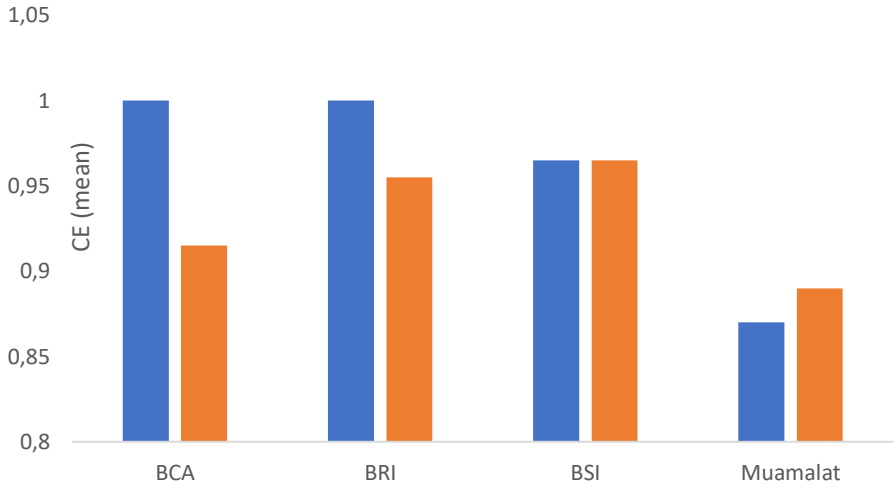


**Figure 3.** Average CE before/non-COVID (blue) vs during COVID (orange) by individual bank

Figure 3 illustrates some of the impacts of COVID-19 on the efficiency of various banks, not all banks, which suggested a decline in CE, while others showed a small decline in CE. This effect is consistent with the evidence in Ikeda et al (2021), which has shown that during the COVID-19 pandemic, a (weaker) "tail" of banks was less profitable, showed higher potential credit losses, and lagged in performance (of the banking system) when system-wide the banking system showed resiliency due to policy support. At the same time, during the COVID-19 pandemic, banks sharply increased provisions which widened the (system-wide) dispersion in provisions within the banking system. This has been attributed to the varying qualities of the banks' portfolios and their varying capacities to absorb risk (de Araujo et al. 2021), which also somewhat explains the differences in banking system efficiency. These findings add to the evidence of the pandemic's significant impact and risk sensitivity on internal and external bank performance indicators (such as NPL, NPF, ROA, CAR, and LDR) COVID-19 has affected, which suggests that the conventional–Islamic comparison should also consider the fundamentals of the banking institutions (units) and not just the types of banks (Couaillier et al., 2022).

## 4. Conclusions

This This study assesses the ramifications of the COVID-19 outbreak on the efficiency of the banking industry, more specifically on the changes in cost efficiency (CE) in the periods pre/non-COVID and during COVID. Overall, the pandemic was an episode of efficiency pressure, as there was a drop in intermediation activities, as well as an increase in risk (although there was a decline in intermediation). The impact, however, was not symmetrical across the banks. The findings presented evidence of disparate efficiency responses at the bank level, and between Islamic banks and conventional banks. This accentuates the fact that efficiency comparisons should be contextualized with the respective attributes of the institutions in question.

As for the efficiency mechanism, the results showed that the principal channel through which the pandemic affected efficiency was via the banking fundamentals, spe-

cifically, the asset quality (NPL), profitability (ROA), capital adequacy ratio (CAR), liquidity and intermediation (LDR). In other words, during the pandemic, efficiency was driven by the interplay and the impact of those fundamentals on the COVID-19 shock, rather than the COVID-19 infection itself. Therefore, the relative inefficiency of Islamic banks as opposed to conventional banks should be situated within their portfolio composition, funding structure, and risk management.

These findings refine the conventional narrative about Islamic banking efficiency during crises. Rather than implying that Islamic banks are inherently more or less efficient than conventional banks under COVID-19, our results show that crisis-time efficiency is fundamentally regime-dependent and driven by how core fundamentals translate into costs. In particular, the pandemic reconfigured the roles of asset quality and profitability, variables that appear efficiency-improving in normal times but become inefficiency-increasing during COVID--while the influence of capital buffers weakens and intermediation conditions become more strongly linked to efficiency. This implies that observed Islamic-conventional efficiency gaps during the crisis should be interpreted as outcomes of differences in portfolio risk, restructuring/provisioning pressures, funding resilience, and intermediation constraints, rather than as a stable "efficiency disadvantage" (or advantage) of the Islamic banking model itself. Accordingly, the contribution of this study is to shift the understanding of Islamic banking efficiency from a static comparison of average performance to a structural view in which the crisis changes the efficiency mechanism and, therefore, the basis on which Islamic banking performance should be assessed.

Future research should broaden the scope of the Bank of the sample survey. The importance of adding macroeconomic variables such as growth, inflation, policy rate, etc. should assist in understanding the external variables. It is also recommended in future research that the pandemic be divided into phases to help understand and portray the dynamics of the efficiency. Finally, for future research that aims to have more balanced conventional-Islamic comparisons, the inclusion of the type of contract and the quality of the contract as a part of the paradigm of financing should be valuable in evaluating and understanding the role of the digital transformation and the operational efficiency in times of cost-related crises.

This investigation also, of course, has limitations. First and foremost, the sample involves only a number of the banks, forcing generalisations to the whole industry to be circumspect. The treatment of the pandemic in the study is, at best, a period/dummy variable approach, which is almost certain to skip differences in the intensity and the imposition of restrictions during the various phases of the pandemic. SFA as a method of estimating efficiency, for example, does, albeit indirectly, depend on the specification of the cost-function and the selection of the variables; any missing relevant variables will certainly produce a specification error. Finally, the non-availability of some variables, as well as the limits of the data at a quarterly frequency, might imply that some of the sudden shifts during the early days of the crisis (including shifts in internal bank policies, which are not usually captured in banks' public financial statements) might be gone.

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