Chapter

Risk Analyses on Islamic Banks in Indonesia

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Abstract

This study aims to analyze the risks on Islamic banks in Indonesia by identifying which risk is significantly dominant in triggering other risks to happen. For that purpose, the study uses time series data on a monthly basis from 2010:M1 to 2018:M8. The data are obtained from the Financial Services Authority (OJK) Indonesia and analyzed using vector autoregression (VAR). Some variables are employed to proxy risk vulnerability including financing-to-deposit ratio (FDR) as a proxy of liquidity risk, nonperforming financing (NPF) as a proxy of financing risk, and cost-to-income ratio (BOPO) as a proxy of operational risk. The findings suggest that financing risk is the most dominant risk triggering vulnerability on Islamic banks in Indonesia.

Keywords: liquidity risk, financing risk, operational risk, Islamic banks, Indonesia

1. Introduction

In 1997, the financial crisis began in Thailand and had destroyed economies of Asian countries, especially countries that had similar economic typologies. This crisis was triggered by speculators who launched a barrage of "attacks" on the Thai currency. Its currency became more deteriorated as the economic structure of Thai currency was not accompanied by strengthening in the real sector [1].

Given such important aspect on exchange rate stability, Bello et al. [2] argue that the efficiency of risk management practices on currency volatility can be sought as the main reason for a banking collapse. The banking collapse is mainly due to mismatch problem in its balance sheet. The balance sheet becomes imbalance as the growth of its assets linked to foreign currency is not as equal as the growth of its liabilities linked to foreign currency. Consequently, risks such as liquidity risk, credit risk, and operational risk are appeared. These risks will impair gradually the bank's balance sheet; hence, this condition would need a special treatment and force a bank into a critical level until it receives bailout funds. Subsequently, when the risks were not mitigated properly, it might transmit into financial system and economic at large.

One example of the impact on banking failure into financial crisis was in August 2007. A financial crisis started when one of the largest French banks announced a freeze of some securities in the United States concerning high-risk housing loans (subprime mortgage). This incident triggered a decline in the level of public confidence in the banking sector and led to bank failures around the world.

Liquidity crisis causes declining in the household and corporate sectors' confidence toward economic conditions. The long-term pressure on banking sector had flowed to currency depreciation, strong inflationary pressures, and rising interest rates [3].

Looking at the severe impact of banking failure, it can be traced out from to what extent the risk is systematically related among systems. According to Bank Indonesia [4], the systemic risk is the main reason on severe impact from the banking failure as it causes instability as a result of contagion in some or all financial systems. The systemic risk happens due to dynamic interaction components within a financial system referring to theirs size, complexity, interconnectedness of institutions and financial markets, and excessive behavioral tendencies from actors or financial institutions to follow the economic cycle (*procyclicality*).

Given such dynamic circumstances, it can trigger banking sector vulnerability and jeopardize economic growth through uncontrolled banking risks. Some common and influential risks in banking sector include the following: *First*, liquidity risk refers to banks that cannot meet the needs of customers due to mismatch balance sheets. According to the Banker Association for Risk Management, liquidity risk is influenced by several factors, including accuracy of cash flow planning, accuracy in managing funds, availability of assets that are ready to be converted into cash, and the ability to create access to the interbank market. Financing-to-deposit ratio (FDR) is used to proxy the liquidity risk given that it represents the potential of liquidity shortage.

Second, credit risk is the risk of loss due to the failure of the counterparties to fulfill their obligations. Credit risk arises from a variety of functional bank activities, such as credit (financing in Islamic banks), treasury activities (placement of funds between banks, buying corporate bonds), and activities related to investment and trade financings. Nonperforming financing (NPF) is used as a proxy to measure credit risk due to greater NPF, which indicates bank vulnerability as it can erode bank's capital through a gradual decrease in profitability.

Third, operational risk is the risk caused by inadequate or non-functioning internal processes, due to human error or technological system failure and external events that affect the bank's operational performance. According to Aldasoro et al. operational risk represents a significant portion of the total bank risks in the banking sector. In this regard, it needs to be measured by considering operational losses compared to operational income, which is proxied by a cost-to-income ratio (BOPO) variable.

The potential risk arising in the banking sector is based on basic banking operational framework. In the case of Islamic bank, **Figure 1** shows the sequential processes which embed risks in every step involved. Bank as a financial intermediary has the main function in connecting left-hand side (funding side) and right-hand side (financing side). The connection implies a build-up risk given that a balance sheet mismatch occurs. Referring to **Figure 1**, number 1 is connected to numbers 2, 3, and 4, which indicates funds deposited are subsequently utilized for financing purposes. Mismatches can be due to dominant proportion between right-hand and left-hand sides. The higher proportion on the left-hand side implies excessive

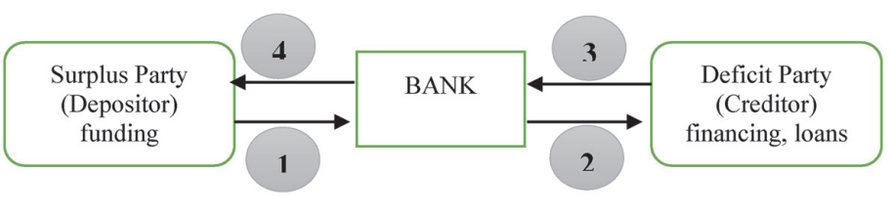

Figure 1.
Islamic banking as a financial intermediary. Sources: Bank Indonesia [5]. 1. Money deposited; 2. Money withdrawal; 3. Financing contract; 4. Profit loss sharing.

unutilized funds, which will burden the bank's balance sheet as profit diminishes, while the greater proportion on the left-hand side implies excessive utilized funds than deposited funds. Therefore, the imbalance, which potentially occurs as continuous banking operation, will always create risks, in the form of financing risk, liquidity risk, or operational risk.

Although Islamic banking cannot avoid from risk promulgation, there is no adequate evidence on what the source of risk which can lead to balance sheet's vulnerability. The existing literature however mainly focuses on factors that lead to build-up risk in Islamic banking. For example, studies by Abdullah [6], Abedifar et al. [7], Adrian and Hyun (2013), Alessi and Detken [8], and Ardiansyah et al. [9] specifically merely elaborate the determinants of risks and their relationship with a particular risk, such as credit, liquidity, and operational risks. In addition, other studies by Avdjiev et al. [10], Aysan et al. [11], and Borio [12] focus on the relationship of bank's risks with its stakeholders without taking peculiar attention to which risks frequently arise. Therefore, this study will close the gap by empirically examining what is the dominant risk in the Islamic banking given the dynamic and interrelated sides—funding and financing sides—on its operation. For that purpose, three main risks are observed—credit, liquidity, and operational—given that those risks are financially connected to Islamic banking operation. Finally, this paper contributes to the literature on risk management by investigating empirically what is the dominant risks, which are quite lacking, particularly looking at Indonesia's case. Hopefully, findings of the paper share benefits to bankers, depositors, investors, and regulators when taking decisions related to the Islamic banking industry.

2. Literature review

Risk arises when there is an unknown or unclear outcome and usually disrupts a particular system. According to Misman [13], risk is the volatility of unexpected results or variability. Risk can be divided into two types, systematic risk and unsystematic risk where numerically it can be measured by standard deviation of historical results. The main risks in the banking system, including Islamic banking, are credit and liquidity risks. The credit cycle, a mismatch of balance sheets [12], and funding constraints [14] are some of the triggering factors for risk exposures. These factors could deteriorate the banking system as a result of an inability to diversify their portfolios [15] and loan syndication [16]. Therefore, to manage risks in the banking system, credit risk and liquidity risk should be linked with the rate of growth of a bank's aggregate balance sheets that remain surplus (high liquidity borrowers and short-term debt) [17–20].

According to Wiranatakusuma and Duasa [21], there are two important risks that are embedded in Islamic bank, which include liquidity risk and credit risk. Credit risk issues are related to banking operations amidst high-nonperforming loans. Banks as financial intermediaries have to meet short-term obligations. When a bank fails to settle its obligations, that means the bank is at risk of bankruptcy. When there is long failure of insolvency situation, the capital will be affected due to the emergency need in maintaining operations and the systematic risk mitigation. Therefore, credit risk is followed by operational risk as capital is gradually eroded. Subsequently, insolvency in financing disbursement would affect the left-hand side (bank-depositor relationship) as the bank is unable to settle its deposited funds' return. It was the signal that the bank is facing liquidity problem due to balance sheet's mismatch.

Therefore, to further clarify the credit, liquidity, and operational risks, some studies explain as follows:

2.1 Liquidity risk

The definition of liquidity risk can be broadly defined as the ability to meet cash at an appropriate cost. Liquidity is important for banks to carry out their business transactions, address urgent needs, satisfy customer demands for loans, and provide flexibility in achieving attractive and profitable investment opportunities. For that purpose, Islamic bank needs to implement liquidity management practices in order to mitigate the potential risk occurrence. According to Sholikhah [22], banking liquidity management is about how banks can fulfill both current liabilities and future liabilities in the event of an asset liability withdrawal or repayment. In other words, the liquidity risk appears in accordance with the agreement which has not been agreed (unexpected) previously. Therefore, bank liquidity management is required to liability management through which banks can convince the depositors concerning their fund withdrawal at any time or at maturity. Hence, looking at the potential mismatch between assets and liabilities, the banking sector needs to monitor the potential liquidity risk through its financing-to-deposit ratio or FDR variable.

2.2 Credit risk

Credit risk is a major source of financial systems. According to the Indonesia Banks Association [23], credit risk is the risk of losses due to failure of counterparties to fulfill their obligations. Usually this risk comes from several banking functional activities such as credit or financing. Nowadays, the productive assets of banks are dominated by loans, while the most important sources of bank funds are from third-party funds or DPK so that if there is a significant increase in credit risk to banks, the influence on bank performance will be severe as the pressure from deposited funds. Hence, due to connected sources between deposited and disbursed funds, the potential loss due to financing activities must be controlled by monitoring nonperforming financing or NPF variable.

2.3 Operational risk

Operational risk affects basically the ability of banking sector to generate profits and its capacity to adjust revenues and expenses. Operational risks are triggered from banking sector activities in the midst of diversity and connectivity. Given that more diverse and competitive banking sectors exist, the banking sector tends to excessively generate assets as profit maximization motive. However, the lack of system and human capacity necessitates more investment or additional cost; otherwise, there will be less competitive and market penetration. Hence, the banking sector needs to properly monitor the ratio between its cost and revenue to ensure its sustainability and continuous profitability. The BOPO is variable to identify the potential operation risk in Islamic banking.

3. Data and methodology

3.1 Research objective and data type

The object in this study is Islamic banking in Indonesia. Its risks are analyzed by time series data published by Bank Indonesia and the Financial Services Authority Indonesia. The data spanned from January 2010 to August 2018 due to the new phase of the new normal of global economy where the global economy starts to increase after the global financial crises indicated by the growth of East Asian

country and China economy, including in Indonesia. The new normal refers to the business cycle (expansion, peak, recession, trough, and recovery phase).

3.2 Data collecting techniques

According to the embedded risks in the banking sector, this study employs three main variables that are the proxies of the three main risks, including financing, liquidity, and operational risks. The FDR, NPF, and BOPO are used to proxy the observed risks.

3.3 Operational definition of observed variables

The operational definition of these variables is as follows:

3.3.1 FDR

FDR is a ratio that shows banking intermediaries and proxies to the liquidity of Islamic banks. The FDR is computed by dividing the total amount of financing with the total third-party funds. The FDR in Islamic bank is used to measure the capabilities of Islamic banking to meet the repayment of deposits upon maturity or without any delays. If the FDR is more than 1, it means that the total financing provided by the bank exceeds the funds collected from depositors. This situation has the potential risk to cause liquidity risk for Islamic banks. The FDR is formulated as follows:

$$FDR = \frac{Total\ Financing}{Total\ Third\ Party\ Funds\ collected} \times 100\% \quad (1)$$

3.3.2 NPF

NPF is the amount of unclaimed credit and represents the low quality of banks' assets. This variable is the ratio between the total nonperforming financing and the total financing provided by Islamic banks. The NPF is a nonperforming financing consisting of financing classified due to the lack of transparency and doubt in repayment. Usually the NPF value is the result of the failure of the debtors to fulfill their obligations. Bank Indonesia stipulated a 5% limit for Islamic banks concerning the NPF value. Technically, the NPF is formulated as follows:

$$NPF = \frac{Non\ Performing\ Financing}{Total\ Financing} \times 100\% \quad (2)$$

3.3.3 The BOPO

The BOPO measures the efficiency and ability of the bank to generate profits from its business activities. A smaller BOPO represents the fact that banks can cover their expenses by using their operational revenues. The BOPO is formulated as follows:

$$CIR = \frac{Total\ Operating\ Expenses}{Total\ Operating\ Revenue} \times 100\% \quad (3)$$

3.4 Research estimation method

Research problems will be analyzed by using vector autoregression (VAR), which is based on the risk of Islamic banks. Technically, if the data is found

stationary at the first difference, the VAR model will be then combined with the error correction model becoming the vector error correction model (VECM). This study refers to the previous study, such as by Ascarya which mathematically develops a general model as:

Risk on Islamic bank, which is formulated as follows:

$$FDR_t = \Phi_0 + \Phi_1 NPF_t + \Phi_2 BOPO_t \quad (4)$$

$$NPF_t = \Phi_0 + \Phi_1 BOPO_t + \Phi_2 FDR_t \quad (5)$$

$$BOPO_t = \Phi_0 + \Phi_1 FDR_t + \Phi_2 NPF_t \quad (6)$$

where FDR_t is the financing-to-deposit ratio; NPF_t is the nonperforming financing; and $BOPO_t$ is the cost-to-income ratio.

3.5 Research model and analysis method

The data analysis technique involves a technique that analyzes data and tests its validity [24]. This study uses parametric inferential statistical techniques, specifically the vector error correction model (VECM) method. It is used to determine the relationship either in the short- or in the long-term relationship among variables. In terms of the research design, the steps for data analysis technique are as follows:

3.5.1 Testing stationary data

The first step that must be done in the VECM estimation is to test stationary data. The data can be declared stationary if the time series data have a tendency to move toward the average. According to Kuncoro [25], those data are stationary when they are drawn against time. It will often pass through the horizontal axis, and autocorrelation will decrease regularly for a considerable lag. Subsequently, the data are considered as stationary if it meets the following two conditions:

a. The average covariance is constant over time.

b. Covariance between two data sequences depends on lags between the two periods.

According to Basuki [26], to test the data stationarity, the augmented Dick-Fuller (ADF) test is used. If the t-ADF value is smaller than the MacKinnon critical value, it can be concluded that the data used are stationary or do not contain unit roots. The testing of the roots of this unit is carried out at the level up to the first difference. If the data level is not statistically achieved, a first difference test is necessary.

3.5.2 Selecting lag length criteria

Time (lag) in economics is used to explain the dependence of one variable on another variable. The determination of lag length is done to determine the parameter estimates in VECM. In the VECM estimation, the causality relationship is strongly influenced by lag length. In addition, Basuki and Yuliadi [27] also explained that if the lag entered is too short, it is feared that the resulted estimation is inaccurate. Conversely, if the lag entered is too long, it will produce inefficient

estimation results. The determination of optimum lag length is then important and can be computed by using EViews software.

3.5.3 Testing the stability of VAR models

Before testing VAR estimation, a stability test must first be carried out. According to Basuki and Yuliadi [27], the stability of the model needs to be tested because it will affect the results of impulse response function (IRF) and variance decomposition (VDC). If stability is not tested, the results of the IRF and VDC analysis are invalid. A VAR system can be said to be stable or fulfill a stability test if the value of the entire root or root has a modulus smaller than one. In this study, it is known that the modulus value is less than one, which means that the result from IRF and VDC analyses is valid.

3.5.4 Testing cointegration test

A cointegration test is the test intended to see whether there is a long-term relationship between a particular variable and another variable. In the VECM estimation, a cointegration test is very necessary to determine whether each variable has a relationship in the long-term or just short-term relationship. Technically, if the observed variables do not have a cointegration relationship, then the VECM estimation does not apply. If, the opposite, data had a relationship in the long term (cointegration), then VECM is applied.

According to Basuki and Yuliadi [27] as stated by Engle-Granger, the existence of non-stationary variables causes the possibility of a long-term relationship between variables in the system. The cointegration test is performed to determine the existence of the relationship between variables, especially in the long term. If there were cointegration on the variables used in the model, it can be ascertained that there is a long-term relationship between the variables. The *Johansen cointegration* method can be then used to test the existence of this cointegration.

3.5.5 Applying VECM

The VECM is a derivative model of VAR. The difference between VAR and VECM is the VECM estimations, particularly in measuring cointegration condition. If there is a cointegration relationship between variables, it indicates a long-term relationship [27]. VECM is often referred for non-stationary series that has a cointegration relationship. The VECM specification limits the relationship of endogenous variables in the long run to remain convergent in cointegration relationships, but still considers the existence of short-term relationships. The process for deciding on the VECM method can be seen in **Figure 2**.

3.5.6 Applying IRF

The IRF analysis was conducted to check the shock response of each variable. Therefore, the effect of shock from one variable can be explained clearly against other variables. The IRF results prove how long it takes from one variable to respond to the other variable.

3.5.7 Applying VDC

VDC analysis aims to measure the size of the contribution or composition of the influence of each variable to other variable. VDC analysis will provide information

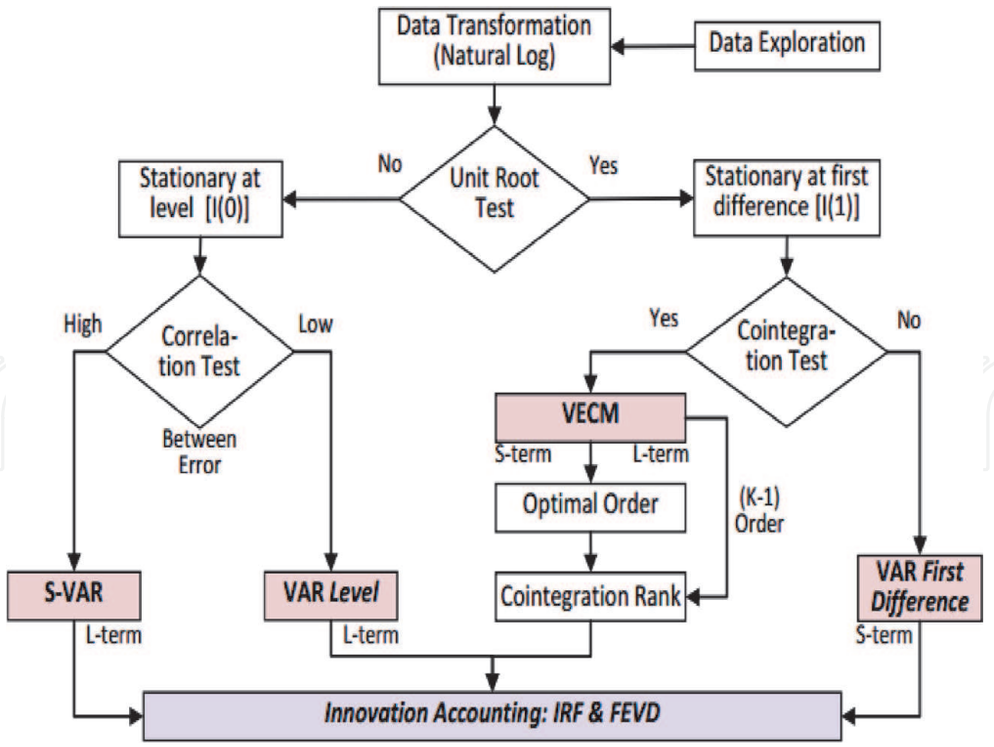

Figure 2.
Vector error correction model. Source: Gujarati [28].

about the magnitude and duration of the shock proportion of a variable to the variable itself and to other variables. According to Basuki [26], variance decomposition aims to measure the magnitude of the contribution or composition of the influence of each independent variable on the dependent variable.

3.5.8 Testing Granger causality

According to Basuki [26], the Granger causality test is used to see whether two variables have a reciprocal relationship or not. The variable can have a causal relationship with other variables significantly. It implies each variable has the opportunity to become an endogenous or exogenous variable.

4. Result and analysis

4.1 Causality test and data instruments

4.1.1 Unit root test

The VECM estimation is started by testing the data stationarity of each variable as the initial process. To detect the stationarity of each variable, the ADF test is used with the intercept model. Data sets are declared stationary if the average values and variants of the time series data do not change systematically over time or the averages and their variants are constant [29]. The ADF stationary test for each variable can be indicated as follows.

According to **Table 1**, at the level, there is no single variable that meets stationary requirements, either from FDR, NPF, or BOPO. It is indicated by the value of t-ADF which is greater than the Mackinnon critical value, so it is necessary to test at the first difference level shown in **Table 2**.

Based on **Table 2**, it can be concluded that all variables are stationary at the *first difference* with a predetermined critical value (α = 5%), as follows:

a. The FDR variable in the *first difference* level test shows that the ADF t-statistic value is smaller than the *MacKinnon critical value* 5%, which is −11.55782 < −2.890037, which means H_0 is rejected and H_1 is accepted or the FDR variable data is stationary.

b. The NPF variable in the *first difference* level test shows that the ADF t-statistic value is smaller than the *MacKinnon critical value* 5%, which is −4.724193 < −2.890623, which means H_0 is rejected and H_1 is accepted or the NPF variable data is stationary.

c. The BOPO variable at the first difference level test shows that the ADF t-statistic value is smaller than the MacKinnon critical value 5%, which is −11.03276 < −2.890037, which means H_0 is rejected and H_1 is accepted or the BOPO variable data are stationary.

From the above tests, all variables have met data stationary. The ADF t-statistics are smaller than the McKinnon critical value 5% at the first difference level. Therefore, the next step is to estimate the data by VECM by selecting its lag length criteria.

4.1.2 Lag length criteria

The lag length is used to determine the effect of the time taken from each variable on the past variable. The selected lag candidates are the length of lag according to the *likelihood ratio* (LR) criterion, *final prediction error* (PPE), *Akaike information criterion* (AIC), *Schwarz information criterion* (SIC), and *Hannan-Quinn criterion* (HQC). The determination of the optimal lag length in this study is based

Variable	t-Statistic	The Mackinnon critical value			Prob	Conclusion
		1%	5%	10%		
FDR	−1.011989	−3.495021	−2.889753	−2.581890	0.7440	Non-stationary
NPF	−1.55662	−3.497029	2.890623	−2.582353	0.5009	Non-stationary
BOPO	−1.786319	−3.495021	−2.889753	−2.58189	0.3854	Non-stationary

Sources: Author's calculation.

Table 1.
Unit root test-augmented Dickey-Fuller (level).

Variable	t-Statistic	The Mackinnon critical value			Prob	Conclusion
		1%	5%	10%		
FDR	−11.55782	−3.495677	2.890037	−2.582041	0.0000	Stationary
NPF	−4.724193	3.497029	2.890623	2.582353	0.0002	Stationary
BOPO	−11.03276	−3.495677	2.890037	−2.582041	0.0000	Stationary

Sources: Author's calculation.

Table 2.
Unit root test-augmented Dickey-Fuller (first difference).

on the sequential modified LR test statistical criteria. The lag length that was included in this study is from 0 to 3.

Based on **Table 3**, the optimal lag on all variables from FDR, NPF, and BOPO is in lag 3, that is, with the sequential modified LR test statistic 24.77971, PPE 4.037246, and AIC 9.907182. Therefore, the optimal lag has been statistically determined and the VAR stability test is carried out.

4.1.3 Stability VAR model test

The stability test of the VAR model was used to test IRF and VDC. The stability test for VAR estimation can be seen in **Table 4**.

Based on **Table 4**, it can be explained that the model used is stable in lags of 0–3. This can be seen from the range of modules with an average value of less than one. Therefore, the results of the IRF and VDC analyses are valid, so that the cointegration test can be done.

4.1.4 Cointegration test

The fourth stage that must be passed in the VECM estimation is the cointegration test. Cointegration tests are conducted to determine whether there is a long-term relationship on each variable. If there is no cointegration relationship, the VECM estimation cannot be used. This study uses the Johansen cointegration test method available in EViews 7.2 software with a critical value of 0.05. The cointegration test results are shown in **Table 5** as follows.

Based on **Table 5**, at the 5% test level, there are three ranks of cointegration variables. This can be proven from the values of trace statistic, which are 80.84738,

Lag	LogL	LR	FPE	AIC
0	−502.5902	NA	4.943996	10.11180
1	−491.1235	22.01603	4.706602	10.06247
2	−479.1256	22.31603	4.435183	10.00251
3	−465.3591	24.77971*	4.037246*	9.907182*

Sources: Author's calculation.
**5% level of significance.*

Table 3.
Lag length criteria.

Root	Modules
0.165181–0.446285i	0.475873
0.165181 + 0.446285i	0.475873
−0.239743–0.404530i	0.470235
−0.239743 + 0.404530i	0.470235
−0.239164–0.036076i	0.241869
−0.239164 + 0.036076i	0.241869

Sources: Author's calculation.

Table 4.
Test of VAR stability.

Hypothesized no. of CE(s)	Trace static	Prob	Critical value	Variable
None *	80.84738	0.0000	29.79707	FDR
At most 1 *	36.79544	0.0000	15.49471	NPF
At most 2 *	12.11161	0.0005	3.841466	BOPO

Sources: Author's calculation.
**5% level of significance.*

Table 5.
Cointegration test.

36.79544, and 12.11161 and which are greater than the critical value of 0.05, namely, 29.79707, 15.49471, and 3.841466, respectively. In this regard, H_0 is rejected and H_1 is accepted. It implies that all variables have influence in the long term or are cointegrated with each other. Therefore, the next step is to carry out analysis with the VECM estimation.

4.1.5 VECM estimation

Having tested the existence of VECM, the analysis is to estimate on how short-term and long-term relationships affect each other. The variables of FDR, NPF, and BOPO show the significant effect on lag 3 in monthly data.

Table 6 shows the influence of each variable to other variables, particularly the relationship between FDR with NPF and FDR with BOPO. The short-term estimation results show that the FDR variable is influenced by the NPF variable in lag 1, which has a positive effect of 1.36%. In lag 2, the relationship of the NPF negatively affects FDR for −0.37%. Furthermore, in lag 3, the NPF has a positive effect to FDR with a value of 0.34%. Then, the FDR variable is influenced negatively by the BOPO in the first lag until the third.

Table 6 shows the influence of BOPO and FDR to NPF. Results show that the NPF variable is influenced by the BOPO in the first lag which has a negative effect of −0.01% and the second lag also shows a negative effect of 0.02%. Then, the NPF variable is influenced by the BOPO in the third lag which has a positive effect that is 0.005%. Then, the NPF variable influenced by the FDR variable negatively affects the first lag until lag 3.

Furthermore, **Table 6** shows the relationship between BOPO with FDR and NPF. Empirically, BOPO is influenced positively by the FDR variable in the first and second lags for 0.12 and 0.11%, respectively, but in the third lag, the variables have a negative effect of −0.22%. On the contrary, the BOPO is influenced by the NPF, which has a negative effect on the first lag and third lag, which is −0.95 and − 0.60%, respectively, but in the third lag, it shows a positive effect on the BOPO, namely, 1%.

Table 7 shows the summary of direction among variables. Results generally indicate that NPF has positive effects toward FDR and BOPO. It implies that NPF that is a proxy variable for financing risk could trigger other risk occurrence, namely, liquidity and operational risks, in the short run.

Based on **Table 8**, VECM estimation analyzes the influence of variables in the long term. The FDR variable is influenced by NPF and BOPO variables. In the first lag, the FDR variable was influenced negatively by −72.58%. However, in contrast to the first lag, the FDR variable was influenced positively by BOPO for 9.02%. The NPF variable is influenced by the BOPO variable and the FDR variable. In the first lag, both variables negatively affect the values of 0.12 and 0.01%. The BOPO variables are influenced by FDR and NPF variables. In the first lag, the BOPO variable is

	Variable	Coefficient	t-Statistic partial
FDR	CointEq1	0.001081	[0.17523]
	D(FDR(−1))	−0.255421	[−2.50543]
	D(FDR(−2))	0.038103	[0.37947]
	D(FDR(−3))	0.271292	[2.86236]
	D(NPF(−1))	1.360963	[2.11235]
	D(NPF(−2))	−0.37662	[−0.59751]
	D(NPF(−3))	0.344605	[0.55659]
	D(BOPO(−1))	−0.207859	[−2.93623]
	D(BOPO(−2))	−0.223429	[−3.27360]
	D(BOPO(−3))	−0.01964	[−0.28727]
	C	−0.112072	[−0.60029]
NPF	CointEq1	−0.197484	[−2.69286]
	D(NPF(−1))	−0.081274	[−0.77003]
	D(NPF(−2))	−0.015491	[−0.15002]
	D(NPF(−3))	0.404753	[3.99059]
	D(BOPO(−1))	−0.015403	[−1.32823]
	D(BOPO(−2))	−0.023770	[−2.12593]
	D(BOPO(−3))	0.005957	[0.53189]
	D(FDR(−1))	−0.010509	[−0.62922]
	D(FDR(−2))	−0.015999	[−0.97261]
	D(FDR(−3))	−0.005072	[−0.32666]
	C	−0.008109	[−0.26512]
BOPO	CointEq1	−0.282793	[−3.19815]
	D(BOPO(−1))	0.042771	[0.38050]
	D(BOPO(−2))	0.034201	[0.31558]
	D(BOPO(−3))	0.052325	[0.48200]
	D(FDR(−1))	0.122321	[0.75564]
	D(FDR(−2))	0.119351	[0.74857]
	D(FDR(−3))	−0.224285	[−1.49029]
	D(NPF(−1))	−0.953621	[−0.93213]
	D(NPF(−2))	−0.600455	[−0.59994]
	D(NPF(−3))	1.006292	[1.02358]
	C	0.101554	[0.34256]

Sources: Author's calculation.

Table 6.
VECM in short term.

influenced by the FDR variable which has a positive effect of 0.01%. Then, in the first lag, the BOPO variable is influenced by the NPF variable, which has a negative effect of −8.03%. Therefore, in the long run, only operational risk—proxied by BOPO—affects positively the liquidity risk, proxied by FDR.

Dependent variables	Independent variables		
	NPF	**FDR**	**BOPO**
NPF	Positive (lag-3)	Not significant	Negative (lag-2)
FDR	Positive (lag-1)	Negative (lag-2)	Negative (lags-1 and − 2)
BOPO	Positive (lag −3)	Negative (lag-3)	Not significant

Source: Author's calculation.

Table 7.
Summary of direction of influence among variables.

	Variable	Coefficient	t-Static partial
FDR	NPF(−1)	−72.5889	[−4.47911]
	BOPO(−1)	9.029681	[4.64308]
NPF	BOPO	−0.1244	[−7.14765]
	FDR	−0.01378	[−0.67799]
BOPO	FDR	0.110746	[0.75713]
	NPF	−8.038916	[−7.70009]

Sources: Author's calculation.

Table 8.
Vector error correction model (VECM) in long term.

4.1.6 Impulse response function (IRF)

The IRF analysis explains the effects of shocks (shock) on one variable from the other variables, both in the short term and in the long term. The IRF also analyzes on how long the shocks take place. The horizontal axis shows the period of the year, while the vertical axis shows the response value in percentage, as the following details:

4.1.6.1 Impulse response FDR to NPF

The first IRF analysis will explain the response received by the FDR to the *shock* of NPF. According to **Figure 3**, the response of the FDR if there was a shock from NPF is positive (+), where it shows an increase trend from periods 1 to 3. But, then in the 3rd to 10th period, the response of the FDR variable to NPF shock decreased. These results are consistent with findings from VECM estimation either in the short or long run where FDR will be fluctuating in short period and tends to be less volatile in the long run due to shocks from NPF. This condition indicates that liquidity risk in Islamic banks is only influenced by financing risk in the short run and decreases toward equilibrium in the long run.

4.1.6.2 Impulse response FDR to BOPO

Figure 4 shows the response of FDR due to shocks coming from BOPO. Its responses are negative in the first three periods but tend to positive afterward. These conditions are consistent with VECM estimation where in the short run its relationship is negative, but positive in the long run. It indicates that liquidity risk is sensitive in both short and long runs due to shocks originated from operational risk.

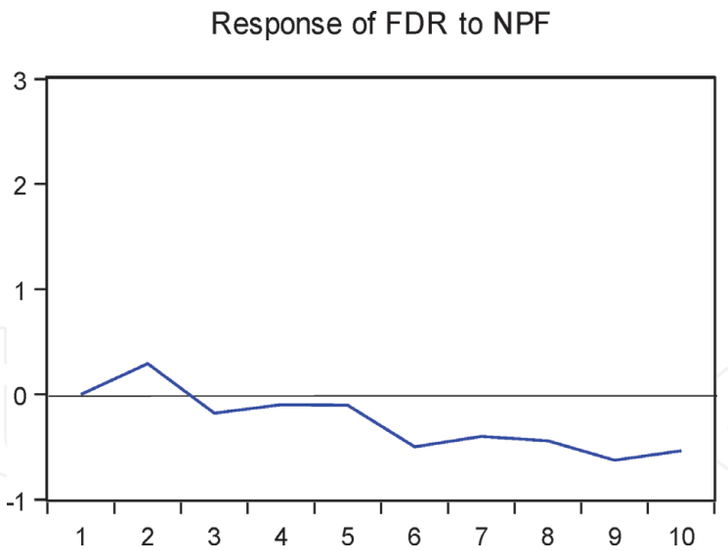

Figure 3.
Impulse response FDR to NPF. Source: Author's calculation.

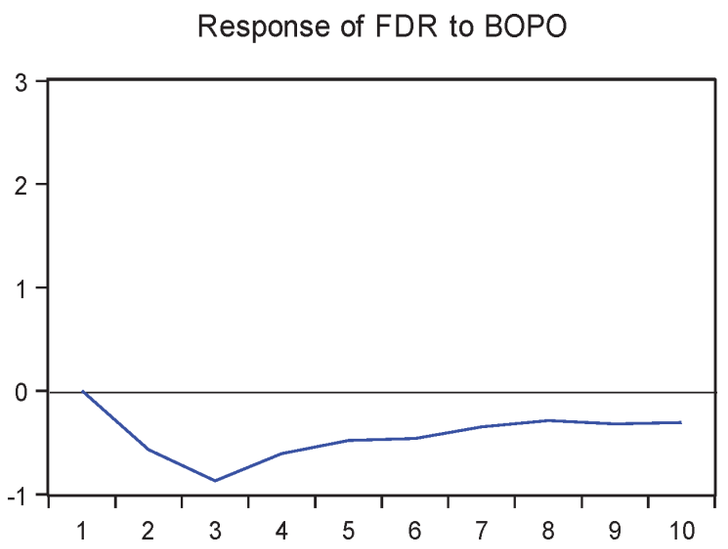

Figure 4.
Impulse response FDR to BOPO. Source: Author's calculation.

4.1.6.3 Impulse response variable NPF to variable FDR

Figure 5 shows the response of NPF due to shocks from FDR. Results indicate that NPF responds negatively but only for less than two periods, and then it is stable toward its long-term movements. These findings are in line with VECM estimation where NPF is significantly affected by FDR in the short run, but not significant in the long run. It implies that financing risk exists and sensitive only in the short run due to liquidity risk, but not in the long run.

4.1.6.4 Impulse response variable NPF to variable BOPO

Figure 6 shows the response of NPF due to shock from BOPO. Results suggest that in the first three periods, NPF responds positively and continues to increase in the long run. These findings are not linear with VECM estimation where NPF is suggested to be negatively influenced by BOPO, either short or long run. Furthermore, the findings suggest that financing risk is quite sensitive toward operational risk.

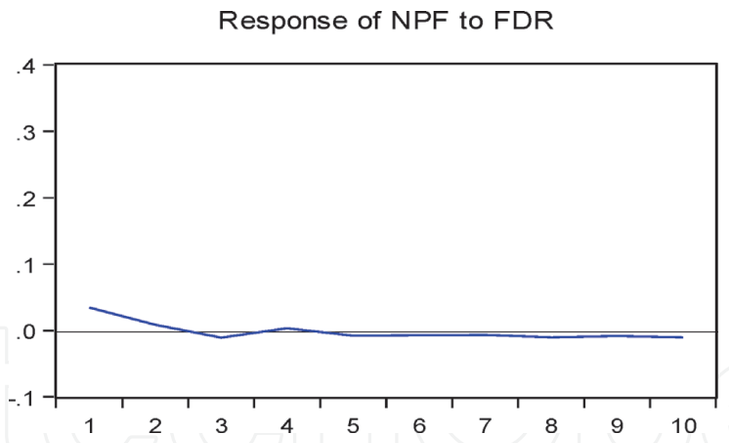

Figure 5.
Impulse response NPF to FDR. Source: Author's calculation.

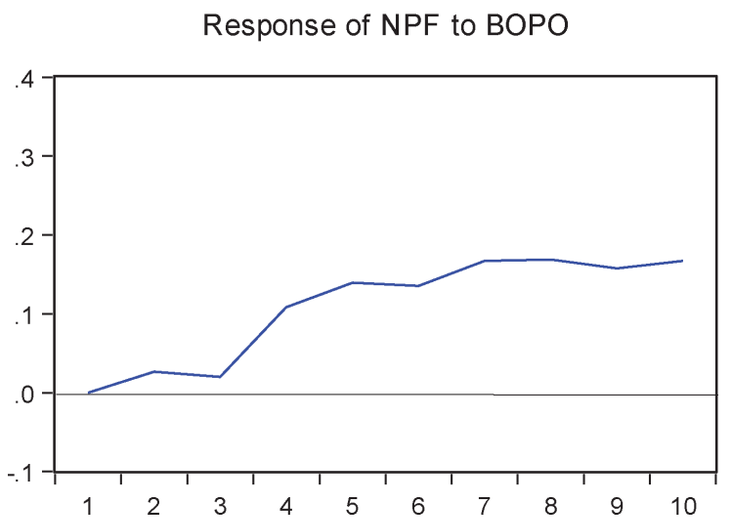

Figure 6.
Impulse response NPF to BOPO. Source: Author's calculation.

4.1.6.5 Impulse response variable BOPO to variable FDR

Figure 7 shows the response of BOPO due to shocks from FDR. The findings suggest initially it responds positively until the first three periods. However, the trend is negative in the long run. These conditions are consistent with VECM estimation where both variables have a negative relationship in the short run, but no relationship in the long run. It indicates that operational risk is only affected in the short run, not in the long run.

4.1.6.6 Impulse response variable BOPO to variable NPF

Figure 8 shows the response of BOPO due to shocks from NPF. The findings suggest that BOPO responds positively in the first four periods due to shocks from NPF, but tend to decline in the long run. In this regard, these findings are consistent with VECM estimation where BOPO is sensitive due to the change of NPF. These conditions also indicate that operational risk is sensitive toward financing risk in Islamic bank.

Table 9 shows the summary of risk sensitivity based on originated shocks into Islamic banks. The findings suggest that the risks in Islamic banks are interrelated to each other, in either the short or long run. Specifically, **Table 9** suggests as follows:

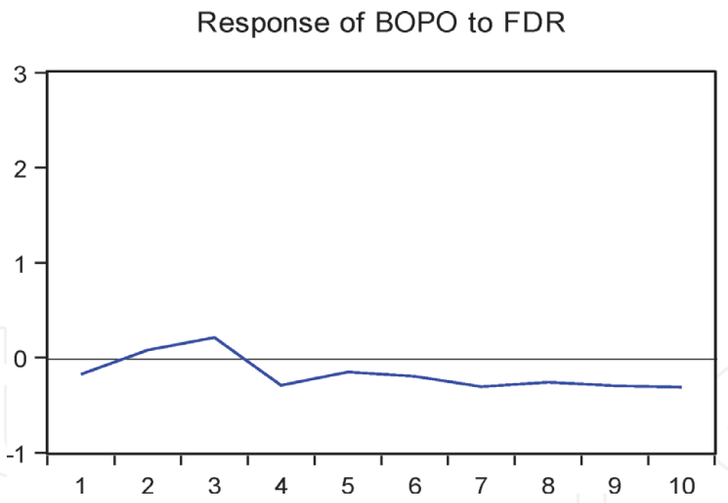

Figure 7.
Impulse response BOPO to FDR. Source: Author's calculation.

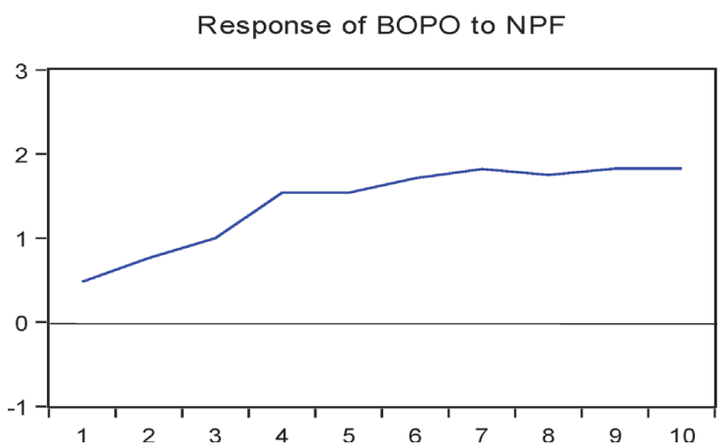

Figure 8.
Impulse response BOPO to NPF. Source: Author's calculation.

a. NPF which is the proxy of financing risk negatively responds shocks from FDR, but positively from BOPO. The former indicates that Islamic banks have conducted sound risk management practices, especially concerning with financing risk in the mid of higher financial intermediaries, while the latter indicates that Islamic banks have high sensitivity of financing risk due to failure in managing operational risk, such us human error, information system, and standard operational procedure.

Sensitivity of risk	**Shock originator**		
	NPF	**FDR**	**BOPO**
NPF—financing risk		Negative (short run)	Positive (short and long runs)
FDR—liquidity risk	Negative (short and long runs)		Negative (short run) and positive (long run)
BOPO—operational risk	Positive (short and long runs)	Positive (short run) and negative (long run)	

Source: Author's calculation.

Table 9.
Summary of impulse response results.

b. FDR which is the proxy of liquidity risk negatively responds originated shocks from both NPF and BOPO. These conditions imply that although the values of NPF and BOPO are high, Islamic banks are able to manage the liquidity risk, shown by negative responses of FDR variable.

c. BOPO which is the proxy of operational risk positively responds positively originated shocks from NPF and FDR. These conditions imply that operational risk in Islamic banks sensitively occurred and risk management procedure needs to be improved. The positive sign indirectly indicates that financing and liquidity risk would easily trigger the operational risk in Islamic banks, which means Islamic banks should take more serious efforts to settle the operational aspects.

4.1.7 Variance decomposition

This analysis aims to measure the composition or contribution of the influence of each variable to other variables. This study focuses on looking at the influence of variables, including FDR, NPF, and BOPO. The findings of VDC are shown as follows.

Table 10 shows the contribution of FDR, NPF, and BOPO toward FDR fluctuations. The findings suggest that FDR fluctuations are mainly influenced by FDR itself, even until the 10th period. Numerically, the shares of other variables are less than 10%. However, although the shares originated from NPF and BOPO are not dominant, any fluctuations of FDR are contributed by other variables. In other words, the liquidity risk existed in Islamic banks is insignificantly contributed by other risks, and it then implies Islamic banks frequently face liquidity problems in their balance sheets. In addition, these findings corroborate the previous findings suggested by impulse response that liquidity risk is negatively affected by financing and operational risks, which means it is mainly caused by liquidity itself (banks' balance sheet mismatch).

Table 11 shows the variance decomposition of NPF due to the fluctuations from NPF itself, FDR, and BOPO. Empirically, the fluctuations of NPF initially are influenced by NPF itself. However, its composition gradually declines as other

Period	SE	FDR	NPF	BOPO
1	1.843409	100.0000	0.000000	0.000000
2	2.433074	93.07333	1.419375	5.507292
3	3.025591	86.88472	1.272146	11.84314
4	3.645556	88.13094	0.948149	10.92091
5	4.108004	89.21504	0.809155	9.975805
6	4.599803	89.21948	1.820409	8.960113
7	5.051028	89.96607	2.130988	7.902945
8	5.459352	90.48151	2.479191	7.039295
9	5.876766	90.34842	3.281494	6.370083
10	6.257649	90.52347	3.623686	5.852848
Total average	4.2300232	90.784298	1.7784593	7.4372431

Sources: Author's calculation.

Table 10.
Variance decomposition of FDR.

Period	SE	FDR	NPF	BOPO
1	0.301986	1.284774	98.71523	0.000000
2	0.375125	0.886743	98.61763	0.495627
3	0.416529	0.785144	98.59483	0.620030
4	0.517248	0.513238	94.73262	4.754143
5	0.579325	0.428273	90.02078	9.550951
6	0.624881	0.380940	86.74632	12.87274
7	0.691786	0.319991	83.37349	16.30652
8	0.742180	0.297634	80.39042	19.31195
9	0.784787	0.277975	78.41862	21.30341
10	0.834778	0.269536	76.93120	22.80826
Total average	0.5868625	0.5444248	88.654114	10.8023631

Sources: Author's calculation.

Table 11.
Variance decomposition of NPF.

variables' shares gradually increase. On the 10th period, the share of NPF stands for 76.93, FDR remains small, but BOPO shares a majority portion around 22.8. These findings imply that financing risk frequently occurs in Islamic banks, and this risk is quite large contributed by the operational risk. In addition, the results strengthen the previous findings obtained through impulse response that financing risk is empirically triggered by operational risk.

Table 12 shows the variance decomposition of BOPO. Empirically, the results suggest that initially the fluctuation on BOPO is contributed by BOPO itself, but gradually other variables influence it. Until the 10th period, BOPO fluctuations are dominantly attributed by NPF for around 46.42%, but with a negligible portion of FDR. It implies that operational risk in Islamic banks is mainly contributed by financing risk and a small portion from liquidity risk.

Period	SE	FDR	NPF	BOPO
1	2.927100	0.357969	2.680542	96.96149
2	3.735015	0.265543	5.788679	93.94578
3	4.198097	0.466521	10.22600	89.30747
4	4.645547	0.781165	19.34129	79.87754
5	5.026835	0.754420	25.87602	73.36956
6	5.431698	0.777258	32.08065	67.14209
7	6.226521	0.940389	37.36899	61.69062
8	6.226521	1.003506	40.89494	58.10156
9	6.612534	1.089031	43.87340	55.03757
10	6.985251	1.172802	46.13966	52.68754
Total average	5.2015119	0.7608604	26.4270171	72.812122

Sources: Author's calculation.

Table 12.
Variance decomposition of BOPO.

Dependent variables	Independent variables		
	NPF	**FDR**	**BOPO**
NPF	76.93120	0.269536	22.80826
FDR	3.623686	90.52347	5.852848
BOPO	46.13966	1.172802	52.68754

Source: Author's calculation.

Table 13.
The summary of variance of decomposition at the 10th period (%).

Table 13 shows the summary of variance decomposition function at the 10th period. The findings suggest that the main risk that triggers Islamic bank is liquidity risk, while other risks that show the highest contribution toward risk vulnerability are financing risk and operational risk. Therefore, Islamic banks will always face these risks, and they are categorized as the core or main risk in Islamic banks, particularly in Indonesia.

4.1.8 The Granger causality test

The Granger causality test is used to determine the causal relationship of each variable with other variables. The test level used in the Granger causality test is the level of confidence ($\alpha = 0.05$) with lag length 2, according to the optimal lag length that has been done previously. Results of the Granger causality test are as follows.

Table 14 shows the causality between variables with various probability values. The findings suggest that the variables have one-directional relationship, namely:

a. There is one-directional relationship between NPF and FDR. It means that the vulnerability in Islamic banks due to liquidity risk is empirically caused by financing risk. This finding strengthens the previous findings obtained through VECM estimation and IRF that financing risk affects the liquidity risk though its relationship is negative and small.

b. There is one-directional relationship between BOPO and FDR. It means that the vulnerability in Islamic banks due to liquidity risk is empirically caused by operational risk. This finding corroborates the previous findings that liquidity

H0	Lag 2	
	f-Statistic	**Prob**
NPF does not Granger cause FDR	**5.44792**	**0.0057**
FDR does not Granger cause NPF	1.67488	0.1927
BOPO does not Granger cause FDR	**7.97421**	**0.0006**
FDR does not Granger cause BOPO	0.16992	0.8440
BOPO does not Granger cause NPF	2.40254	0.0959
NPF does not Granger cause BOPO	**4.91669**	**0.0092**

Source: Author's calculation.
1% level of significance

Table 14.
The Granger causality test.

risk exists if Islamic banks fail to settle operational problems, especially in the long run.

c. There is one-directional relationship between NPF and BOPO. It means that the vulnerability in Islamic banks due to operational risk is empirically caused by financing risk. This finding strengthens the previous results that operational risk is positively affected by financing risk, either short or long term, with a quite high degree of contribution.

In short, empirically the risks in Islamic banks are mainly caused by financing risk. The one-directional relationship implies that bank's vulnerability exists due to the inability of the bank to manage nonperforming financing. Bank's balance sheet is vulnerable toward any disruptions on financing problems. It is rational in the midst that Islamic banks have limited funds than conventional banks and offer various Islamic contracts. These conditions enable Islamic banks to face systemic risks when a problem occurs on the asset side as both sides are connected according to the bank's balance sheet flow process.

4.2 Analysis

Table 15 summarizes some empirical findings concerning embedded risks in Islamic banks with various assessment methods. In general, there is an interrelated risk in Islamic banks. However, based on several assessment methods, the findings suggest that only financing and operational risks have causal relationship with liquidity and operational risks. The details concerning these relationships are as follows:

4.2.1 Financing risk

According to **Table 15**, the financing risk will affect liquidity risk. The Granger causality test suggests that the one-directional relationship from financing risk to liquidity risk exists. It implies that this causal relationship is triggered by financing side which will affect the liquidity positively in the short run only. This situation is supported by IRF results where any shocks coming from financing side will be negatively responded by liquidity risk. The variance decomposition also informs

Risks	**Financing risk → liquidity risk**	**Operational → liquidity risk**	**Financing risk → operational risk**
Assessment methods			
VECM estimation—short term	Positive, significant (lag-1)	Negative, significant (lag-1 and lag-2)	Positive (lag-3)
VECM estimation—long term	Negative, significant (lag-1)	Positive, not significant (lag-1)	Negative, significant (lag-1)
IRF	Negative (short and long runs)	Negative (short run) and positive (long run)	Positive (short and long runs)
VDC	3.623686	5.852848	46.13966
Granger causality test	Significant	Significant	Significant

Source: Author's calculation.

Table 15.
Summary of empirical findings from various assessments.

that there is a small contribution of risk variation from financing risk to liquidity risk. Therefore, overall findings suggest that Islamic banks are resilient in absorbing shocks when financing side is vulnerable. In other words, Islamic banks are not sensitive to risk originated from financing side as its liquidity is sound. In addition, the findings elaborate that the liquidity management on Islamic banking in Indonesia is strong and resilient against financing risk.

4.2.2 Liquidity risk

Table 15 demonstrates the relationship of liquidity risk with other risks. The Granger causality test suggests that liquidity risk has a directional relationship with financing and operational risks. Given that liquidity risk is affected by other risks, generally it was affected negatively in the short run and positively in the long run, but did not show a significant sign according to VECM estimation. The IRF further explains that even though the liquidity risk gets shocks originated from financing and operational risks, Islamic banks remain resilient. The VDC results also strengthen the findings that the variation on liquidity risk is negligibly contributed by financing and operational risks. In other words, financing and operational risks do not matter for Islamic banks, especially related to liquidity side.

4.2.3 Operational risk

Table 15 shows the general performance of operational risk on Islamic banks in Indonesia. According to the Granger causality test, operational risk exists in Islamic banks where it was influenced by financing risk and liquidity risk. The former indicates that Islamic banks are sensitive toward operational risk particularly due to failure in repayment counterparty obligations. This condition is supported by some empirical evidences including the following: (1) VECM estimation suggests that there is a positive relationship between financing and operational risks only in the short run, but not in the long run. This implies that Islamic banks have adjustment capacity to settle their operational problems when financing problems exist; (2) IRF result explains that operational risk is quite sensitive in Islamic banks as the variation in operational risk is highly contributed by financing risk according to VDC estimations. In short, operational risk in Islamic banks is connected with the ability of Islamic banks to manage their financing allocations. In other words, financing risk matters for Islamic banks.

The latter shows that liquidity risk has a directional causal relationship with liquidity risk. However, some empirical evidences suggest operational problems in Islamic bank are not closely affected by liquidity risk. For example, VECM estimation found no positive and significant influence in either short or long run and small portion variation of liquidity due to operational problems. It implies that liquidity management in Islamic banks is strong and sound in absorbing any shocks from operational risk. In other words, operational risk does not matter for Islamic banks, particularly related to liquidity side.

5. Conclusion, research limitation, and further research

Islamic banking in Indonesia is a new institutional approach in promoting economic development. Although its shares are small, it has been growing rapidly and now becomes a new national policy in spreading growth and prosperity. Islamic banks, technically, have two sides, funding and financing, which are operationally connected and integrated. Given this condition, the potential risks are quite large to

occur and might become systematic risk if not well managed. By using the VECM approach, this study investigates what is the main source of risk and how embedded risks in Islamic banks interacted with each other. After conducting sequential steps of analysis for financing, liquidity, and operational risks on Islamic banks in Indonesia since 2010–2018, the findings suggest that (1) liquidity risk is manageable and sound given that Islamic banks can absorb transmitted risk, particularly originated from financing and operational problems, indicated by no liquidity problems exist; (2) financing risk is considered as the strong source triggering operational risk in Islamic banks, and (3) operational risk matters for Islamic banks as it is quite sensitive with the problems from financing side.

Based on the findings, there are some research limitations concerning as follows: (1) the research does not analyze the policy rule concerning the tolerated level of risks, specific to Islamic banks in order to implement intervention for risk mitigation; (2) the research does not investigate the tolerated level of shocks, particularly from macroeconomic indicators in order to mitigate potential systemic risk due to adverse exogenous shocks; and (3) the research does not develop a comprehensive heat map as a surveillance tool to monitor the growing risks given the dynamic and interrelated aspects in Islamic banking operations.

Given the above findings and limitations, the research suggests some further potential and important investigation related to risk analyses in Islamic banks, including (1) developing a surveillance tool through a credible composite index to monitor regularly and intensively the growing risks in Islamic banks; (2) building the optimal thresholds of risks and shocks in order to ensure the vulnerability is manageable and resilience is maintained; and (3) building an early-warning system for risk mitigation as a risk management technique specific for Islamic banks.

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