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Stage-I Shariah compliant Macaulay's duration model testing

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Abstract

Purpose – The purpose of this study is to develop, test and examine econometric methodology for Sharīʿah-compliant duration models of Islamic banks.

Design/methodology/approach – The research evaluates all existing duration models from Sharīʿah's perspective and develops a four-stage framework for testing Sharīʿah-compliant duration models. The econometric methodology consists of multiple regression, Johansen co-integration, error correction model, vector error correction model (VECM) and threshold vector error models (TVECM).

Findings – Regressions analysis suggests that returns on earning assets and interbank offered rates are significant factors for calculating the duration of earning assets, whereas returns paid on return bearing liabilities and average interbank rates of deposits are significant factors for duration of return bearing liabilities. VECM suggests that short run duration converges into long run duration and TVECM suggests that management of assets and liabilities also plays a significant role that can bring about a change of about 15% in respective durations.

Practical implications – Sharīʿah-compliant duration models will improve risk and Sharīʿah efficiency, which will ultimately improve market capitalization and returns stability of Islamic banks in the long run.

Originality/value – Sharīʿah-compliant duration models testing provides insight into how various factors, namely, rates of return, benchmark rates and managerial skills of Islamic bank risk managers impact durations of assets and liabilities. It also explains the future course of action for Sharīʿah-compliant duration model testing.

Keywords Islamic banks, Earning assets, Return bearing liabilities, Duration model, Maturity gap risk management model testing

Paper type Research paper

1. Introduction

The focus of developments in the Islamic financial services industry is Islamic banking. Islamic banks share a common platform with conventional banks in all counties, except in Iran and Sudan. This makes them face similar risks with different impacts (Archer and Karim, 2019). The impact of sharing a common platform is also evident in their respective balance sheets (Chattha *et al.*, 2020). The activities of Islamic banks are exposed to a variety of risks such as credit risk, counterparty risk, equity investment risk, market risk, rate of return risk and liquidity risk (Islamic Financial Services Board [IFSB], 2005; Archer and Karim, 2019; Shah *et al.*, 2021). A major affect of such risks is the reduced market value of equity (Bierwag and Kaufman, 1992; Bierwag *et al.*, 2000; Entrop *et al.*, 2009; Chattha and Alhabshi, 2018).

ROR risk is similar to interest rate risk in Islamic financial institutions (Chattha *et al.*, 2020). Sometimes it is also referred to as "benchmark rate risk" (Chattha and Alhabshi,

JEL classification – C32, C33, C34, G21, G28, P43

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2018). It has very much potential to affect the net worth and off-balance sheet positions in case not properly managed (Archer and Karim, 2019; Chattha *et al.*, 2020). Islamic Financial Services Board has stressed to guard against the pitfalls of ROR risk using the duration gap approach.

Duration is the most common measure of risk management introduced by Macaulay (1938). Hicks (1939) extends its use for measuring the sensitivity of financial assets against yield curve movements by estimating interest rate risk (Radermacher and Recht, 2020). Fisher and Weil (1971) extend the duration for portfolio immunization and Ho (1992) uses duration for non-parallel shifts of the yield curve by introducing duration based on key rates. Bierwag *et al.* (1978) identify an important consideration in the development of duration models that the choice of weights is arbitrary and is dependent on its use. This requires the development of unique risk management models and other similar measures for Islamic banks as well. However, research on Islamic and conventional finance share similar techniques (Chattha and Alhabshi, 2018; Chattha *et al.*, 2020).

The purpose of this study is to test the Sharīʿah-compliant duration models of Shah *et al.* (2020a). This is achieved by following the theme of implementing duration models under the theory of Macaulay's duration (Shah *et al.*, 2020b). The research first develops a framework for testing financial models and proceeds by developing an econometric methodology based on the works of Gultekin and Rogalski (1984). The models have been tested by proposing alternate Sharīʿah-compliant duration models excluding principal amounts.

2. Review of literature

2.1 Literature on rate of return risk in Islamic banks

Islamic financial sector has done better allocation of resources than their conventional counterparts (Shah and Masood, 2017). Chattha and Alhabshi (2018) report that Islamic banks respond similarly to changes in interest rates because they use similar benchmark rates as used by their conventional counterparts. Chattha and Alhabshi (2018) and Chattha *et al.* (2020) further observe that Islamic banks have longer durations than conventional banks. These longer durations create a paradox. This is because a longer duration means the higher risk that should lead to higher profitability. Contrary to this risk-return principle Islamic banks are less profitable (Chattha and Alhabshi, 2018; Chattha *et al.*, 2020). This creates the "Islamic-conventional bank risk-return paradox" that requires investigation.

This research proceeds by reviewing all existing duration models under Sharīʿah parameters, followed by developing a framework and methodology for testing Sharīʿah-compliant duration models. The parameters of Sharīʿah-compliance as developed by Shah *et al.* (2020a) are hereunder:

> Parameters of a financial model for Islamic banks:
>
> It should incorporate realized rates of returns earned and paid, benchmark rates, interbank offered rates and industry standards.
>
> Avoiding all future based transaction rule applies to a financial model as well.
>
> Accordingly, the financial model should avoid incorporating variables that can give rise to excessive gharrar i.e., the model should not include all future value based variables.

For the purpose of a model, this condition shall be applied in such a way that future based variables should not be more than 50% of the total variables used in the model and the composition of variables should not give rise to results of which more than 50% will be expected.

The composition of variables in the model should not give rise to overall results that breach the 5,33,49 rule.

As the returns earned and paid are determined at the end of the period, therefore model shall utilize only realized values not the expected values as are used in the case of Macaulay's duration model.

The model shall function backwards i.e., it will calculate values from end of the year to beginning of the year. It is because the model uses realized values. The values so calculated shall be termed as "Reversed Present Values".

Models should be proposed for intra-year and inter-year risk analysis and management.

2.2 Sharīʿah review of duration models

2.2.1 Additive multiplicative models. Gultekin and Rogalski (1984) examine seven models of duration proposed by Macaulay (1938), Hicks (1939), Cooper (1977), Bierwag (1977), Bierwag and Kaufman (1978) and Khang (1979), which are all based on different assumptions about yield curves. All these models are based on interest and expected values of cash flows involving excessive gharrar rendering them all non-compliant with Sharīʿah.

2.2.2 Stochastic duration models. Cox *et al.* (1979) argue that, as interest rates move in an unpredicted manner stochastic duration models may better serve the purpose. However, a stochastic process is actually a process that produces significant but less predictable results, therefore such models are subject to excessive gharrar rendering them all non-Sharīʿah compliant.

2.2.3 Duration using Taylor expansion and linear approximation. Livingston and Zhou (2005) introduce Taylor expansion-based expected cash flows, expected present values and related duration. Tchuindjo (2008) extends this work to convexity. Dierkes and Ortmann (2015) incorporate changes in interest rates and respective yield curves for estimating present values of cash flows using linear approximation. From Sharīʿah's perspective, more complex methods of estimating cash flows merely increase gharrar, making the models non-Sharīʿah compliant.

2.2.4 Effective duration. Leland (1994) and Leland and Toft (1996) introduce the notion of "effective duration" for ascertaining optimal capital structure. Their models are, however, based on interest, which is categorically prohibited in Islam making them non-Sharīʿah complaints.

2.2.5 Duration of net income of banks. Bierwag and Kaufman (1992) extend the work of Toevs (1983) to introduce the duration of net income. Bierwag and Kaufman (1996) use this duration model to measure the performance of financial institutions. From Sharīʿah's perspective, these models suffer from the involvement of interest that is *riba*, making them non-Sharīʿah compliant.

2.2.6 Duration using logarithmic process. Pattitoni *et al.* (2012) incorporate logarithmic price variations and Taylor expansion in duration models. The purpose is to estimate the effect of changes in interest rates and changes in prices of market portfolios on changes in real estate investment trust prices. From Sharīʿah's perspective, such models only amount to excessive gharrar making them non-Sharīʿah compliant.

2.2.7 Key rate duration. Ho (1992) introduces a vector based on changes in prices of securities in response to changes in some "key" rates of interest. His results are very similar to "effective duration." From Sharīʿah's perspective, this model is highly non-Sharīʿah compliant as it suffers from *riba* and excessive gharrar simultaneously.

2.2.8 Principal component duration. Willner (1996) extends key rate duration into "principal component duration" where he regard to slope, height and convexity of the yield curve as principal components of duration. He simply linearly adds the factor-loading matrix of each component. From Sharīʿah's perspective, this model is non-compliant, as its base i.e. key rate duration is non-Sharīʿah compliant.

2.2.9 Polynomial time value duration. Osborne (2005) and Osborne (2014) introduce and approximate present value duration models based on polynomial time values. Dierkes and Ortmann (2015) use them for computing the duration of various financial instruments. From Sharīʿah's perspective, these models suffer from *riba* and the involvement of excessive gharrar, which makes them non-Sharīʿah compliant.

2.2.10 Approximation of duration in non-flat yield curve environment. This model is an extension of Ho (1992) model of key rate duration that is non-Sharīʿah compliant itself. Therefore, this model is non-Sharīʿah compliant as well.

2.2.11 Dedicated duration. Zaremba (2017) uses the work of Zaremba and Rządkowski (2016) to extend the work of Macaulay (1938), Redington (1952) and Fisher and Weil (1971) for calculating a sensitivity of bonds using a new measure of "dedicated duration" and "dedicated convexity." His work consists of dividing yield curve shifts into many classes and calculating duration for every class. These models suffer from *riba* and expected values of interest rates involving excessive gharrar making them non-Sharīʿah compliant.

2.2.12 First-order, second-order durations and convexities. Alps (2017) uses duration to calculate present values of cash flows. He refers methods before him as first-order methods where present values are a function of Mcaulay's duration and interest rates; and his method as second-order where present values are a function of modified duration, modified convexity and interest rates. Second-order duration models again suffer from interest rates and expected values involving *riba* and excessive gharrar making them non-compliant with Sharīʿah.

2.2.13 Approximating duration using insurance risk management properties. Schlütter (2017) identifies that insurance companies have a larger duration of liabilities than assets. Using this notion, Möhlmann (2017) proposes a duration model that incorporates present and book values and discounts them with interest rates. Such models are non-compliant with Sharīʿah due to the involvement of *riba* and excessive gharrar.

2.2.14 Orthogonalising the duration. Chu *et al.* (2017) while extending the work of Dechow *et al.* (2004), Chen (2014) and Weber (2017) for orthogonalizing duration observe that it has time series and cross-sectional characteristics. A concept that is primarily based on firm cash flows, market prices and equity returns. This model is also a non-Sharīʿah compliant model on the basis of excessive gharrar.

2.2.15 Implied duration: a measure for equity duration. Dechow *et al.* (2004) propose a duration model based on perpetuities. However, their model is based on interest and expected values i.e. *riba* and excessive gharrar making them non-Sharīʿah-compliant.

2.2.16 Duration of an organization. Weber (2018) combines the work of Dechow *et al.* (2004), Campbell and Vuolteenaho (2004) and Hansen *et al.* (2008) about cash flow duration and links them with the works of Lettau and Wachter (2007) and Santos and Veronesi (2010) about cash flow timing and risk premium of cash flows. He offers a modified model of duration based on negative correlations between higher cash flows and returns that bisects duration into "finite" and "infinite." From Sharīʿah's perspective, this model suffers from the involvement of interest and excessive gharrar, making it non-compliant with Sharīʿah.

2.2.17 Equity duration and book value duration. Mohrschladt and Nolte (2018) extend the works of Merton (1973), Sweeney and Warga (1986), Dechow *et al.* (2004), Lettau and Wachter (2007), van Binsbergen *et al.* (2012), Schröder and Esterer (2012) and Weber (2018) in the area of equity duration and propose a new model of duration incorporating a new factor. The resultant model measures equity duration based on the difference between only such assets and liabilities that exist on the balance sheet date. From Sharīʿah's perspective book value measures are the most compliant measures of duration. However, a measure of Mohrschladt and Nolte (2018) involve excessive gharrar and *riba* making them non-Sharīʿah compliant.

2.2.18 Duration model of accounts receivable. Xu and Ma (2018) propose a duration model for the pricing of account receivables using the concept of expiration time, risk free rate and book values. From Sharīʿah's perspective, this model is also non-compliant due to the involvement of *riba*.

2.2.19 Duration of assets and liabilities of insurance company. Fernándeza *et al.* (2018) in their work on insurance companies propose duration models based on expected values of cash flows, time and interest. From Sharīʿah's perspective expected value-based models are subject to excessive gharrar that makes them non-Sharīʿah compliant.

2.2.20 Duration measures for corporate project valuation. Arnold and North (2008) measure duration by taking reciprocal of the negative partial derivative of cash flows of the project by the value of the project. From Sharīʿah's perspective, this model is non-compliant because it is based on expected values of cashflows that involve excessive gharrar.

2.2.21 Sharīʿah-compliant duration model. Chattha *et al.* (2020) and Shah *et al.* (2020b) recommend and Shah *et al.* (2020a) propose Sharīʿah-compliant models of duration for earning assets and return bearing liabilities of Islamic banks. These models are based on Sharīʿah-compliant benchmark rates, rates of return earned, rates of return paid, book values of assets and liabilities and Sharīʿah-compliant concept of the time value of money, which they termed as "reversed present values." However, they do not provide empirical results.

3. Methodology

3.1 Framework of testing methodology

This study devises a framework and econometric methodology that uses maturity-wise data of earning assets and return bearing liabilities of Islamic banks in Pakistan from 2010 to 2019. Maturities are calculated in terms of Stohs and Mauer (1996). According to them, maturities of less than one year are taken at actual. Maturities from 1 to 2 years are taken at 1.5 years, 2 to 3 years are taken at 2.5 years, 3 to 4 years are taken at 3.5 years and 4 to 5 years are taken as 4.5 years. For the last category that is normally over 5 years or 10 years, the maturities have been calculated on the assumption that every following year has the same proportion of assets or liabilities as in the immediately preceding year until 100% of the values are allocated.

Descriptive statistics consists of mean, variance, Skewness, Kurtosis and Studentized range. Skewness has been measured taking the third moment from mean divided by the second moment to the ½ power. Kurtosis is the square root of the fourth moment from mean divided by the second moment. Finally, the studentized range is a range of the observations divided by the standard deviation of the sample. Descriptive statistics conform to the recommendations of Bildersee (1975), Gultekin and Rogalski (1984), Chen (2014), Weber (2017) and Chu *et al.* (2017) that returns are skewed and leptokurtic. The research also calculates p-values to ensure that $\overline{\gamma}$ equals zero. Finally, the average of R^2 and standard deviation of R^2 have been presented after adjusting for degrees of freedom. These are meant to measure the dependency between risk and return.

Testing a financial model before its full and independent implementation is a complex and lengthy process. It is actually a four-stage process. First stage is testing a model for compliance with econometric properties. Second stage is backward and forward testing based on historical, forward and/or artificial data. Third stage is parallel running the model in real time environment along with any existing model to examine the difference and impact before independent use. The first and the second stage tests are normally performed by the researchers. Third stage tests are performed by the researchers and practitioners. Besides, testing a model is a continuous process that carries on even after its independent implementation to suggest any improvements. This is regarded as Stage-IV testing. Framework of testing a financial model has been explained in Figure 1 hereunder:

3.2 Econometric methodology

A majority of studies on duration modeling are based on Stage-II testing skipping Stage-I. Recent works on Stage-II testing include Arnold and North (2008), Chu *et al.* (2017), Mohrschladt and Nolte (2018), Xu and Ma (2018) and Fernándeza *et al.* (2018). Gultekin and Rogalski (1984) conduct a landmark study on Stage-I testing of seven duration models by evaluating relationships between profitability and duration. Similar concept has been applied by Chu *et al.* (2017), who examine the relationship of duration with value and profitability. However, Chu *et al.* (2017) do not take into account the hypotheses of Gultekin and Rogalski (1984). According to Gultekin and Rogalski (1984), the relationship of returns with duration can be expressed using the following equation:

$$R_{i,t} = \alpha + b_1 DUR_{i,t} + \varepsilon_{i,t} \tag{1}$$

where $R_{i,t}$ is the net return margin, b_1 is the estimated coefficient and $DUR_{i,t}$ is duration.

Ingersoll (1981), Gultekin and Rogalski (1984) and many other recent studies such as Chen (2014), Weber (2017) and Chu *et al.* (2017) recommend that duration models with a higher number of factors better explain variability in returns. Accordingly, Sharīʿah-compliant duration models have a higher number of variables. For testing the relationship between returns and duration, the regression equation also consists of all such variables. Gultekin and Rogalski (1984) provide three hypotheses to be tested on duration models using multiple regression analysis:

> First, the relation between security price changes and duration is linear. Second, duration is a complete measure of risk; that is, duration incorporates the effect of maturity and coupon differences on price volatility. Implicit in this condition is that the yield curve on average demonstrates the functional form assumed by the duration measure. The last hypothesis is that capital markets for bonds are efficient. The linearity, completeness, and efficiency hypotheses can be tested with actual market data for many time periods with the use of securities and portfolios of securities.

However, as the objective of this research is to test duration models of Islamic banks, therefore, it amends the above hypotheses as follows:

- The relationship between volatility and Sharīʿah-compliant duration is linear.
- Sharīʿah-compliant duration translates the effect of changes in rates of return, benchmark rates and maturities on returns volatility of Islamic banks.
- The markets for Islamic banks are efficient.

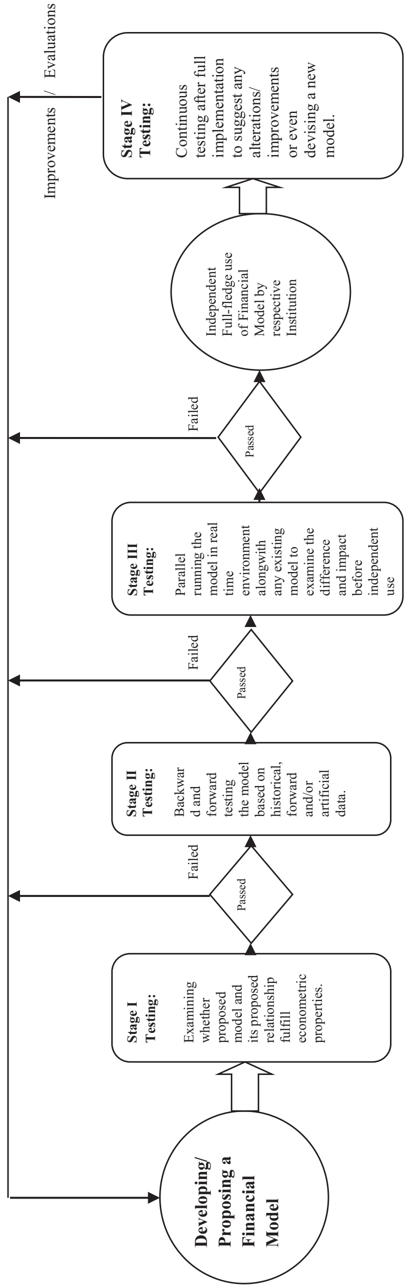

Figure 1.
Four-stage conceptual framework for testing a financial model

All three hypotheses have been tested using the equation as under:

$$\mathrm{R}(n)_{r,o,t} = \overline{\gamma}1(n)_{r,o,t} + \overline{\gamma}2(n)_{r,o,t}Dk(n)_{(r-1)(o-1)(t-1)} + \overline{\gamma}3(n)_{r,o,t}Dk^2_{(r-1)(o-1)(t-1)} + \overline{\gamma}4(n)_{r,o,t}\frac{ROR_{A(o-1)(t-1)}}{IBOR_{(r-1)(t-1)}} + \overline{\in}(n)_{r,o,t} \quad (2)$$

In the above equation $\mathrm{R}(n)_{r,o,t}$ is the net return margin, $\overline{\gamma}'s$ are average estimated coefficients, $Dk_{(r-1)(o-1)(t-1)}$ is the duration of kth bank calculated using returns and benchmark rates of the previous periods, $Dk^2_{(r-1)(o-1)(t-1)}$ is the square of duration to check linearity and finally, $\frac{ROR_{A(o-1)(t-1)}}{IBOR_{(r-1)(t-1)}}$ is the factor to check whether duration normalizes reversed present values.

Second, Gultekin and Rogalski (1984) observe that all measures of duration perform well in the short run and need to be implemented with caution in the long run. To address this issue, this research applies the vector error correction model (VECM) proposed by Sargan and Bhargava (1983) and validated by Engle and Granger (1987) for short and long term relationships between returns and duration. This is because; due to continuous structural changes in Islamic banking the chances of a mere short or long-term relationship between dependent and independent variables are remote. In such scenarios, latency errors serve as adjusted parameters that measure long-term equilibrium relationship with short-term dispersion.

The application of VECM starts from the Augmented Dickey-Fuller test that takes its roots from the works of Dicky and Fuller (1979) and Said and Dickey (1984). Next, vector autoregression has been used to examine long-term relationships. If the series is found non-stationary up to the first difference but integrated, then VECM is recommended. Non-stationarity prevails in all financial data (Nelson and Plosser, 1982).

Engle and Granger (1987) VECM for the purpose of this research shall have the following function:

$$\Delta x_t = \alpha ecm_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta x_{t-i} + u_t \quad (3)$$

In the above equation Δx_t means ($\Delta \ln D_{EA(t)}$, $\Delta \ln D_{ROEA(t)}$, $\Delta \ln D_{RBL(t)}$ and $\Delta \ln D_{RORL(t)}$), $ecm_{t-1} = \beta' x_{t-1}$ is the error correction term reflecting long term relationship and α is the adjustment parameter meant to restore the long run equilibrium between variables at a certain speed of adjustment.

This relationship extends into threshold error correction model that examines the relationship within certain ranges (Liu, 2010) defined as:

$$\Delta x_t = \begin{cases} M_1' X_{t-1}(\beta) + \mu_t, ecm_{t-1}(\beta) \le \gamma \\ M_2' X_{t-1}(\beta) + \mu_t, ecm_{t-1}(\beta) > \gamma \end{cases} \quad (4)$$

where M_1 and M_2 are coefficient matrices with dynamic parameters $ecm_{t-1}(\beta)$ is the error correction term dividing the system as threshold variable and γ is the threshold parameter. The model is divided into two modes of operations depending upon the size of the threshold parameter $ecm_{t-1}(\beta)$ with each variable exhibiting different dependency. The results will be read as $ecm_{t-1} \leq \gamma$ that will lead threshold VECM following the first mechanism and the second mechanism into the remaining scenarios.

This research uses four alternates models of Sharī'ah-compliant duration. Two long run duration models are from Shah *et al.* (2020a) and two alternate models of short run duration are proposed on the same parameters as recommended by Shah *et al.* (2020a). The model of Shah *et al.* (2020a) to be tested in this research are:

For earning assets:

$$D_{EA} = \sum_{i=1}^{n} \frac{\left[\frac{\sum_j^J \sum_i^{N_j} P_{EAij} (1+ror_{EAij})^{t_n}}{(1+IBOR_{ij})^{t_n}}\right] \times t_n}{\sum_j^J \sum_i^{N_j} P_{EAij} (1+ror_{EAij})^{t_n}} \tag{5}$$

For return bearing liabilities:

$$D_{RBL} = \sum_{i=1}^{n} \frac{\left[\frac{\sum_j^J \sum_i^{N_j} P_{RBLij} (1+ror_{RBLij})^{t_n}}{(1+IBAR_{RBLit})^{t_n}}\right] \times t_n}{\sum_j^J \sum_i^{N_j} P_{RBLij} (1+ror_{RBLij})^{t_n}} \tag{6}$$

Alternate models proposed for this research are hereunder:

For earnings on earning assets:

$$D_{ROEA} = \sum_{i=1}^{n} \frac{\left[\frac{\sum_j^J \sum_i^{N_j} P_{Aij} (1+ror_{Aij})'^{t_n}}{(1+IBOR_{ij})^{t_n}} - \sum_j^J \sum_i^{N_j} P_{Ai_j}\right] \times t_n}{\sum_j^J \sum_i^{N_j} P_{Aij} (1+ror_{Aij})^{t_n} - \sum_j^J \sum_i^{N_j} P_{Aij}}. \tag{7}$$

For returns on return bearing liabilities:

$$D_{RORL} = \sum_{i=1}^{n} \frac{\left[\frac{\sum_j^J \sum_i^{N_j} P_{Lij} (1+ror_{Lij})^{t_n}}{(1+IBAR_{Lit})^{t_n}} - \sum_j^J \sum_i^{N_j} P_{Li_j}\right] \times t_n}{\sum_j^J \sum_i^{N_j} P_{Lij} (1+ror_{Lij})^{t_n} - \sum_j^J \sum_i^{N_j} P_{Lij}}. \tag{8}$$

Finally, this research also examines duration in terms of Lettau and Wachter (2007) where they observe securities with short duration are sensitive to cash flow variations and with long duration are sensitive to interest rate variations i.e. long and short duration securities have different dynamics. This results in a higher premium in the long run (Fama and French, 2006; Novy-Marx, 2013).

For the purpose of this research, changes in returns of Islamic banks have been calculated in terms of Shah *et al.* (2020a) as hereunder:

$$\Delta NI = \left(D_{EA} \times EA \times \frac{1 + \Delta ROR_{EA}}{1 + \Delta IBOR} - 1\right) - \left(D_{RBL} \times RBL \times \frac{1 + \Delta ROR_{RBL}}{1 + \Delta IBAR} - 1\right) \tag{9}$$

where:

- Δ = Change.
- NI = Net income.
- D_{EA} = Duration of earning assets.
- D_{RBL} = Duration of risk bearing liabilities.
- EA = Earning Assets.
- RBL = Return Bearing Liabilities.
- ΔROR_{EA} = Change in rate of return on assets.
- $\Delta IBOR$ = Change in interbank offered rates.
- ΔROR_{RBL} = Change in rate of return on liabilities.
- $\Delta IBAR$ = Change in industry average rates of return on liabilities.

4. Results and discussion

Descriptive statistics have been reported in Tables 1 to 4. Variance skewness and kurtosis have been reported in Columns 2 to 4 that infer skewed and leptokurtic distributions of data. The results of the duration 5–8 after transforming into multiple regression equation (2) have been reported in Tables 5 to 10. Tables 5 to 7 relate to the duration of earning assets and Tables 8 to 10 relate to the duration of return bearing liabilities. Tables 7 and 10 are based on equation (3) exactly. Regression coefficients have been reported in Columns 1 to 4,

Table 1. Summary descriptive of earnings on earning assets (millions Pak rupees)

Maturities M = months Y = years	Variance (%)	Skewness	Kurtosis	Studentized range
Up to 3M	4.17	0.3517	3.14	5.17
3M> to 6M `	3.71	0.6119	4.33	6.12
6M> to <12M	10.79	−0.4613	1.47	7.11
1Y	23.12	−0.5145	1.09	5.14
1Y> to 2Y	21.74	−0.6257	2.51	5.81
2Y> to 3Y	74.841	0.3444	5.11	7.54
3Y> to 5Y	81.178	0.4115	6.67	7.33
5Y>	67.125	0.4132	5.83	6.84

Note: Explanation: The data has skewed and leptokurtic distributions

Table 2. Summary descriptive of returns paid on return bearing liabilities (millions Pak rupees)

Maturities M = months Y = years	Variance (%)	Skewness	Kurtosis	Studentized range
Up to 3M	5.11	0.4545	2.97	3.49
3M> to 6M `	4.38	0.7126	3.28	5.14
6M> to <12M	3.54	0.1245	2.14	5.65
1Y	7.45	−0.4997	1.92	4.46
1Y> to 2Y	38.14	−0.1295	3.01	5.61
2Y> to 3Y	31.85	0.4550	3.97	3.47
3Y> to 5Y	47.25	0.7587	5.15	5.69
5Y>	45.22	0.6169	4.87	6.67

Note: Explanation: The data has skewed and leptokurtic distributions.

autocorrelations in Columns 6 to 10, *p*-values in Columns 11 to 14 and the last two columns report means and standard deviations of coefficients of determination.

The results of the duration of earnings on earnings assets D_{EOEA} and returns paid on return bearing liabilities D_{RORL} are not produced here because they converge into the duration of earning assets D_{EA} and duration of return bearing liabilities $D_{RBL,}$ respectively, in the long run.

The results in Tables 5 and 8 do not let us accept linearity hypotheses because long-term relationship of duration with returns is quadratic i.e. upwards sloping. Tables 6 and 9 lead us to the findings that rates of return, benchmark rates, principal sum and maturities have significant relationships with duration and returns, accepting our second hypothesis. Tables 7 and 10 lead us to the finding that reversed present value factors do not affect the relationship of duration in the original state. This can be confirmed from making a combined analysis of Tables 6, 7 and 9, 10, where by incorporating reversed present value factor into regression function neither the linear relationship is affected nor the non-linear relationship.

To apply the VECM hypotheses of supLM, Hansen and Seo (2002) construction is the fitting of the relationship between variables using VECM as per equation (4) above. With an unknown co-integration matrix, the LM statistic is expressed as under and the relevant threshold where *p*-values are obtained using the bootstrap method:

Maturities M = months Y = years	Variance (%)	Skewness	Kurtosis	Studentized range
Up to 3M	21.23	0.3218	3.14	5.17
3M> to 6M `	17.28	0.5214	4.33	6.12
6M> to <12M	19.48	−0.4114	1.47	7.11
1Y	27.25	−0.6728	1.09	5.14
1Y> to 2Y	19.83	−0.6987	2.51	5.81
2Y> to 3Y	68.79	0.4589	5.11	7.54
3Y> to 5Y	84.22	0.3737	6.67	7.33
5Y>	61.136	0.3515	5.83	6.84

Note: Explanation: The data has skewed and leptokurtic distributions.

Table 3. Summary descriptive of earning assets (billions Pak rupees)

Maturities M = months Y = years	Variance (%)	Skewness	Kurtosis	Studentized Range
Up to 3M	24.35	0.3981	3.14	3.71
3M> to 6M `	18.21	0.6121	3.01	6.25
6M> to <12M	28.25	0.1591	2.97	4.17
1Y	17.26	−0.5876	2.77	5.26
1Y> to 2Y	42.36	−0.1371	3.27	5.91
2Y> to 3Y	38.45	−0.3868	4.27	2.41
3Y> to 5Y	44.67	0.7127	6.17	4.71
5Y>	51.25	0.5169	5.27	5.81

Note: Explanation: The data has skewed and leptokurtic distributions.

Table 4. Summary descriptive of return bearing liabilities (millions Pak rupees)

Table 5.
Regression results D_{EA} equation (2) $\bar{r}\cdot(\mathbf{n})_{\mathbf{r,o,t}} = \mathbf{Y}1(\mathbf{n})_{\mathbf{r,o,t}} + \mathbf{Y}2(\mathbf{n})_{\mathbf{r,o,t}}\,\mathbf{Dk}(\mathbf{n})_{\mathbf{EA(r-1)(o-1)(t-1)}} + \mathbf{Y}3(\mathbf{n})_{\mathbf{r,o,t}}\,\mathbf{Dk}^2_{\mathbf{EA(r-1)(o-1)(t-1)}} + \overline{\in}(\mathbf{n})_{\mathbf{r,o,t}}$

Period	$\overline{\gamma}1$	$\overline{\gamma}2$	$\overline{\gamma}3$	$\overline{\gamma}4$	($\acute{\gamma}1$)	($\acute{\gamma}2$)	($\acute{\gamma}3$)	($\acute{\gamma}4$)	p($\overline{\gamma}1$)	p($\overline{\gamma}2$)	p($\overline{\gamma}3$)	p($\overline{\gamma}4$)	$\overline{R}\cdot^2$	S($\overline{R}2$)
Up to 3M	29.1	0.43	−1.21		−0.281	−0.117	−0.018		0.001*	0.137	0.017*		0.74	0.49
3M> to 6M`	27.2	0.37	−0.81		0.059	−0.012	−0.127		0.024*	0.081	0.049*		0.61	0.36
6M> to <12M	31.4	0.25	−0.61		0.381	0.092	0.125		0.000*	0.077	0.024*		0.45	0.29
1Y	25.7	0.31	−0.43		0.414	0.375	0.237		0.000*	0.065	0.032*		0.74	0.47
1Y> to 2Y	28.6	0.29	−0.56		0.218	0.281	−0.112		0.041*	0.121	0.018*		0.65	0.35
2Y> to 3Y	27.2	0.41	−0.81		−0.313	0.127	−0.179		0.038*	0.547	0.041*		0.59	0.29
3Y> to 5Y	51.4	0.43	−0.93		−0.218	−0.281	0.114		0.045*	0.125	0.025*		0.64	0.42
5Y>	49.6	0.51	−0.82		−0.121	−0.313	−0.128		0.042*	0.341	0.044*		0.42	0.18

Note: **at 5% level of significance,* **Explanation:** Long term relationship of duration is quadratic i.e. upwards sloping, therefore linearity hypotheses rejected.

Table 6.
Regression results D_{EA} equation (3) $\overline{r} \cdot (\mathbf{n})_{r,o,t} = \mathbf{Y1}(\mathbf{n})_{r,o,t} + \mathbf{Y2}(\mathbf{n})_{r,o,t} \mathbf{Dk}(\mathbf{n})_{EA(r-1)(o-1)(t-1)} + \mathbf{Y4}(\mathbf{n})_{r,o,t} \frac{\mathbf{ROR}_{A(o-1)(t-1)}}{\mathbf{IBOR}_{(r-1)(t-1)}} + \overline{\in}(\mathbf{n})_{r,o,t}$

Period	$\overline{\gamma}1$	$\overline{\gamma}2$	$\overline{\gamma}3$	$\overline{\gamma}4$	$(\dot{\gamma}1)$	$(\dot{\gamma}2)$	$(\dot{\gamma}3)$	$(\dot{\gamma}4)$	$p(\overline{\gamma}1)$	$p(\overline{\gamma}2)$	$p(\overline{\gamma}3)$	$p(\overline{\gamma}4)$	$\overline{R}\cdot^2$	$S(\overline{R}2)$
Up to 3M	41.43	−0.49		1.21	0.617	0.047		0.212	0.000*	0.192		0.049*	0.55	0.29
3M> to 6M`	26.21	−0.35		1.41	0.524	0.025		−0.018	0.004*	0.243		0.016*	0.47	0.34
6M> to <12M	23.67	−0.17		0.91	0.423	−0.017		0.127	0.019*	0.095		0.009*	0.63	0.45
1Y	37.68	−0.08		0.43	0.317	0.015		0.011	0.000*	0.067		0.047*	0.74	0.52
1Y> to 2Y	32.67	−0.21		0.57	0.491	0.156		−0.287	0.024*	0.125		0.037*	0.37	0.25
2Y> to 3Y	18.91	−0.35		1.47	0.312	0.172		−0.125	0.041*	0.128		0.017*	0.41	0.27
3Y> to 5Y	22.54	−0.29		1.58	0.278	−0.018		−0.117	0.037*	0.313		0.013*	0.46	0.26
5Y>	27.75	−0.48		1.62	0.212	−0.022		−0.014	0.018*	0.073		0.012*	0.48	0.26

Notes: *at 5% level of significance, **Explanation:** Rates of return, interbank offered rates, principal sum and maturities are complete determinants of relationship between duration and returns. Factor of reversed present values do have relationship with duration in original state

Table 7.
Regression results D_{EA} equation (4) $\bar{r}\cdot(\mathbf{n})_{\mathbf{r,o,t}} = \mathbf{Y1}(\mathbf{n})_{\mathbf{r,o,t}} + \mathbf{Y2}(\mathbf{n})_{\mathbf{r,o,t}} \mathbf{Dk}(\mathbf{n})_{\mathbf{EA(r-1)(o-1)(t-1)}} + \mathbf{Y3}(\mathbf{n})_{\mathbf{r,o,t}} \mathbf{Dk}^2_{\mathbf{EA(r-1)(o-1)(t-1)}} + \mathbf{Y4}(\mathbf{n})_{\mathbf{r,o,t}} \frac{\mathbf{ROR}_{\mathbf{A(o-1)(t-1)}}}{\mathbf{IBOR}_{\mathbf{(r-1)(t-1)}}} + \overline{\in}(\mathbf{n})_{\mathbf{r,o,t}}$

Period	$\overline{\gamma}1$	$\overline{\gamma}2$	$\overline{\gamma}3$	$\overline{\gamma}4$	$(\dot{\gamma}1)$	$(\dot{\gamma}2)$	$(\dot{\gamma}3)$	$(\dot{\gamma}4)$	$p(\overline{\gamma}1)$	$p(\overline{\gamma}2)$	$p(\overline{\gamma}3)$	$p(\overline{\gamma}4)$	$\overline{R}\cdot^2$	$S(\overline{R}2)$
Up to 3M	27.24	0.32	−1.20	−0.29	0.371	0.131	0.018	0.021	0.001*	0.089	0.046*	0.047*	0.52	0.39
3M> to 6M`	32.51	0.89	−1.27	−0.81	0.251	0.042	0.131	0.078	0.024*	0.125	0.041*	0.037*	0.57	0.29
6M> to <12M	21.26	0.94	−1.10	0.12	0.328	0.171	0.005	0.123	0.000*	0.137	0.017*	0.044*	0.64	0.34
1Y	25.47	0.91	−0.87	0.57	0.427	0.007	0.009	0.257	0.000*	0.257	0.015*	0.031*	0.81	0.57
1Y> to 2Y	17.89	0.47	−1.23	−0.65	0.129	0.019	0.127	0.014	0.002*	0.077	0.047*	0.047*	0.73	0.49
2Y> to 3Y	33.47	−0.55	−1.37	−1.39	0.239	−0.031	0.111	−0.031	0.014*	0.087	0.042*	0.042*	0.77	0.51
3Y> to 5Y	44.59	0.31	−0.65	−0.63	−0.129	0.027	−0.037	0.008	0.007*	0.234	0.035*	0.034*	0.54	0.29
5Y>	47.61	0.29	−1.12	−0.87	−0.112	0.131	0.003	0.002	0.035*	0.186	0.045*	0.032*	0.52	0.34

Note: **at 5% level of significance,* **Explanation:** Factor of reversed present values do have relationship with duration in original state

Table 8. Regression results D_{RBL} equation (2) $\bar{r}\cdot(\mathbf{n})_{\mathbf{r,o,t}} = \mathbf{Y1}(\mathbf{n})_{\mathbf{r,o,t}} + \mathbf{Y2}(\mathbf{n})_{\mathbf{r,o,t}} \mathbf{Dk}(\mathbf{n})_{\mathbf{RBL(r-1)(o-1)(t-1)}} + \mathbf{Y3}(\mathbf{n})_{\mathbf{r,o,t}} \mathbf{Dk}^2_{\mathbf{RBL(r-1)(o-1)(t-1)}} + \overline{\in}(\mathbf{n})_{\mathbf{r,o,t}}$

Period	$\overline{\gamma}1$	$\overline{\gamma}2$	$\overline{\gamma}3$	$\overline{\gamma}4$	$(\dot{\gamma}1)$	$(\dot{\gamma}2)$	$(\dot{\gamma}3)$	$(\dot{\gamma}4)$	p($\overline{\gamma}1$)	p($\overline{\gamma}2$)	p($\overline{\gamma}3$)	p($\overline{\gamma}4$)	$\overline{R}\cdot^2$	S($\overline{R}2$)
Up to 3M	27.52	0.61	−1.62		0.487	0.007	−0.014		0.000*	0.098	0.072*		0.61	0.33
3M> to 6M`	32.34	0.48	−1.37		0.217	0.112	0.025		0.000*	0.125	0.033*		0.59	0.27
6M> to 12M	41.89	0.63	−1.45		0.112	0.005	0.045		0.034*	0.074	0.047*		0.71	0.52
1Y	34.37	0.56	−1.59		0.157	0.018	−0.154		0.000*	0.085	0.042*		0.75	0.61
1Y> to 2Y	39.25	0.47	−1.27		0.007	0.009	0.008		0.012*	0.137	0.045*		0.60	0.43
2Y> to 3Y	25.54	0.55	−1.89		−0.015	0.014	0.127		0.007*	0.124	0.047*		0.49	0.31
3Y> to 5Y	27.88	0.57	−1.44		0.157	−0.021	0.006		0.041*	0.066	0.032*		0.46	0.34
5Y>	31.32	0.55	−1.25		0.251	0.004	−0.012		0.038*	0.079	0.012*		0.41	0.26

Notes: **at 5% level of significance,* **Explanation:** Long term relationship of duration is quadratic i.e. upwards sloping

Table 9.
Regression results D_{RBL} equation (3)
$\bar{r}\cdot(\mathbf{n})_{\mathbf{r,o,t}} = \mathbf{Y}1(\mathbf{n})_{\mathbf{r,o,t}} + \mathbf{Y}2(\mathbf{n})_{\mathbf{r,o,t}}\,\mathbf{Dk}(\mathbf{n})_{\mathbf{RBL(r-1)(o-1)(t-1)}} + \mathbf{Y}4(\mathbf{n})_{\mathbf{r,o,t}}\,\frac{\mathbf{ROR}_{\mathbf{RBL(o-1)(t-1)}}}{\mathbf{IBAR}_{\mathbf{(r-1)(t-1)}}} + \in(\mathbf{n})_{\mathbf{r,o,t}}$

Period	$\overline{\gamma}1$	$\overline{\gamma}2$	$\overline{\gamma}3$	$\overline{\gamma}4$	$(\dot{\gamma}1)$	$(\dot{\gamma}2)$	$(\dot{\gamma}3)$	$(\dot{\gamma}4)$	$p(\overline{\gamma}1)$	$p(\overline{\gamma}2)$	$p(\overline{\gamma}3)$	$p(\overline{\gamma}4)$	$\overline{R}\cdot^2$	$S(\overline{R}2)$
Up to 3M	24.89	−0.17		1.31	0.523	0.039		−0.143	0.003*	0.149*		0.029*	0.68	0.51
3M> to 6M`	31.72	−0.24		1.52	0.479	0.021		−0.124	0.017*	0.097*		0.041*	0.74	0.59
6M> to 12M	27.27	−0.16		1.49	0.424	−0.018		−0.014	0.000*	0.082*		0.023*	0.59	0.49
1Y	34.76	0.10		1.46	0.391	0.026		0.196	0.000*	0.132*		0.045*	0.63	0.52
1Y> to 2Y	29.25	−0.12		1.36	0.453	0.009		0.182	0.042*	0.117*		0.022*	0.72	0.62
2Y> to 3Y	26.17	−0.25		0.82	0.381	0.028		−0.028	0.034*	0.075*		0.029*	0.49	0.35
3Y> to 5Y	34.29	−0.27		1.36	0.482	−0.036		0.037	0.041*	0.029*		0.034*	0.52	0.39
5Y>	29.45	−0.21		1.57	0.377	0.091		0.046	0.022*	0.074*		0.035*	0.47	0.29

Note: *at 5% level of significance, **Explanation:** Rates of return, interbank offered rates, principal sum and maturities are complete determinants of relationship between duration and returns. Factor of reversed present values do have relationship with duration in original state

Table 10. Regression results D_{RBL} equation (4) $\bar{r}\cdot(\mathbf{n})_{\mathbf{r,o,t}} = \mathbf{Y1}(\mathbf{n})_{\mathbf{r,o,t}} + \mathbf{Y2}(\mathbf{n})_{\mathbf{r,o,t}}\,\mathbf{Dk}(\mathbf{n})_{\mathbf{RBL(r-1)(o-1)(t-1)}} + \mathbf{Y3}(\mathbf{n})_{\mathbf{r,o,t}}\,\mathbf{Dk}^2_{\mathbf{RBL(r-1)(o-1)(t-1)}} + \mathbf{Y4}(\mathbf{n})_{\mathbf{r,o,t}}\,\frac{\mathbf{ROR}_{\mathbf{RBL(o-1)(t-1)}}}{\mathbf{IBAR}_{\mathbf{(r-1)(t-1)}}} + \in(\mathbf{n})_{\mathbf{r,o,t}}$

Period	$\overline{\gamma}1$	$\overline{\gamma}2$	$\overline{\gamma}3$	$\overline{\gamma}4$	$(\dot{\gamma}1)$	$(\dot{\gamma}2)$	$(\dot{\gamma}3)$	$(\dot{\gamma}4)$	p($\overline{\gamma}1$)	p($\overline{\gamma}2$)	p($\overline{\gamma}3$)	p($\overline{\gamma}4$)	$\overline{R}\cdot^2$	S($\overline{R}2$)
Up to 3M	38.22	0.28	−1.09	−0.27	0.539	−0.002	−0.017	−0.062	0.000*	0.091*	0.021*	0.047*	0.69	0.52
3M> to 6M`	41.45	0.71	−0.91	−1.18	0.012	−0.028	−0.036	−0.074	0.000*	0.137*	0.046*	0.032*	0.72	0.61
6M> to 12M	17.32	0.83	−0.65	−1.25	−0.431	−0.125	−0.042	0.018	0.000*	0.122*	0.045*	0.016*	0.71	0.52
1Y	15.47	0.77	−1.21	0.95	0.127	−0.147	−0.007	0.022	0.002*	0.042*	0.039*	0.015*	0.89	0.72
1Y> to 2Y	27.25	0.51	−0.67	1.12	0.258	−0.025	0.019	−0.017	0.025*	0.127*	0.045*	0.013*	0.65	0.51
2Y> to 3Y	42.77	0.11	−0.98	−0.45	0.112	0.026	−0.025	0.056	0.037*	0.144*	0.012*	0.012*	0.69	0.57
3Y> to 5Y	44.37	−0.27	−1.37	−0.21	−0.198	−0.156	−0.061	−0.078	0.014*	0.129*	0.017*	0.016*	0.54	0.41
5Y>	49.88	−0.21	−1.41	−0.41	0.242	−0.192	−0.076	0.026	0.000*	0.147*	0.036*	0.015*	0.51	0.44

Note: *at 5% level of significance, **Explanation:** Factor of reversed present values do have relationship with duration in original state

$$SupLM = \overbrace{\gamma 1 \leq \gamma \leq \gamma 2}^{sup} LM\left(\tilde{V}, \gamma\right) \tag{10}$$

where $\tilde{V}$ is the estimated value of β in equation (4) with the search to be conducted within the limits $\gamma 1$ and $\gamma 2$.

To apply VECM the first statistic is the Augmented Dickey Fuller test the results of which have been reported in Table 11 hereunder:

Table 11 shows that the data of two duration measures are stationary at Level 2 at 5% level of significance and can be further used to apply co-integration for examining long run relationships. Next, Johansen Co-integration has been applied to arrive at co-integration equations.

Table 12 shows that in both cases of assets and liabilities null hypotheses $r = 0$ is rejected at 5% level of significance, whereas the results fail to reject hypotheses $r > 1$. The estimated co-integration equations for durations of assets and liabilities are hereunder:

For the duration of assets:

$$ln\Delta\Delta D_{ROEA(t)} = 0.1632 + 1.0827 ln\Delta\Delta D_{EA(t)} + u_t \tag{11}$$

Moreover, for the duration of liabilities:

$$ln\Delta\Delta D_{RORL(t)} = 0.1727 + 1.0331 ln\Delta\Delta D_{RBL(t)} + u_t \tag{12}$$

Variable	ADF test	*P*-value	Conclusion
lnDEA	1.6298	0.752*	No
lnDROEA	4.7585	0.679*	No
Δ*lnDEA*	−0.5106	0.723*	No
Δ*lnDROEA*	0.6128	0.256*	No
ΔΔ *lnDEA*	−3.2518	0.004*	Yes
ΔΔ*lnDROEA*	−7.6769	0.000*	Yes
lnDRBL	1.4598	0.256*	No
lnDRORL	3.8565	0.253*	No
Δ*lnDRBL*	0.4937	0.091*	No
Δ*lnDRORL*	0.7469	0.139*	No
ΔΔ *lnRBL*	−4.4562	0.013*	Yes
ΔΔ*lnDRORL*	−0.8612	0.021*	Yes

Table 11.
Unit root test results

H0	Characteristic root	Characteristic root test		Maximum Eigen value test	
		Duration of assets			
		Test statistics	5% threshold	Test statistics	5% threshold
r = 0	0.5918	36.7461*	19.896	20.6128	18.5961
r > 1	0.0431	1.0318	3.7149	1.0318	3.7149
		Duration of liabilities			
r = 0	0.5752	38.2529	19.1716	21.1256	17.6549
r > 1	0.0429	1.0292	3.2569	1.0292	3.2569

Table 12.
Johansen co-integration test results

Using equations (11) and (12), co-integration dynamic adjustment behavior can be studied between the variables using equation (3) that leads to the application of VECM. The results of VECM have been reported in Table 15 as under:

Table 13 explains that in $\Delta\Delta \ln D_{ROEA(t\text{-}1)}$ the coefficient of co-integration vector is -0.0314 and for $\Delta\Delta \ln D_{(RORL)}$ it is -0.0212 that are both significant at 5%. This leads us to the finding that if short run duration deviates from long run equilibrium the error correction system will pull it back to long run duration.

4.1 Estimation of threshold vector error correction model

For establishing the threshold vector error correction model (TVECM) the preliminary measure is to examine the threshold effect. The results of statistic trimming parameter at 5% level of significance have been reported in Table 14 as under:

The results suggest that as estimated values are greater than threshold values, there exist non-linear internal dependencies between short run and long run measures of duration. The estimated function for error correction model of the duration of assets turns out to be $ln\Delta\Delta D_{ROEA(t)} - 0.90254 ln\Delta\Delta D_{EA(t)}$ with threshold γ of -0.42; and error correction term of duration of liabilities is $ecm_t = ln\Delta\Delta D_{RORL(t)} - 0.90314 \ln\Delta\Delta D_{RBL(t)}$ with threshold γ of 0.43. Furthermore, with a duration of assets at $ln\Delta\Delta D_{ROEA(t)} \leq 0.90254 ln\Delta\Delta D_{EA(t)} - 0.42$ and duration of liabilities at $ln\Delta\Delta D_{RORL(t)} \leq 0.90314 ln\Delta\Delta D_{RBL(t)} - 0.43$ the models fall in the first mechanism with approximately 85% of the values in both cases. The results of the models have been reported in Table 15 hereunder:

In Table 15, $\Delta\Delta \ln D_{ROEA}$ and $\Delta\Delta \ln D_{RORL}$ have negative and significant error correction coefficients at 5% level of significance, meaning thereby D_{ROEA} and D_{EA} along with D_{RORL} and D_{RBL} co-exist below a threshold value. Furthermore, long-term co-integration relationship adjusts from non-equilibrium to equilibrium at the rate of 0.0618 for the duration of earning assets and at the rate of 0.0724 for the duration of return bearing liabilities. In the second mechanism, however, error correction terms become insignificant and the co-integration mechanism disappears when the error correction term exceeds a

Particulars	$\Delta\Delta \ln D_{(ROEA)}$	$\Delta\Delta \ln D_{(EA)}$
B	1.3011	1.3011
$D_{ROEA} ecm_{(t\text{-}1)}$	−0.0314(0.0122)*	0.0137(0.0231)*
C	−0.0369(0.0627)*	0.0491(0.0295)*
$\Delta\Delta \ln D_{ROEA(t\text{-}1)}$	−0.1243(0.0854)*	0.2244(0.0210)*
$\Delta\Delta \ln D_{EA(t\text{-}1)}$	0.8125(0.0291)*	−0.7978(0.0314)*
	$\Delta\Delta \ln D_{(RORL)}$	$\Delta\Delta \ln D(R_{BL})$
B	1.4127	1.4127
$D_{RORL} ecm_{(t\text{-}1)}$	−0.0212(0.0231)	0.0194(0.0313)*
C	−0.0428(0.0765)*	0.0365(0.0221)*
$\Delta\Delta \ln D_{RORL(t\text{-}1)}$	−0.1323(0.0912)*	0.0292(0.0317)*
$\Delta\Delta \ln D_{RBL(t\text{-}1)}$	0.7652(0.0366)*	−0.8661(0.0267)*

Table 13. Vector error correction model

Statistic	Estimated value	Threshold	*P*-value	Conclusion
$SupLM_{Dur\ (Assets)}$	20.367	19.81	0.0365	Reject H_0
$SupLM_{Dur(Liabilities)}$	22.528	20.25	0.0401	Reject H_0

Table 14. Threshold effect test results

threshold value. This means that long-term relationship disappears when the threshold limit is violated.

5. Conclusion

The findings of the first hypothesis conform to Gultekin and Rogalski (1984) that durations of assets and liabilities do not have a linear relationship. However, the findings in the case of the second and third hypotheses do not conform to the findings of Gultekin and Rogalski (1984). This is because returns earned on earning assets and interbank offered rates are significant factors for determining the duration of earning assets; and returns paid on return bearing liabilities and interbank average rates of deposit are significant factors for determining the duration of return bearing liabilities. In addition, the behavior of reversed present value factor corresponds with the behavior of duration. In addition, regarding the third hypotheses, as Islamic banking is in its developing stages with only a few Islamic banks in operation therefore, the Islamic banking market is not efficient.

The TVECM further confirms our earlier observations that D_{ROEA} and D_{RORL} models coexist with D_{EA} and D_{RBL} models in the short run with a threshold limit of approximately 85% in both cases. Therefore, models proposed by Shah *et al.* (2020a) are robust for the measurement of the duration of Islamic banks in the short run and in the long run. The results of this study also augment the results of Lettau and Wachter (2007), who observe that short and long run durations have different dynamics. This is because in the case of Islamic banks short run duration measures i.e. D_{ROEA} and D_{RORL} converge into long run duration measures i.e. D_{EA} and D_{RBL}.

The findings imply that regulatory policymakers can now consider the platforms of Islamic banks for effective evaluation, implementation and formulation of monetary policies. This is because Sharīʿah-compliant risk management model will go a long way in calibrating Sharīʿah risk.

Sharīʿah-compliant duration gap model will also help in a Sharīʿah-compliant competing product pricing policy at the bank level. This is because by incorporating Sharīʿah-compliant weights the quantified affect of Sharīʿah risk will also be taken into account as recommended by Shah *et al.* (2021).

5.1 Limitations and future research directions

This study mainly focuses on the duration of earning assets and return bearing liabilities and their relationship with earnings in Islamic banks. As a result, this study does not address holistic management of earning assets and return bearing liabilities, which may

Variable	First mechanism $\Delta\Delta \ln D_{ROEA}$	First mechanism $\Delta\Delta \ln D_{EA}$	Second mechanism $\Delta\Delta \ln D_{ROEA}$	Second mechanism $\Delta\Delta \ln D_{EA}$
ecm_{t-1}	−0.0618(0.0029)*	0.0181(0.0172)*	0.1045(0.5411)*	0.0610(0.5991)*
C	−0.0471(0.0261)*	0.0312(0.0171)*	0.0725(0.0114)*	0.0341(0.0091)*
$\Delta\Delta lnD_{ROEA}$	0.2551(0.0049)*	−0.8771(0.4121)*	0.5439(0.3927)*	0.9675(0.0125)*
$\Delta\Delta lnD_{EA}$	−0.4981(0.0041)*	1.1291(0.0411)*	−0.4271(0.4929)*	0.4771(0.2611)*
Proportion	84.89%		15.11%	
ecm_{t-1}	−0.0724(0.0035)*	0.0129(0.0169)*	0.1038(0.5473)*	0.0586(0.6282)*
C	−0.0528(0.0298)*	0.0337(0.0178)*	0.0719(0.0175)*	0.0351(0.0082)*
$\Delta\Delta lnD_{RORL}$	0.2626(0.0101)*	−0.9135(0.4368)*	0.5722(0.4012)*	0.9525(0.0138)*
$\Delta\Delta lnD_{RBL}$	−0.5127(0.0185)*	1.1354(0.0428)*	−0.4581(0.5018)*	0.4829(0.2739)*
Proportion	85.25%		14.75%	

Table 15. Theoretical vector error correction model results

have a strong impact on durations. Furthermore, as the study is only conducted on Islamic banks operating in Pakistan, therefore a larger sample and testing in various other countries is also recommended to validate the model.

The study only deals with earning assets and return bearing liabilities that have maturities. As Islamic banks have various other assets and liabilities that do not have returns and maturities, therefore a study encompassing such assets and liabilities will yield comprehensive results regarding the duration of an Islamic bank. The study also severely suffers from the availability of data because most of the Islamic banks do not have long histories with the difference in the year of commencement of business.

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