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Threshold effects of liquidity risk and credit risk on bank stability in the MENA region

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Abstract

This paper studies the relationships between both liquidity and credit risks on bank stability for a panel data set of 75 conventional banks belonging to 11 countries of the MENA region observed during the period 1999–2017. By performing a Panel Smooth Threshold Regression (PSTR) model developed by Gonzalez et al. (2005), estimation results show that the relationships between bank stability-credit risk and bank stability-liquidity risk are non-linear and characterized by the presence of two optimal thresholds which are equal to 13.16% for credit risk and 19.03% for liquidity risk. Contrary to their positive effects below these optimal thresholds, credit risk and liquidity risk become detrimental to bank stability in high regime.

To ensure their stability, banks are encouraged to revise the primacy given to credit activity and diversify their activities to improve profitability. They are also recommended to strengthen their own funds and opt for appropriate restructuring to ease their small size. As for the States of the selected countries, they have to deeply reform their financial systems and develop the legal framework relating to new techniques of external management of banking risks including securitization and defeasance. Likewise, these states are fortified to ensure political stability, which is a key factor for banking and financial stability.

JEL classification: F3; G21; G28; O16; F36; O53

Keywords: Liquidity risk; Credit risk; Bank stability; PSTR model; MENA region

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1. Introduction

Bank stability is difficult to define and even harder to measure. A banking system can be described as unstable in the presence of excessive volatility of assets or crises. Such a definition of banking stability is simple to formulate, but does not capture the positive contribution to understand the stability of the banking and financial system. Bank stability is a characteristic of financial stability. In general, a bank is considered stable if it meets two basic requirements: improving economic performance and eliminating imbalances caused by endogenous factors of unforeseen or unwanted events from different banking risks.

In most countries, especially developing ones, banks play a vital role in financing their economies and promoting their economic growth. Hence, the need to ensure their stability. This is why, in recent years, several studies have examined the factors that ensure the stability of banks or those who destabilize them. In particular, credit risk and liquidity risk are retained by the majority of authors who considered them as major risks.

The debate on the relationship between these risks and bank stability is not conclusive since the empirical results found are divergent. These findings can be divided into three types. The first one supports the negative impact of these two risks on the stability of banks. The second type, on the other hand, shows the positive effect of both risks on the stability of banks. The third current of literature proves the insignificant impact of liquidity and credit risks on bank stability.

On the one hand, these studies have the merit of adopting different empirical approaches, but on the other hand, they assume a linear relationship between risks and banking stability. This linearity hypothesis can lead to erroneous results that can mislead decision-makers and bank managers, since the sign of risks on bank stability does not change; negative or positive.

This paper tries to fill this gap and contributes to the existing literature by studying the non-linear relationship between risks and bank stability by using new econometric approach based on the Panel Smooth Threshold Regression (PSTR) model developed by Gonzalez, Terasvirta, and Van Dijk (2005).

Unlike other works, our paper seeks to show that the relationships between credit and liquidity risks and bank stability are non-linear and characterized by the presence of threshold effects. Our paper has the advantage to show that the impact of banking risks on stability is not the same below and above the thresholds. As far as we know, there are no published empirical studies which apply the PSTR model to investigate the non-linear relationship between risks and bank stability for an important number of banks. This paper is intended to be a contribution that can help the bank's supervisors to monitor and evaluate the stability of the banking system and its determinants. This paper allows us to identify a number of destabilizing factors that have created instability throughout the system.

To do this, we use a new econometric approach based on the PSTR model, which is the most appropriate for endogenously determining the optimal threshold beyond which bank stability is affected by risks. We use a sample of 75 conventional banks from 11 MENA countries observed over the period 1999–2017.

The remainder of this paper is organized as follows. A review of literature is given in section 2. Data and PSTR model specification are presented in section 3. Empirical Results and interpretation are developed in section 4, while section 5 concludes.

2. Literature review

In the MENA countries, the majority of banks continue to develop traditional activities (including the provision of credit and the collection of resources in the form of deposits), despite reforms and the exhaustion of major factors that have supported these activities for a long time. These activities carry risks, mainly credit risk and liquidity risk.

The effects of credit and liquidity risks on the stability of banks have been the subject of several academic works (Acharya & Mora, 2013; Adusei, 2015; Amara & Mabrouki, 2019; DeYoung & Jang, 2016; Ghenimi, Chaibi, & Omri, 2017; Imbierowicz & Rauch, 2014; Li & Zou, 2014; Rajhi & Hassairi, 2013; Khemais, 2019, etc.). Their results are not consensual. There is works that have shown that these two risks have destabilized the banks. On the other hand, a second group of authors highlighted the positive effect of these two risks on the stability and sustainability of banks. A third group of studies showed the neutral effect of credit and liquidity risks on bank stability, which is fundamentally dependent on other factors.

The negative effect of credit and liquidity risks on bank stability has been analyzed in several studies. Ghenimi et al. (2017) used 49 banks observed over the period 2006–2013 to study the effects of credit and liquidity risks on bank stability. These banks belong to eight countries in the MENA region: Bahrain, Jordan, Qatar, Saudi Arabia, Turkey, United Arab Emirates, Kuwait and Yemen. Following the approach proposed by Arellano and Stephen (1991), Arellano and Olymia (1995) and Blundell and Stephen (1998), their results revealed that the interaction between credit and liquidity risks (CR * LR) contribute to bank instability.

Adusei (2015) used quarterly data from 2009 to 2013 to pick out the main factors destabilizing the rural banking sector in Ghana. To do this, the author retained three measures of bank stability which are *Z*-score, risk-adjusted return on assets (RAROA) and risk-adjusted equity on assets ratio (RAEA). Empirical results indicated that credit risk is harmful to the stability of banks when the latter is measured by RAEA.

Imbierowicz and Rauch (2014) analyzed the relationship between liquidity and credit risks and their joint impact on banks' probabilities of default for a sample of 4300 US commercial banks over the period 1998–2010. Their main results showed that the two risks influence the probabilities of default of banks although they do not have a reciprocal relationship. Added to that, the influence of their interaction depends on the overall level of bank risks and can worsens or mitigates the risk of default of banks.

For Acharya and Mora (2013), the role of banks as liquidity providers is a strong guarantor during the period of the 2008 financial crisis. Their results proved that the banks that failed during the recent financial crisis suffered from liquidity problems. The study shows that banks that have failed attract deposits by offering high interest rates. Indirectly, the results indicate that the presence of both liquidity and credit risks could push banks to default.

In a comparative analysis during the period (2006–2009), Rajhi and Hassairi (2013) suggested that credit risk reduces the stability of banks in the MENA region. Using a measure of default distance and *Z*-score, their results showed that credit risk and income diversity are the most common cause of insolvency for banks. Credit risk measured by the ratio of loan loss provisions to net interest income, decreases *Z*-score in small banks in MENA countries.

Using panel data analysis for the period 2005–2015, Khemais (2019) examined the impact of credit risk, liquidity risk, and operational risk on Tunisian conventional bank stability proxied by both *Z*-score (ROA) and *Z*-score (ROE). Empirical results show that the credit risk threatens the stability of Tunisian banks when the latter is measured by *Z*-score (ROA). The interaction of both credit and liquidity risks worsens also their stability.

Other authors support the positive effect of credit and liquidity risks on the stability of banks, since profitability and risks are tightly linked. Credit and liquidity risks are not detrimental for bank stability. Contrary to the credit risk, Khemais (2019) reveals that the liquidity risk improves the stability of Tunisian banks.

The financial crisis has proven that liquidity and credit risks are two important factors in the banking sector that can affect the survival of banks (DeYoung & Jang, 2016). Li and Zou (2014) studied the impact of credit risk measured by the non-performing loans ratio on bank stability using data from 47 commercial banks in Europe from 2007 to 2012. Their results showed that credit risk has a significant effect on the increase in bank performance measured by return on equity (ROE) and return on assets (ROA).

The third kind of works retains the neutrality hypothesis. Credit and liquidity risks do not affect significantly the stability of banks. Amara and Mabrouki (2019) examined the relationship between liquidity and credit risk and their impact on the stability of Tunisian banks during the period 2006–2015 by using the *Z*-score function as an indicator of stability. They found that credit risk and liquidity risk do not have an economically significant reciprocal relationship and that each risk category has a non-significant impact on bank stability. In addition, authors reached to the result that the interaction between the two risks has an insignificant effect on bank stability.

3. Data and PSTR model specification

The motivation of our paper is to investigate the relationships between both liquidity and credit risks on bank stability for the MENA region which is an interesting case study.

In the MENA region, financial intermediation has remained dominated by banking intermediation. Banks are the main financial intermediaries. They continue to collect their resources in the form of deposit through a branch network, and grant credit to their clients. These traditional activities, not exclusive of others, carry risks, which can destabilize banks.

Countries in the MENA region have undergone widespread reforms in recent decades, affecting all sectors of activity. That is why their economies have become highly open to the outside and competitive. In particular, MENA's banks are more integrated into the global financial markets and exposed to the shocks that affect international capital markets.

Furthermore, the banking sector in the MENA region is characterized by the presence of Islamic banks. In fact, the presence of the Islamic banking sector can affect the stability of conventional banks. Because of their structure, Islamic banks generally have higher liquidity ratio and lower credit risk than conventional banks.

Finally, it is quite true that banks of the MENA countries have been recovering from the recent financial crisis, but recent political turmoil and sudden regime can decrease economic growth and destabilize banks.

These main characteristics presented above explain the choice of the MENA banking system as an interesting framework for analyzing the relationships between credit risk, liquidity risk and bank stability for a panel data set of 75 conventional banks belonging to 11 countries observed during the period 1999–2017. Table 1 displays the number of conventional banks per country.

To highlight the possible non-linear relationship between credit risk, liquidity risk and bank stability, we relied on one of the econometric techniques used to estimate non-linear relations, namely the Panel Smooth Threshold Regression (PSTR) model developed by Gonzalez et al.

Table 1
Number of conventional banks per country.

Countries	Number of conventional banks per country
Algeria	6
Bahrain	8
Egypt	8
Jordan	8
Kuwait	3
Lebanon	8
Morocco	4
Qatar	4
Saudi Arabia	8
Tunisia	10
United Arab Emirates	8
Total	75

Source: Authors.

(2005), who extended Hansen's PTR (Panel Threshold Regression) model (1999). Theoretical form of the PSTR model is presented as follows:

$$y_{it} = \mu_i + \beta^0 x_{it} + \beta^1 x_{it} g(q_{it}, \gamma, c) + \varepsilon_{it} \tag{1}$$

where (i) and (t) represent respectively cross-section and time dimensions of the panel. μ_i indicates the vector of the individual fixed effects. ε_{it} is the error term. β^0 and β^1 indicate respectively the parameter vectors of linear and non-linear models. y_{it} and x_{it} represent respectively dependent and independent variables. $g(q_{it}, \gamma, c)$ is the function of transition which depends on the transition variable q_{it}, the transition parameter (γ) and the parameter of threshold (c). This transition function of the PSTR model is continuous and normalized taking values between 0 and 1. It allows system to transit from one regime to another. In order for this function of transition to be operational, Granger and Teräsvirta (1993), Teräsvirta (1994), Eliev and Timo (1996), and Gonzalez et al. (2005) proposed the following logistic form of order m:

$$g(q_{it}, \gamma, c) = \left(1 + \exp\left(-\gamma \prod_{j=1}^{m} (q_{it} - c_j)\right)\right)^{-1} \tag{2}$$

With $c = (c_1, \ldots, c_j, \ldots, c_m)$ is a vector of threshold parameters with $c_1 < \cdots < c_m$ and $\gamma > 0$. When $\gamma \to 0$, the transition function approaches a constant and the PSTR model becomes homogenous linear panel with fixed effects. However, when $\gamma \to +\infty$, the function of transition $g(q_{it}, \gamma, c)$ tends to an indicator function $g(q_{it}, c_j)$ which takes 1 if $q_{it} > c_j$. Ibarra and Trupkin (2011) showed that if γ is very high, the PSTR model can be confused with a two-regime model (or one threshold). Given this function of transition $g(q_{it}, \gamma, c)$, Eq. (1) can be written as follows:

$$y_{it} = \mu_i + \beta^0 x_{it} + \sum_{j=1}^{m} \beta_j x_{it} g(q_{ij}^{j}, \gamma_j, c_j) + \varepsilon_{it} \tag{3}$$

In this paper, we used an unbalanced annual data of 604 observations for 75 banks belonging to 11 countries observed during the period 1999–2017 to investigate the effects of credit risk and liquidity risk on bank stability by using the PSTR model which can be written as follows:

$$BSTAB_{it} = \mu_i + \beta^0 x_{it} + \beta^1 x_{it} g(q_{it}, \gamma, c) + \varepsilon_{it} \tag{4}$$

where i refers to banks ($i = 1, \ldots, 75$) and t represents time period in years ($t = 1999, \ldots, 2017$). μ_i, ε_{it}, β^0 and β^1 keep the same definitions mentioned above. BSTAB is bank stability, which represents the dependent variable. $g(q_{it}, \gamma, c)$ represents the function of transition. In our model, we test the threshold effect of two variables which are credit risk (CR) and liquidity risk (LR). Consequently, we have two transition functions $g(CR_{it}, \gamma, c)$ and $g(LR_{it}, \gamma, c)$.

Eq. (4) can be divided into two equations:

$$BSTAB_{it} = \mu_i + \beta^0 x_{it} + \beta^1 x_{it} g(CR_{it}, \gamma, c) + \varepsilon_{it} \tag{4-1}$$

$$BSTAB_{it} = \mu_i + \beta^0 x_{it} + \beta^1 x_{it} g(LR_{it}, \gamma, c) + \varepsilon_{it} \tag{4-2}$$

In Eq. (4-1), credit risk (CR) is the variable of transition, while in Eq. (4-2) liquidity risk (LR) is the variable of transition.

In both equation, we kept the same explanatory variables (which are the size (SIZE), the capital adequacy ratio (CAP), the performance of bank (PERF) and the Lerner index (LERNER)) and the same exogenous variables (which are inflation rate (INF) and political stability and absence of violence and terrorism (POLIS)).

Replacing the vector *of* independent variables x_{it} with its components, we get the empirical model to be estimated which is presented as follows:

$$\begin{aligned} BSTAB_{it} = {} & \mu_i + \beta_0^0 CR_{it} + \beta_1^0 LR_{it} + \beta_2^0 SIZE_{it} + \beta_3^0 CAP_{it} + \beta_4^0 PERF_{it} \\ & + \beta_5^0 LERNER_{it} + \beta_6^0 INF_{it} + \beta_7^0 POLIS_{it} \\ & + [\beta_0^1 CR_{it} + \beta_1^1 LR_{it} + \beta_2^1 SIZE_{it} + \beta_3^1 CAP_{it} + \beta_4^1 PERF_{it} + \beta_5^1 LERNER_{it} \\ & + \beta_6^1 INF_{it} + \beta_7^1 POLIS_{it}] g(CR_{it}, \gamma, c) + \varepsilon_{it} \end{aligned} \tag{5}$$

$$\begin{aligned} BSTAB_{it} = {} & \mu_i + \beta_0^0 LR_{it} + \beta_1^0 CR_{it} + \beta_2^0 SIZE_{it} + \beta_3^0 CAP_{it} + \beta_4^0 PERF_{it} \\ & + \beta_5^0 LERNER_{it} + \beta_6^0 INF_{it} + \beta_7^0 POLIS_{it} \\ & + [\beta_0^1 LR_{it} + \beta_1^1 CR_{it} + \beta_2^1 SIZE_{it} + \beta_3^1 CAP_{it} + \beta_4^1 PERF_{it} + \beta_5^1 LERNER_{it} \\ & + \beta_6^1 INF_{it} + \beta_7^1 POLIS_{it}] g(LR_{it}, \gamma, c) + \varepsilon_{it} \end{aligned} \tag{6}$$

Table 2 displays definitions, measures and sources of all variables.

The dataset covers annual data relative to a sample of 75 banks for 11 countries, namely Algeria, Bahrain, Egypt, Jordan, Kuwait, Lebanon, Morocco, Qatar, Saudi Arabia, Tunisia and United Arab Emirates over the period 1999–2017. Accounting and financial data were collected directly from Bankscope database and bank's financial statements, while data on macroeconomic environment was extracted from World Bank Development Indicators (WDI) online database.

4. Empirical results and interpretation

We first display the descriptive statistics of the variables used in the PSTR model. In the second stage, we present the correlation matrix between variables. We move in the third stage to linearity

Table 2
Definitions, measures and sources of variables.

Variables	Definitions	Measures	Sources
BSTAB	Bank stability	Z-Score(roe) = $[E(\text{ROE}) + \text{CAP}]/\sigma(\text{ROE})$	Laeven and Levine (2008), Demirgüç-Kunt and Huizinga (2010), Hakimi, Zaghdoudi, Zaghdoudi, and Djebali (2017), and Amara and Mabrouki (2019).
CR	Credit risk	Non-performing loans/total loans	Cai and Zhang (2017), Mpofu and Nikolaidou (2018), Natsir et al. (2019), and Buthiena (2019).
LR	Liquidity risk	Liquid assets/total assets	Ghenimi et al. (2017) and Amara and Mabrouki (2019).
SIZE	Bank size	ln(total assets)	Anginer, Demirguc-kunt, and Zhu (2014) and Hakimi et al. (2017).
CAP	Capital adequacy ratio	Total equity/total assets	Pathan (2009), Hakimi et al. (2017).
PERF	Bank performance	ROA = net income/total assets	Rashid and Jabeen (2016), Hakimi and Zaghdoudi (2017), Ghenimi et al. (2017), and Amara and Mabrouki (2019).
LERNER INDEX	Market power measure	A measure of market power in the banking market[a]	Natsir et al. (2019).
INFL	Inflation rate	Consumer price index	Imbierowicz and Rauch (2014), Adusei (2015), and Kharabsheh (2019).
POLIS	Political stability	Variable that takes values between −2.5 and +2.5	Hakimi et al. (2017).

Source: Authors from literature review.
[a] It is defined as the difference between output prices and marginal costs (relative to prices). Prices are calculated as total bank revenue over assets, whereas marginal costs are obtained from an estimated translog cost function with respect to output. https://datacatalog.worldbank.org/lerner-index.

test between credit risk, liquidity and bank stability. Once the non-linearity is verified, we find out in the fourth step the number of regimes in the PSTR model. In fine, we estimate the PSTR model and discuss the results.

4.1. Descriptive statistics

Descriptive statistics are presented to reveal the main characteristics of data used in this study. For each variable, we display mean, standard deviation, minimum and maximum values. Table 3 summarizes variable descriptive statistics of the PSTR model.

The average value of bank stability (bstab) measured by Z-score (ROE) is equal to 4.835 with a maximum value of 24.721 and a minimum value of −2.327. The average of credit risk (CR) of conventional banks is 0.087 with a maximum value of 1.993. The average value of liquidity risk (LR) is 0.262 with minimum and maximum values of 0.017 and 2.795 respectively.

Size of banks which is equal on average to 8.703 is small. It has a maximum value of 12.314 and a minimum value of 4.002. Conventional banks in the MENA region are undercapitalized, with equity accounting for an average of 11.6% of their assets. In addition, the banks perform

Table 3
Variable Descriptive Statistics.

Variable	Mean	Std. Dev.	Min	Max
BSTAB	4.835	3.949	−2.327	24.721
CR	0.087	0.130	0.000	1.993
LR	0.262	0.159	0.017	2.795
Size	8.703	1.412	4.002	12.314
CAP	0.116	0.069	−0.314	0.699
PERF	0.016	0.032	−0.216	1.014
LERNER	0.342	0.212	−0.800	0.640
INF	0.037	0.040	−0.049	0.295
POLIS	−0.358	0.797	−2.117	1.224

Table 4
Correlation Matrix.

	BSTAB	CR	LR	SIZE	CAP	PERF	LERNER	INF	POLIS
BSTAB	1.000								
CR	−0.088	1.000							
LR	0.014	0.225	1.000						
SIZE	−0.061	−0.396	−0.170	1.000					
CAP	0.422	−0.197	0.045	−0.160	1.000				
PERF	0.044	−0.251	0.042	0.038	0.118	1.000			
LERNER	−0.061	−0.145	−0.131	0.121	0.150	0.083	1.000		
INF	−0.152	−0.059	0.066	0.055	−0.139	0.057	−0.049	1.000	
POLIS	0.099	−0.045	−0.071	−0.027	0.248	0.055	0.405	−0.223	1.000

poorly, since the economic profitability is on average very low and it is equal to 1.6% over the entire period selected. The average Lerner Index is equal to 34.2%, meaning that the banking market is not strongly dominated by banks. In the majority of MENA countries, the banking markets, which play a leading role in financing their economies, have still been controlled by the state, despite excessive waves of financial liberalization made by these countries.

As for the inflation rate, it was equal on average to 3.7% with a minimum value of −4.9% and a maximum value of 29.5%. The average value of political stability (Polis) is equal to −0.358, which is negative showing the deterioration of institutional quality, which can destabilize banking sector.

4.2. Correlation matrix

The correlation matrix gives information on the level and the nature of linkages between variables by determining the coefficients of their linear correlations. Table 4 below presents the correlation matrix of all variables used in this study.

Credit risk (CR), size (SIZE), Lerner index (LERNER) and inflation (INF) are negatively associated with bank stability. While liquidity risk (LR), capital adequacy ratio (CAP), performance and political stability (POLIS) are positively linked to bank stability. Results displayed in Table 4 show a weak correlation between all variables, rejecting hence the existence of multi-colinearity problem.

4.3. Linearity test

To show the non-linearity relationship between Credit Risk (CR), Liquidity Risk (LR) and Bank Stability (BSTAB), we apply linearity test based on two hypotheses presented as follows: Null hypothesis is $H_0 : \beta^1 = 0$ against Alternative hypothesis $H_1 : \beta^1 \neq 0$. However, this test of linearity is not standard, since under the null hypothesis, the PSTR model contains unidentified nuisance parameters (Hansen, 1999). To solve this problem, Luukkonen, Saikkonen, and Teräsvirta (1988) proposed to replace the transition function with Taylor's limited first-order development around $\gamma = 0$. Null hypothesis becomes $H_0{:}\gamma = 0$. Eqs. (4-1) and (4-2) can be written as follows:

$$BSTAB_{it} = \mu_i + \beta^{*0} x_{it} + \beta^{*1} x_{it} g(CR_{it}, \gamma, c) + \varepsilon^*_{it}$$

$$BSTAB_{it} = \mu_i + \beta^{*0} x_{it} + \beta^{*1} x_{it} g(LR_{it}, \gamma, c) + \varepsilon^*_{it}$$

After replacing the vector x_{it} with its components, we get the following equation:

$$\begin{aligned} BSTAB_{it} &= \mu_i + \beta_0^{*0} CR_{it} + \beta_1^{*0} LR_{it} + \beta_2^{*0} SIZE_{it} + \beta_3^{*0} CAP_{it} + \beta_4^{*0} PERF_{it} \\ &\quad + \beta_5^{*0} LERNER_{it} + \beta_6^{*0} INF_{it} + \beta_7^{*0} POLIS_{it} \\ &+ [\beta_0^{*1} CR_{it} + \beta_1^{*1} LR_{it} + \beta_2^{*1} SIZE_{it} + \beta_3^{*1} CAP_{it} + \beta_4^{*1} PERF_{it} \\ &\quad + \beta_5^{*1} LERNER_{it} + \beta_6^{*1} INF_{it} + \beta_7^{*1} POLIS_{it}] g(CR_{it}, \gamma, c) + \varepsilon^*_{it} \end{aligned}$$

$$\begin{aligned} BSTAB_{it} &= \mu_i + \beta_0^{*0} LR_{it} + \beta_1^{*0} CR_{it} + \beta_2^{*0} SIZE_{it} + \beta_3^{*0} CAP_{it} + \beta_4^{*0} PERF_{it} \\ &\quad + \beta_5^{*0} LERNER_{it} + \beta_6^{*0} INF_{it} + \beta_7^{*0} POLIS_{it} \\ &+ [\beta_0^{*1} LR_{it} + \beta_1^{*1} CR_{it} + \beta_2^{*1} SIZE_{it} + \beta_3^{*1} CAP_{it} + \beta_4^{*1} PERF_{it} \\ &\quad + \beta_5^{*1} LERNER_{it} + \beta_6^{*1} INF_{it} + \beta_7^{*1} POLIS_{it}] g(LR_{it}, \gamma, c) + \varepsilon^*_{it} \end{aligned}$$

Where the parameters $\beta_0^{*1}, \beta_1^{*1}, \ldots, \beta_7^{*1}$ are multiples of γ and $\varepsilon^*_{it} = \varepsilon_{it}$ + residual of Taylor's limited first-order development. The null hypothesis of linearity test becomes $H_0 : \beta_0^{*1} = \cdots = \beta_7^{*1} = 0$. To test this null hypothesis, we use three tests which are Wald test (LM_W), Fisher test (LM_F) and likelihood ratio test (LRT).

The Wald test (LM_W) is written as follows: $LM_w = \frac{NT(SSR_0 - SSR_1)}{SSR_0}$ Where SSR_0 is the panel sum of squared residuals under H_0 (linear panel model with individual effects) and SSR_1 is the panel sum of squared residuals under H_1 (PSTR model with m regimes). N and T represent respectively cross-section and time.

The Fisher test (LM_F) is defined as: $LM_F = \frac{NT(SSR_0 - SSR_1)/mk}{SSR_0/TN - N - mk}$ with k and m are respectively the numbers of explanatory variables and regimes.

The likelihood ratio test (LRT) is expressed as follows: LRT = −2[log (SSR1) − log(SSR0)].

Under null hypothesis, Wald and likelihood statistics follow Chi (2) distribution with k degrees of freedom ($\chi^2(k)$) while Fisher Statistic pursues a Fisher distribution (F(mk, NT − N − mk)).

For a logistic transition function of order one (m = 1), results of these three tests are presented in Table 5.

Table 5 shows that the null hypothesis (linear model) is rejected at 1% level of significance for the three tests. Consequently, the relationships between:

Table 5
Linearity tests.

Test	BSTAB	CR	BSTAB	LR
	Statistics	*P*-value	Statistics	*P*-value
Wald test (LM_W)	63.817	0.000	45.639	0.000
Fisher test (LM_F)	10.298	0.000	7.125	0.000
Likelihood Ratio Test (LRT)	67.447	0.000	47.456	0.000

Table 6
Tests for the number of regimes.

Tests	BSTAB	CR	BSTAB	LR
	Statistics	*P*-value	Statistics	*P*-value
Fisher test (LM_F)	153.673	0.000	135.523	0.000
Likelihood Ratio Test (LRT)	10.379	0.000	8.799	0.000

i) Bank Stability (BSTAB)and Credit Risk (CR)
ii) Bank Stability (BSTAB) and Liquidity Risk (LR)

are non-linear.

4.4. Determination of the number of regimes

After rejecting linear model and verifying non-linearity, PSTR model has hence at least one threshold. To find out the number of thresholds (or regimes) in the PSTR model, we test the following hypothesis H_2: PSTR model has at least two thresholds (r = 2). Alternative hypothesis is the following H_a: PSTR model has one threshold (r = 1). To check hypothesis H_2, we use two tests which are Fisher test (LM_F) and likelihood ratio test (LRT). If Fisher and likelihood statistics are significant, we reject the hypothesis H_2 and we conclude that the PSTR model has one threshold and has then two regimes. Results of these two tests are reported in Table 6.

Results from Table 6 indicate that hypothesis H_2 is rejected at 1% level of significance for the two tests. For the two transition variables used in this study (Credit risk CR and Liquidity risk LR), the two PSTR models have only one threshold and they are therefore a two-regime models.

4.5. PSTR model estimation

We use hence PSTR models with two regimes to estimate the relationships between Bank Stability (BSTAB) and Credit Risk (CR), and Bank Stability (BSTAB) and Liquidity Risk (LR) for 75 banks by applying non-linear least squares technique. Results of the PSTR models estimations are presented in Table 7.

Estimation results of PSTR model reported in Table 7 show that both the relationship between bank stability (BSTAB) and credit risk (CR), and bank stability (BSTAB) and liquidity risk (LR) are characterized by the presence of a threshold effects. The optimal thresholds are equal to 13.16% for credit risk and 19.03% for liquidity risk.

Estimation results of Eq. (5) show that below the threshold of 13.16%, credit risk and liquidity risk exert a positive and significant effect on bank stability. This positive effect can be explained

Table 7
PSTR models estimations.

	Estimation results of equation (5)		Estimation results of equation (6)	
	Coeff.	*T*-Stat	Coeff.	*T*-Stat
CR	915.482***	2.910	0.182	0.572
LR	2216.502**	2.426	1.348***	7.082
SIZE	233.439**	2.019	0.152***	3.687
CAP	2885.709***	4.183	18.367***	40.332
PERF	10440.466**	2.352	−2.746*	−1.801
LERNER	751.004	0.749	−0.047	−0.440
INF	0.396	0.719	−0.126	−0.238
POLIS	0.202***	3.265	0.094	1.560
CR * $g(q_{it}, \gamma, c)$	**−1826.540*** **	**−2.903**	1.010***	3.504
LR * $g(q_{it}, \gamma, c)$	−4456.932**	−2.425	**−1.173*** **	**−2.786**
SIZE * $g(q_{it}, \gamma, c)$	−469.228**	−2.017	0.029	1.348
CAP * $g(q_{it}, \gamma, c)$	−5759.691***	−4.151	5.206***	10.575
PERF * $g(q_{it}, \gamma, c)$	−21,013.899**	−2.353	−7.900***	−3.760
LERNER * $g(q_{it}, \gamma, c)$	−1510.857	−0.749	−0.592	−1.442
γ	0.200		5.000	
C	**0.1316**		**0.1903**	
AIC	−1.815		−1.892	
BIC	−1.698		−1.776	
Obs	604		604	

Note: ***, ** and * indicate level of significance respectively at 1%, 5% and 10%.

by the fact that banks in the MENA countries continue to give primacy to credit activity, despite the exhaustion of the main factors, which have supported the bank intermediation for a long time. Also, the ressources of these banks are collected from their customs in form of deposits which are less expensive. Howevre, beyond the optimal thresholds of 13.16%, both credit and liquidity risks become detrimental to the stability of banks. This result is in line with those of Adusei (2015), Khemais (2019), Ghenimi et al. (2017), etc. When non-performing loans exceed 13.16% of total credits, the risk of non-recovery increases and banks find it difficult to recover their credits, which should have been allocated to more productive activities. Banks' rentability decreases affecting hence their stability. Above the optimal threshold of credit risk of 13.16%, liquidity risk has a negative and significant effect at the 5% level on bank stability. Liquidity risk is added to credit risk to destabilize banks in selected countries. Excessive bank liquidity could push banks to grant a lot of credits (quantity effect) their probability of return is low. This risk taking could adversely affect their profitability and solvency and threaten their longevity.

Estimation findings of Eq. (6) reveal that below the threshold of 19.03%, contrary to credit risk which has a positive but non significant impact, liquidity risk acts positively at 1% level of significance on bank stability in the MENA region. Above the optimal threshold of 19.03%, credit risk becomes significant and continues to affect positively bank stability. Over the selected period 1999–2017, bank liquidity, which equals on average to 26.2% of total assets of banks, that is above the threshold of 19.03%, favors the granting of loans, which generates interests that reinforces their net income and ensures their stability. As for the liquidity risk, econometrical results reveal that it destabilizes banks of the MENA region. This negative effect is explained by the shortfall for banks that hold a significant portion of their assets in liquid form. Beyond this threshold, liquidity is expensive for banks, which are deprived of investment opportunities.

Unlike the other works, our paper has the merit of showing that the effects of the other variables on bank stability depend on the optimal thresholds of the credit and liquidity risks. In fact, when the credit risk and the liquidity risk exceed the thresholds of 13.16% and 19.03% respectively, the performance destabilizes banks. Over the selected period, the return on assets is equal on an average to 1.6%, which is low. The profits generated by banks come mainly from their balance sheet intermediation (granting of loans, collection of deposits, provision and management of means of payment). As a result, MENA banks are encouraged to develop new businesses and provide new personalized and online services to their customers around the world.

The effect of the capital adequacy ratio (cap) on bank stability depends on the transition variable. On the one side, beyond the credit risk threshold of 13.16%, this variable is detrimental to the stability of banks. This negative and destabilizing effect can be explained by the under-capitalization of the selected banks, since equitys represent on average 11.6% of the total assets over the selected period 1999–2017. This under-capitalization adds to their low profitability to destabilize the banking sector of MENA countries.

On the other side, above the liquidity risk threshold of 19.03%, this variable (cap) favors the stability of banks. Bank liquidity plays the same role of reassuring banks' customers and shareholders. Even if the equity is not enough, bank liquidity comes in supplement and indicates the good financial health of banks.

As for the effect of the size variable, it has a negative and significant effect on bank stability only beyond the credit risk threshold of 13.16%. This damaging effect is due to the small size of the majority of banks in the MENA region which prevents them from recovering nonperforming loans. Banks are finding it difficult to use new credit risk management techniques such as securitization and defeasance. In the various capital markets, this small size is overwhelming banks and limiting their margin of negotiation. This undermines their stability. For this reason, MENA banks are required to make adequate banking restructurings to become regional champions, able to not only strengthen their market share, but also to conquer new foreign markets.

Regarding the exogenous variables (INF and POLIS), empirical results show that only political stability is important for banking stability. As a result, MENA countries are encouraged to ensure political stability and combat violence and terrorism.

5. Conclusion and recommendations

Many researches examined the relationship between credit risk, liquidity risk and bank stability. They assumed a linear relationship between bank risks and stability. The purpose of this paper is threefold:

i) showing the non-linear relationship between credit risk, liquidity risk and bank stability.
ii) determining the optimal credit risk and liquidity risk thresholds.
iii) studying the impact of this threshold effect on the stability of banks.

To achieve this goal, we selected a sample of 75 conventional banks from 11 MENA countries over the period 1999–2017. We performed the Panel Smooth Threshold Regression (PSTR) model developed by Gonzalez et al. (2005).

Different from other studies, our paper has the advantage of endogenously determining two thresholds above which bank stability is affected. Indeed, our results show hence that the relationships between both bank stability-credit risk and bank stability-liquidity risk are non-linear and characterized by the presence of two optimal thresholds which are equal to 13.16% for credit risk and 19.03% for liquidity risk.

Contrary to their positive effects below the threshold of 13.16%, credit risk and liquidity risk become detrimental to bank stability in high regime. For credit risk, this negative effect can be explained by the difficulties or even the inability of banks to return the granted credits, which are colossal and which should have been allocated to more profitable activities that can ensure bank stability. Banks in the MENA region are still slow to apprehend and functionalize financial innovations. New banking risk management techniques (such as securitization and defeasance) are not developed by banks, which still rely on banking personnel who do not know how markets work. As a result, the activities of banks in the MENA region remained confined to traditional activities. Concerning liquidity risk, its negative effect can be explained by the multiform competition and the superfluous bank liquidity which can push banks to take risks and grant more credits to their customers without taking into account their solvability. This risk taking increases nonperforming loans, decreases their profitability and threatens their stability.

Estimation findings of Eq. (6) reveal that below the threshold of 19.03%, contrary to credit risk which has a positive but non significant impact, liquidity risk acts positively at 1% level of significance on bank stability in the MENA region. Above the optimal threshold of 19.03%, credit risk becomes significant and continues to affect positively bank stability. Over the selected period 1999–2017, bank liquidity, which is equal on average to 26.2% of total assets of banks, which is superior than the threshold of 19.03%, favors the granting of loans. This generates interests that reinforce their net income and ensure their stability. As for the liquidity risk, econometrical results reveal that it destabilizes banks of the MENA region. This negative effect is explained by the shortfall for banks that hold a significant portion of their assets in liquid form. Beyond this threshold, liquidity is expensive for banks, which are deprived of investment opportunities.

For the other explanatory variables, results reported in Table 7 show that above the two optimal thresholds of 13.16% and 19.03%, the profitability of banks, which is very weak, threatens their stability. Banks are called to revise the primacy given to credit activity and focus on new activities and services. States in selected countries are encouraged to fundamentally reform their financial systems and develop the legal framework for new external risk management techniques, including securitization and defeasance.

The effect of the capital adequacy ratio (cap) on bank stability depends on the transition variable. On the one hand, beyond the credit risk threshold of 13.16%, this variable is detrimental to the stability of banks. This negative and destabilizing effect can be explained by the under-capitalization of the selected banks, since equities represent on average 11.6% of the total assets over the selected period 1999–2017. This under-capitalization adds to their low profitability to destabilize the banking sector of MENA countries.

On the other hand, above the liquidity risk threshold of 19.03%, this variable (cap) favors the stability of banks. Banking liquidity plays the same role of reassuring banks' customers and shareholders. Even if the equity is not enough, the bank liquidity comes in supplement and indicates the good financial health of the banks.

As for the effect of the size variable, it has a negative and significant effect on bank stability only beyond the credit risk threshold of 13.16%. This damaging effect is due to the small size of the majority of banks in the MENA region which prevents them from recovering nonperforming loans. Banks find difficults in using new credit risk management techniques. In the various capital markets, this small size is overwhelming banks and limiting their negotiation margin. This undermines their stability. For this reason, MENA banks are required to make adequate banking restructurings to compete with giant foreign banks, which can set up in the region under signed agreements.

As for the exogenous variables, empirical results show that only political stability (POLIS) impacts positively and significantly bank stability of the MENA region, showing the importance of political stability for bank and financial stability. That is why MENA countries are encouraged to guarantee political stability and combat violence and terrorism.

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