Received 24 August 2022
Revised 25 January 2023
29 March 2023
Accepted 3 April 2023

Bank risk exposures and bank stability in Africa: the role of regulations in a non-linear model

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Abstract

Purpose – This paper aims to examine the interaction effect of regulations (monetary and macro-prudential) in explaining the possible non-linear effect of bank risk exposures (credit risk and insolvency risk) on banking stability in Africa.

Design/methodology/approach – The study uses a two-step system generalized method of moments (GMM) estimator for a data set of banks across 54 African countries over the period 2006–2020.

Findings – The authors find that the relationships between bank credit risk–bank stability and bank insolvency risk–bank stability are non-linear and characterized by the presence of optimal thresholds, which are 5.3456 for credit risk and 2.3643 for insolvency. Contrary to their positive effects below these optimal thresholds, credit risk and insolvency risk become negatively linked to bank stability in Africa. The authors find that macro-prudential action and monetary policy both have a positive and significant relationship with bank stability. The authors provide evidence to support that the marginal effect of excessive credit risk and insolvency risk on bank stability is reduced when interacted with monetary and macro-prudential regulations, and the impact is significant in strong institutional environment.

Research limitations/implications – Future research should extend data to include developing and emerging economies in the world. Also, policymakers, researchers and practitioners should consider different regulatory and institutional frameworks in explaining the relationship between the thresholds of bank risk exposures and bank stability in the world.

Practical implications – Regulatory authorities should have to deeply reform their financial systems, develop risk-based regulatory framework and effective supervision mechanism relating to appropriate

JEL classification – D8, G2, G3, G32, G33, G38

Declarations: Availability of data and materials: The data sets used and/or analysed during the current study are available (with corresponding author) on reasonable request.

Competing interests: The authors declare that they have no competing interests.

Funding: This study received no financial support from any institution or person. The study was carried out as a result of collaborative efforts by authors without any direct or indirect support from any institution.

Journal of Financial Regulation and Compliance
Vol. 31 No. 5, 2023
pp. 546-567
© Emerald Publishing Limited
1358-1988
DOI 10.1108/JFRC-08-2022-0099

techniques that maintain an optimal and desired level of bank risks and risk-taking behaviours required to ensure a stable banking system.

Originality/value – To the best of the authors' knowledge, this is the first study to examine how different regulatory frameworks shape the non-linear impact of bank risk exposures on bank stability in Africa.

Keywords Bank stability, Non-linear thresholds, Bank risk exposures, Regulations

Paper type Research paper

1. Introduction

The stability of the banking sector is critical for the growth and development of every economy in the world. Lessons from the 2008/2009 global financial crisis and the recent COVID-19 pandemic have stirred up interests among researchers, policymakers and banking practitioners to come up with financial sector reforms to build a resilient financial system (Caruso *et al.*, 2021; Djebali and Zaghdoudi, 2020). In view of that, extant literature, in recent times, has focused on the complex banking behaviour and their interrelationship with banking system stability (Vo *et al.*, 2021, 2018; Ozili, 2018). Among the many complex banking behaviours, bank risk exposures (e.g. credit risk and insolvency risk) have been widely studied as important determinant of bank stability (ALrfai *et al.*, 2022; Naili and Lahrichi, 2022; Djebali and Zaghdoudi, 2020; Fratzscher *et al.*, 2016; Ghosh, 2015; Adusei, 2015; Beltratti and Stulz, 2012; Jokipii and Monnin, 2013; Apatachioae, 2015).

The debate on the relationship between bank risk exposures and bank stability is not conclusive because the empirical results from the literature have been divergent. For instance, several studies support the negative impact of bank risk exposures on the stability of banks (Khemais, 2019; Ghenimi *et al.*, 2017; Adusei, 2015; Imbierowicz and Rauch, 2014; Rajhi and Hassairi, 2013), while others show the positive effect of bank risk exposures on bank stability (Khemais, 2019; DeYoung and Jang, 2016; Li and Zou, 2014). On one hand, these studies have the advantage of adopting different empirical approaches but, on the other hand, assume a linear relationship between bank risks measures and bank stability. This linear relationship can lead to mixed results that can mislead policymakers and bank managers.

Firstly, this paper attempts to fill this gap and contributes to the existing literature by examining the non-linear relationships and threshold effects of bank risk exposures on bank stability. This paper argues that banks may engage in risky activities that may yield greater profits and strengthen the banking system but excessive risk exposures may lead to financial distress and destabilize the banking system (see, e.g. Djebali and Zaghdoudi, 2020). Drawing insight from the literature, this study differ from that of Djebali and Zaghdoudi (2020) by showing that the relationship between bank risk exposures (credit risk and insolvency risk) and bank stability is non-linear and the impact is not the same below and above the optimal thresholds of bank risk exposures. Furthermore, it is evident that excessive risk exposures of banks reduce the stability of banks (Uhde and Heimeshoff, 2009; Shehzad and De Haan, 2009; Beck and Cull, 2013; Ozili, 2018). The higher the risk exposures of banks, the higher the propensity of the bank to experience instability (Almarzoqi *et al.*, 2015). Thus, at higher levels of bank risk exposure, banks may be unstable. This supports the non-linearity that exists between bank risks and bank stability, as indicated by Djebali and Zaghdoudi (2020), who found a positive impact of credit risk and liquidity risk on bank stability. Contrary to their positive effects, below certain thresholds, these risks become detrimental to bank stability.

Second, bank deregulation across many economies caused significant structural changes that impacted the fragility of the banking system (Ozili, 2018). Thus, improving the argument on how excessive risk exposures adversely affect bank stability may cutback the probability of insolvency and provide greater stability of the banking system (Segoviano and Goodhart, 2009; Ozili, 2018). For that reason, studies have shown the role of regulations, like monetary and macro-prudential policies, in mitigating the build-up of risks in the financial sector (Stein, 2013; Smets, 2014; Martinez-Miera and Repullo, 2019). For instance, the recent study by Martinez-Miera and Repullo (2019) found that monetary and macro-prudential policies are effective in fostering financial stability. However, these studies were silent on the role that monetary and macro-prudential regulations play in taming the excessive risk exposures of banks that lead to unstable banking.

It is obvious that a more robust risk framework is thus critical for banks to boost their stability. It is argued earlier that, beyond an optimal thresholds of bank risk exposures, banking stability may reduce. Therefore, policymakers would be interested to understand how regulations control the threshold levels of bank risk exposures that induce lower banking stability. In particular, policymakers may be interested in ensuring that proper monetary and macro-prudential policies are implemented to address excessive risk exposures to improve bank stability. The study fills this gap and contributes to empirical literature by interacting the square term of measures of bank risk exposures (i.e. excessive credit risk and insolvency risk exposures) with regulations (monetary and macro-prudential regulation) to examine how bank stability is improved when additional risk exposures interact with regulations.

Given that the restructuring and regulatory initiatives have taken place over the past decades, Africa provides an interesting case for the role of monetary and macro-prudential regulation in shaping the relationship between bank risk exposure and the predicted bank stability. Moreover, most of the studies done in developed economies found inconsistent results (Beltratti and Stulz, 2012; Jokipii and Monnin, 2013; Fratzscher *et al.*, 2016; Amara and Mabrouki, 2019) and failed to investigate whether monetary and macro-prudential regulations play a key role in shaping the threshold effects of bank risk exposures on banking system stability. Moreover, for Middle East and North Africa (MENA) regions, Djebali and Zaghdoudi (2020) established the thresholds and non-linearity between bank stability–credit risk and bank stability–liquidity risk without considering the role that regulation play. However, Klomp and de Haan (2014) investigated the interrelationship between banking regulation, the quality of institutions and banking risk emerging and developing countries without considering the impact of these variables on banking system stability in Africa. A recent study in Africa focused on the determinants of bank stability (Ozili, 2018) but ignored the interactive role of monetary and macro-prudential regulation on the relationship between bank risk exposures and bank stability.

Finally, it is well known that banks behave differently under different institutional settings (Haselmann and Wachtel, 2006; Klomp and de Haan, 2014), which implies that results obtained for the interactive effects of bank risk exposures and bank stability may differ across institutional frameworks. The paper conducts a robust estimation to ascertain how the interactions differ across different institutional settings. The study makes novel contributions to the literature by establishing that initial levels of bank risk exposures increase stability, but at higher levels of risk exposures, the relationship is negative. In addition, different regulatory policies moderate the threshold effect of bank risk exposures on banking stability. Thus, regulations alter the negative effect of bank risk exposures on bank stability in the non-linear model.

2. Literature review

This study draws inspiration from the economic theory of regulation. Den Hertog (2012) and Gaffikin (2005) explain two main theories of regulations, including the public interest theory of regulation and the private interest theory of regulation. The public interest theory of regulation seeks to explain the protection and benefits given to the public in terms of the best possible allocation of scarce resources for collective and individual goods (Hantke-Domas, 2007; McCraw, 1975), while private interest theory of regulation advances that regulations promote the interest of dominant individuals and groups in society, but not the public interest (Gaffikin, 2005). Thus, a number of studies have argued that regulations have both economic and financial implications (Leuz and Wysocki, 2016; Avgouleas, 2009; Tadesse, 2006). Although regulations may not always yield a desired outcome, the control of excessive risk exposures through proper risk management mechanisms and strong regulations can enhance the interactions of bank risk exposures and regulations in improving the stability of banks. Given that bank stability is a characteristic of financial stability, the important role of regulations in improving risks–stability nexus remains an assertion, which needs to be empirically tested. In particular, regulations may reduce excessive risk exposures of banks (Djebali and Zaghdoudi, 2020) and may better yield desirable outcomes in maintaining bank stability.

The effects of bank risks on the stability of banks have been the subject of several academic works (Khemais, 2019; Amara and Mabrouki, 2019; Atoi, 2018; Acharya and Mora, 2013; Ghenimi *et al.*, 2017; DeYoung and Jang, 2016; Adusei, 2015; Imbierowicz and Rauch, 2014; Li and Zou, 2014; Rajhi and Hassairi, 2013). The results in these works appear not consensual because some works have shown that bank risks have destabilized the banks, while others have shown that bank risks have led to stability and sustainability of banks. The other studies have also shown the neutral effect of bank risks on bank stability, which is basically dependent on other factors. For instance, Atoi (2018) explained the effect of non-performing loan on bank stability by using a restricted dynamic generalized method of moments (GMM) for national and international licensed banks in Nigeria. 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 and found a negative relationship. The empirical results of Adusei (2015), who used quarterly bank data from 2009 to 2013 in the Ghanaian context, established that credit risk is harmful to the stability of banks. Imbierowicz and Rauch (2014) analysed the relationship between liquidity and credit risks and their joint impact on banks' probability of default for US banks. They extended their findings to show that their interaction depends on the overall level of bank risks and can worsen or curb the risk of default of banks. Contrary to these findings, studies have revealed that liquidity risk improves the stability of Tunisian banks (Khemais, 2019), while credit risk has a significant effect on bank performance among commercial banks in Europe from 2007 to 2012 (Li and Zou, 2014). Amara and Mabrouki (2019) examined the relationship between liquidity and credit risk and their impact on bank stability of Tunisian banks during the period 2006–2015 by using the *Z*-score. They found that these risks have no significant impact on bank stability.

Conversely, these studies ignored the non-linear effect of bank risk measures and banking stability. Studies that considered the non-linear bank risk–stability nexus were focused on the MENA countries. For instance, Djebali and Zaghdoudi (2020) used a panel smooth threshold regression model for a panel data set of 75 banks in 11 countries in MENA region over the 1999–2017 period. Their results show that the relationships between bank risks and bank stability are non-linear and characterized by the presence of optimal thresholds. However, below these optimal thresholds, bank risks' positive effect becomes hazardous to bank stability in high regime.

In the case of regulatory impact, Bermpei *et al.* (2018) used a panel data of 1,050 commercial banks from developing and emerging economies between 2004 and 2013 and examined how institutional quality affects banking regulations and on bank stability. Specifically, they found that institutional quality enhances the positive effect of regulation and supervision on bank stability measured with the *Z*-score. Martinez-Miera and Repullo (2019) show that monetary and macro-prudential policies are useful in improving financial stability and leads to higher social welfare.

In bank stability empirics, Dayong *et al.* (2016) found that bank stability varies across bank types and that when a threshold panel regression model is applied, the result confirms a moral hazard hypothesis, where an increase in non-performing loans leads to higher lending risk and banking system instability (Lui, 2016). Several studies have shown that factors that influence bank stability differ across economies (Tan and Floros, 2013; Tan, 2014; Tan and Anchor, 2016). For example, empirical work by Barth *et al* (2013) separately examined that incomplete regulation and ineffective supervision result in banking instability. Moreover, regulation and supervision may not significantly influence bank stability and that these mixed results are attributed to differences in supervision and regulation quality across countries. Some studies considered institutional factors like banking regulation, supervision and capital regulation as key determinants of bank stability while controlling for institutional framework and country effect (Klomp and de Haan, 2014; Beltratti and Stulz, 2012). In using 50 advanced and emerging market economies, Fratzscher *et al.* (2016) analysed how the post-crisis stringent supervision and the tightening of regulation helped to reduce credit growth and improved bank stability. They observed that bank regulation and institutions are substitutes rather than complements for bank stability and for that matter both effects were stronger for countries operating in low institutional quality.

From the theoretical and empirical reviews, it is evident that the relationship between the level of bank risk exposures and bank stability may be influenced by regulations. However, empirical studies to this effect are non-existent from the African context. Furthermore, the existing literature on bank risk, regulation and bank stability have focused on the independent effect of bank risks and regulations on stability of banks.

Based on the above literature, the study presents the following hypotheses:

H1. There is an inverted U-shaped non-linear relationship between bank risk exposures and bank stability.

H2. Regulation reduces the negative impact of bank risk exposures on bank stability.

H3. Regulations play a significant role in reducing the negative impact of bank risk exposures on bank stability.

3. Data and methodology

The study examines the complex relationship between bank risk exposures, regulations and bank stability. The study uses a panel data set of the banking sector in 54 African countries over the period, 2006–2020. The data was selected based on data availability. The data was sourced from the BankScope database and from the Global Financial Development Database of the World Bank.

3.1 Model specification

Following Fernández *et al.* (2016), we adopt a baseline model as follows:

$$\text{Bank stability} = f(\text{Bank Risk Exposures, Regulations, Controls}) + \text{error term} \quad (1)$$

From the general model in equation (1), the study examines two key hypotheses.

Firstly, we show the non-linear impact of bank risk exposures on bank stability (see, e.g. Djebali and Zaghdoudi, 2020). We specify the model as:

$$Z\_score_{jt} = \beta_1 Z\_score_{jt-1} + \sum_{l=1}^{2} \alpha_l Bank\,Risk\,Exposures_{jt} + \sum_{l=1}^{2} \delta_l Bank\,Risk\,Exposures^2{}_{jt} + \sum_{p=1}^{2} \alpha_i Regulations_{jt} + \sum_{k=2}^{N} \beta_k X_{jt} + \theta_j + \mu_t + \varepsilon_{jt} \quad (2)$$

where Z-score$_{jt}$ represents the Z-score of the aggregate banking sector in country j at time t; subscript j denotes the cross-sectional dimension (countries in Africa), $j = 1, [\ldots], M$; and t denotes the time series dimension (time period), $t = 1, [\ldots], T$; β_1 is the coefficient of the lag of the dependent variable; α_l: $l = 1, [\ldots], 2$, represent the regression coefficients of a vector of two bank risk exposure variables (credit risk and insolvency); δ_l: $l = 1, [\ldots], 2$, represent the regression coefficients of the square terms on bank risk exposure variables; α_i: $i = 1, [\ldots], 2$, represent the coefficients of the regulation variables.

β_k; $i = 2, [\ldots], k$ are regression parameters (for the set of control variables) to be estimated; ε_{jt} is idiosyncratic error term which controls for unit-specific residual in the model for *the* jth *country* at *period* t; θ_j is the country fixed effect j; and μ_t is the time fixed effect t.

X_{jt} is a vector of control variables in equation (2). These include foreign bank entry, measured with a dummy equal to 1, if a bank entered into a country in a particular year, 0 otherwise; bank size is the natural logarithm of total asset; bank funding is measured as the ratio of bank deposit to total asset; competition, measured as the inverse of Lerner index, bank concentration (the ratio of asset of the three largest commercial banks to total commercial banking assets in a country); equity to asset ratio; real gross domestic product (GDP) per capita; inflation (adjusted consumer price index); institutions, which is measured as an aggregate of six indicators (rule of law, government effectiveness, control of corruption, political stability, regulatory quality and voice and accountability) obtained from the World Governance Indicators.

Bank level data was obtained from BankScope, and data on macroeconomic variables was obtained from the World Bank Global Financial Development database.

3.1.1 Dependent variable – bank stability

The dependent variable is the Z-score. We primarily measure bank stability using the Z-score, which equals the return on assets plus the capital asset ratio dividend by the standard deviation of asset returns (Ozili, 2018; de Nicolo *et al.*, 2006). The Z-score measures the distance from insolvency such that higher Z-score implies that the bank is more stable. Data on the Z-score was obtained from the BankScope database. We introduce the lag of the dependent variable (Z-score) to capture its persistent over time. We expect past stability in the banking system to positively impact the next stability in the banking sector.

3.1.2 Impact of bank risk exposures

In this case, bank risk exposures is the key independent variable decomposed into credit risk and insolvency risk. Following Atoi (2018) and Djebali and Zaghdoudi (2020), credit risk is measured as ratio of non-performing loans to gross loans. Data on credit risk was obtained from BankScope database, indicating that higher values imply greater bank risk exposure.

We argue for a non-linear relationship between bank risk exposures and bank stability. In view of that we introduce the square term of each of the bank risk exposure variables to estimate the non-linear relationship and the threshold effect. For meaningful interpretation, we compute the threshold level from equation (2) as:

$$\text{Threshold effect } = \frac{\partial Z - scroe_{j,t}}{\partial\, External\, governance\, mechanism_{jt}} = \alpha_l + 2\alpha_l Bank\, Risk\, Exposures_{jt} \tag{3}$$

For instance, we introduce the square term of credit risk (which measures the excessive levels of credit risk exposure) into the model and observe the relationship. We expect a positive linear relationship between credit risk and bank stability. However, we expect the square term of credit risk to be negatively linked to bank stability. This confirms the non-linear relationship examined by Djebali and Zaghdoudi (2020), who found that credit risk and liquidity risk negatively impact bank stability at higher levels. The estimated threshold level shows the level below which bank risk exposures may reduce a stable banking system.

Next, we simultaneously introduce insolvency risk and its square term (i.e. excessive insolvency risk exposure) into the model and observe their impact on bank stability. Insolvency risk is measured as the ratio of loan loss reserves to total loans. Data on insolvency ratio was obtained from BankScope database, indicating that higher values represent greater risk exposure by banks. We also expect a positive impact of insolvency on bank stability while the square term is expected to negatively impact bank stability. This shows that excessive risk exposure by banks is likely to lead to banking instability. This is in line with Shehzad and De Haan (2009), who found that excessive insolvency leads to banking failure. We compute and interpret the threshold effect. The estimated threshold level shows the level below which insolvency risk may lead to an unstable banking system.

3.1.3 Impact of regulation

From equation (2), we examine the independent effect of bank regulations on bank stability in the non-linear model without the interaction terms.

Regulation is decomposed into two key indicators: (1) monetary policy and (2) macro-prudential action. Monetary policy is regulation or policy actions taken by the central bank to control money supply and the interest rate payable on short-term borrowings. We use monetary policy rates as proxy for monetary policy, such that higher values indicate contractionary policy. We obtained data on monetary policy (proxied as monetary policy rates) from IMF (International Financial Statistics). We expect a positive impact of monetary policy on bank stability. This suggests that countries that operate in tight monetary policy regime are able to maintain a stable banking system. This supports the quest to maintain price stability and financial stability goals by monetary authorities.

Data on macro-prudential policy is the weighted aggregate (composite index) of 17 indicators of macro-prudential action. Data was obtained from the iMaPP database constructed by Alam *et al.* (2019), integrating information from major existing data basses (the global macro-prudential policy instruments and IMF annual macro-prudential policy survey), national sources (Lim *et al.*, 2011, 2013; Alam *et al.*, 2019). The macro-prudential index from the database varies between −1 and 1, with positive values indicating tightening or stringent policy action and negative values indicating loosening of the policy action. Following Martinez-Miera and Repullo (2019), macro-prudential policy is expected to positively impact *Z*-score. A positive impact of macro-prudential on *Z*-score suggests that countries that operate in stringent macro-prudential environment limits risk exposures while shaping bank stability.

3.1.4 Control variables

In terms of control variables, we expect either a positive or a negative relationship between foreign bank entry and bank stability. A positive impact implies that countries that open their economy for foreign bank entry increase stability in the banking system while a negative impact indicates that foreign bank entry jeopardizes the stability of the banking system. We expect bank size to positively affect bank stability. This means that as banks grow in size, they have the capacity to be more stable. We expect a positive relationship between bank funding and bank stability because banks that mobilize more deposits are able to undertake activities that generate more profits and improve the stability of the banks. In addition, we expect either a positive or negative impact of competition on possibility of bank stability. A positive impact suggests that greater competition leads to a more stable banking system. On the other hand, less competitive banking market (greater market power) is likely to increase bank stability, as supported by Ukaegbu and Oino (2014). We expect equity to total asset to either increase or decrease bank stability. A positive relationship between capital ratio and bank stability suggests that a well-capitalized banks are able to become more stable. However, the use of equity capital exposes the banks to more risk, leading to a negative impact on stability. Inflation rate is expected to negatively affect the *Z*-score. This suggests that banks that face greater inflationary regime may take excessive risk. Real GDP is expected to negatively affect *Z*-score. We expect a positive effect of institutions on bank stability. This implies that good institutions are expected to increase banks' stability.

In what follows, we examine the interaction estimations of bank risk exposures, regulations and bank stability.

3.1.5 Interaction effect of bank risk exposure and regulations on bank stability

Given that regulations are enacted to control the excessive risk exposures of banks and improve bank stability, we interact the square term (excessive levels) of the two measures of bank risk exposures with country-level regulations to observe their impact on bank stability.

Based on this we express the model as follows:

$$
\begin{aligned}
Z\_score_{jt} = {} & \beta_1 Z\_score_{jt-1} + \sum_{l=2}^{3} \beta_l Bank\,Risk\,Exposures_{jt} + \sum_{l=1}^{2} \lambda_l Bank\,Risk\,Exposures^2_{jt} \\
& + \sum_{p=1}^{2} \alpha_p Regulations_{jt} + \sum_{q=1}^{2} \gamma_q \left(Bank\,Risk\,Exposures^2_{jt} * Regulations_{jt} \right). \\
& + \sum_{k=1}^{N} C_k X_{jt} + \delta_j + \theta_t + \mu_{jt}
\end{aligned}
\tag{4}
$$

where β_1 is the coefficient of the lag of the dependent variable; β_l: $l = 2, [\ldots], 3$, represent the regression coefficients of the bank risk exposure variables (credit risk and insolvency) as explained above. α_p: p = 1, [...], 2, represent the regression coefficients of a vector of two regulation variables; γ_q is the coefficients of the interaction terms between bank risk exposure variables and regulation; and C_k are regression parameters (for the set of control variables) to be obtained.

μ_{jt}, δ_j and θ_t are the idiosyncratic error term, country fixed effect and time fixed effect, respectively.

We have established that bank risk exposures (credit risk and insolvency risk) have an inverted U-shaped non-linear relationship. Next, we introduce the interaction terms between the squared term of bank risk exposures and regulations and run it on bank stability. We interpret our results by computing the net effects of bank risk exposures at levels of regulations.

From equation (4), the marginal effect is computed as:

$$\text{Net effect} = \frac{\partial Z-score_{j,t}}{\partial Bankriskexposures} = \beta_1 + 2\lambda_l BankRiskExposures_{jt} + \gamma_q 2\left(Bankriskexposure * Regulationvariables\right)_{ijt} = 0$$

After estimating the threshold level at which bank risk exposures reduce bank stability, we expect regulation to reduce or alter the negative impact of higher bank risk exposures levels on bank stability. For instance, a positive net effect suggests that the negative impact of excessive levels of bank risk exposures (credit risk and insolvency risk) on bank stability is reduced at stringent regulations (monetary policy and macro-prudential action).

We conduct a robust analysis by showing the interaction effect of bank risk exposures and regulations on bank stability in strong and weak institutional environment. We then split the data into strong institutions (i.e. countries that have institution equal to the mean or above the mean in Africa) and weak institutions (i.e. countries that strictly fall below the average of institutional quality). Institutional quality is measured as the weighted average of six indicators (political stability, regulatory quality, corruption, voice and accountability, government effectiveness and rule of law) obtained from the Global Financial Development Database. We expect the marginal conditional impact of bank risk exposures on bank stability to be enhanced at stringent regulatory policy in countries with strong institutions compared to weak institutions.

In relation to the control variables, we expect similar results as shown in equation (2).

3.2 Estimation technique and diagnostics

Prior to the analysis, we perform some diagnostic tests. To enhance reliability, efficiency and accuracy of the result, the study uses a number of techniques. Firstly, using the statistic table, the study screens for outliers to reduce the biases caused by outliers. Hence, no evidence of outliers was identified. Secondly, normality of each variable is assessed by using Shapiro–Wilk (SWILK) normality test. Thirdly, the study uses the Pearson's correlation to screen for multicollinearity and realized high correlations between bank risk exposure variables and their squared term, which is accepted in non-linear studies (Allison, 2012) but was not reported. Similarly, cross-sectional dependence is tested using the Pesaran (2015) approach because our panel is unbalanced. With a null hypothesis of weak cross-sectional dependence, the Pesaran (2015) results fail to reject the null hypothesis of weak cross-sectional dependence, implying that the severity of and presence of cross-sectional dependence can be ignored for the models. On the problem of autocorrelation, no evidence of first-order autocorrelation is found.

A potential problem that may arise from the model specified above is the problem of endogeneity. Based on the dynamic term and bi-causal relationship that may exist between some of the explanatory variables and the dependent variable, both the ordinary least squares (OLS) and fixed effects may not be useful. In the presence of endogeneity, OLS and fixed effects are biased upwards and downwards, respectively. We use the two-step system generalized method of moments (SGMM) estimator with small sample size adjustments, forward orthogonal deviations and robust standard errors. This improves efficiency and reduces finite sample bias (Arellano and Bover, 1995; Blundell and Bond, 1998). The GMM resolves issues of unobserved heterogeneity that may arise between countries and endogeneity that may exist from bi-causality and mismeasurements. The use of system GMM helps to generate its own instruments from the data. The Hansen test is distributed as chi-square under the null that the instruments are valid. We apply Windmeijer (2005) correction to produce robust standard errors because the two-step estimator has been shown to be biased without this correction.

The error term of the model was tested for their assumptions of normality, autocorrelation and homoscedasticity. The coefficient variables were tested to address the presence of multicollinearity among the predictors.

4. Empirical results and discussion

The study presents descriptive statistics of the variables. Summary statistics and Pearson's correlation are used to screen and test the reliability of the data set. These are presented to ensure consistency, efficiency, reliability and robustness of findings. Table 1 shows the summary statistics of the variables used in the study, while Table 2 reports the Pearson correlation coefficient matrix to check for possible multicollinearity between the explanatory variables. For multicollinearity to occur, the correlation coefficient between two variables should be 0.7 or more (Kennedy, 2008). As shown in Table 2, we observe low correlation between the variables, which indicates no multicollinearity problem in the model. Thus, multicollinearity is not an issue in our model because each of the variables has a variance inflation factor (VIF) below 10 (see Table 2) as is the case of related study like Fernández *et al.* (2016).

4.1 Bank risk exposures and bank stability

In this section, we show the non-linear relationship between bank risk exposures and bank stability in an SGMM estimation. In Table 3, we observe that the lag of the dependent variable is positively linked to bank stability. Thus, past year's stability in the banking sector enhances current stability in the banking system. This is consistent across all the Models (1–15). In Model 1, credit risk has a positive and significant relationship with bank stability (see Model 1). This shows that banks that are exposed to initial levels of credit risk promote banking system stability. However, the squared is observed to negatively affect bank stability across all the estimations. This implies that when credit risk becomes extremely large or increase in size, the positive effect on stability reverses, showing a fall in the *Z*-score, leading to banking instability. The negative effect may be as a result of extreme loan default in the credit market. The results agree with the work by Dayong *et al.* (2016), who found that higher non-performing loans trigger instability in the banking system. Again, the study supports the work by Fernández *et al.* (2016) and Ozili and Uadiale (2017) that higher credit risk exposures of banks reduce bank stability.

Similarly, insolvency risk was positively and significantly linked to bank stability (see Model 2). This suggests that banks' exposure to initial levels of insolvency risk increase

Variables	Obs	Mean	SD	Min	Max	SWILK
Stability	777	0.501	0.501	0	1.000	
Credit risk	794	9.617	7.559	1.1	45.3	0.000***
Insolvency risk	788	8.26	8.697	0.73	41.42	0.000***
Macro prudential	787	0.012	0.143	−1	1.000	0.000***
Monetary policy	787	7.916	5.792	2.277	26	0.000***
Foreign bank entry	781	0.4065	0.4932	0.0000	1.0000	0.000***
Bank size	787	8.7154	0.4562	7.6522	10.3343	0.000***
Bank funding	781	0.6709	0.1341	0.2189	0.8942	0.000***
Capital ratio	781	2.291	38.031	−94.656	53.777	0.000***
Lerner	787	0.642	0.495	−0.281	2.138	0.000***
Bank concentration	781	65.965	15.883	32.521	100	0.000***
Institutions	786	−0.46	0.558	−1.66	0.853	0.000***
Real GDP per capita	786	7.281	0.912	5.53	9.23	0.000***
Inflation	788	8.268	5.578	−1.801	29.488	0.000***

Notes: SWILK, ****p*-value = 0.000; stability is the dependent variable measured with the *Z*-score; credit risk is measured as the ratio of non-performing loans to gross loan; insolvency risk is measured as the ratio of loan loss reserve to gross loans; macro-prudential policy is weighted aggregate (composite index) of 17 indicators of macro-prudential action. Data was obtained from the iMaPP database constructed by Alam *et al.* (2019), monetary policy is measured as the monetary policy rates of each country at a specific time; foreign bank entry is a dummy equal to 1, if a bank entered into a country in a particular year, 0 otherwise; bank size is the natural logarithm of total asset; bank funding is measured as the ratio of bank deposit to total asset; competition is measured as the inverse of Lerner index, Lerner is the ratio of the difference between interest income and marginal cost to income interest; bank concentration (the ratio of asset of the three largest commercial banks to total commercial banking assets in a country); bank capital ratio is the ratio of equity to total asset; real GDP per capita is measured as real GDP per capital; inflation is measured as consumer price index; institutions is measured as the weighted average of six indicators (political stability, regulatory quality, corruption, voice and accountability, government effectiveness and rule of law)
Source: Authors' own creation

Table 1.
Descriptive statistics

bank stability. However, the squared term of insolvency risk is observed to negatively affect bank stability across all the estimations. This shows that additional increase in the level or size of insolvency risk leads to a decrease in bank stability. According to Ozili (2018), a higher loan loss coverage subsequently increases bank stability because loan loss coverage provides greater protection against loan loses which is not consistent with our findings. The implication is that banks undertake risky lending practices with higher loan loss coverage, which eventually reduces bank stability. In effect, the result is not surprising because higher insolvency exposures reduce bank stability, as supported by Ozili (2018).

In Models 1 and 3, the estimated thresholds of credit risk are 5.3456 and 5.5279, respectively, which implies that below these thresholds, credit risk may lead to banking instability. The thresholds are significant and lies between the minimum and maximum values of 1.1 and 45.3. Similarly, in Models 2 and 3, the estimated thresholds are 2.3643 and 1.5416, respectively (found between the 0.73 and 41.42 range), which implies that below these thresholds, insolvency risk may expose the bank to possible instability.

In general, the results show that an inflexion points of 5.3456 and 2.3643 are the respective levels of credit risk and insolvency risk below which the positive effects on bank stability change to negative. The study supports the work by Djebali and Zaghdoudi (2020) who provide evidence to support that the relationships between bank credit risk–bank stability and bank liquidity risk–bank stability are non-linear and characterized by the presence of optimal thresholds for credit risk and liquidity risk.

Table 2. Pairwise correlations

Variables	VIF	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) Stability		1.000													
(2) Credit risk	2.41	0.216	1.000												
(3) Insolvency risk	2.51	0.190	−0.078	1.000											
(4) Macro-prudential action	1.36	0.022	0.276	0.145	1.000										
(5) Monetary policy	2.10	0.084	0.188	0.432	0.133	1.000									
(6) Foreign bank entry	1.22	−0.030	−0.029	0.117	−0.034	0.138	1.000								
(7) Bank size	1.17	0.119	0.124	0.189	0.135	0.097	0.073	1.000							
(8) Bank funding	2.97	0.197	0.247	0.284	0.136	−0.103	0.962	0.670	1.000						
(6) Lerner	1.89	0.097	0.047	−0.021	0.027	−0.042	−0.057	−0.008	−0.037	1.000					
(7) Institutions	1.81	−0.209	−0.455	0.088	−0.441	−0.076	−0.045	0.142	−0.032	−0.041	1.000				
(8) Bank concentration	1.43	−0.167	−0.007	0.292	−0.026	−0.067	0.012	−0.080	0.015	0.106	−0.053	1.000			
(9) Real GDP per capita	1.24	0.124	−0.332	0.433	−0.129	−0.222	0.100	0.059	0.102	−0.108	0.472	−0.190	1.000		
(10) Inflation	1.31	0.021	−0.153	0.248	−0.224	0.170	0.186	0.109	0.119	0.109	0.095	0.008	−0.034	1.000	
(11) Capital ratio	1.16	−0.107	0.245	−0.221	0.274	0.087	0.069	−0.036	0.118	0.041	0.004	−0.199	−0.288	−0.393	1.000

Notes: Mean VIF = 1.7705; stability is the dependent variable measured with the *Z*-score; credit risk is measured as the ratio of non-performing loans to gross loan; insolvency risk is measured as the ratio of loan loss reserve to gross loans; macro-prudential policy is weighted aggregate (composite index) of 17 indicators of macro-prudential action. Data was obtained from the iMaPP database constructed by Alam *et al.* (2019), monetary policy is measured as the monetary policy rates of each country at a specific time; foreign bank entry is a dummy equal to 1, if a bank entered into a country in a particular year, 0 otherwise; bank size is the natural logarithm of total asset; bank funding is measured as the ratio of bank deposit to total asset; competition is measured as the inverse of Lerner index; Lerner is the ratio of the difference between interest income and marginal cost to income interest; bank concentration (the ratio of asset of the three largest commercial banks to total commercial banking assets in a country); bank capital ratio is the ratio of equity to total asset; real GDP per capita is measured as real GDP per capital; inflation is measured as consumer price index; institutions is measured as the weighted average of six indicators (political stability, regulatory quality, corruption, voice and accountability, government effectiveness and rule of law)
Source: Authors' own creation

Variables	Model 1	Model 2	Model 3
Stability$_{t-1}$	0.646*** (0.128)	0.718*** (0.239)	0.664** (0.313)
Credit risk	0.232*** (0.0652)		0.178** (0.0718)
Credit risk^2	*−0.0217*** (0.00669)*		*−0.0161** (0.00820)*
Insolvency risk		0.183** (0.0713)	0.152** (0.0723)
Insolvency risk^2		*−0.0387** (0.0151)*	*−0.0493** (0.0244)*
Foreign bank entry	−0.1055*** (0.03396)	−0.1034*** (0.03624)	−0.2286*** (0.0572)
Bank size	0.175*** (0.0506)	0.1589*** (0.0498)	0.1612*** (0.0525)
Bank funding	3.709** (1.721)	3.709** (1.718)	3.930** (1.776)
Capital ratio	−0.0199*** (0.00722)	−0.0161** (0.00820)	−0.0203*** (0.00720)
Lerner	0.0111 (0.0121)	0.0716 (0.0629)	0.155* (0.0917)
Bank concentration	0.152** (0.0723)	0.183** (0.0713)	−0.0167 (0.0182)
Real GDP	−3.768*** (1.274)	−1.262 (0.861)	−1.586** (0.752)
Inflation	−3.384*** (1.298)	−1.616** (0.793)	0.0163 (0.203)
Institutions	0.697** (0.330)	0.629** (0.308)	0.664** (0.313)
Country fixed effect	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes
2008/2009 GFC	Yes	Yes	Yes
Constant	6.732 (5.884)	9.270* (5.085)	7.401 (5.858)
Observations	780	784	780
Number of years	9	9	9
p-value	0.000	0.000	0.000
Threshold level [5]	*5.3456****		*5.5279****
Threshold level [6]		*2.3643****	*1.5416****
Diagnostics			
AR(1)	0.022	0.003	0.494
AR(2)	0.178	0.090	0.062
Sargen test	0.012	0.002	0.021
Hansen: Chi^2 (p)	31.18	16.90	31.61

Diagnostics	
Breusch and Pagan Lagrangian multiplier test Chibar^2 (p-value)	55.63 (0.000)
Pesaran (2015) Test for weak cross-sectional dependence cd (p-value)	−0.501 (0.601)
Modified Wald test for groupwise heteroscedasticity Chi^2 (p-value)	5.6e + 36 (0.000)
Wooldridge test for autocorrelation in panel data F-stats (p-value)	0.851 (0.3632)

Notes: This table shows the non-linear relationship between bank risk exposures and bank stability. Stability is the dependent variable measured with the Z-score; credit risk is measured as the ratio of non-performing loans to gross loan; insolvency risk is measured as the ratio of loan loss reserve to gross loans; the square terms of credit risk and insolvency risk measures the excessive levels of credit and insolvency risks; macro-prudential policy is weighted aggregate (composite index) of 17 indicators of macro-prudential action. Data was obtained from the iMaPP database constructed by Alam et al. (2019), monetary policy is measured as the monetary policy rates of each country at a specific time; foreign bank entry is a dummy equal to 1, if a bank entered into a country in a particular year, 0 otherwise; bank size is the natural logarithm of total asset; bank funding is measured as the ratio of bank deposit to total asset; competition is measured as the inverse of Lerner index; Lerner is the ratio of the difference between interest income and marginal cost to income interest; bank concentration (the ratio of asset of the three largest commercial banks to total commercial banking assets in a country); bank capital ratio is the ratio of equity to total asset; real GDP per capita is measured as real GDP per capital; inflation is measured as consumer price index; institutions is measured as the weighted average of six indicators (political stability, regulatory quality, corruption, voice and accountability, government effectiveness and rule of law). Standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
Source: Authors' own creation

Table 3.
System GMM estimation: non-linear relationship between bank risk exposures and bank stability

In terms of the controls, foreign bank entry was negatively linked to bank stability. This was expected because, penetration of foreign banks induces market risks and become more competitive, they choose to lend more and choose a more risky balance sheet – which in turn destabilizes the banking system. Bank size was positively liked to bank stability. This means that as banks grow in size, they have the capacity to improve on their intermediation activities, which tend to improve bank stability. A positive relationship between bank funding and bank stability was found because banks that mobilize more deposits are able to undertake activities that generate more profits and improve the stability of the banks. However, competition was negatively and significantly linked to stability of banks (see Model 3). This suggests that a competitive banking system leads to greater risk taking, which in turn reduces bank margins and impede on the stability of the banking system. Banks that are competitive bring innovative products, lend more from their capital base and attract more customers. This results into excessive risk taking, leading instability. The study found a negative relationship between equity to total asset and bank stability (Models 1–3). This gives the indication that banks that use equity funds reduce stability in the banking system. This is because equity investment funds attract greater market risk and may destabilize the banking system. Bank concentration has a positive and significant relationship with bank stability (Models 1 and 2). This suggests that a concentrated banking system gives banks the ability to exercise greater market power to increase bank stability. Real GDP has a negative relationship with bank stability. For instance, in Models 1 and 3, real GDP has a negative relationship with bank stability in the presence of bank risk measures. This implies that countries in high income to GDP are not able to maintain a stable banking system. This may probably be due to the fact that high income per capita countries may not demand credit in the credit market. This leads to lower charter value and subsequently reduce the probability of bank stability. Inflation also has a negative impact on bank stability in Model 1. This indicates that countries with high inflation rates reduce bank stability. Institution has a positive and significant relationship with bank stability. This implies that countries with strong institutions are able to maintain a stable banking system.

4.1.1 Impact of regulations. This section presents the unconditional effect of regulations on bank stability. We used monetary policy and macro-prudential action to proxy regulations. In Model 4, we introduce bank risk variables and regulations in the model and run them on predicted probability of bank stability. In Model 4, macro-prudential action has a positive and significant relationship with bank stability. This implies that stringent macro-prudential policy offers banks the incentive to maintain bank stability. The reason is that stringent macro-prudential forces banks to increase their interest rates, shift their risk to the best clients to maximize their returns and increase stability. Lubis *et al.* (2019) explained that macro-prudential policy is used by the central bank to achieve financial stability goals. The study agrees with the review of Lubis *et al.* (2019) and supports that stringent macro-prudential action is likely to increase the predicted probability of bank stability.

Similarly, monetary policy has a positive impact on bank stability (see Model 4). This suggests that contractionary monetary policy impacts bank stability positively. This means that tight monetary policy provides a form of discipline for managers of banks to reduce risky lending and increase interest rate. Monetary policy is set by the central bank to maintain price stability in the financial system (Lubis *et al.*, 2019). Thus, higher interest rates from tight monetary policy offer banks the opportunity to make profits and reduce costs, leading to greater stability in the banking system. In general, monetary and macro-prudential policies foster bank stability as shown by Martinez-Miera and Repullo (2019).

In terms of the controls, similar results are observed as discussed above.

4.1.1.1 Interaction effect. In our models, the squared terms of bank risk variables denote excessive risk exposures. We have established a negative unconditional effect of extreme levels of bank risk exposures (i.e. the square terms) on bank stability. Also, we found that monetary policy and macro-prudential actions have a positive unconditional effect on bank stability. In this section, we examine the effect of regulations on the relationship between the squared terms of bank risk exposures (i.e. the excessive levels of bank risk exposures) and bank stability.

We interact each regulation variable with the squared terms of bank risk exposures and compute their marginal effect. Thus, we interpret the conditional effect of the levels of bank risk exposures on bank stability when interacted with regulation. We compute the marginal effect and interpret the results. For instance, in Table 4, the marginal effect of the square of credit risk is 0.15963 ([$-0.290 + (2 \times 0.0284 \times$ monetary policy)]) [1] and significant, when the average level of monetary policy is 7.916 (see Model 5). The marginal effect (i.e. the coefficient of the square of credit risk without the presence of monetary policy) is positive. This can be interpreted as the negative impact of excessive credit risk exposure on bank stability is further reduced when interacted with monetary policy. Similarly, in Model 6, the marginal effect of excessive credit risk is negative (0.0138) [2] and significant. The negative marginal effect is less negative compared to the unconditional effect. This implies that at stringent macro-prudential actions, the negative impact of excessive credit risk on bank stability is reduced.

In terms of the conditional effect of excessive insolvency risk on bank stability, we compute the marginal effect and interpret the results. It was earlier found that the unconditional effect of excessive insolvency risk (squared term) on bank stability is negative without the interaction terms. However, in Model 7, the marginal effect is computed to be negative (0.21083) [3] and significant. This suggests that the negative impact of excessive insolvency risk on bank stability is further tamed when interacted with monetary policy. Again, the marginal effect of excessive insolvency risk is -0.8686 [4] (i.e. less negative and significant). This implies that the negative impact of excessive insolvency risk on bank stability is reduced at greater levels of macro-prudential regulation.

In general, it is evidenced that monetary and macro-prudential policies are effective in taming the excessive risk exposures of banks to improve banking system stability.

4.1.2 Robustness checks: interaction effect of bank risk exposures in strong and weak institutional environment. It is evident that institutions have a role to play in the determination of banking system stability. Just examining the interaction effect of bank risk exposures and regulations on bank stability may not be informative to policymakers. For robustness checks, we find out the marginal effect of regulations in reducing the effect of excessive bank risk exposures on bank stability in countries with strong institutions and those in weak institutional framework.

In Table 5, excessive credit risk was negatively and significantly linked to bank stability conditioned on monetary policy (Model 8) and macro-prudential action (Model 9) in countries with strong institutions. Similarly, excessive insolvency risk was negatively linked to bank stability conditioned on monetary policy (Model 10) and macro-prudential action (Model 11) in strong institutional environment. In Models 14 and 15, insolvency risk was negatively linked to bank stability conditioned on monetary policy and macro-prudential action in countries with weak institutions.

In Table 5, we compute the marginal effect of excessive bank risk exposures in different institutions. For instance, the marginal effect of excessive credit risk on bank stability is significant in countries with strong institutions when conditioned on regulations (monetary

Table 4. Interaction effect of bank risk and regulations on bank stability

Variables	Independent effect with regulation	Interaction effect			
	Model 4	Model 5	Model 6	Model 7	Model 8
Stability$_{t-1}$	2.558*** (0.916)	2.836*** (0.982)	2.625*** (0.961)	2.478** (0.980)	3.047*** (0.961)
Credit risk	0.0549** (0.0249)	*0.0542** (0.0260)*	*0.0559** (0.0252)*		
Credit risk^2	0.0386 (0.0472)	*−0.290*** (0.0785)*	*−0.0146*** (0.00506)*		
Insolvency risk	0.0274* (0.0161)			0.0312** (0.0156)	0.0282* (0.0167)
Insolvency risk^2	*−0.455*** (0.124)*			*−0.358*** (0.110)*	*−1.874** (0.746)*
Macro-prudential action	0.237*** (0.0559)		−0.316*** (0.0989)		*−0.554*** (0.151)*
Monetary policy	*0.236** (0.0964)*	*0.361** (0.147)*		−0.121* (0.0658)	
Credit risk^2 * Monetary policy		*0.0284* (0.0159)*			
Credit risk^2 * Macro-prudential action			*0.0305* (0.0156)*		
Insolvency risk^2 * Monetary policy				*0.0468* (0.0245)*	
Insolvency risk^2 * Macro-prudential action					*0.219*** (0.0495)*
Foreign bank entry	−0.266** (0.106)	−0.274*** (0.0866)	−0.355*** (0.124)	0.0852 (0.137)	−0.214* (0.114)
Bank size	0.3355*** (0.0895)	0.3052*** (0.0885)	0.2874*** (0.0974)	0.2057*** (0.0716)	0.1846*** (0.0716)
Bank funding	3.827** (1.809)	4.441*** (1.141)	0.542 (0.717)	2.591** (1.061)	0.802 (0.744)
Capital ratio	−0.0639** (0.0306)	−0.125* (0.0658)	−0.121* (0.0658)	−0.0578* (0.0330)	−0.132** (0.0658)
Lerner	0.225** (0.113)	0.175*** (0.0656)	0.203*** (0.0649)	0.125* (0.0707)	0.0949 (0.161)
Bank concentration	0.544 (0.457)	0.221 (0.212)	0.873* (0.475)	0.756 (0.471)	0.0198 (0.567)
Institutions	4.463*** (1.212)	1.293* (0.714)	4.237*** (1.165)	3.807*** (1.197)	3.713** (1.518)
Real GDP	8.620*** (2.834)	3.632*** (1.100)	7.751*** (2.716)	7.254*** (2.452)	6.165* (3.444)
Inflation	0.250*** (0.0772)	0.177*** (0.0435)	0.224*** (0.0605)	0.190*** (0.0436)	0.209*** (0.0463)
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes
2008/2009 GFC	Yes	Yes	Yes	Yes	Yes
Constant	−3.393*** (1.191)	−2.040** (0.933)	−1.914 (1.417)	−0.211 (1.098)	−3.491*** (1.331)
Observations	766	781	784	781	784
p-value	0.000	0.000	0.000	0.000	0.000
Number of years	9	9	9	9	9
Marginal effect	NA	0.1596***	−0.0138***	0.21083***	−0.8686***
Diagnostics					
AR(1)	0.390	0.718	0.403	0.472	0.400
AR(2)	0.219	0.182	0.917	0.106	0.331
Sargen test	0.003	0.002	0.001	0.001	0.002
Hansen: Chi^2	14.11	26.41	11.20	30.57	0.0633

Notes: Stability is the dependent variable measured with the *Z*-score; credit risk is measured as the ratio of non-performing loans to gross loan; insolvency risk is measured as the ratio of loan loss reserve to gross loans; macro-prudential policy is weighted aggregate (composite index) of 17 indicators of macro-prudential action. Data was obtained from the iMaPP database constructed by Alam *et al.* (2019), monetary policy is measured as the monetary policy rates of each country at a specific time; foreign bank entry is a dummy equal to 1, if a bank entered into a country in a particular year, 0 otherwise; bank size is the natural logarithm of total asset; bank funding is measured as the ratio of bank deposit to total asset; competition is measured as the inverse of Lerner index; Lerner is the ratio of the difference between interest income and marginal cost to income interest; bank concentration (the ratio of asset of the three largest commercial banks to total commercial banking assets in a country); bank capital ratio is the ratio of equity to total asset; real GDP per capita is measured as real GDP per capital, Inflation is measured as consumer price index; institutions is measured as the weighted average of six indicators (political stability, regulatory quality, corruption, voice and accountability, government effectiveness and rule of law). Standard errors in parentheses; ***p <0.01, **p <0.05, *p <0.1

Source: Authors' own creation

Table 5.
Robustness checks: interaction effect of regulations and bank risk on bank stability in different institutional environment

Variables	Model 8	Countries in strong institution Model 9	Model 10	Model 11	Model 12	Countries in weak institution Model 13	Model 14	Model 15
$Stability_{t-1}$	0.635*** (0.172)	1.586** (0.752)	0.572*** (0.166)	1.616** (0.793)	0.438** (0.211)	0.477*** (0.165)	0.550*** (0.159)	0.482*** (0.153)
Credit risk	0.0328** (0.0164)	0.0283* (0.0161)			−0.0920** (0.0422)	−0.0203 (0.0164)		
Credit risk^2	0.335*** (0.107)	−0.0283* (0.0161)			0.0677 (0.112)	−0.0471 (0.109)		
Insolvency risk			*0.0493*** (0.0244)*	*0.0454* (0.0242)*			0.00695*** (0.00137)	0.00388** (0.00192)
Insolvency risk^2			*−0.0386* (0.0209)*	*−0.0938** (0.0467)*			*−0.0938** (0.0467)*	*−0.456*** (0.123)*
Monetary policy	*0.350*** (0.0658)*		0.176*** (0.0619)		0.0113 (0.0161)		0.279*** (0.0562)	
Macro-prudential action		−0.00571 (0.0193)		−0.0203 (0.0282)		−0.0720* (0.0397)		−0.0421* (0.0251)
Credit risk^2 * Monetary policy	*−0.0493** (0.0244)*				0.00577 (0.0200)			
Credit risk^2 * Macro-prudential action		*0.337*** (0.0771)*				0.0179 (0.0432)		
Insolvency risk^2 * Monetary policy			*0.234*** (0.0543)*				−0.0621** (0.0268)	
Insolvency risk^2 * Macro-prudential action				*0.456*** (0.123)*				*0.0421* (0.0251)*
Foreign bank entry	−0.135*** (0.0414)	−0.125*** (0.0351)	−0.167*** (0.0475)	0.0157 (0.0665)	−0.141*** (0.0519)	−0.111*** (0.0415)	−0.206*** (0.0660)	0.0946 (0.0589)
Bank size	0.1837*** (0.0508)	0.1837*** (0.0508)	0.3553*** (0.0931)	0.3466*** (0.0915)	0.22093*** (0.0740)	0.2113*** (0.0725)	0.1846*** (0.0716)	0.1669** (0.0765)
Bank funding	4.463*** (1.212)	1.293* (0.714)	4.237*** (1.165)	3.807*** (1.197)	3.713** (1.518)	4.048** (1.636)	2.276** (0.922)	3.488** (1.475)
Capital ratio	−0.00394 (0.0369)	0.00836 (0.0228)	−0.0328** (0.0164)	−0.00228 (0.0370)	−0.0150 (0.0121)	−0.0253 (0.0161)	−0.0161 (0.0121)	−0.0128 (0.0132)
Lerner	−13.55* (7.984)	−13.90* (8.087)	−13.87* (8.012)	−13.55* (7.989)	−4.448** (2.004)	−3.026 (2.011)	−2.016 (1.905)	−5.665** (2.552)
Real GDP	0.480*** (0.129)	0.0677 (0.112)	0.335*** (0.107)	0.109 (0.103)	0.0677 (0.112)	0.0471 (0.109)	0.125* (0.0658)	−0.0798 (0.0511)
Inflation	0.612** (0.302)	0.603** (0.296)	0.390 (0.303)	0.694** (0.312)	0.379 (0.470)	0.511 (0.507)	0.456 (0.468)	0.330 (0.506)
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.338** (1.006)	3.719*** (0.994)	4.186*** (1.357)	1.910 (1.276)	2.673*** (0.972)	1.856 (1.617)	1.888 (1.625)	1.848 (1.602)
Observations	396	395	397	395	381	383	384	383
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Number of years	9	9	9	9	9	9	9	9
Marginal effect	*−0.4455****	*−0.0199****	*3.6661****	*−0.0825****	*NA*	*NA*	*−1.077****	*−0.4549****
Diagnostics								
AR(1)	0.391	0.422	0.820	0.409	0.311	0.402	0.908	0.333
AR(2)	0.501	0.899	0.593	0.200	0.202	0.501	0.417	0.612
Sargen test	0.002	0.017	0.011	0.001	0.001	0.041	0.02	0.041
Hansen: Chi^2	13.79	14.65	16.19	12.86	22.06	23.21	23.08	17.92

Notes: Stability is the dependent variable measured with the *Z*-score; credit risk is measured as the ratio of non-performing loans to gross loan; insolvency risk is measured as the ratio of loan loss reserve to gross loans; macro-prudential policy is weighted aggregate (composite index) of 17 indicators of macro-prudential action. Data was obtained from the iMaPP database constructed by Alam *et al.* (2019), monetary policy is measured as the monetary policy rates of each country at a specific time; foreign bank entry is a dummy equal to 1, if a bank entered into a country in a particular year, 0 otherwise; bank size is the natural logarithm of total asset; bank funding is measured as the ratio of bank deposit to total asset; competition is measured as the inverse of Lerner index; Lerner is the ratio of the difference between interest income and marginal cost to income interest; bank concentration (the ratio of asset of the three largest commercial banks to total commercial banking assets in a country); bank capital ratio is the ratio of equity to total asset; real GDP per capita is measured as real GDP per capital; inflation is measured as consumer price index; institutions is measured as the weighted average of six indicators (political stability, regulatory quality, corruption, voice and accountability, government effectiveness and rule of law). Standard errors in parentheses; ***p <0.01, **$p < 0.05$, *$p < 0.1$
Source: Authors' own creation

and macro-prudential policies) (see Models 8–11), while the marginal effect of excessive credit risk exposure in countries with weak institution is insignificant (Models 12 and 14). This suggests that regulations reduce the negative impact of excessive credit risk exposures on bank stability in countries with strong institutions, while regulation has no impact on bank risk–stability nexus in weak institutional environment.

On the other hand, regulations further reduce the negative impact of excessive insolvency risk exposures on bank stability in countries with strong institutions compared to countries in weak institutional environment.

This implies that strong institution is likely to support excessive bank risk exposure and stable banking system when interacted with regulations compared to weak institutions. This agrees with Klomp and de Haan (2014), who indicated that institutional quality reduces bank risk and increases bank stability. The implication is that weak institutional environment should be strengthened in Africa to be able to manage banks' excessive risk exposures to improve bank stability.

5. Conclusion and policy implications

The main aim of the study is to investigate the mediating effect of regulations in explaining the non-linear effect of bank risk exposures on bank stability. The study uses data set of banks in 54 African countries over the period 2006–2020. Firstly, the study analyses the possible non-linear relationship between bank risk exposures and bank stability using the two-step SGMM estimator. Firstly, we observe that past year's stability leads to a stable banking system in the next year. We found that the initial levels of credit risk positively affect bank stability but banks that are heavily exposed to credit risk reduce banking system stability. Similarly, initial levels of insolvency risk were positively and significantly linked with bank stability but additional increase of insolvency risk leads to unstable banking system. These results confirm the inverted U-shaped non-linearity between bank risk exposures and bank stability. Thus, the initial levels of credit risk and insolvency risk positively affect bank stability but banks that are heavily exposed to these risks become unstable. We provide evidence to support that the relationships between bank credit risk–bank stability and bank insolvency risk–bank stability are non-linear and characterized by the presence of optimal thresholds which are 5.3456 for credit risk and 2.3643 for insolvency. Thus, below these optimal thresholds, credit risk and insolvency risk become negatively linked to bank stability in Africa.

We found that macro-prudential action and monetary policy both have a positive and significant relationship with bank stability. In general, monetary and macro-prudential policies foster bank stability, as shown by Martinez-Miera and Repullo (2019), and support that stringent monetary and macro-prudential policies are important in achieving bank stability goals. The implication is that countries with tight monetary and macro-prudential actions are able to maintain a stable banking system.

We show that regulations have a significant role to play in the relationship between bank risk exposures and bank stability. We found the marginal effect of excessive credit risk and insolvency risk on bank stability is reduced when interacted with regulations. For instance, we found that the negative impact of increasing levels (excessive) bank risk exposures (credit risk and insolvency risk) on bank stability is reduced at higher levels of monetary and macro-prudential regulations. Also, we show that the interaction effect of bank risk exposures on bank stability at levels of regulations is greater for countries with strong institution compared with countries with weak institutions. Thus, institutions are important in moderating the impact of banking risk exposures on bank stability at levels of regulations.

Our results have policy implications. To ensure banking stability, the financial sector is encouraged to revise the priority given to credit activity and use of their capital provisions, by diversifying their activities and restructuring their own funds or capital provisions to reduce excessive risk exposures. Regulatory authorities, policymakers and practitioners should have to deeply reform the financial sectors and develop regulatory framework relating to new techniques of external management of banking risks, which is a key factor for banking stability. Specifically, regulators and policymakers should put forward appropriate policies that incorporate a risk-based regulatory framework that is needed to control the level of bank risks and maintain a stable banking system. Thus, effective regulatory and banking supervision mechanism should continue to shape the level of risk exposures and risk-taking behaviours of the banking sector to maintain an optimal and desired level of risk that would yield greater return and improve stability in the banking system. Again, regulatory authorities in countries with weak institutions should strengthen their institutional mechanism by providing a robust regulatory framework needed to reduce the negative impact of excessive bank risk exposures on bank stability. The novel contribution of this research is to provide a model that serve as a robust tool for researchers, practitioners and policymakers to improve stability through the complex relationship between bank risk exposures and stability.

5.1 Limitation and future research

The study is limited to only Africa. In addition, it was not able to collect data on various characteristics of banks from the African perspective. Acquiring this data was very difficult because some are not available publicly as a secondary source.

Future research should extend data to include developing and emerging economies in the world. Also, policymakers, researchers and practitioners should consider different regulatory and institutional frameworks in explaining the relationship between the thresholds of bank risk exposures and bank stability in the world.

Notes

1. Banking stability = (0.15963) [−0.290 + (2 × 0.0284 × monetary policy)], average monetary policy is 7.916
2. Banking stability = (−0.0138) [−0.0146 + (2 × 0.0305 × macro-prudential)], average macro-prudential action is 0.0124
3. Banking stability = (0.21083) [−0.358 + (2 × 0.0468 × monetary policy)], average monetary policy is 7.916
4. Banking stability = (−0.8686) [−1.874 + (2 × 0.219 × macro-prudential)], average macro-prudential action is 0.0124
5. Threshold for credit risk
6. Threshold for insolvency risk

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