“Bank solvency: The role of credit and liquidity risks, regulatory capital and economic stability”

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BANK SOLVENCY: THE ROLE OF CREDIT AND LIQUIDITY RISKS, REGULATORY CAPITAL AND ECONOMIC STABILITY

Abstract

Banking stability is essential to any economy due to its many functions, including intermediation, payment facilitation, and credit creation. Thus, the stability of the banking industry is one of the critical ingredients in economic growth. This paper analyzes how bank capital, credit and liquidity requirements impact bank solvency, using ten major banks controlling 90% of the UK market share in 2009–2018.

The GMM model indicates a strong association between credit and liquidity risks. That is, when banks finance a risky or distressed project, this will lead to an increase in non-performing loans (NPL), which reduces bank liquidity. Poor liquidity profile of a bank may restrict its ability to act as a financial intermediary. In addition, the findings indicate that efficiency, asset quality, and economic growth have a significant positive effect on the solvency of banks. The results also show that the regulatory capital (Tier1) has a positive significant influence on bank solvency. Further, the results indicate that during the economic boom, banks tend to increase their regulatory capital. Therefore, there is a need to ensure that during the "good time", banks can accumulate enough capital that is genuinely capable of absorbing negative shock. Also, it is important for banks to ensure that they are efficient but also have a robust credit appraisal system to reduce NPL. This paper also demonstrates the implications of increased capital requirements. That is, increased capital requirements ensure not only banks are liquid but also solvent, which allows them to provide financial intermediation.

Keywords banks, stability, capital, profitability, risks, efficiency, GDP

JEL Classification E02, G21, G33

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INTRODUCTION

Banks are the most regulated firms because of the various risks they face and the role they play in the economy. Regulation range consists of many aspects, including minimum capital requirements, liquidity level, investment activities and financial and non-financial disclosures. The underpinning objective of regulation is to ensure that banks not only engage in risky activities, but also ensure that banks are solvent and sustainable. The objective of this paper is to analyze how liquidity and credit risk, efficiency, economic freedom, and regulatory capital affect bank solvency.

Following the 2009 financial crisis, significant reforms were implemented that led to Basel III, which requires banks to have a minimum common equity of 4.5% and capital conservation buffer of 2.5% of risk weighted assets. In addition, banks are required to have sufficient high-quality liquid assets (HQLA) that can withstand a 30-day liquidity stressed scenario. This is commonly called a liquidity coverage ratio that came into force in 2016. From 2016, banks were required to have a minimum LCR of 70%, and 100% from 2019. This liquidity requirements enhance the ability of banks to withstand financial and economic

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shocks, which could spill to the rest of the economy. Related to LCR is the net stable funding ratio (NSFR) that took effect in 2018 to assess how much funding is available versus how much funding is required in the long term. Basel III requires the NSFR to be equal or more than 100% at any given time.

Based on liquidity and credit risks that banks face, several researchers (Acharya & Mora, 2012; Cai & Thakor, 2008) have examined the relationship between the two (liquidity and credit risks) and the impact on bank solvency. The authors note a positive relationship between liquidity and credit and jointly contribute to bank solvency. However, Imbierowicz and Rauch (2014), using USA commercial banks, noted that there is no contemporaneous relationship between the liquidity and credit risks. In terms of the impact of regulatory capital on liquidity creation, Berger and Bouwman (2009) noted that the impact differs across the size of banks. That is, with large banks, higher capital requirements had a greater and significant positive effect on liquidity creation. With small banks, the authors noted a small magnitude of regulatory capital on liquidity creation. However, other studies have shown a negative effect of regulatory capital on lending (e.g. Angelini et al., 2011). The authors noted a 1% increase in capital requirements leads to a 0.09% decrease in lending. In the same vein, Slovik and Cournède (2011) noted a negative effect of increased capital requirements on GDP. That is, the study noted whenever there was an increase in capital requirements, the financing costs, including compliance costs, increased. The increase in costs leads to a -0.05% growth in the economy annually. Such findings are fueling a debate about whether banks should be left to self-regulation or reduced regulation (Omarova, 2014).

Therefore, there is a trade-off between the benefits of financial stability and the costs of lower liquidity creation to the economy. This paper extends the literature by examining how economic growth and the regulatory capital interplay between liquidity and credit risks. In addition, this paper assesses the impact of efficiency using the cost-income ratio (CIR) on solvency. In addition, unlike the previous study, the effect of economic freedom on banking is considered.

Using 10 largest banks in the UK (HSBC, Barclays, Natwest, Lloyds, Nationwide, RBS, Halifax, Santander, Bank of Scotland and Cooperative) that control 90% of the market share, the results show that there is a positive correlation between solvency and GDP growth. This implies that during economic growth, most of banks will be solvent. The results also indicate a cyclical nature of regulatory capital. That is, banks increase the regulatory capital as the economy grows. Also, a 1% increase in profitability leads to a 0.02% reduction in credit risk compared to 0.023 % liquidity risk. The results also indicate that a 1% increase in the total regulatory capital leads to a 2.35% and 0.006% reduction in credit and liquidity risk, respectively. This is in line with Salachas et al. (2017) who noted that less capitalized banks engage in risky activities. In addition, a 1% growth in GDP leads to an 8% improvement in solvency level. In other words, economic downturn exacerbates bank insolvency because there will be an increase in NPLs, which in turn will worsen the liquidity position of banks.

1. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The solvency of a bank mirrors its capability to perform the intermediation function. The risk of insolvency emanates from liquidity, credit, and market risk. Gualandri et al. (2009) define a bank's liquidity as its monetary obligations on demand, in the form of deposits in current accounts and credit lines. This indicates the importance of the bank's ability to meet its financial obligation, both short-term and long-term. Kim and Santomero (1988) analyzed how bank capital regulation can help control liquidity risk. The study noted that the standard capital ratio is not an effective way of controlling the likelihood of insolvency in banks. The need for banks to increase their capital requirements and liquidity will ensure that the governments do not bail banks as it was in the 2009 case as a result of the global financial crisis. Post the 2009 financial crisis, studies have shown that weak regulation and

supervision lead to the banking crisis (Barth et al., 2012; Hogan, 2014). Although highly capitalized banks may lead to moral hazard, Jokipii and Milne (2011) argued that highly capitalized banks with effective risk management reduce excessive risk managerial behavior. Indeed, Beltratti and Stulz (2012) noted that large banks with large Tier 1 capital and deposits performed better during the financial crisis. Recently Ayele (2021) examined the Ethiopian banks and noted that when there are lower capital requirements, private banks tend to take more risks, but lower reserves and tend to increase domestic credit. Contrary to Betratti and Stulz (2012), Osei-Assibey and Asenso (2015), when studying Ghanian banks, noted that excess capital requirements increase risk-taking activities of banks. This is because the study indicated a positive significant relationship between the increase in capital requirements and NPL. This implies that higher capital requirements may have adverse effects on the economy in terms of lending. The trade-off between these two (that is, capital requirements and lending) should be carefully balanced, setting off the benefits of a more stable banking industry against the macro-economic costs of tighter regulation.

Hovakimian and Kane (2000) also noted that one weakness with the regulatory capital is the over-emphasis on accounting measures. The study also argued that regulatory regimes do not prevent shifting risk assets to a safety net, especially for large banks. Regulatory capital and loan loss provisions (LLP) are seen as a way of mitigating insolvency risk. LLPs cover the expected losses, while regulatory capital covers unexpected losses (Duran & Lozano-Vivas, 2014). In both cases, that is LLPs, regulatory capital will have an impact on profitability. However, when Novokmet and Pavić (2021) examined profitability of Croatians in a capital requirement regime, the study noted that regulatory capital not only reduces insolvency, but also has a positive impact on ROE in the long run. In similar vein, Asghar et al. (2018) examined managerial risk-taking behavior of too-big-to-fail (TBTF) entities and argued that Basel III capital requirements are driven by increased risk appetite among large Chinese banks.

In terms of regulatory liquidity coverage ratio (LCR) and Net Stable Funding ratio (NSFR), Resti (2011) argues that these will have a significant impact on banks' activities, including a decline in revenue and interest margin. LCR, which came into effect in 2015, requires banks to hold a stock of liquid assets in an amount covering the net liquidity outflows that might be experienced, under stressed conditions, over the following 30 days. The net cash outflows are computed based on some assumptions concerning run-off, rollover, and draw-down rates. Du (2017) examined the importance of the LCR to the US banks; the author noted that the ratio is very important in predicting ex ante that banks are most exposed to a crisis, considering the banks that had LCR of less than 100% pre-financial crisis of 2008 experienced liquidity strains. However, Boyao et al. (2017) noted that LCR does reduce liquidity creation during the economic downturn. This is contrary to Abdul-Rahman et al. (2018) who noted a weak relationship between GDP and LCR when examining Malaysian conventional and Islamic banks. The net stable funding ratio (NSFR) requires that available stable funding (i.e., equity and liability financing expected to remain stable over a one-year time horizon) be at least equal to the matching assets (i.e., illiquid assets that cannot be easily turned into cash over the following 12 months).

Berger and Bouwman (2009) argued that regulatory capital has two effects. First, through the "financial fragility structure" in which higher capital requirement may result in less monitoring, leading to less liquidity creation. Second, higher capital requirements may lead to "crowding-out of deposits" and reduce liquidity creation (Gorton & Winton, 2000). The study noted that customer deposits are more effective liquidity hedges compared to equity.

Also, Berger et al. (2012) analyzed the effects of regulatory interventions and capital support on bank risk-taking and liquidity creation. They noted that both types of actions are generally associated with statistically significant reductions in risk-taking and liquidity creation in the short and long run. A recent study by Nguyen and Nghiem (2015) analyzed the nexus between default risk, regulatory capital, and bank efficiency in 40 banks. The results indicated that those banks with high capital levels were efficient and had fewer insolvency risks.

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Bougatef and Mgadmi (2016) examined the association between regulatory capital and the risk level using 24 banks within Middle East North African (MENA) countries from 2004 to 2012. Unlike previous studies, the authors noted that there was an insignificant relationship between regulatory capital and risk. The study concluded that risk-taking behavior in banks is not affected by the changes in the regulatory capital. However, when Ozsuca and Akbostanci (2016) examined risk-taking behavior of the Turkish banking sector between 2002 and 2012, they concluded that banks with good capitalization took less risks compared to less capitalized banks. Therefore, financial stability and resilience primarily depend on a bank's regulatory capital requirements, efficiency, and economic stability.

In terms of liquidity risks, Bandta et al. (2021) examined French banks using Granger causality; they noted that liquidity shocks can deteriorate banking liquidity and solvency. The authors noted that the effect of solvency on liquidity was stronger than the effect of liquidity on solvency. This will have a negative impact on liquidity creation.

Also, Chiaramonte and Casu (2017) argue that capital and liquidity only play a complementary role for large banks. When examining a panel with all banks, they noted the only significant determinant of bank failure is the Basel III structural liquidity ratio. The impact of regulatory capital may also change liquidity and risk taking. Therefore:

H1: Regulatory capital affects both solvency and liquidity and credit risks.

Existing literature also indicates that increased capital requirements increase a bank's risk (Lee & Hsieh, 2013). This view implies that a bank's lending capacity will be reduced or weakened. Indeed, evidence from the recent study (Sum, 2016) has shown that in the short run, increased capital requirements may constrain bank activities, reduce deposit funding, increase the costs of lending and limit credit expansion. Also, in terms of entry barriers, higher capital requirements will restrict entry, which may reduce competition. Limiting credit creation will lead to lower credit risk, but also this will lead to lower profitability. This is because the main business of banks is to offer credit. Indeed, Mendes and Abreu (2003) and Valverde and Fernández (2007) noted a positive relationship between credit risk and profitability. Using bank capital as a channel, it is safe to state that highly capitalized firms, in the long run, will be profitable and, in turn, will have a well-documented credit policy that will reduce both liquidity and credit risks. Therefore:

H2: Profitability affects both credit and liquidity risks and solvency.

Economic growth (GDP) is one of the determinants of bank profitability (Athanasoglou et al., 2008). Other studies have noted that GDP growth controls for cyclical output effects (Flamini et al., 2009). Therefore, GDP can significantly affect the supply, demand, and repayment of loans and deposits. For instance, during the economic boom, the need for loans will increase, positively impacting profitability (all other factors held constant). On the flip side, poor economic growth or recession will lead to an increase in non-performing loans, affecting the liquidity and profitability of the banks. Therefore:

H3: GDP growth affects credit and liquidity risks.

Although regulation is essential, especially when there is market failure, excessive control also may be seen as a threat to the efficient functioning of the banking industry (Beach & Kane, 2008). As a result of the recent financial crisis, there has been a restriction on banking activities and payment arrangements. Past studies have suggested that good government policies are critical to financial stability and economic growth (Acemoglu, 2008; Giavazzi & Tabellini, 2005). Other studies (Demirguc-Kunt & Huizinga, 2004) noted that a better institutional framework, as captured by the index of economic freedom, dampens bank profitability. The study indicated that a 1% improvement in the economic freedom index lowers the interest margin by 1.1%. Therefore:

H4: Economic freedom affects credit and liquidity risks and solvency.

2. METHODOLOGY

2.1. Data sources

Using BankScope and Fitchconnect, the study extracted a set of reported annual series for a period for bank-specific data. The study used 10 largest banks in the UK (HSBC, Barclays, Natwest, Lloyds, Nationwide, RBS, Halifax, Santander, Bank of Scotland, and Cooperative) that control 90% of the entire market share. Time series data from 2009 to 2018 were used to avoid the overlap of 2008 financial crisis. For economic growth (gross domestic product), the growth rate was extracted from the World Bank database and economic freedom from the Heritage Foundation for economic growth (gross domestic product).

2.2. Definition of variables

In line with Laeven and Levine (2009), to measure bank solvency, the study uses the Z-score (ZROA) that indicates the number of standard deviations that the bank's ROAA must fall below its expected value before equity is entirely exhausted. Following Ghenimi et al. (2017), a higher Z-score is interpreted as a decrease in bank insolvency risk, ZROA is formulated as follows:

$$Z = \frac{u + k}{\sigma}, \quad (1)$$

where u – average performance of a bank's assets (ROA); ROA is the return on assets, and the standard deviation of the σ ROA calculated moving averages over eight periods; k – equity as a percentage of total assets; σ – standard deviation of ROA as a proxy for return volatility.

Regulatory capital requirement is measured using Tier 1 capital. Tier 1 capital is calculated based on risk-weighted assets. In addition, each asset in a bank is classified according to the probability of default, as shown in Table A2 (Appendix). Further, to assess the impact of efficiency on profitability, the cost-to-income ratio (CIR) is used; this ratio measures the bank's overhead or running costs as a percentage of the income generated before provisions.

2.3. Econometric modeling

This section evaluates the impact of bank capital regulation, efficiency, credit risk, liquidity risk, and economic growth on bank stability in the UK. After testing for the stationarity of the data, the model is plugged in the form:

Table 1. Measurement of variables

Variable	Proxy	Measurement
Efficiency of banks	*CIR*	(Total cost/Total revenue) x100
Economic freedom	*EF*	An index based on the 12 qualitative and quantitative factors on the rule of law, government size, regulatory efficiency, and open market
Equity Ratio	*EQUITY_TA*	(Total equity/Total assets) 100
Economic growth	*GDPG*	% change in gross economic growth
Credit risk	*GROWTH_LOAN*	% change in gross loans
	IMPAIRMENTLOANS_GROSS_EQ	(Total impaired loans/Total gross loans) ·100
Liquidity risk	*LIQUID_ASSETS_TOTAL_AS*	(Total liquid assets/Total assets)·100
	LOANS_DEPOSITS	(Total loans/Total deposits)·100
	CUST__DEPS_TOTAL_FUND	(Total customer deposits/Total funds)·100
Profitability	*ROE*	(Operating income/Total equity)·100
Solvency	*Sol*	Z score
Regulatory capital	*Tier1*	(Equity capital + disclosed reserves)/Total risk-weighted assets)·100
	TOTAL_REG_CAP	((Tier 1 + Tier 2)/Credit risk-adjusted assets)·100

Note: Sol (Solvency-ratio); *CIR* (Cost income ratio); *CUST_DEPS_TOTAL_FUND* (Customer deposit to total funds ratio); *EF* (Economic Freedom); *EQUITY_TA* (Equity to Total Assets ratio); *GDPG* (Gross domestic product growth); *GROWTH_LOAN* (Growth of loans); *IMPAIRMENTLOANS_GROSS_EQ* (Impairment of gross loans to equity ratio; *LIQUID_ASSETS_TOTAL_AS* (Liquid assets to total assets ratio); *LOANS_DEPOSIT* (Loans to total deposit ratio); *ROE* (Return on Equity); *Tier* 1 (Tier 1 Capital requirement); *TOTAL_REG_CAP* (Total Regulatory Capital).

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$$Sol_{i,t} = \alpha_i + \beta_1 Prof_{i,t-1} + \beta_2 REG_{i,t-1} + \\ + \beta_3 Credrisk_{i,t-1} + \beta_4 liqrisk_{i,t-1} + \beta_5 EFF_{i,t-1} \\ + \beta_6 ECON_t + \beta_7 Assetqual_{i,t-1} + \beta_8 EFt + \varepsilon it, \quad (2)$$

where $Sol_{i,t}$ is the solvency of a bank; $Prof_{i,t-1}$ is the profitability measured by ROA; $REG_{i,t-1}$ is the regulatory capital; $Credrisk_{i,t-1}$ is the credit risk measured by the probability of asset default; $liqrisk_{i,t-1}$ is the liquidity risk; $EFF_{i,t-1}$ is the efficiency of a bank expressed as a total expense as a ratio of total income; $ECON_t$ is the economic growth measured by gross domestic product growth, and $Assetqual_{i,t-1}$ is the quality of the asset measured by the percentage of impaired gross loans to equity, and $\beta_8 EFt$ stands for Economic Freedom expressed through the Fraser index from Heritage.

In running the regression, it is ensured that the classical linear assumptions are met. For instance, the assumption var(μt) = σ2 < ∞ is tested that the error variance is constant. If the errors do not constant variance, they are said to be heteroscedastic. However, there is no solid evidence to suggest heteroscedasticity using the Breusch-Pagan-Godfrey test, as shown in Table 2. Both F and scaled explained SS p values are considerably more than 0.05.

Table 2. Heteroskedasticity test: Breusch-Pagan-Godfrey

F-Statistic	12.601	Prob. F	0.154
Obs·R-squared	28.798	Prob. Chi-Square	0.107
Scaled explained SS	20.129	Prob. Chi-Square	0.092

In addition, cov(μ*i*,μ*j*) = 0 for $i \neq j$ is tested, which is the zero covariance between the error terms over time. In other words, the errors are uncorrelated with one another. Table 3 shows that the null hypothesis of autocorrelation can be rejected.

Table 3. Breusch-Godfrey serial correlation LM test

F-Statistic	16.769	Prob. F	0.124
Obs·R-squared	40.275	Prob. Chi-Square	0.201

Furthermore, there is a need to test whether there is an appropriate functional form that is linear. The suitable model is assumed to be linear in the parameters, and that in the bivariate care, the relationship between *y* and *x* can be represented using a straight line.

To do so, the Ramsey RESET test that works with higher-order terms of fitted values in an auxiliary regression takes the form:

$$y_t = \alpha_1 + \hat{y}_t^2 + \ldots \cdot \alpha_\rho \hat{y}_t^p + \sum B_i x_{it} + u_t. \quad (3)$$

Running the above equation (4) as shown in Table 4, both F and the fitted value indicate that the model is expressed appropriately.

Table 4. Ramsey RESET test

Statistic	Value	df	Probability
t-statistic	0.796	99	0.428
F-statistic	0.633	(1.99)	0.428
Likelihood ratio	0.726	1	0.394
F-test summary	Sum of Sq	df	Mean-squares
Test SSR	0.557	1	0.557
Restricted SSR	87.671	100	0.877
Unrestricted SSR	87.114	99	0.879

To deal with endogeneity issue, this study lags the bank variables by one year as suggested by Lindquist (2004). In addition, to address heteroskedasticity of errors, the generalized method of moments (GMM) is used with economic growth and economic freedom as the instrumental variables as it is considered more efficient than two-stage least squares (2SLS) regression. This is in line with Hall's (2005) recommendations. Finally, the fixed effect model (Table A3 Appendix) is also used to assess the results robustly.

3. RESULTS

Table 5 reports summary statistics of the key variables used in the analysis. Within the sample, the profitability indicator measured by ROE suggests that, on average, the profitability is 1.19%, with the highest and lowest being 15.17% and –13.59%, respectively. The indicator of solvency ratio was measured by a log Z-score. The results indicate that, on average, the Z score is 4.56. The maximum solvency ratio is 6.95 and the minimum 1.50. The results show a negative relationship between CIR and solvency level. However, the results indicate a positive correlation between solvency and GDP growth, taking into account the solvency level and economic status. This implies that most banks will be solvent during the economic growth but begs if they will withstand during the dry spell.

In terms of capital adequacy, the results indicate an average of 11.95 and 16.04 for Tier 1 and total regulatory capital, respectively. Table 5 shows that banks tend to increase the regulatory capital during the economic boom or growth. This implies the cyclical nature of the regulatory capital. Therefore, banks need to build a buffer capital sufficient to absorb any shock during the economic downturn. Examining the efficiency of the banks, on average, the cost-income ratio is 62.5%. The standard deviation is very significant, i.e., 12.008, indicating a considerable variation in efficiency across banks in the UK. The Pearson correlation suggests a positive association between GDP growth and CIR. This suggests that during economic growth, banks lose their financial discipline, especially on bonuses. Analyzing the total funds for the banks, the results indicate that 67.8% comes from the customers' deposits. As one would expect, there is a positive association between GDP growth and customer deposits to total funds. Loans form a significant part of a bank's earnings. Table 5 indicates that on average, grant of loans increased by 7.5%, compared to 32% impairment of loans within the same period of study 2005 to 2017.

When analyzing the relationship between solvency and other variables, Table 6 shows a negative correlation between the cost-income ratio and solvency. That is, efficiency enhances the solvency of a bank. In other words, inefficiency impairs the long-term stability of banks. Similarly, unsustainable growth in loans reduces the stability of the banks. Table 6 also shows that the more profitable the bank is, the more stable or solvent it is. In addition, the results point out the need for banks to be more capitalized to enhance the solvency level. Finally, in terms of liquidity measured by liquid assets to total assets and growth in a customer's deposit, the more liquid the bank is, the more solvent it is likely to be.

3.1. The association between credit risk and liquidity risk using GMM

Before running any regression, the stability of data was tested, i.e., the presence of a unit root. As shown in Table A1 (Appendix), all series except ROE are stable, i.e., there is no strong evidence of a unit root. Therefore, with ROE as a possible remedy, the data are lagged. Table 7 presents the results estimated by employing the GMM technique. Credit risk is proxied by the ratio of impairment of loans gross to total equity ratio, and liquidity (inverse of liquidity risk) is proxied by the ratio of liquid to total assets. The results indicate that the ratio of liquid assets to total assets significantly positively influences credit risk. Unlike Ghenimi et al. (2017), credit risk positively influences liquidity risks. This implies the when a bank has so much of the NPL, it will face liquidity challenges.

Table 5. Summary statistics

Variable	Mean	Maximum	Minimum	Std. dev.	Obs.
CIR	62.492	123.100	41.580	12.008	117
CUST_DEPS_TOTAL_FUND	0.678	0.994	0.304	0.136	117
EF	77.023	80.400	74.100	2.1734	117
EQUITY_TA	4.426	23.622	0.014	3.249	117
GDPG	1.477012	3.096089	–4.18776	1.853656	117
GROWTH_LOAN	0.075	2.025	–0.253	0.239	117
IMPAIRMENTLOANS_GROSS_EQ	32.812	168.106	0.027	33.558	117
LIQUID_ASSETS_TOTAL_AS	0.150	1.120	0.000	0.223	117
LOANS_DEPOSIT	1.004	1.904	0.642	0.243	117
ROE	1.195	15.170	–13.598	3.306	117
Sol	4.567	6.950	1.500	1.411	117
Tier1	11.953	28.400	6.800	3.760	117
TOTAL_REG_CAP	16.046	36.100	9.000	4.318	117

Note: Sol (Solvency ratio); *CIR* (Cost income ratio); *CUST_DEPS_TOTAL_FUND* (Customer deposit to total funds ratio); *EF* (Economic Freedom); *EQUITY_TA* (Equity to Total Assets ratio); *GDPG* (Gross domestic product growth); *GROWTH_LOAN* (Growth of loans); *IMPAIRMENTLOANS_GROSS_EQ* (Impairment of gross loans to equity ratio); *LIQUID_ASSETS_TOTAL_AS* (Liquid assets to total assets ratio); *LOANS_DEPOSIT* (Loans to total deposit ratio); *ROE* (Return on Equity); *Tier 1* (Tier 1 Capital requirement); *TOTAL_REG_CAP* (Total Regulatory Capital).

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Table 6. Correlation matrix

	CIR	CUST_DEPS_TOTAL_FUND	EF	EQUIT_TA	GDPG	GROWTH_LOAN	IMPAIRMENTLOANS_GROSS_EQ	LIQUID_ASSET_TOTAL_AS	LOANS_DEPOSIT	ROE	Sol	Tier 1	TOTAL_REG_CAP
CIR	1.000	–	–	–	–	–	–	–	–	–	–	–	–
CUST_DEPS_TOTAL_FUND	–0.070	1.000	–	–	–	–	–	–	–	–	–	–	–
EF	–0.126	–0.087	1.000	–	–	–	–	–	–	–	–	–	–
EQUITY_TA	–0.207	0.154	–0.044	1.000	–	–	–	–	–	–	–	–	–
GDPG	0.041	0.222	–0.243	0.100	1.000	–	–	–	–	–	–	–	–
GROWTH_LOAN	–0.008	0.092	0.173	–0.264	0.076	1.000	–	–	–	–	–	–	–
IMPAIRMENTLOANS_GROSS_EQ	–0.158	–0.063	0.375	0.140	–0.136	–0.008	1.000	–	–	–	–	–	–
LIQUID_ASSETS_TOTAL_AS	–0.039	–0.350	0.185	–0.056	0.107	0.216	0.457	1.000	–	–	–	–	–
LOANS_DEPOSIT	–0.136	–0.480	0.162	–0.116	–0.192	0.137	0.314	0.363	1.000	–	–	–	–
ROE	–0.130	–0.167	0.086	0.227	–0.093	–0.096	0.522	0.534	0.330	1.000	–	–	–
Sol	–0.299	0.424	0.189	0.611	0.233	–0.256	–0.007	0.165	–0.353	0.138	1.000	–	–
Tier1	0.012	0.295	–0.528	0.021	0.151	–0.093	–0.328	–0.270	–0.006	–0.161	0.083	1.000	–
TOTAL_REG_CAP	–0.020	0.268	–0.500	0.041	0.089	–0.092	–0.377	–0.302	–0.010	–0.213	0.106	0.912	1.00

Note: Sol (Solvency ratio); *CIR* (Cost income ratio); *CUST_DEPS_TOTAL_FUND* (Customer deposit to total funds ratio); *EF* (Economic freedom); *EQUITY_TA* (Equity to total assets ratio); *GDPG* (Gross domestic product growth); *GROWTH_LOAN* (Growth of loans); *IMPAIRMENTLOANS_GROSS_EQ* (Impairment of gross loans to equity ratio); *LIQUID_ASSETS_TOTAL_AS* (Liquid assets to total assets ratio); *LOANS_DEPOSIT* (Loans to total deposit ratio); *ROE* (Return on equity); *Tier* 1 (Tier 1 capital requirement); *TOTAL_REG_CAP* (Total regulatory capital).

The results also show that the efficiency of a bank (CIR) significantly influences liquidity risk. That is, the higher the cost-income ratio, the higher the liquidity risk. In other words, inefficiency increases both liquidity and credit risks.

Further, the results indicate the need to increase funding as a ratio of customer deposit. The higher the customer deposit to total funding, the more credit and liquidity risk tends to decrease. This is probably because the likelihood of bank run is low when there is an increase in customer deposits. The growth of loans is significant in influencing both credit (negatively) and liquidity (positively) risk. This implies that if there is uncontrolled granting of loans, the credit risk will be magnified. This was noticeable in the 2007–2008 global financial crisis when there was "free" credit because of low-interest rates that encouraged mortgage lending. Also, during the period preceding the global financial crisis, many US banks bundled the mortgages into mortgage-backed securities with loose underwriting criteria.

The profitability of banks is essential in inversely influencing credit and liquidity risks. However, in terms of the magnitude, a 1% increase in profitability will lead to a 0.02% reduction in liquidity risk, compared to 2.6% credit risk. Similarly, the results demonstrate the importance of regulatory

Table 7. Credit and liquidity risk models

Independent variable	Credit risk model 1		Liquidity risk model 2	
	Coefficient	P value	Coefficient	P value
C	–257.4341 (28.7529)	0.0000	–0.238873 (0.18148)	0.1883
LIQUID_ASSETS_TOTAL_AS	22.65401 (3.91324)	0.0000	–	–
Sol	–3.001709 (0.64910)	0.0000	0.000557 (0.00032)	0.0888
CIR	0.122113 (0.05296)	0.0213	0.593108 (0.03721)	0.0000
CUST__DEPS_TOTAL_FUND	–58.37630 (6.31255)	0.0000	–0.008785 (0.00220)	0.0001
EF	3.299892 (0.35035)	0.0000	0.001309 (0.00147)	0.3733
EQUITY_TA	–1.483240 (0.23561)	0.0000	–0.004144 (0.00208)	0.0468
GDPG	–0.058046 (0.33806)	0.8637	–0.076064 (0.02340)	0.0012
IMPAIRMENTLOANS_GROSS_EQ	-	-	0.01478 (0.00510)	0.0021
GROWTH_LOAN	–38.77662 (3.68664)	0.0000	0.000862 (0.00014)	0.0000
LOANS_DEPOSIT	37.59315 (3.25651)	0.0000	0.069387 (0.02080)	0.0009
ROE	–2.600010 (0.23303)	0.0000	–0.023065 (0.00138)	0.0000
TIER1	–0.437934 (0.39852)	0.2720	–0.003648 (0.00245)	0.1380
TOTAL_REGULATORY_CAPITAL	–2.350485 (0.33995)	0.0000	–0.006394 (0.00212)	0.0026
Adj. *R*-squared	0.501	–	0.583	–
F-statistic	64.55	0.000	88.21	0.000
AIC	9.184	–	–0.992	–
DW	1.915	–	1.739	–

Note: This table shows the results using GMM for a balanced panel of the UK banks over 2009–2018; *Sol* (Solvency ratio); *CIR* (Cost income ratio); *CUST_DEPS_TOTAL_FUND* (Customer deposit to total funds ratio); *EF* (Economic freedom); *EQUITY_TA* (Equity to total assets ratio); *GDPG* (Gross domestic product growth); *GROWTH_LOAN* (Growth of loans); *IMPAIRMENTLOANS_GROSS_EQ* (Impairment of gross loans to equity ratio); *LIQUID_ASSETS_TOTAL_AS* (Liquid assets to total assets ratio); *LOANS_DEPOSIT* (Loans to total deposit ratio); *ROE* (Return on equity); *Tier* 1 (Tier 1 capital requirement); *TOTAL_REG_CAP* (Total regulatory capital).

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capital as it inversely influences both credit and liquidity risks. The results also indicate that a 1% increase in the total regulatory capital leads to a 2.35% and 0.006% reduction in credit and liquidity risk. This shows the motivation why banks tend to have higher capital requirements than the minimum requirement.

Table 8 indicates that the banks' efficiency is significant in influencing the solvency level of a bank. In addition, the analysis suggests the need for increased savings from customers. That is, the more customer deposits are, the more solvent it is likely to be. This implies that banks with good and diversified customer deposits are likely to reduce the risk of solvency. This enhances financial stability, which is the core of any regulatory regime.

Like Baselga-Pascual et al. (2015) noted that capital, earnings, and efficiency are inversely related to banking risk, while loan-to-assets are positively correlated; the results indicate that ROE significantly influences a bank's solvency level. This implies that capital, earnings, and efficiency have a negative impact on banking failure. This suggests that highly profitable banks are less likely to become insolvent.

Similarly, an increase in regulatory capital (both Tier 1 and total regulatory) is paramount in determining a bank's solvency. This underscores the importance of Basel III that requires banks to maintain higher levels of capital, with minimum common equity holdings at banks increasing from 2% to 7% of risk-weighted assets. Therefore, this study fails to reject Hypothesis 1. That is, increased regulatory capital reduces the likelihood of insolvency of a bank. The main objective of the regulatory capital is to increase the loss absorption capacity. That is, increased regulatory capital enhances bank stability and resilience. Also, higher capital requirements reduce credit and liquidity risks. This is in line with Acharya et al. (2016) and Barth and Seckinger (2018), who noted that increased regulatory capital restricts risk appetite. Basell III requires banks to classify their assets according to the probability of defaults so that a prudent credit appraisal policy will mitigate haphazard lending. Indeed, the lack of a clear credit appraisal policy will lead to irresponsible lending, which was prevalent before the 2009 global financial crisis. As a result, bankers were more motivated to the commission or bonuses without regard to the payment capability. However, it is essential to note that responsible lending is not only aimed at only the bankers but all market participants, including borrowers.

In addition, as shown in Table 7 and Table 8, profitability reduces credit and liquidity risks and significantly reduces the insolvency in banking. In other words, profitable banks reduce credit and liquidity risks and increase a bank's solvency. Therefore, this study fails to reject Hypothesis 2. Post the global financial crisis, there has been an emphasis on capital requirements and bank financial performance and liquidity (Vickers Report, 2011). This is not surprising, given that recent studies consider profitability as a macro-prudential indicator (Adusei, 2015). This is because profitable banks are able to safeguard themselves in an economic or financial downturn. In other words, profitable banks are able to build a buffer of earning, which will improve the liquidity level and hence lower liquidity risks.

In terms of the impact of economic growth on liquidity, past empirical results have been mixed. For example, Bunda and Desquilbet (2008) and Moussa (2015) stated that GDP has a positive impact on bank liquidity, while Aspachs et al. (2005) and Chen and Phuong (2014) indicated a negative influence of GDP on bank liquidity. However, this study has shown a positive association between GDP growth and liquid assets to total assets. In addition, the growth of the economy has a positive impact on the solvency of banks. In terms of significance, GDP growth is significant at 1% in influencing the solvency level of banks. The results indicate that a 1% increase in GDP leads to an 8% improvement in solvency level. Therefore, the study fails to reject Hypothesis 3. That is, during the economic boom, there will be reduced credit and liquidity risks and improved profitability of a bank. This is because economic booms do lead to job creation and, to some extent, improved earnings. With job security and earnings, loan defaults are likely to be low. As borrowers will be honoring their obligation, this will improve banks' liquidity level. However, it is noted that economic freedom has a positive and significant impact on credit risks and negatively affects the banks' sol-

Table 8. Determinants of the solvency ratio

Independent variable	Coefficient	P value
C	10.19693 (1.07004)	0.0120
CIR	–0.024990 (0.00188)	0.0000
CUST__DEPS_TOTAL_FUND	2.769935 (0.23191)	0.0010
EF	–0.072921 (0.01330)	0.0070
EQUITY_TA	0.192288 (0.00756)	0.0000
GDPG	0.084559 (0.01245)	0.0000
GROWTH_LOAN	–1.253236 (0.13874)	0.0000
IMPAIRMENTLOANS_GROSS_EQ	–0.004182 (0.00090)	0.0000
LIQUID_ASSETS_TOTAL_AS	–0.254061 (0.14738)	0.0849
LOANS_DEPOSIT	–0.726073 (0.12503)	0.0210
ROE	0.063562 (0.00888)	0.0000
Tier1	0.075545 (0.01476)	0.0000
TOTAL_REG_CAP	0.027751 (0.01285)	0.0310
Adj. *R* squared	0.615	–
F-statistic	99.5460	0.000
AIC	2.6080	–
DW	1.855	–

Note: This table shows the results of estimating using GMM for a balanced panel of the UK banks over 2009–2018; Dependent variable *Sol* (Solvency ratio); Independent variables: *CIR* (Cost income ratio); *CUST_DEPS_TOTAL_FUND* (Customer deposit to total funds ratio); *EF* (Economic freedom); *EQUITY_TA* (Equity to total assets ratio); *GDPG* (Gross domestic product growth); *GROWTH_LOAN* (Growth of loans); *IMPAIRMENTLOANS_GROSS_EQ* (Impairment of gross loans to equity ratio); *LIQUID_ASSETS_TOTAL_AS* (Liquid assets to total assets ratio); *LOANS_DEPOSIT* (Loans to total deposit ratio); *ROE* (Return on equity); *Tier* 1 (Tier 1 capital requirement); *TOTAL_REG_CAP* (Total regulatory capital).

vency level. This drums the need for regulations. Indeed, past studies have demonstrated a positive association between investors protection and capital growth (Houston et al., 2010). This suggests that the government needs to improve macroeconomic policies, which can be the driving force behind economic growth. This helps reduce the risk of banking failure.

CONCLUSION

Recent years have demonstrated the critical role that banks play and, therefore, the need to determine how the banks' stability is influenced by the degree of economic growth, a sound regulatory framework, and internal factors. The stability of banks affects the financial intermediation role they play. By extension, to play the financial intermediation role, banks must be profitable. Assessing what influences the solvency of banks, the results indicate that the more profitable the bank is, the more solvent it would be. However, profitability is impacted by various risks, including credit and liquidity risks. Provision of credit is one of the bank's functions and hence the importance of being liquid enough. Therefore, it calls for a careful balance of credit and liquidity. This paper studies the effect of liquidity and credit risks on banking solvency using a panel dataset of the UK's ten major banks from 2009 to 2018. The ten banks control a combined market share of more than 90% of the UK banking asset base. The results indicate

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that both credit and liquidity risk are significant in influencing the solvency of banks. The ratio of liquid assets to total assets significantly influences both credit risk and liquidity risk. The level of liquidity is essential as it affects the well-functioning of an institution. While it is necessary to ensure that banks do not hold too much liquid assets, it is crucial to ensure that they are sufficiently liquid enough to meet liquidity obligations. From 2019, banks are required to have a minimum liquidity coverage ratio of 100%. Liquidity requirements are to ensure banks have sufficient assets to mitigate liquidity disruptions due to changing economic climate. Illiquidity in banks will trigger a bank run, and this will have a ripple effect on the economy.

Additionally, the liquidity of a bank is influenced by how efficient the bank is. That is, the higher the cost-income ratio, the higher the liquidity risk. Tier 1 and total regulatory capital appear to have a detrimental impact on bank profitability and a tendency to reduce the risk of bankruptcy. In the case of greater economic growth, the results indicate that it positively affects solvency in banking. In addition, there is a negative association between economic freedom and banking solvency. However, it is noted that economic freedom has a significant positive influence on liquidity and credit risk.

The findings have several interesting policy implications that provide several recommendations for bank managers and bank supervisors. First, the financial crisis has shown that bank failures driven by credit risk in their portfolios can cause a freeze of the liquidity market. Second, the results indicate that during the economic boom, banks tend to increase their regulatory capital. Therefore, there is a need to ensure that during the "good time", banks can accumulate sufficient capital that is genuinely capable of absorbing negative shock during the economic downturn. Second, the results imply that a bank's joint liquidity management and credit risks could substantially increase banking stability. Finally, the results support recent regulatory efforts mainly by the new Basel III framework, which put more emphasis on capital conservation buffer, designed to enforce corrective action when a bank's capital ratio deteriorates, and a countercyclical buffer to require banks to hold more capital in good times to prepare for the inevitable rainy days ahead.

AUTHOR CONTRIBUTIONS

Conceptualization: Isaiah Oino.
Data curation: Isaiah Oino.
Formal analysis: Isaiah Oino.
Investigation: Isaiah Oino.
Methodology: Isaiah Oino.
Project administration: Isaiah Oino.
Software: Isaiah Oino.
Writing – original draft: Isaiah Oino.
Writing – reviewing & editing: Isaiah Oino.

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APPENDIX A

Table A1. Panel unit root tests

Variables	Levin, Lin & Chu		Im, Pesaran & Shin		ADF – Fisher Chi-square	
	t* t statistics	t* p value	W-stat	W-stat p value	t statistics	p value
CUST__DEPS_TOTAL_FUND	–0.72401	0.2345	0.15311	0.5608	14.9513	0.6653
GDPG	–4.72350	0.0807	–1.81245	0.0350	26.4497	0.0899
Tier 1	–0.11937	0.4525	1.99195	0.9768	6.25633	0.9950
Sol	–1.18810	0.1174	–0.16299	0.4353	14.0256	0.5968
CIR	–2.66244	0.0639	–1.37969	0.0838	23.6575	0.0973
EF	–6.38700	0.0367	–2.95400	0.0716	37.1794	0.0650
LIQUID_ASSETS_TOTAL_AS	–2.63619	0.0042	–0.87628	0.1904	20.5161	0.3045
EQUITY_TA	–1.14215	0.1267	0.07217	0.5288	14.2430	0.7131
TOTAL_REG_CAP	0.02596	0.5104	2.60196	0.9954	6.53070	0.9935
GROWTH_LOANS	–1.66789	0.0477	–0.96539	0.1672	18.9424	0.2717
LOANS_DEPOSIT	0.59388	0.7237	1.32136	0.9068	10.7728	0.9038
IMPAIRMENTLOANS_GROSS_EQ	–2.20765	0.0136	–0.58842	0.2781	22.1762	0.2243
****ROE*	–2.61293	0.0045	–9.14691	0.0000	43.4930	0.0007

Note: Sol (Solvency ratio); *CIR* (Cost income ratio); *CUST_DEPS_TOTAL_FUND* (Customer deposit to total funds ratio); *EF* (Economic Freedom); *EQUITY_TA* (Equity to Total Assets ratio); *GDPG* (Gross domestic product growth); *GROWTH_LOAN* (Growth of loans); *IMPAIRMENTLOANS_GROSS_EQ* (Impairment of gross loans to equity ratio); *LIQUID_ASSETS_TOTAL_AS* (Liquid assets to total assets ratio); *LOANS_DEPOSIT* (Loans to total deposit ratio); *ROE* (Return on Equity); *Tier* 1 (Tier 1 Capital requirement); *TOTAL_REG_CAP* (Total Regulatory Capital).

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Table A2. Overview of revised standardized risk-weighted bank assets

Risk weights in jurisdictions where the rating approach is permitted							
External rating	**AAA to AA–**	**A+ to A–**	**BBB+ to BBB–**	**BB+ to B–**	**Below B–**	**Unrated**	
Risk weight	20%	30%	50%	100%	150%	As for SCRA below	
Risk weights where the rating approach is not permitted and for unrated exposures							
Standardized Credit Risk Assessment Approach (SCRA) grades	**Grade A**		**Grade B**		**Grade C**		
Risk weight	40%		75%		150%		
Risk weights for rated covered bonds							
External issue-specific rating	**AAA to AA–**	**A+ to BBB–**		**BB+ to B–**		**Below B–**	
Risk weight	10%	20%		50%		100%	
Risk weights for unrated covered bonds							
Risk weight of issuing bank	20%	30%	40%	50%	75%	100%	150%
Risk weight	10%	15%	20%	25%	35%	50%	100%
Exposures to general corporates							
Risk weights in jurisdictions where the rating approach is permitted							
External rating of the counterparty	**AAA to AA–**	**A+ to A–**	**BBB+ to BBB–**	**BB+ to BB–**	**Below BB–**	**Unrated**	
Risk weight	20%	50%	75%	100%	150%	100% of 85% if corporate SME	
Retail exposure excluding real estate							
Retail	**Regulatory retail (non-revolving)**		**Regulatory retail (revolving)**		**Other retail**		
			Transactions	**Revolvers**			
Risk weight	75%		45%	75%	100%		
Residential real estate exposure							
LTV bands	Below 50%	50% to 60%	60% to 70%	70% to 80%	90% to 100%	Above 100%	Criteria not met
Whole loan approach RW	20%	25%	30%	40%	50%	70%	RW of the counterparty
Commercial real estate exposure (CRE)							
General CRE							
Whole loan approach	LTV < –60%		LTV > 60%		Criteria not met		
	Min (60%, RW of counterparty)		RW of counterparty		RW of the counterparty		
Loan splitting approach	LTV < –55%		LTV > 55%		Criteria not met		
Percentage	Min (60%, RW of counterparty)		RW of counterparty		RW of the counterparty		
Income-producing commercial real estate (IPCRE)							
Whole loan approach	LTV < –60%		60% < LTV < –80%		LTV > 80%		
Percentage	70%		90%		110%		
Land acquisition, development, and construction (ADC) exposures							
Loan to company ADC loan	150%						
Residential ADC loan	100%						

Table A3. Fixed effect model

Independent variable	Credit risk model 1		Liquidity risk model 2	
	Coefficient	p value	Coefficient	P value
C	–162.9293 (80.4299)	0.0457	–0.82199 (0.6522)	0.2107
LIQUID_ASSETS_TOTAL_AS	23.4373 (12.4911)	0.0638	–	–
Sol	–2.3929 (2.4439)	0.0000	0.0125 (0.0201)	0.0528
CIR	0.1770 (0.1714)	0.0014	0.0016 (0.0015)	0.0267
CUST_DEPS_TOTAL_FUND	3.3031 (2.3188)	0.0000	0.0811 (0.1913)	0.0050
EF	2.8429 (0.0946)	0.0000	0.0046 (0.0080)	0.5660
EQUITY_TA	0.0171 (0.0990)	0.0000	0.0121 (0.0081)	0.1361
GDPG	0.0617 (0.0120)	0.0610	0.0038 (0.0083)	0.0643
GROWTH_LOAN	–7.3150 (11.2874)	0.0000	0.0017 (0.0932)	0.0000
LOANS_DEPOSIT	37.4406 (19.1125)	0.0000	0.6149 (0.1443)	0.0000
ROE	1.2470 (0.0714)	0.0000	0.0172 (0.0056)	0.0000
Tier1	–1.0771 (0.1714)	0.0410	–0.0129 (0.0116)	0.0027
TOTAL_REGULATORY_CAPITAL	–2.3437 (0.0124)	0.0000	–0.0155 (0.0100)	0.0001
Adj. R-squared	0.8128	–	0.7118	–
F-statistic	19.0279	0.000	11.6124	0.000
AIC	8.5725	–	–0.992	–
DW	1.816	–	1.959	–

Note: This table shows the results using FE for a balanced panel of the UK banks over 2009–2018; *CIR* (Cost income ratio); *CUST_DEPS_TOTAL_FUND* (Customer deposit to total funds ratio); *EF* (Economic Freedom); *EQUITY_TA* (Equity to total assets ratio); GDPG (Gross domestic product growth); GROWTH_LOAN (Growth of loans); *IMPAIRMENTLOANS_GROSS_EQ* (Impairment of gross loans to equity ratio); *LIQUID_ASSETS_TOTAL_AS* (Liquid assets to total assets ratio); LOANS_DEPOSIT (Loans to total deposit ratio); ROE (Return on equity); *Tier* 1 (Tier 1 Capital requirement); *TOTAL_REG_CAP* (Total regulatory capital); *Sol* (Solvency ratio).

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