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Guarango Banerjee

Abhimanyu Gupta


Abhiman Das

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Effects of financial statement and macroeconomic factors on risk measures of banks in India: Panel and Decision Tree Analysis Approach

 Gaurango Banerjee ^{(a)*}, Abhimanyu Gupta ^(b), Abhiman Das ^(c)



^(a) Plaster College of Business & Entrepreneurship, Lindenwood University, USA

^(b) Richard A. Chaifetz School of Business, Saint Louis University, USA

^(c) Indian Institute of Management Ahmedabad, India

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ABSTRACT

This paper aims to analyse the effects of financial statement indicators and off-balance sheet items affecting risk measures among Indian banks employing both panel data regression and a non-parametric decision tree approach. We explore the effects of bank size, leverage, exposure to contingent liabilities including off-balance sheet derivatives usage and macroeconomic factors on risk measures for banks. In this paper, it is also aimed to examine the effects of the major financial liberalization policy period in the domestic market in India that started in the mid-1990s and ended around 2004 as well as impacts of the 2008 global financial crisis on the risk measures of banks operating in India. As risk measures, we present a comparative analysis of liquidity, solvency, and interest rate risk measures of Indian banks across public (government) and private ownership categories. Main findings from our study demonstrate (i) significant impact of capital adequacy and the bank size on all the risk measures, (ii) contingent liabilities (including derivatives usage) at banks is observed to significantly impact the asset management measure of liquidity risk and the solvency risk of banks, (iii) GDP growth is observed to impact the asset management and liability management measure of liquidity risk, (iv) the global financial crisis is found to have a significant impact on the liquidity risk measures and interest rate risk, but a weak effect on solvency risk of Indian banks, (v) bank ownership category (government owned versus private sector banks) is observed to have a significant impact on all the risk measures, and finally (vi) financial liberalization reforms had a highly significant effect on the liquidity risk at banks.

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Introduction

The possible effects of financial liberalization and deregulation reforms in India that were initiated the Indian financial markets in the mid-1990s and the liquidity crunch in the global markets following the financial crisis of 2008 provides a motivation to study bank risk measures in an emerging banking market in India. In the last few decades, the banking industry has been affected worldwide due to the rapid globalization trends in combination with deregulation and the application of technology in the banking sector. Due to the rise in competition and liberalization policies (Beju and Ciupac-Ulici, 2012; Angkinand et.al .2010; Hermes and Nhung, 2008) banks have increased exposure to off-balance sheet derivatives items with the purpose of hedging specific risks. However, the increased usage of derivatives items may also expose banks to speculative risks if these items are not used prudently as they provide incentives for more risk taking, and may affect performance of financial institutions (Lazarus, 1997). This is an area of concern especially in the post 2008 global financial crisis period and is being debated globally regarding its increased usage and effects on financial stability (Karim et al, 2013).

This paper aims to analyse the relationship between risk measures of financial institutions and financial statement items such as asset size, leverage, capital asset requirements, contingent liabilities including off-balance sheet derivatives exposure and macroeconomic

* Corresponding author. ORCID ID: <https://orcid.org/0000-0001-7007-5030>

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GDP growth. Specifically, the paper uses risk metrics for liquidity risk, solvency risk, and interest rate risk and examines their relationships with bank level characteristics of domestic government owned public sector and domestic private sector banks operating in India between 1996 and 2016. We employ both time-series and cross-section panel analysis as well as a non-parametric decision tree analysis in our paper.

We analyze risk from various perspectives. The liquidity risk of banks is analyzed from both a deposit liability management viewpoint as well as from an asset management viewpoint of liquidity for banks (Imbierowicz and Rauch, 2014; Baldan and Zen, 2012). The solvency risk of banks are analyzed from leverage data for banks. Solvency measures of bank look at the capital to risk adjusted assets of banks, to check for banks meeting the recommended capital adequacy guidelines of the Basel Accord (Pham et al., 2015). The literature provides different measures of risk that can be analyzed in this context (e.g. the Z-score measures obtained from average return on assets, capital asset ratios, and standard deviation of returns on assets). Further, the results of the research shed some light on whether larger financial institutions continue to take higher risks after the recent financial crisis under the assumption of guaranteed protection by the government of the “too big to fail” entities (Demsetz and Strahan, 1997; Srivastava, 1999; Hakenes and Schnabel, 2011).

The liberalization of interest rates resulted in increased interest rate volatility in India. As a result, the monitoring of interest rate risk at Indian banks is important from the perspective of its stakeholders and investors. The interest rate risk arises from timing differences in the repricing of banks' assets and liabilities and off-balance sheet instruments. Interest rate sensitive assets and liabilities at banks provide measures of net interest margins for banks and its effects on bank profitability.

In our paper, we consider the effects of financial statement items as well as usage of derivatives items on the risk measures of banks with different ownership structures, namely private sector and state-owned public sector banks operating in an emerging financial market in India. (Oino, 2016) In terms of methodological innovation, we use both panel data analysis as well as a non-parametric decision tree approach. The decision tree analysis is a novel approach introduced in our paper that provides specific threshold range values for financial statement items and off-balance sheet contingent liabilities at banks that have a significant effect on their liquidity, solvency and interest rate risk measures.

The rest of the paper is organized as follows. The hypotheses and related literature review on the issues of bank risks and financial stability is presented in Section 2. In Section 3, we present the methodology employed in the study including the panel regression and decision tree analysis. Results based on both panel data regression and decision tree analysis are presented in Section 4. Finally, Section 5 concludes with some policy implications based on the results.

Literature Review

In this section, we include our hypotheses and related literature on the effects on risk measures at banks related to accounting statement items as well as off-balance sheet items. The paper investigates the effects on liquidity, solvency and interest rate risks on public sector and private sector banks operating in India before and after two major structural periods in the banking system. The first involves the major financial liberalization period in India that was initiated in the 1990s (and whose major reforms ended around 2004). The second major structural period included in our hypotheses includes the period before and after the global financial crisis of 2008.

Solvency risk and liquidity risk are considered as the two major risks measures that affect the probability of bank default. Imbierowicz and Rauch (2014) investigated the relationship between liquidity risk and credit risk using a sample of US commercial banks (1998-2010). They find that the effect of the interaction of liquidity and credit risk measures could increase the probability of the overall risk of default of banks. As a result, regulatory policies may need to be aimed at the joint risk management of both solvency and liquidity risk. Baldan and Zen (2012) concluded that the liquidity risk and the interest rate risk of financial institutions were related with specific attention to their interest margin. In this context, we investigate risk measures for liquidity, solvency and interest rate risk of public and private sector banks in India between 1996 and 2016.

Null Hypothesis 1: Bank size does not influence the bank liquidity risk (solvency risk) (interest rate risk)

Demsetz and Strahan (1997) found an inverse relationship between the size of banks and idiosyncratic non-systematic risks for bank holding companies in US. Srivastava (1999) demonstrated that Indian banks were operating at below their optimal size and concluded that larger banks could provide cost efficiencies. Stever (2007) found evidence of larger market risk of large banks compared to small banks. The paper concluded that the lower level of diversification of smaller banks forced them to select more low risk borrowers or make loans backed by more collateral. Berger and Bouwman (2009) emphasized the positive correlation between bank liquidity and value and tested theories of the relationship between capital and liquidity creation. The findings revealed a positive relationship for large banks while smaller banks revealed a negative relation between capital and liquidity creation. Hakenes and Schnabel (2011) analyzed the relationship between risk taking under the Basel II Capital Accord and bank size. They demonstrate that internal ratings based (IRB) approach may be more effective, and as a consequence smaller bank may be driven to more risk taking due to the competition. In our paper, we investigate empirically the effect of bank size on the risk metrics for public sector and private sector banks operating in India.

Null Hypothesis 2: The core capital to risk-adjusted asset ratio at banks does not influence their liquidity risk (solvency risk) (interest rate risk)

Pham, Nguyen, and Nghiem (2015) applied seemingly unrelated regression equations to study the relationships among capital, default risk, and efficiency among Indian banks in the period 1990-2011. They obtained a negative association between default risk and capital ratios. We examine the relationship between capital to risk-adjusted assets ratios of banks and the banks' Z-scores that provide a measure of solvency risk. Based on their findings, public sector banks had higher likelihood of default, lower capital ratios, but demonstrated higher efficiency level compared to private banks.

Baldan and Zen (2012) demonstrated that actions taken to reduce the liquidity risk also lowered its interest margin, but also enabled the bank to reduce the amount of capital absorbed by the interest rate risk.

Null Hypothesis 3: The level of contingent liability usage by banks does not influence their level of liquidity risk (solvency risk) (interest rate risk)

Lazarus (1997) tested whether banks with more interest rate risk exposure and riskier would choose loan and deposit rates to obtain higher net interest margins. The study found that differences in liquidity risk and interest-rate risk were related to differences in the banks' off-balance sheet exposure. We check for the effects of off-balance sheet exposure of Indian banks to their liquidity, solvency and interest rate risk measures.

Null Hypothesis 4: Bank ownership structure does not influence the level of their liquidity risk (solvency risk) (interest rate risk)

Oino (2016) studied the effect of credit risk management on public and private sector banks in India during 2009-2012. Using OLS and fixed and random effects models, the paper finds that private banks are more capitalized and more profitable than public banks. Non-performing loans had the largest negative impact on bank profitability. Our paper includes non-parametric decision tree analysis in addition to the OLS and fixed and random effects model to investigate factors affecting risk measures for both private and public sector banks.

Makkar and Singh (2013) addressed the problem of interest rate risk in Indian commercial banks. The paper used a GAP analysis model to measure the interest rate risk at banks from 2008-2011. On comparing the combined performance of all public and private sector banks, the paper finds that private sector banks were able to manage their interest rate risk better compared to the public sector banks. Charumathi (2010) assessed the interest rate risk at public sector banks in India by studying how banks conducted their assets and liabilities management in order to achieve a specified net interest income. Our paper investigates the effects of bank specific and macroeconomic factors on the net interest margin relative to assets for both public and private sector banks.

Null Hypothesis 5: Economic growth has no influence on the bank liquidity risk (solvency risk) (interest rate risk)

Among India specific studies, Sharma and Singh (2016) explore bank specific and macroeconomic factors affecting liquidity risk of banks in India between 2000 and 2013. The paper employed OLS and panel data analysis including fixed and random effects models, and found that deposits, profitability and capital adequacy had a positive effect on liquidity, while bank size and GDP had a negative effect on the liquidity

Thiagarajan, Ayyappan and Ramachandran (2011) utilized a panel data to obtain determinants of credit risk in Indian banks. The paper revealed that both macroeconomic factors such as GDP and bank specific factors had an important role in determining the credit risk at banks. Maji and Hazarika (2016) found that profitability, capital and GDP growth are negatively correlated to credit risk for all Indian banks, while loan loss provision had a positive correlation with credit risk. In our model, we also investigate the effect of GDP growth on the risk measures for banks.

Null Hypothesis 6: Domestic financial liberalization reform had no effect on the level of bank liquidity risk (solvency risk) (interest rate risk)

Angkinand et.al (2010) used dataset across 48 countries between 1973 and 2005 that underwent financial reforms and found that the relationship between financial liberalization and banking crises depended on the strength of the capital regulation and banking supervision. The paper finds the probability of banking crises increased with weaker banking supervision and regulation following the liberalization. Similar observation is obtained by Beju and Ciupac-Ulici (2012) using data from developing countries in Central and Easter Europe in which they conclude that the speed of liberalization policies need to be commensurate with the adequate supervision to reap the benefits of financial reforms in the banking sector in the countries. In this paper, we focus on the effects on bank risk measures in India before and after its period of financial liberalization. The effects of capital regulations would be analyzed using the capital to risk adjusted ratios at banks before and after the major liberalization period.

Hermes and Nhung (2008) investigated the impact of financial liberalization on the efficiency of banks in ten emerging economies in Latin America and Asia between 1991 and 2000. The paper finds a positive effect on bank efficiency following the financial reform programs.

Brooks (2003) investigated the effects on the costs of intermediation and profitability of banks in India during the financial liberalization period and found that the profitability of public sector nationalized banks was significantly lower than private and foreign banks operating in India during the reform period. Gupta et al (2011) found that public sector banks in India held more government securities to support the fiscal deficits of the government compared to the private sector banks after the liberalization period. In our paper, we look at the impact of risk measures on both the public sector and private sector banks during and after the liberalization period.

Null Hypothesis 7: Global 2008 financial crisis had no effect on the level of bank liquidity risk (solvency risk) (interest rate risk)

Vasquez and Federico (2012) investigated the effects of bank funding structure in terms of leverage and liquidity on the solvency risk of banks operating in U.S. and Europe from 2001 to 2009. Based on their results they found banks with weaker liquidity position and higher leverage in the period before the 2007-08 global financial crisis (GFC) had a greater likelihood of failure during and after the GFC. Also, they concluded that smaller domestically oriented banks suffered from more liquidity risk compared to the larger cross-border banks. The larger banks were however more prone to solvency risk due to their higher leverage levels. They also obtained evidence for the macroeconomic and monetary conditions to be directly related to the probability of bank failure following the crisis period. Gambacorta et al. (2011) tested the influence of banks business models and market funding patterns on the monetary transmission mechanism in US and Europe in the period before the global financial crisis and demonstrated structural changes during the financial crisis period. Their findings supported the Basel III recommendations on the significance of banks' core capital on liquidity risk. Banks with weaker core capital positions restricted loan supply more significantly during the financial crisis thereby curbing the intended monetary transmission mechanism. Baker, Cumming and Jagtiani (2017) discussed the increase in the number of financial regulations in the period after the financial crisis that concentrated on capital requirements and liquidity at banks in the U.S. They find that larger banks had been holding more equity tier 1 capital as well as higher levels of high-quality liquidity assets in the period following the financial crisis. We study the differential effects, if any, on risk measures at banks operating in India in the pre- and post-global financial crisis period.

Research Methodology

Our baseline empirical econometric model is as follows:

$$\text{Bank Risk}_{i,t} = a_0 + b_1 \text{ASSETS}_{i,t} + b_2 \text{CRAR}_{i,t} + b_3 \text{CONT-LIAB}_{i,t} + b_4 \text{GDP growth}_{i,t} + b_5 \text{PrivateBank}_{i,t} + b_6 \text{PublicBank}_{i,t} + b_7 \text{Financial Liberalization Dummy} + b_8 \text{Financial Crisis Dummy} + \epsilon_{it}$$

where, ASSETS = log value of total assets at banks, CRAR = Capital-to-risk-adjusted-assets ratio

CONT-LIAB= log value of Contingent Liabilities at banks (including off-balance sheet derivatives and letters of credit)

GDP growth = annual growth in gross domestic product;

Ownership of banks is captured by 3 different dummy variables as: Private Bank = Domestic private sector banks; Public Bank = Domestic public sector state and nationalized banks;

Financial Crisis Dummy = 1 (after 2008 global financial crisis); = 0 (prior to 2008 crisis)

Financial Liberalization Dummy = 1 (during major financial liberalization reforms in market, 1996-2004); = 0 (after the end of the major reforms period)

Different risk metrics were tested for Liquidity risk, Credit (Solvency) risk, and Interest rate risk for banks operating in India between 1996 and 2016. The data was compiled from the Statistical Tables Relating to Banks of the Reserve Bank of India. A panel dataset of 32 private sector banks and 29 public sector (government owned) banks has been analyzed from 1996-2016. The financial statement items studied in the model include the bank assets and the capital to risk weighted asset ratios. The bank assets would be a proxy for bank size and could shed some light on whether there were differential effects on risk measures of banks operating in India during the period in terms of bank size. Also, the effects of capital to risk adjusted ratios for banks on bank risk show whether adequately capitalized banks were able to lower their risk measures as prescribed by the regulatory authorities.

In addition to financial statement items, we also investigate the effects of off-balance sheet contingent liabilities on risk measures for banks. The contingent liability item included in the analysis comprises off-balance sheet derivatives exposure of banks. The risk hedging or speculative outcome of the derivatives exposure on bank risk measures may be a useful indicator for both regulatory authorities as well as private investors in the banking market. The emerging Indian financial market has experienced unprecedented growth in the last 2 decades, and so the effects of GDP growth on the banks risk measures is also examined in the analysis.

The effects of bank ownership on risk measures are examined by using dummy identifiers for private sector and public sector banks. The private sector banks were further segmented into domestic private sector banks and foreign private banks. The domestic public sector banks are partially privatized in the Indian banking market, with the government having a majority 51% ownership and the remaining owned by the private investors. The public sector banks are further segregated into nationalized banks and state banks.

The sample period 1996 to 2016 also covered two major structural periods that affected the banking market dynamics. Although financial liberalization is an ongoing phenomenon in the developing banking market in India, the major financial reforms started in the mid-1990s were completed around 2003. As a consequence, we employ a financial liberalization dummy to examine any changes in the risk measures for banks operating in India during the major liberalization period (1996-2003) and post liberalization period (2004-2016). In addition, we test for any significant changes, if any, on risk metrics for banks before and after the 2008 global financial crisis.

A number of risk metrics were considered for liquidity risk, credit (solvency) risk and interest rate risk measures for banks. We highlight the results for the risk metrics that provided higher accuracy measures in explaining the baseline model presented above. Since liquidity management at banks includes both liability management and asset management, the most accurate measures for liquidity risk corresponding to liability and asset management were separately analyzed in the paper. The liquidity risk metric that provided the highest accuracy measure based on liability management was the Core Deposits-to- Assets, (Liquidity Risk I, in Table 1 appendix). We use the definition of core deposits as provide by the Reserve Bank of India. In general, banks with larger percentage holdings of core deposits (and lesser holdings of short-term non-core liabilities) are considered more liquid.

The second liquidity risk metric studied in the paper was based on asset management of banks. The liquidity ratio that provided the highest accuracy measure for the risk metric was the Temporary Assets-to- Total Assets (Liquidity Risk II, in appendix Table 2). Following guidelines of the central bank, Temporary Assets consisted of cash + balances with banks + balances with Central Bank (RBI). Banks with larger proportion of temporary assets as a fraction of total assets are considered to have a better liquidity position, or lower liquidity risk.

The solvency risk metric with the highest accuracy measure was identified as the Z-score measure. The Z-score used is the standard solvency risk measure ($= (ROA + CAR) / \text{Std. Dev of ROA}$) where ROA represents the returns on assets and CAR represents the Capital to Assets ratio at banks. A higher Z-score would represent a lower solvency risk at banks.

The interest rate risk metric with the highest accuracy measure was identified as the Net Interest Margin to Assets of banks. A lower interest margin relative to bank assets implies increase in interest rate risk measure for banks. A reduction in net interest income of a bank may result when the increase in interest expenses exceed the increase in interest income for banks.

We employ both the standard panel data methodology as well as introduce non-parametric Decision Tree analysis to test the risk measures in the baseline model. Since linearity and normality assumptions may be violated in the baseline parametric model, we use the Decision Tree analysis to account for non-normality and possible non-linear relationship in the model.

Among the machine learning models, decision trees are the most robust and interpretable. It is a rule-based technique where, based on some logical rules identified using the influencer variables, it separates records into homogeneous subgroups in terms of the values of the response variable and the corresponding p-values for the chi-square tests. The decision tree does not assume linearity or normality of the data, making it robust and flexible. Decision trees are common in solving both regression and classification problems. They are also beneficial for feature selection which is selecting the most significant predictors for the response variable. They need little effort from the user for transforming the variables as any monotone transformation of the variables will result in the same tree. Decision trees are also robust with outliers.

However, a weakness of the decision tree is that it requires a moderately large dataset, for example, with more than a few hundred rows, to extract the rules. The time-series, cross-section panel data used in our paper that includes all domestic public sector (state and nationalized banks), private sector banks as well as foreign banks operating in India between 1996 and 2016, more than adequately meets the requirements to extract the rules in the decision tree analysis. However, unlike the linear regression models that demand a linear relationship between the response and the predictor variable, decision trees allow for a wide range of relationships. An important feature of a decision tree is that it handles missing data without having to impute values or delete records with missing values. Lastly, an important practical advantage of a decision tree is that it generates rules that are transparent and easy to interpret.

One of the primary motivations for using the decision tree in our analysis is to complement our results from the standard linear panel regression methods to take into account possible non-linear relationships between the financial statement items, contingent liabilities, macroeconomic factors and the different risk measures for banks. Also, in addition to identifying significant factors affecting bank risk measures using the panel regression analysis, the decision tree provides a critical range of values for the independent variables (based on rules in the form of the branches of the trees) as illustrated in the figures relating to the respective risk measures in the paper.

Findings and Discussions

The risk metrics for liquidity, solvency and interest rate risk were selected from among alternative metrics based on the highest accuracy provided using non-parametric decision tree analysis and the panel data methodology.

Liquidity Risk

(i)Liquidity Risk I: The results for panel data analysis and the non-parametric Decision Tree analysis using Core Deposits to Assets as a liability management measure of liquidity risk in the baseline model have been included in this section.

The panel data analysis results are presented in Table 1 below. The LM tests showed that the random effects and the fixed effects were preferred to the pooled OLS model. The Hausman test confirmed that the fixed effects model was more appropriate relative to the random effects model for the Liquidity Risk I measure (i.e. Core Deposits to Assets).

Table 1: LiquidityRisk-1 (= Core Deposits / Assets)
 [Core deposits = Time-deposits + 78% of Savings Deposits, as defined in RBI Data Source]

	Pooled OLS	Fixed Effects*** (within)	Random Effects
Dependent variable: LiquidityRisk-1			
CRAR	-0.0047*** (0.0003)	-0.0033*** (0.0003)	-0.0035*** (0.0003)
GDP	-0.0072*** (0.0014)	-0.0054*** (0.0011)	-0.0058*** (0.0011)
ASSETS	0.0113** (0.004)	0.0207*** (0.0049)	0.01903*** (0.0047)
CONT.LIAB	-0.027*** (0.002)	-0.0209*** (0.0034)	-0.0226*** (0.003)
factor(BankCat)2	0.057*** (0.0067)	-0.0952*** (0.024)	0.0316 (0.0214)
factor(BankCat)3	0.015* (0.0074)	-	0.0431* (0.0209)
factor(FinCrisisDummy)1	0.032*** (0.0067)	0.0161** (0.0056)	0.0191*** (0.0055)
factor(FinLibDummy)1	0.0468*** (0.0072)	0.0297*** (0.0062)	0.0334*** (0.0061)
Constant	0.9383*** (0.0392)	-	0.7497*** (0.0498)
Observations	1100	1100	1100
R2	0.374	0.182	0.3298
F Statistic	81.288*** (df=8; 1091)	32.639*** (df=7;1029)	271.69*** (Chi-sq; df=8)

*p<0.1; **p<0.05; ***p<0.01

*** Fixed Effects model selected based on following tests:

#F-Test individual effects (Fixed vs OLS): F = 18.411, df1 = 62, df2 = 1029, p-value < 2.2e-16

#LM Test(Honda) unbalanced panel; (Random vs OLS): normal = 45.337, p-value < 2.2e-16

#Hausman Test(Fixed vs Random) chisq = 120.8, df = 7, p-value < 2.2e-16

Based on the fixed effects model, banks' capital to risk adjusted assets, CRAR, has a significant negative effect on Core Deposits to Assets ($p < 0.01$). A decrease in core deposits at banks relative to assets would increase the liquidity risk. An increase in capital to assets also implies a reduction in deposit leverage at banks that may result in a higher liquidity risk from a liability management perspective. Using the fixed effects model, the size of bank assets is observed to have a highly significant positive effect on Core Deposits to Assets ($p < 0.01$) implying liquidity risk from a liability management viewpoint is reduced at larger banks. Contingent Liabilities at banks (that include banks' derivatives exposure in addition to letters of credit, etc.) has a highly significant negative effect on the Core Deposits to assets ($p < 0.01$), revealing an increase in liquidity risk at banks associated with higher usage of contingent liabilities /derivatives contracts by banks. Also, the bank category is seen to have a significant effect ($p < 0.01$) on the Core Deposits to Assets. Based on the results, the nationalized banks (bank category 2) are associated with lower core deposits to assets implying higher liquidity risk. The financial crisis dummies reveals that the post financial crisis period (after 2008) has a positive effect on the core deposits to assets ($p < 0.05$). This suggests lower liquidity risk at banks in the period after the global financial crisis (2009-2016). The financial liberalization dummy shows a highly significant positive effect on Core Deposits/Assets implying lower liquidity risk based on liability management at banks in the period after the end of the major liberalization reforms (i.e. after 2004).

The Decision Tree branches for Liquidity Risk 1 measure are illustrated in Fig.1 below.

Decision Tree of LiqRisk2 with Maximum Depth = 4 and R-squared = 39.82%

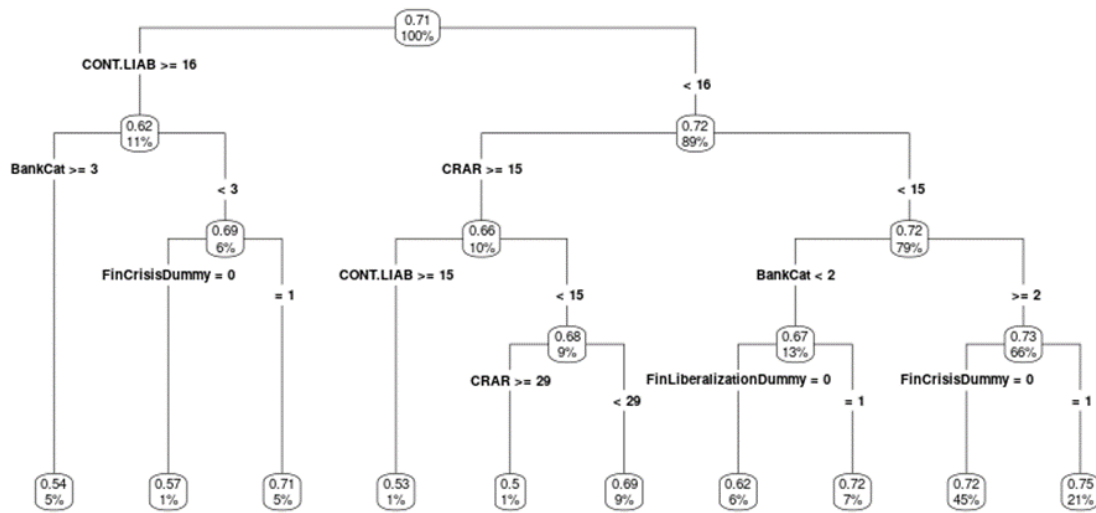


Figure 1: Decision Tree of Liquidity Risk 1

The median value of Core Deposits to Assets for all banks is 0.71. At the next level of the tree, we observe that banks with log of contingent liabilities less than 16 (89% of all banks) have a higher median value of Core deposits to assets (=0.72) relative to banks with log of contingent liabilities greater than or equal to 16 (11% of all banks). This is consistent with our findings from the fixed effects panel model that showed a significant negative effect of contingent liability usage on the Liquidity risk of the banks.

For banks with log of contingent liabilities greater than or equal to 16, the separate effects of the different bank categories (public sector state banks =1, public sector nationalized banks =2, and private sector banks = 3) are illustrated in the decision tree for Liquidity Risk 1 (Fig 1). The median value of the core deposits to assets for bank categories less than 3 (implying public sector state banks (Cat.1) and public sector nationalized banks (Cat.2)) equals 0.69 which is higher than the median value for the private sector (Cat.3) banks) obtained as 0.54. This implies that for banks with log of contingent liabilities > 16, the public sector banks have a higher share of core deposits to assets, or a lower liquidity risk compared to private sector banks. Further, for the public sector banks in this group (Bank Cat < 3), the median value of core deposits to assets is higher (=0.71) in the period after the financial crisis (Financial Crisis dummy =1) compared to the period before the financial crisis (median value = 0.57). This could be inferred as more prudential liability management of liquidity measure for public sector banks after the crisis period.

For banks with log of contingent liabilities less than 16, the differential effect of CRAR is illustrated in the tree. The median value of core deposits to assets is lower (=0.66) for banks with CRAR >= 15, compared to a median value (=0.72) for banks with CRAR < 15. This is again consistent with our results in the fixed effects model that showed a negative effect of CRAR on the core deposits to assets measure for banks. Further branches for banks with CRAR > 15, confirm the earlier findings that banks with higher contingent liabilities (log value >15) have a lower median core deposits to assets, implying higher liquidity risk compared to banks with lower contingent liabilities (log value <15).

Analyzing the subsequent bottom level branches for banks with CRAR <15, we observe that for Bank Cat. < 2 (i.e. public sector state banks in the sample), the core deposits to assets for banks is higher (median value =0.72) after the end of the major financial liberalization compared to the median value of 0.62 during the period of the liberalization. This is again consistent with our findings of a positive relation of the post liberalization period with the core deposits to assets at banks as obtained in the fixed effects panel regression model.

The accuracy measure of the non-parametric Decision Tree analysis model using Core Deposits to Assets as a liquidity risk measure increased relative to the panel data fixed effects model discussed above. The decision tree model also provides specific conditional factors and threshold values for financial statement and off-balance sheet contingent liability items of banks that have a significant effect on the average measure of core deposits to assets at banks.

(ii) Liquidity Risk 2: Using the alternative asset management measure of liquidity risk in terms of ratio of temporary assets to total assets at banks, we obtained results for the Pooled OLS, Fixed effects and Random effects models. The LM tests showed that the fixed effects and the random effects were again preferred to the pooled OLS model. The fixed effects model was chosen over the random effects model based on the Hausman test for the Liquidity Risk-2 measure (= Temporary Assets / Assets). The results are presented in Table 2.

Table 2: LiquidityRisk-2 (=Temporary Assets/Total Assets)

[Temporary assets = cash + balances with banks + balances with Central Bank (RBI) , as defined in RBI Data Source]

Dependent Variable: LiquidityRisk-II	Pooled OLS Fixed Effects*** Random Effects (within)		
CRAR	0.0002 (0.0002)	-0.0005*** (0.0002)	-0.00004 (0.0001)
GDP	0.004*** (0.001)	0.003*** (0.001)	0.003*** (0.001)
ASSETS	0.011*** (0.002)	-0.016*** (0.003)	-0.007*** (0.002)
CONT.LIAB	-0.017*** (0.001)	-0.002 (0.002)	-0.008*** (0.002)
factor(BankCat)2	0.002 (0.003)	0.029** (0.013)	0.012 (0.008)
factor(BankCat)3	0.011*** (0.004)	-	-0.003 (0.008)
factor(FinCrisisDummy)	-0.003 (0.003)	0.006** (0.003)	0.005 (0.003)
factor(FinLibDummy)	-0.026*** (0.004)	-0.016*** (0.003)	-0.017*** (0.003)
Constant		0.133*** (0.019)	0.283*** (0.025)
Observations	1100	1100	1100
R2	0.494	0.40	0.447
F Statistic	133.353 *** (df = 8; 1091)	98.393 *** (df = 7; 1029)	770.388*** (Chi-sq; df =8)

Note: *p<0.1; **p<0.05; ***p<0.01

*** Fixed Effects model selected based on following tests:

#F-Test individual effects (Fixed vs OLS): F = 10.945, df1 = 62, df2 = 1029, p-value < 2.2e-16

#LM Test (Honda) unbalanced panel; (Random vs OLS): normal = 28.267, p-value < 2.2e-16

#Hausman Test (Fixed vs Random) chisq = 105.02, df = 7, p-value < 2.2e-16

In this case, based on the fixed effects model, CRAR has a significant negative effect on Temporary Assets to Total Assets ($p < 0.01$). A decrease in temporary assets relative to total assets would increase the liquidity risk. An increase in capital to risk adjusted assets allocations for banks may imply increases reserves allocated for loan loss provisions, resulting in fewer temporary asset reserves available for banks. This may result in a higher liquidity risk from an asset management perspective.

The GDP growth was seen to have a highly significant positive effect ($p < 0.01$) on the temporary assets to assets at banks. This would imply that liquidity risk based on the asset management component for banks was lower during periods of economic growth. Using the fixed effects model, the size of bank assets is observed to have a highly significant negative effect on Temporary Assets to Assets ($p < 0.01$) revealing higher liquidity risk from an asset management viewpoint at larger banks. The financial liberalization dummy is observed to have a significant negative effect ($p < 0.01$), implying higher liquidity risk in the post financial liberalization period (2004-2016 in our sample). The financial crisis dummy reveals that the post financial crisis period (after 2008) has a positive effect on the temporary assets to assets ($p < 0.05$). This points to lower liquidity risk at banks in the period after the global financial crisis (2009-2016).

The decision tree analysis for Liquidity Risk 2 measure (included in Fig 2 below) provided more specific information on the effects of contingent liabilities, financial liberalization, global financial crisis, and GDP growth on the liquidity risk at banks.

Decision Tree of LiquidityRisk4 with Maximum Depth = 4 and R-squared = 61.59%

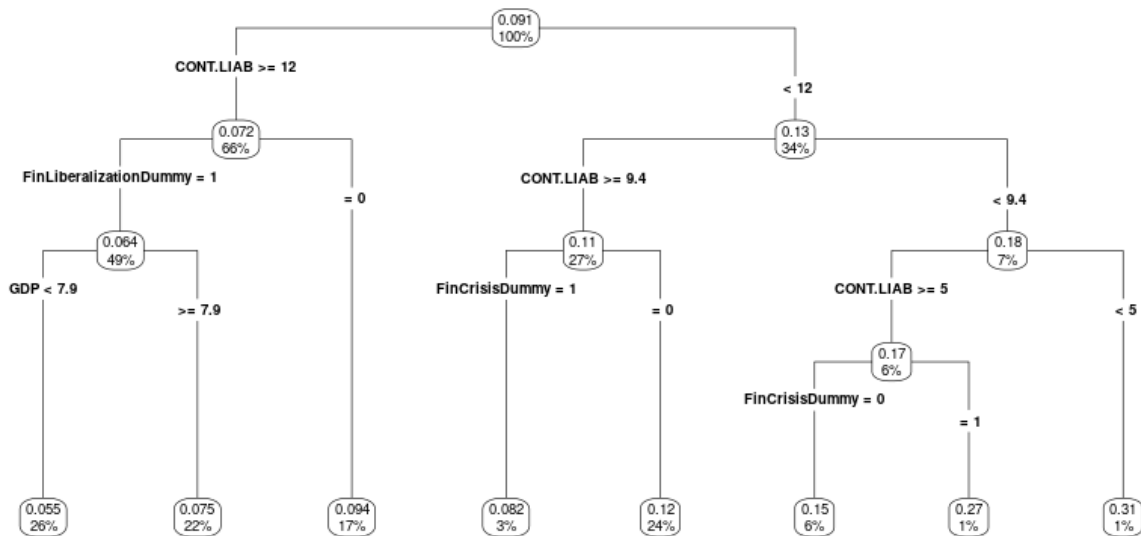


Figure 2: Decision Tree of Liquidity Risk-2

The average Liquidity Risk-2 measure (Temporary Assets to Total Assets) for all banks in the available data is 0.091. However, for the banks with log of CONT.LIAB < 12, the average value of the Temporary Assets to Total Assets is 0.13, whereas for the banks with log of CONT.LIAB >= 12, the average value drops to 0.072, implying higher liquidity risk from an asset management viewpoint with the rise in Contingent Liabilities. For the banks with log of CONT.LIAB >= 12, if FinLiberalizationDummy=0, then the average value of Temporary Assets to Total Assets goes up to 0.094, otherwise it comes down to 0.064. This implies that Liquidity risk from an asset management perspective increased after the end of the major financial liberalization programs for banks with higher levels of contingent liability. This is again consistent with the results of the significant negative effect of the financial liberalization dummy on the Temporary Assets to Total assets at banks. Further, the following branch reveals that for such banks, the liquidity risk was lower (Average value of Temporary Assets to Total assets was higher =0.075) when GDP growth was higher than 7.9% compared to the average value of 0.055 when GDP growth was lower than 7.9%. The effect of GDP growth on Liquidity risk is consistent with the results of the Fixed effects model.

On the other hand, for the banks with log of CONT.LIAB < 12, if log of CONT.LIAB >=9.4, then the average Liquidity Risk-2 measure increases (as average Temp assets to Total assets drops to 0.11. Otherwise, the liquidity risk measure decreases with the average value of Temp Assets to total assets rising to 0.18. This is consistent with our general finding that the asset management measure of liquidity risk is higher for banks with higher levels of contingent liabilities.

Solvency Risk

Using the panel data, the LM tests showed that the random effects and the fixed effects were again preferred to the pooled OLS model. The Hausman test confirmed the choice of the fixed effects model over the random effects model. The fixed effects model confirms that CRAR is significantly positively related ($p < 0.01$) to the Z-score measure. In other words, our model confirms that banks operating in India with higher capital to risk-adjusted asset ratios had an effect of reducing the solvency risk measure. The model also shows a significant negative effect of assets ($p < 0.01$) on Z-scores, implying larger banks demonstrated higher solvency risk. Contingent Liabilities are seen to have a significant positive effect on the Z-score ($p < 0.01$) suggesting that the use of derivatives may have served to hedge the bank risk during the sample period considered. Public sector banks (bank category 2) reveals a significant negative effect on the Z-scores ($p < 0.01$) implying the public sector banks demonstrated significantly higher solvency risk. The global financial crisis dummy showed a weak positive effect on the Z-score ($p < 0.1$), resulting in lower solvency risk for banks operating in India in the period after the 2008 financial crisis, that may be attributed to more prudential regulations on banks following the global financial crisis.

Table 3: Solvency Risk (= Z-score = (ROA + CAR) / Std.Dev (ROA)
 [CAR = Equity / Total Assets; Equity = Capital + Reserves; ROA = Profits / Total Bank Assets]

Dependent variable: SolvencyRisk1

	Pooled OLS	Fixed Eff***	Random Eff
CRAR	1.251*** (0.042)	1.423*** (0.027)	1.369*** (0.027)
GDP	0.362* (0.188)	0.009 (0.093)	0.048 (0.099)
ASSETS	2.744*** (0.549)	-1.365*** (0.429)	-1.421*** (0.447)
CONT.LIAB	0.241 (0.309)	0.814*** (0.297)	1.297*** (0.299)
factor(BankCat)2	-8.242*** (0.899)	-14.439*** (2.113)	-12.720*** (3.192)
factor(BankCat)3	0.964 (0.980)	-	-2.464 (3.131)
factor(FinCrisisDummy)1	-1.404 (0.889)	0.946* (0.493)	0.444 (0.516)
factor(FinLiberalizationDummy)1	-3.701*** (0.967)	0.091 (0.551)	-0.525 (0.576)
Constant	-39.094*** (5.188)	-	6.436 (5.318)
Observations	1,100	1,100	1,100
R2	0.501	0.762	0.727
F Statistic	136.665*** (df =8; 1091)	471.519*** (df =7; 1029)	2,886.567*** (chi-sq; df= 8)

*p<0.1; **p<0.05; ***p<0.01

*** Fixed Effects model selected based on following tests:

#F-Test individual effects (Fixed vs OLS): F = 62.95, df1 = 62, df2 =1029,

p-value < 2.2e-16

#LM Test (Honda) unbalanced panel; (Random vs OLS): normal = 62.976, p-value < 2.2e-16

#Hausman Test (Fixed vs Random) chisq = 165.36, df = 7, p-value < 2.2e-16

Based on the Decision Tree analysis for Solvency Risk (Fig. 3 below), the median Z-Score for all banks in the available data is 17. However, for the banks with CRAR < 15, the median Z-Score is 15, whereas for the banks with CRAR ≥ 15, it is 27. This is consistent with our findings in the fixed effects model that a higher CRAR value demonstrated lower solvency risk for banks. For the banks with CRAR ≥ 15, if the CONT.LIAB (or, log of contingent liabilities at banks) < 7.8, then the median Z-Score increases to 67, otherwise it drops down to 25. This implies that banks which were more capitalized (CRAR ≥ 15), further reduced their solvency risk (higher Z-scores) with lower usage of contingent liabilities. On the other hand, for banks with CRAR < 15, (but ≥ 12), higher levels of contingent liabilities (CONT LIAB ≥ 18) revealed higher Z-scores (median value of 35, compared to median value of 17 for CONT LIAB < 18), implying reducing solvency risk using derivatives (included in contingent liabilities) to hedge the risk as confirmed in the fixed effects results. Also, the decision tree branch relating to the financial crisis dummy confirms that the solvency risk at banks reduced in the period after the 2008 crisis (Z-Score =31, compared to a Z-score of 23 for the period before the crisis) as obtained in the fixed effects panel result.

Decision Tree of SolvencyRisk1 with Maximum Depth = 4 and R-squared = 29.26%

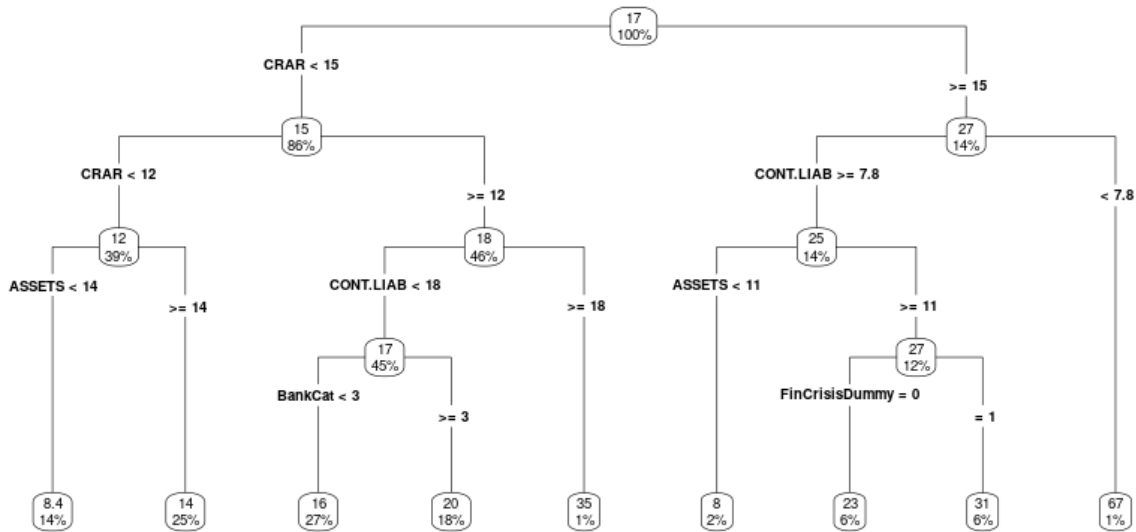


Figure 3: Decision Tree of Solvency Risk

Interest Rate Risk

The LM tests confirmed that the random effects and fixed effects models were preferred over the pooled OLS model. The Hausman test confirmed the selection of the fixed effects model relative to the random effects model. The results are presented in Table 4 below.

Table 4: Interest Rate Risk (Net Interest Margin /Assets)

Dependent variable : InterestRateRisk

	Pooled OLS	FixedEff.***	RandomEff.
CRAR	0.0003*** (0.00003)	0.0003*** (0.00003)	0.0003*** (0.00003)
GDP	-0.00001 (0.0001)	-0.00001 (0.0001)	0.00004 (0.0001)
ASSETS	-0.001** (0.0005)	-0.001** (0.0005)	-0.001 (0.0005)
CONT.LIAB	0.00000 (0.0003)	0.00000 (0.0003)	0.0001 (0.0003)
factor(BankCat)2	-0.005** (0.002)	-0.005** (0.002)	-0.004** (0.003)
factor(BankCat)3	- (0.002)	- (0.002)	-0.004** (0.002)
factor(FinCrisisDummy)1	-0.002*** (0.001)	-0.002*** (0.001)	-0.003*** (0.001)
factor(FinLiberalizationDummy)1	0.00004 (0.001)	0.00004 (0.001)	-0.001 (0.001)
Constant	-	-	0.036*** (0.005)
Observations	1,100	1,100	1,100
R2	0.235	0.235	0.239
F Statistic	45.254*** (df = 7; 1029)	45.254*** (df = 7; 1029)	285.874*** (df = 8; Chi-sq)

*p<0.1; **p<0.05; ***p<0.01

*** Fixed Effects model selected based on following tests:

#F-Test individual effects (Fixed vs OLS): F = NaN, df1 = 0, df2 = 1029, p-value = NA

#LM Test (Honda) unbalanced panel; (Random vs OLS): normal = 32.716, p-value < 2.2e-16

#Hausman Test (Fixed vs Random) chisq = 225.13, df = 7, p-value < 2.2e-16

The fixed effects model revealed that the CRAR had a significant positive effect (< 0.01) on the net interest margin for banks, implying lower interest rate for banks that maintained higher capital to risk-adjusted asset ratios. Bank assets had a significant negative effect on the net interest margin for banks, implying higher interest rate risk demonstrated by larger banks. Public sector banks (bank category 2) reveals a significant negative effect on the net interest margin ($p < 0.05$) implying the public sector banks demonstrated higher interest rate risk. Also, based on the fixed effects model, the net interest margin to assets for banks decreased significantly in the post financial crisis period ($p < 0.01$), showing higher interest rate risk at banks in the period following the global crisis.

The decision tree analysis for interest rate risk is illustrated in Fig.4.

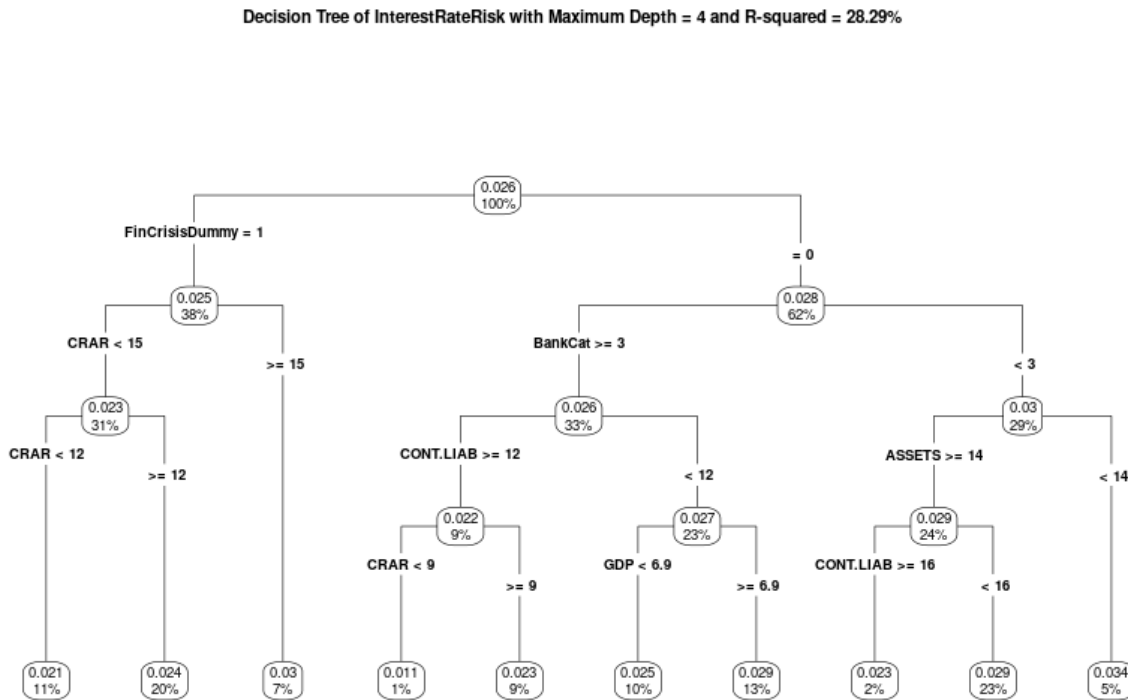


Figure 4: Decision Tree of Interest Rate Risk

Based on the decision tree (Fig.4), the median value of net interest margin to assets for all banks in the data sample is 0.026. In the period following the global financial crisis (FinCrisisDummy=1), the median value of the interest margin to assets 0.025. Further analyzing the tree in the post financial crisis period we observe that banks with CRAR < 15 had lower interest margin relative to assets (median value=0.023) compared to banks with CRAR >=15 (median value = 0.03). This implies banks that were more adequately capitalized (with CRAR values exceeding 15) demonstrated higher interest margins and lower interest rate risk.

The median value of interest margin to assets is obtained as 0.028 in the period before the crisis (FinCrisisDummy=0). Further branches of the tree in the pre-financial crisis period illustrate that private sector banks (Bank Category >=3) had a lower median value of interest margin to assets (=0.026) compared to public sector banks (median value = 0.03). This reveals that public sector banks displayed a lower interest rate risk in terms of higher interest margins compared to private sector banks. Further, for public sector banks it appears that smaller banks (log of Assets < 14) had higher interest margin relative to assets (median value of 0.034) implying lower interest rate risk compared to larger banks (log of Assets >=14). This is again consistent with our findings of a negative relation between bank assets size and interest margin to assets obtained in the fixed effects model.

Conclusions

In this paper, we identify and analyze the factors affecting risk measures for public sector (government owned) banks and private sector banks operating in India using the panel data methodology as well as the non-parametric decision tree analysis.

Overall results suggest that liquidity risk (based on deposits liability management) is reduced at larger banks, but increases with higher capital to risk-adjusted assets (CRAR) at banks. An increase in capital to assets implies a reduction in core deposit leverage at banks that may result in a higher liquidity risk from a liability management perspective. Higher usage of contingent liabilities /derivatives contracts by banks is found to be associated with higher liquidity risk from a liability management viewpoint. Public sector banks demonstrate higher liquidity risks due to lower core deposits to assets compared to private sector banks operating in India. Policies could be implemented to promote core deposits at public sector banks through higher interest rates offered or lower taxes deducted at source for customers for core deposits that may be financed through government subsidies. Banks operating in the period after the global financial crisis (i.e. after 2008) show lower liquidity risks in terms of core deposit as a proportion of assets. Similarly, in the period after the major financial liberalization reforms in India (i.e. after 2004), lower liquidity risk is revealed for

banks compared to the period during the reforms (1996-2004). This could be inferred as more prudential liability management of liquidity for banks after the crisis period.

The liquidity risk at banks (based on temporary assets management) increased with larger banks. This could imply larger share of assets tied up in longer term loans at bigger banks that may pose short term liquidity management issues in terms of availability of temporary assets. Policies to promote increase in bank balances at other banks and with the central bank could be implemented to provide incentives for larger banks to maintain higher cash reserves to control their liquidity risk from an asset management perspective. We also find that liquidity risk was lower during periods of economic growth, implying better liquidity position based on larger fraction of temporary assets during growth periods. On the other hand, an increase in contingent liabilities of banks tends to raise the liquidity risks based on the decision tree analysis. Therefore, we conclude that contingent liabilities at banks had an effect on increasing liquidity risk from both asset and liability management of liquidity at banks. Policies aimed at controlling the use of contingent liabilities at banks could help reduce liquidity risk at banks.

Further, higher capital buffer in terms of higher CRAR values is associated with higher liquidity risk from an asset management perspective. An increase in capital to risk adjusted assets allocations for banks may imply increased reserves allocated for loan loss provisions, resulting in fewer temporary asset reserves available for banks. This may result in a higher liquidity risk from an asset management perspective. We can therefore conclude that higher capital to risk adjusted asset ratios (CRAR) at banks increased liquidity risk from both an asset and liability management measures of liquidity. Thus, banks whose CRAR exceeds the minimum capital adequacy requirements as per the Basel norms should periodically monitor their levels of temporary cash reserves and core deposits to avoid a liquidity management issue. Liquidity risk at banks from an asset management measure was lower in the period after the global financial crisis similar to the effect on the liability management measure of liquidity discussed earlier. We can infer that banks in general were monitored better in the period after the crisis which helped reduce their overall liquidity risk.

From the solvency standpoint, the results conform to the Basel Accord guidelines of capital adequacy requirements for banks in order to lower solvency risk. However, higher solvency risk for larger banks remains a concern as this may be an issue with the implicit guarantee of protection for larger banks based on the 'too big to fail' doctrine. At the same time, contingent liabilities (including derivatives) usage by banks helped in hedging their solvency risk. From a policy viewpoint, the use of contingent liabilities has to be evaluated based on its implication on increasing bank liquidity risk while hedging its solvency risk exposure. Also, since liquidity risk is reduced during high economic growth period (as obtained in our model), banks may be recommended to increase its usage of contingent liabilities (derivatives exposure) during periods of economic growth. Public sector banks were observed to demonstrate higher solvency risk implying recommendations for more stringent monitoring of state and nationalized banks with respect to their capital adequacy and profitability which affected their Z-score solvency measures. Also, based on the results, the solvency risk of banks reduced in the period after the major financial crisis (i.e., after 2008). This may again be attributed to prudential regulation at banks in the period after the global financial crisis.

In analyzing the results for the interest rate risk measure, it is observed that larger banks had higher interest rate risk in terms of larger reductions in interest income relative to interest expenses. Increased focus on monitoring rate sensitive assets and liabilities could be prescribed for larger banks to address their adverse effects on interest margins. The interest rate risk was observed to be higher at the government owned public sector banks. Government subsidies to public sector banks to enable the public sector banks to offer lower interest rate loans could potentially increase their volume of rate sensitive loan assets and help improve their interest margins. The net interest margin to assets for banks reduced in the post-financial crisis period. As overall short-term market interest rates dropped following the great recession, banks could have been incentivized (e.g. through government subsidies, tax deductions on deposit accounts, etc.) to increase their volume of short maturity rate sensitive liabilities deposits relative to their short-term assets in order to improve their net interest margins during the post financial crisis period. As a future research study, we could consider the effects of foreign banks operating in India and compare their risk, efficiency and performance measures with both domestic public sector and private sector banks.

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Institutional Review Board Statement: Ethical review and approval were waived for this study, due to that the research does not deal with vulnerable groups or sensitive issues.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

Conflicts of Interest: The author declares no conflict of interest.

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