The interrelationships among default risk, capital ratio and efficiency

Evidence from Indian banks

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Abstract

Purpose – The purpose of this paper is to examine the interrelationships among default risk, capital and efficiency of the Indian banking system over 1990-2011. This study also took into account the impact of ownership on these interrelationships

Design/methodology/approach – This paper employed Data Envelopment Analysis (DEA) Windows Analysis to estimate efficiency levels and trends of individual banks. This paper then used a model of seemingly unrelated regression equations (SURE) to examine the interrelationships among default risk, capital and efficiency.

Findings – This study found a two-way negative association between efficiency and default risk, and between capital ratio and default risk. However, this study found a two-way positive relationship between capital ratio and only profit efficiency. Public banks behaved differently from private banks regarding the association between capital and efficiency. Moreover, public banks had greater probability of default risk, lower capital ratio but higher efficiency level than private banks. Further, default risk, capital ratio and efficiency of the Indian banking system increased over time, but the two formers were driven by public banks while the latter was driven by private banks.

Practical implications – The findings of this study appear to favour capital ratio as an efficient tool to improve efficiency and reduce default risk of the Indian banking system.

Originality/value – This paper is the first investigating the interrelationships between bank risk, capital and efficiency of the Indian banking system, where bank risk is measured by *Z*-score value and efficiency is captured by cost, revenue and profit efficiencies, and then considering the impact of agency issues on these interrelationships.

Keywords India, Capital, Ownership, Efficiency, Insolvency risk, SFA, Three-stage least squares

Paper type Research paper

1. Introduction

India is an Asian giant, with impressive economic growth rates over the last two decades (Heffernan and Fu, 2012). The Indian government gradually implemented banking sector reforms by way of deregulation, aiming at promoting competition and strengthening stability (Zhao *et al.*, 2010). On the one hand, the increased competition has exerted considerable pressure on banks to operate closer to the "best-practice"

JEL Classification — G21, G32, C61, C33

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(Casu and Girardone, 2006; Schaeck and Cihák, 2008). The literature on the efficiency levels and efficiency determinants of Indian banks is vast (e.g. Das *et al.*, 2005; Das and Ghosh, 2009; Das and Drine 2011). However, there have been no studies examining the effects of technological changes and scale economies on costs and profits of Indian banks.

Increased competition in the Indian banking market erodes banks' market power and profit margins that encourage risk-taking (Berger *et al.*, 2009, 2013). Competition also requires banks to operate at higher capital ratios (Schaeck and Cihak, 2012). The introduction of the 1988 Basel Accord on international bank capital standards (Basel I) reignited interest in the effectiveness of bank capital regulations in reducing risk and increasing efficiency. Berger and DeYoung (1997) pioneered the investigation of inter-temporal relationships between efficiency, risk and capital with the application to US banks. Based on signs and temporal order among operational efficiency, risk and capital of banks, the authors posited four management behaviours: bad management, bad luck, skimping and moral hazard (see Section 2.1 for more details). The investigation of banks operational efficiency and its interplay with risk and capital ratio, thus, provide useful policy and managerial applications.

Public and private banks may have different priorities and operating environment, and hence one may expect public banks to have different performance, risk taking and capital holding compared to private banks. Despite there being a number of studies comparing the efficiency levels across bank ownership types (e.g. Nguyen *et al.*, 2014, Reddy and Nirmala, 2013; Ray and Das 2010; Das *et al.*, 2005), to the best of our knowledge, only one study by Altunbas *et al.* (2007) examined effects of bank types on efficiency, risk and capital which related to European banks.

Thus, the objective of this study is to extend the current literature by examining the effects of bank types on operational efficiency and identifying management behaviours in Indian banks. We also decompose efficiency of banks into technical changes and returns to scale, and compare efficiency and managerial behaviours across bank types.

The rest of the paper is organized as follows. Section 2 presents the framework of the management behaviour and the related literature. Section 3 discusses research methodology and the data. Section 4 analyses empirical results and Section 5 draws conclusions and addresses policy implications.

2. Literature review

2.1 Managerial hypothesis

Berger and DeYoung (1997) suggested that there are four types of behaviours underlying the interrelationships between risk, capital and operational efficiency of banks: bad management, bad luck, skimping and moral hazard. Since the main objective of this study is to identify the presence of these managerial behaviours in Indian banks, we summarize them briefly below.

Bad management is identified if a decrease in cost efficiency precedes an increase in the level of risk. Banks with poor management may fail to control operational costs or monitor borrowers, and hence, increase risk which leads to lower cost efficiency. Such banks also tend to have poor loan and investment portfolios, causing low revenue efficiency. In order to improve low economic efficiency, these poorly managed banks tend to take additional risks, leading to a growth in insolvency risk.

Bad luck has the reverse temporal ordering to bad management where an increase in risk occurs before a reduction in economic efficiency. One possible explanation is that when exogenous shocks (economic downturns) reduce asset quality and fuel insolvency risk, bank managers allocate additional resources, like personnel monitoring loans and seizing and disposing of collateral, to remedy this adverse situation. As a consequence, banks incur additional operating costs and lose some income, leading to deterioration of efficiency.

Moral hazard is identified if a reduction in capital ratio in poorly capitalized banks leads to a growth in risk. Banks which face risks due to a reduced capital ratio have incentives to take risky portfolios. Under this hypothesis, we expect that a reduction in financial capital precedes an increase in non-performing loans.

Skimping behaviour is identified if an increase in cost efficiency precedes an increase in insolvency risk, which is an opposite sign to the bad management behaviour despite having the same temporal order. Possible reason is that banks tend to skimp on operating costs by reducing credit monitoring, collateral valuing and marketing activities to become more economically efficient. However, the improvement in economic efficiency due to the skimping may be achieved only in the short term; consequences of skimping are due to the deterioration in the quality of loans and investments, resulting in greater insolvency risk.

2.2 Review of the literature

Despite the literature on bank efficiency in India being vast (Das and Ghosh, 2004, 2009; Das *et al.*, 2005; Sensarma, 2005; Kalluru, 2009; Ray and Das, 2010; Das and Drine, 2011; Sahoo and Mandal, 2011; Wanniarachchige and Suzuki, 2011; Kumar, 2013; Reddy and Nirmala, 2013), only one study (Das and Ghosh, 2004) examined the interrelationships between risk, capital and cost efficiency in Indian public banks. The authors found that capital ratio reduced bank risk, while cost efficiency had no effect on bank risk and capital ratio. Moreover, an increase in bank risk led to a decrease in cost efficiency while capital ratio had no effect on banks' efficiency. Other studies documented conflicting results of the efficiency trend, the efficiency gap between public banks and private banks, and the effects of capital ratio and risk on efficiency. For example, Das *et al.* (2005) and Sahoo and Mandal (2011) argued that there was an increase in efficiency of Indian banks, while Sensarma (2005), Kalluru (2009) and Wanniarachchige and Suzuki (2011) found the reverse. Also, the effects of capital ratio on profit efficiency were found to be positive in the study by Reddy and Nirmala (2013), but negative in the study by Das and Ghosh (2009).

The literature on the interrelationships between risk, capital and efficiency in international banks is limited: Berger and DeYoung (1997), and Kwan and Eisenbeis (1997), Williams (2004), Altunbas *et al.* (2007), Deelchand and Padgett (2010), Fiordelisi *et al.* (2011) and Tan and Floros (2013). But all four types of managerial behaviour associated with operational efficiency (bad management, bad luck, skimping and moral hazard) were found in the literature. For example, a decrease in cost efficiency that precedes an increase in risk (i.e. bad management) was found in European banks (Williams, 2004; Fiordelisi *et al.*, 2011), Japanese cooperative banks (Deelchand and Padgett, 2010), and the US banks (Berger and DeYoung, 1997; Kwan and Eisenbeis, 1997). Meanwhile, signs of an increase in risk that occurs before a decline in cost efficiency (i.e. bad luck), and a reduction in capital ratio in the poorly capitalized banks that leads to a growth in risk (moral hazard) were detected in Japanese cooperative banks (Deelchand and Padgett, 2010) and US banks (Berger and DeYoung, 1997; Kwan and Eisenbeis, 1997). An increase in cost efficiency that temporarily precedes a rise in risk (skimping) was evident in European banks (Altunbas *et al.*, 2007) and US banks (Berger and DeYoung, 1997).

The role of capital in bank efficiency was unclear in the banking literature. For example, banks with more capital face less risk in China (Tan and Floros, 2013), the US (Kwan and Eisenbeis, 1997), and Europe (Altunbas *et al.*, 2007), but European banks seem to experience no significant impact of increased capital on risk (Williams, 2004; Fiordelisi *et al.*, 2011). In Europe, the more cost-efficient banks were better capitalized (Fiordelisi *et al.*, 2011), but the reverse was found in Japan (Deelchand and Padgett, 2010).

Overall, the literature seems to provide conflicting signs and temporal order of interrelationships between capital, risk and operational efficiency of banks. There are two possible explanations for different results of previous banking studies. First, these results reflect differences in: choice of variables, sample size, analysis periods and estimation methods. For example, Das *et al.* (2005), Das and Ghosh (2009), and Sahoo and Mandal (2011) applied data envelopment analysis (DEA) whilst Sensarma (2005) and Reddy and Nirmala (2013) used stochastic frontier analysis (SFA). Second, inverse signs and temporal orders may simply reflect different management behaviours: bad luck, bad management, skimping, and moral hazard (Berger and DeYoung, 1997). One possible way to differentiate these behaviours is to estimate the interrelationships between risk, capital and operational efficiency simultaneously as a system.

3. Methodology

3.1 Efficiency estimation

We apply a SFA approach proposed by Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) to estimate cost and profit efficiency scores. We adopt the transcendental logarithm (translog) functional form since it is more flexible and provides desired properties (e.g. monotonicity and asymmetry) to decompose changes in technical efficiency into technological changes and returns to scale (Berger and Mester, 1997; Huang *et al.*, 2010; Košak and Zorić, 2011). To take into account effects of environmental factors, we apply the technical efficiency effects SFA model proposed by Battese and Coelli (1995). Also, the efficiency component was assumed to follow a truncated distribution, and technological changes were proxied by a time trend (t). We follow the intermediation approach, which views a bank as an intermediary between depositors and borrowers, to specify inputs and outputs. Based on the data available, the production of banking services in this study involves two outputs – net loans (Y_1) and other earning assets (Y_2) – and three inputs – fund (X_1), fixed assets (X_2) and personnel (X_3). Therefore, prices of inputs $X_{1\text{-}3}$ are the financial capital price (W_1), physical capital price (W_2) and labour price (W_3), respectively.

The translog stochastic cost frontier to estimate cost efficiency for the panel data is as follows:

$$\begin{aligned} lnTC_{it} = {} & \alpha_0 + \sum_{m=1}^{2}\alpha_m lnY_{itm} + \frac{1}{2}\sum_{m=1}^{2}\sum_{k=1}^{2}\alpha_{mk} lnY_{itm} lnY_{itk} + \sum_{n=1}^{3}\beta_n \ln W_{itn} \\ & + \frac{1}{2}\sum_{n=1}^{3}\sum_{l=1}^{3}\beta_{nl} lnW_{itn} lnW_{itl} + \frac{1}{2}\sum_{m=1}^{2}\sum_{n=1}^{3}\delta_{mn}\ln Y_{itm}\ln W_{itn} + \gamma_1 t + \frac{1}{2}\gamma_2 t^2 \qquad (1) \\ & + \sum_{m=1}^{2}\gamma_{2+m} t\ln Y_{itm} + \sum_{n=1}^{3}\gamma_{4+n} t\ln W_{itn} + (v_{it} + u_{it}) \end{aligned}$$

where the subscript i denotes the cross-sectional dimension across banks; subscript t denotes the time dimension; α, β, δ and γ are parameters to be estimated. Total costs (TC) is the observed total cost, which consists of interest expenses, other operating expenses and personnel expenses. The composite error term includes random noise v, which is – assumed to follow a normal distribution; and lastly the cost inefficiency u, which is assumed to follow non-negative distributions (e.g. half-normal, truncated normal, exponential and gamma).

By exploiting the linear homogeneity condition, Equation 1 can be transformed into a cost function by normalizing the dependent variable and all input prices by the price of input 3 (W_3) as follows (subscripts i and t are dropped for ease of viewing):

$$\begin{aligned}\ln(TC/W_3) = {} & \alpha_0 + \sum_{m=1}^{2}\alpha_m lnY_m + \frac{1}{2}\sum_{m=1}^{2}\sum_{k=1}^{2}\alpha_{mk} lnY_m lnY_k + \sum_{n=1}^{2}\beta_n \ln(W_n/W_3) \\ & + \tfrac{1}{2}\sum_{n=1}^{2}\sum_{l=1}^{2}\beta_{nl} ln(W_n/W_3)\ln(W_l/W_3) + \frac{1}{2}\sum_{m=1}^{2}\sum_{n=1}^{2}\delta_{mn}\ln Y_m \ln(W_n/W_3) \\ & + \gamma_1 t + \frac{1}{2}\gamma_2 t^2 + \sum_{m=1}^{2}\gamma_{2+m} t\ln Y_m + \sum_{n=1}^{2}\gamma_{4+n} t\ln(W_n/W_3) + (v+u) \end{aligned} \qquad (2)$$

We define the SFA profit function in a similar manner: replacing the notation of TC by that of the profit before tax (PBT), and changing the sign for the non-negative component of the error term u (i.e. the composite error term in Equation 2 is defined as v-u). We also transform the original profits, which have negative values, by subtracting the minimum and adding the mean to ensure the validity when taking a natural logarithm.

The cost and profit efficiency scores are calculated, respectively, as $CE_{it} = \exp(-u_{it})$ and $PE_{it} = \exp(-u_{it})$. CE and PE will range from 0 (very poorly operated banks) to 1 (best-practice banks).

Technological changes. To investigate the effects of technological changes on costs and profits of banks, we calculate cost elasticity (CES_T) and profit elasticity (PES_T) with respect to time (t) as follows:

$$CES_T = \frac{\delta \ln TC}{\delta \ln t} \qquad (3)$$

$$PES_T = \frac{\delta \ln PBT}{\delta \ln t} \qquad (4)$$

Technological progress is defined as having negative time derivatives in the cost function (i.e. reduces costs over time) and positive time derivatives in the profit function (i.e. increases profits over time). Technological regresses occur if the derivatives are negative (for the profit function) and/or positive (for the cost function) while neutral technological changes occur if the derivatives are equal to zero.

Economy of scale. To examine effects of operational scale on bank costs, we estimate cost elasticity (CES_Y) by taking the derivatives of the transformed cost function with respect to all output variables as follows (note that the transform function is assumed to follow the monotonicity assumption, hence the cost elasticity can be calculated by taking derivatives of total cost with respect to outputs):

$$CES_Y = \sum_{i=1}^{2} \frac{\delta \ln TC}{\delta \ln Y_i} \tag{5}$$

An estimate of CES_Y less than, equal to, or greater than one respectively indicates increasing, constant and decreasing returns to scale. We do not assess scale economies for the profit function because they would include economies on the consumer side, and would not be comparable (Berger and Mester, 1997).

3.2 Management behaviours

We employ the three-stage least squares (3SLS), introduced by Zellner and Theil (1962), to investigate the interrelationships between variables of risk, capital and efficiency as in the study by Tan and Floros (2013). Some other approaches in the literature are two-stage least squares (Kwan and Eisenbeis, 1997; Deelchand and Padgett, 2010), seemly unrelated regressions (SUR) (Altunbas *et al.*, 2007), Granger causality tests (Berger and DeYoung, 1997; Williams, 2004; Fiordelisi *et al.*, 2011), and decomposing technical efficiency into operating efficiency and risk management efficiency (Yang, 2014). However, results obtained by the Granger causality are sensitive to model specification and the number of lags. Also, the efficiency decomposition approach required data on non-performing loans which we cannot obtain. Therefore, for our study, we select the 3SLS estimator, which combines the two-stage least squares and SUR.

We measure bank risk by *Z*-scores, efficiency by the technical efficiency scores of cost and profit functions, and capital by the ratio of equity to total assets. *Z*-scores are computed by the ratio of return on assets (ROA) plus the capital ratio divided by the standard deviation of ROA, which measures the degree of bank insolvency (Roy, 1952). The choice of *Z*-scores as a risk measure was applied in various studies by Tan and Floros (2013), Beck *et al.* (2013), Demirgüç-Kunt and Huizinga (2010), Houston *et al.* (2010), Laeven and Levine (2009) and many others. Literature also exists for other measures of risk such as the ratio of loan loss provision to gross loans (Williams, 2004; Tan and Floros, 2013), ratio of loan loss reserves to total assets (Altunbas *et al.*, 2007; Deelchand and Padgett, 2010), ratio of non-performing loans to gross loans (Berger and DeYoung, 1997; Das and Ghosh, 2004; Fiordelisi *et al.*, 2011), and one or five-year expected default frequency (Fiordelisi *et al.*, 2011). The latter approach (expected default frequency) requires data on stock prices, but many Indian banks do not hold publicly traded securities. The three former measures (loan loss/total loans, loan loss/assets, and non-performing ratio) are subject to managerial discretion and capture only credit risks, while non-lending earning assets accounts for approximately 40 per cent of the outputs of Indian banks. Hence, in our study *Z*-scores are more appropriate for measuring bank risk.

Therefore, the interrelationships between operational efficiency, risk and capital of Indian banks in this study are estimated using a system of simultaneous equations as follows:

$$R_{it} = \propto_0 + \propto_1 E_{it} + \propto_2 C_{it} + \propto_3 A_{it} + \propto_4 A_{it}^2 + \propto_5 RD_{it} + \propto_6 I_{it} + \omega_{it} \tag{6}$$

$$C_{it} = \beta_0 + \beta_1 E_{it} + \beta_2 LD_{it} + \beta_3 G_{it} + \beta_4 I_{it} + \varepsilon_{it} \quad (7)$$

$$E_{it} = \gamma_0 + \gamma_1 R_{it} + \gamma_2 C_{it} + \gamma_3 RD_{it} + \gamma_4 LA_{it} + \gamma_5 G_{it} + \gamma_6 I_{it} + \theta_{it} \quad (8)$$

where R is the measure of risk (proxied by Z-scores), C is capital, E is efficiency, A is assets (in log), RD is revenue diversification, LD is the ratio of loans to deposits, LA is ratio of loans to assets, G is GDP growth rate, I is inflation rate; ω, ε and θ are random errors. These variables are described in more detail in Table I. Because the distribution of Z-scores is highly skewed, we take the natural logarithm of Z-scores to mitigate this issue. For brevity, we still use the label "Z-score" to represent the natural logarithm of the Z-score in the remainder of the study. Equation 6 tests whether efficiency and capital precede variations in risk. Equation 7 assesses if efficiency temporarily precedes variations in capital, whereas Equation 8 examines whether the level of capital together with risk determine changes in efficiency.

Based on hypotheses explaining the relationships between bank risk, capital and efficiency proposed by Berger and DeYoung (1997), bad management, skimping, bad luck, and moral hazard behaviours can be tested by the sign and significant level of parameters α_1 (positive), α_1 (negative), γ_1 (positive), and α_2 (positive), respectively (note that a higher Z-score indicates that the bank is more stable). In particular, a positive α_1 confirms that a reduction in cost/profit efficiency precedes an increase in bank risk (i.e. bad management occurs) whilst a negative α_1 suggests an increase in cost/profit efficiency happens just before an increase in risk (i.e. skimping exists). The positive parameter γ_1 is interpreted as an increase in risk preceding a reduction in cost/profit efficiency (i.e. banks face bad luck). The moral hazard hypothesis tests whether low capital leads to risky behaviour by bank managers, which representing by the positive parameter α_2. We focus this test on banks with low capital, where moral hazard is more likely to occur. We expect that capital is negatively affected by operational efficiency, thus parameter β_1 is expected to have a negative sign.

In order to check the sensitivity of results on bank management behaviour, we also use two alternative risk measures: volatility of returns on assets (ROA) and volatility of returns on equity (ROE), which are respectively measured by standard deviations of ROA and standard deviations of ROE. A higher volatility of ROA or ROE indicates that a bank is less stable.

3.3 Data

The data used in this study were collected from the International Bank Credit Analysis Ltd (Fitch-IBCA). In particular, we constructed a balanced panel from 25 public banks and 15 private banks over the period 1994-2011. The banks included in this data set account for more than 85 per cent of the deposits of the Indian banking system. Descriptive statistics of selected variables by bank types are presented in Table I.

Net loans and other earning assets (Y_1 and Y_2) indicate that outputs of public banks are, on average, two times larger than those of private banks. The input price data show that public banks have a lower financial capital price, but a higher physical capital price and labour price than private banks. The period-averaged capital ratio is 5.5 per cent with a lower level in public banks than private banks. Data on risk measures (Z-score, ROA volatility and ROE volatility) show that public banks have greater risk-taking than private banks. Data on the remaining variables show that Indian banks, on average, lend 63 per cent of their deposits received, and public banks

Variables	Description	All banks	Public banks	Private banks
Variables used for efficiency estimation				
TC (total cost)	The sum of interest expenses, other operating expenses and personnel expenses (million $US)	934.24 (1,840.99)	1,215.92 (2,063.86)	464.76 (1,263.05)
PBT (profit)	Pre-tax profit (million $US)	147.73 (338.22)	184.71 (394.08)	86.11 (201.08)
Y_1 (output 1)	Net loans measured by gross loans minus reserves for impaired loans (million $US)	6,818.58 (14,298.85)	9,024.48 (16,792.18)	3,142.08 (7,356.49)
Y_2 (output 2)	Other earning assets measured by investments and other earning assets (million $US)	4,577.51 (8,699.21)	5,993.99 (9,950.21)	2,216.71 (5,297.67)
W_1 (price of input 1)	Financial capital price calculated by the ratio of interest expenses to total funding	0.063 (0.014)	0.062 (0.012)	0.066 (0.017)
W_2(price of input 2)	Physical capital price computed by the ratio of other operating expenses to fixed assets	0.935 (0.631)	0.958 (0.603)	0.895 (0.675)
W_3 (price of input 3)[a]	Labour price which is proxied by the ratio of personnel expenses to total assets	0.014 (0.006)	0.016 (0.006)	0.011 (0.005)
Variables used for examining the relationships between risk, capital and efficiency				
C	The capital ratio measured by the ratio of equity to total assets	0.055 (0.027)	0.047 (0.016)	0.067 (0.036)
R (*Z*-score)	The ratio of ROA plus the capital ratio divided by the standard deviation of ROA	12.110 (6.150)	11.014 (5.565)	13.937 (6.636)
R (ROA volatility)	Standard deviation of ROA which shows the volatility of ROA	0.006 (0.004)	0.007 (0.005)	0.006 (0.001)
R (ROE volatility)	Standard deviation of ROE which shows the volatility of ROE	0.156 (0.174)	0.187 (0.212)	0.104 (0.031)
A	Logarithm of total assets which captures bank size	8.603 (1.344)	9.211 (0.894)	7.589 (1.357)
LD	Intermediation ratio computed by the ratio of gross loans to deposits	0.630 (0.148)	0.604 (0.131)	0.675 (0.165)
LA	The ratio of gross loans to total assets	0.496 (0.097)	0.490 (0.102)	0.505 (0.087)
RD	Revenue diversification computed by the ratio of non-interest income to total income	0.138 (0.056)	0.128 (0.038)	0.154 (0.073)
G	The GDP growth rate (annual %)	7.040 (2.150)	7.040 (2.151)	7.040 (2.153)
I	Consumer prices (annual %)	7.28 (3.07)	7.28 (3.07)	7.28 (3.07)

Notes: Data on GDP growth and inflation are from World Bank database; standard deviation in parentheses; [a]we cannot obtain data on the number of employees, this study follows Bos and Schmiedel (2007), Huang *et al.* (2010) and Liu and Chen (2012) to proxy labour price as a ratio of personnel expenses to total assets

Table I.
Descriptive statistics

percentage show a lower conversion percentage. Lending volume accounts for approximately 50 per cent of total assets, of which public banks show a slightly lower lending-intensive rate. However, the income of Indian banks is mainly driven by income from lending. The average annual GDP growth rate and inflation rate are 7.04 per cent and 7.28 per cent, respectively.

4. Empirical results

4.1 Operational efficiency and its components

To assess the validity of the model, we conduct a Likelihood-Ratio (LR) test, which is defined as: $LR = -2[L(H_0)-L(H_1)]$, where $L(H_0)$ is the log likelihood of the unrestricted model and $L(H_1)$ is the log likelihood of the restricted model (i.e. the efficiency component equals zero). The test statistics, which follows the $\chi^2(n)$ distribution with n being the number of restrictions, for the cost and profit models were 133.57 and 64.29, respectively. In our case the number of restrictions is 1 (i.e. $u = 0$), hence the null hypothesis of no efficiency is rejected at 1 per cent level of significance. The signal-to-noise ratio (γ) is significant in both functions and reveals that unexplained variations in costs of Indian banks were 21.5 times more likely due to inefficiency than random noise; the relative ratio in bank profits is 9.3 (see Table II).

Estimates for cost and profit functions show that, on average, Indian banks reduced costs and increased profits during the study period (see parameter t in Table II). Note that the magnitude of this parameter does not capture the full effects of technical changes as one need to take into account parameters of the quadratic term and interactions of the time trend. The parameter lny_2 shows an interesting finding that other earning assets are associated with reduction in PBT. One possible explanation is that Indian banks may over-invest in other earning assets. However, the parameters of quadratic term $(lny_2)^2$ and its interaction with the time trend and input ratios are positive, hence, the elasticity of other earning assets to profit is not necessarily negative.

Technological changes. Figure 1 indicates that the average time derivatives of the cost function (CES_T) for all banks, public banks and private banks are all below zero. In particular, the cost reduction due to technical progress was −0.53 per cent per year for public banks, and –0.46 per cent for private banks. The CES_T for Indian banks experiences an increasing trend, but the value remains below zero over the period

Variables	Cost function Coef.	SE	Profit function Coef.	SE
Constant	1.771***	0.080	9.656***	0.233
Log of net loan ($\ln y_1$)	0.580***	0.053	0.318*	0.155
Log of other earning asset ($\ln y_2$)	0.414***	0.051	−0.784***	0.154
Log of price ratio of financial capital/ labour ($\ln w_1/w_3$)	0.733***	0.049	0.901***	0.139
Log of price ratio of physical capital /labour ($\ln w_2/w_3$)	−0.127***	0.035	0.314**	0.102
Time trend (t)	−0.027***	0.005	0.045**	0.015
$(\ln y_1)^2$	0.200***	0.025	0.325***	0.071
$\ln y_1 \times \ln y_2$	−0.207***	0.025	−0.275***	0.068
$\ln y_1 \times \ln w_1/w_3$	−0.075***	0.017	−0.176***	0.049
$\ln y_1 \times \ln w_2/w_3$	0.030**	0.011	−0.045	0.031
$\ln y_1 \times t$	0.001	0.002	−0.025***	0.007
$(\ln y_2)^2$	0.214***	0.025	0.320***	0.070
$\ln y_2 \times \ln w_1/w_3$	0.061***	0.017	0.176***	0.048
$\ln y_2 \times \ln w_2/w_3$	−0.026*	0.011	0.014	0.031
$\ln y_2 \times t$	0.001	0.002	0.027***	0.007
$(\ln w_1/w_3)^2$	0.165***	0.020	−0.060	0.056
$\ln w_1/w_3 \times \ln w_2/w_3$	−0.033**	0.012	0.041	0.034
$\ln w_1/w_3 \times t$	0.006**	0.002	−0.022***	0.005
$(\ln w_2/w_3)^2$	0.036***	0.010	0.003	0.029
$\ln w_2/w_3 \times t$	0.0001	0.001	0.002	0.003
t^2	0.0002	0.0002	−0.001	0.001
σ_u	0.680 ***	0.181	1.326 ***	0.594
$\gamma\ (\sigma_u / \sigma_v)$	21.51***	0.182	9.34 ***	0.594

Notes: *,**,***10, 5 and 1 per cent level of significance, respectively

Table II.
Cost and profit functions

1994-2011 (except public banks in year 2011). This suggests that technological changes reduced costs incurred by Indian banks at a diminishing rate over the analysis period. Moreover, public banks reduced more costs before 1994 but private banks showed greater cost reduction after that.

Figure 2 shows that time derivatives of the profit function (PES_T) are positive (except for the years 2008 and 2011), but experience a decreasing trend over the study period. In particular, profit efficiency of Indian banks could be improved due to technical progress by 2 per cent per year, of which public banks gained 2.6 per cent per year and private banks gained 1% per year. PES_T for public banks was greater than private banks before 2006; but after that both bank types experienced similar technical changes.

Returns to scale. Figure 3 shows that the average output derivatives of the cost function (CES_Y) of all banks, public banks and private banks are 0.997, 0.999 and 0.993, respectively. Thus, on average, banks in India operate at increasing returns to scale (i.e.

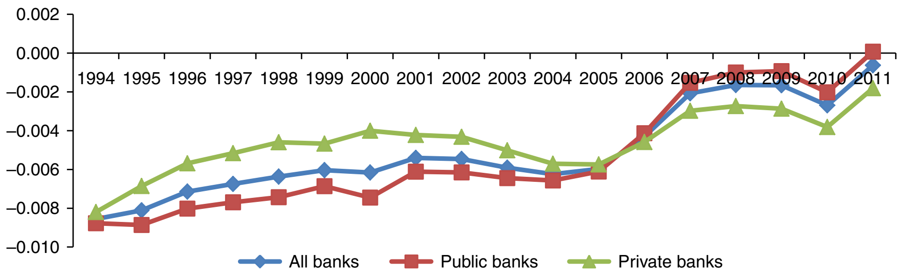

Figure 1.
Technological progress by cost

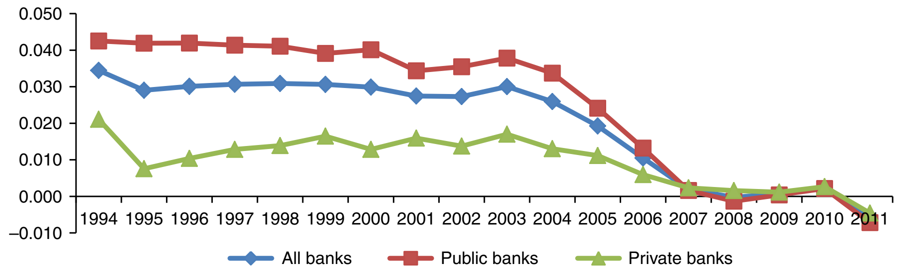

Figure 2.
Technological progress by profit

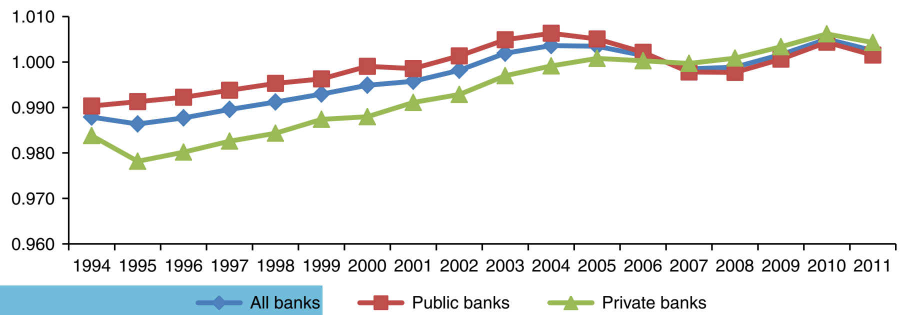

Figure 3.
Returns to scale by cost

they can reduce unit cost by increasing the scale of operation). But when results are disaggregated by bank type, we can see that private banks have more room to improve cost efficiency by upscaling than public banks. Also, Indian banks expanded operational scale in the study period and mostly achieved optimal operational scale ($CES_Y = 1$) from 2004 onwards. The scale changes (measured as the ratio of scale efficiency of two consecutive years) suggest that exploiting scale economies improve cost efficiency of Indian banks by 2 per cent per year, on average.

Technical efficiency. Table III shows that the average cost and profit efficiency scores of banks in the 1994-2011 period are 0.950 and 0.934, respectively (i.e. banks can reduce costs by 5 per cent, and increase profits by 6.6 per cent, compared with best practices). Our estimates of cost and profit efficiency are similar to the findings by Sensarma (2005) and Kalluru (2009). Public banks are more cost-efficient, which is similar to the studies by Sahoo and Mandal (2011) and Wanniarachchige and Suzuki (2011); but they are slightly less profit-efficient, which is consistent with the study by Sensarma (2005). This difference between cost efficiency of public and private banks is only statistically significant after 2001 while the differences in profit efficiency only occurred in 1999-2001 and 2004-2005. Moreover, there is a significant and negative association between cost and profit efficiency scores, but the magnitude is weak (the correlation coefficient is − 0.11 and has a p-value of 0.005). One possible explanation is that bank managers practise both bad management (low efficiency leads to high risk) and moral hazard (low capital leads to high risk) behaviours.

Table III. Cost and profit efficiencies of the Indian banking system and its bank types

Year	Cost efficiency All banks	Cost efficiency Public banks	Cost efficiency Private banks	Gap	Profit efficiency All banks	Profit efficiency Public banks	Profit efficiency Private banks	Gap
(1)	(2)	(3)	(4)	(3)-(4)	(6)	(7)	(8)	(7)-(8)
1994	0.929	0.935	0.920	0.015	0.949	0.947	0.953	−0.006
1995	0.952	0.947	0.960	−0.013	0.918	0.906	0.937	−0.031
1996	0.959	0.960	0.957	0.003	0.932	0.932	0.931	0.001
1997	0.957	0.961	0.949	0.012	0.937	0.939	0.933	0.006
1998	0.958	0.958	0.960	−0.002	0.923	0.924	0.923	0.001
1999	0.961	0.963	0.957	0.006	0.925	0.920	0.933	−0.013**
2000	0.962	0.968	0.951	0.017	0.917	0.909	0.932	−0.024***
2001	0.962	0.970	0.950	0.020**	0.922	0.916	0.933	−0.018***
2002	0.957	0.970	0.935	0.035***	0.932	0.929	0.936	−0.007
2003	0.939	0.960	0.905	0.055***	0.950	0.948	0.954	−0.005
2004	0.930	0.956	0.885	0.072***	0.952	0.947	0.959	−0.011***
2005	0.936	0.960	0.895	0.065***	0.949	0.944	0.957	−0.013***
2006	0.944	0.965	0.908	0.057***	0.946	0.943	0.950	−0.007
2007	0.938	0.954	0.911	0.043***	0.935	0.934	0.937	−0.003
2008	0.958	0.962	0.951	0.011	0.932	0.933	0.932	0.001
2009	0.950	0.965	0.924	0.041***	0.938	0.937	0.939	−0.002
2010	0.951	0.969	0.920	0.050***	0.935	0.929	0.945	−0.016*
2011	0.965	0.977	0.947	0.030***	0.918	0.913	0.925	−0.012
Mean	0.950	0.961	0.932	0.029***	0.934	0.931	0.939	−0.009***

Notes: *t*-test is used to check mean differences in efficiency among bank types. *,**,***10, 5 and 1 per cent level of significance, respectively

Overall, the results of efficiency analysis reveal that Indian banks were highly efficient during the study period. They seemed to be able to exploit both scale economies and show technical progress but the rate of improvement diminished. In the next section we examine the interrelationships among operational efficiency, risk and capital of banks in order to identify common management behaviours.

4.2 Management behaviour

Table IV displays the 3SLS estimation for the system of three simultaneous Equations (6-8). The χ^2 values obtained from the 3SLS estimator indicate that the system of three simultaneous equations for the samples of all banks, public banks and private banks are significant. Regarding Equation 6, cost efficiency of all banks is found to have positive and significant effects on Z-scores (higher Z-scores imply more stability). Since the deterioration in cost efficiency leads to an increase in insolvency risk, this finding supports the bad management hypothesis. Also, our results show that an increase in profit efficiency is associated with an increase in insolvency risk with the exception of private banks, hence supporting the skimping hypothesis. These contrary behaviours could be due to the presence of moral hazard behaviour, which explains a negative correlation between the cost and profit efficiency scores discussed above. We found that moral hazard behaviour does exist and more detailed results of the test for moral hazard are presented at the end of this section.

Table IV also shows that better capitalized banks face less insolvency risk. This finding is consistent with that of Tan and Floros (2013) for Chinese banks and Kwan and Eisenbeis (1997) for US banks. When capital is increased, private banks, with well-defined shareholders (individuals and organizations), tend to have more incentives to monitor management performance. This leads to the negative effects of capital ratio on insolvency risk is significant in private banks, but insignificant in public banks. There is an inverse U-shape relationship between bank size (proxied by total assets) and risk, suggesting that Indian banks intensify risk management activities when their total assets exceed a certain level. Revenue diversification in Indian banks seems to reduce the insolvency risk, as non-interest income is less vulnerable to idiosyncratic shocks.

Regarding Equation 7, a decrease in cost efficiency is associated with an increase in capital ratio in Indian banks, which is consistent with findings by Deelchand and Padgett (2010) and Kwan and Eisenbeis (1997) for US banks. Banks often respond to a deterioration in cost efficiency by raising capital (numerator of capital ratio) as a precautionary step, while public banks also respond to profit efficiency improvement by using their retained earnings as a supplement to equity (numerator of capital ratio). The ratio of loans to deposits is positively and significantly related to capital ratio. One possible explanation is that banks with higher intermediation of deposits into loans have higher earnings to supplement equity (numerator of capital ratio).

Macroeconomics indicators have no effects on the capital of Indian banks in profits while their impacts on the cost side are minimal. For example, the effects of GDP growth on capital ratio are only significant at 10 per cent for the cost efficiency estimation of public banks. An increase in inflation rate is associated with a decrease in capital ratio in public banks, but an increase in this ratio in private banks. We argue

Models	Cost efficiency All banks	Cost efficiency Public banks	Cost efficiency Private banks	Profit efficiency All banks	Profit efficiency Public banks	Profit efficiency Private banks
Equation (6) Dependent variable is risk (Z-score)						
Efficiency	2.6035***	4.7340***	1.6269**	−3.5804**	−7.2236***	−3.2190
	(0.4943)	(1.1350)	(0.5537)	(1.2824)	(1.6365)	(1.8147)
Equity to Total Assets	6.3685***	1.9718	3.8148***	5.9253***	3.8797	2.3918*
	(0.7124)	(3.9205)	(0.9392)	(0.6333)	(3.7833)	(1.0400)
Ln(Total Assets)	−0.1293**	−0.0803	0.1316*	−0.1102**	0.2036	0.2915***
	(0.0418)	(0.2139)	(0.0584)	(0.0380)	(0.2611)	(0.0862)
Ln(Total Assets)^2	0.0091***	0.0070	−0.0066	0.0083***	−0.0051	−0.0170**
	(0.0024)	(0.0103)	(0.0039)	(0.0023)	(0.0127)	(0.0053)
Revenue Diversification	1.0789***	0.1688	1.0145***	0.1792	1.4101***	0.1684
	(0.2112)	(0.2488)	(0.2207)	(0.1163)	(0.4136)	(0.1910)
Inflation	−0.0012	−0.0023	0.0013	−0.0073**	−0.0034	0.0007
	(0.0022)	(0.0033)	(0.0035)	(0.0026)	(0.0041)	(0.0050)
Constant	0.8021	−1.2074	0.8591	6.7063***	8.2501***	5.0360***
	(0.6118)	(1.7588)	(0.5590)	(1.1977)	(1.6882)	(1.4807)
Equation (7) Dependent variable is capital (ratio of equity to total assets)						
Efficiency	−0.1931***	−0.4647***	−0.1409**	1.3475	0.5816***	−0.1078
	(0.0396)	(0.1044)	(0.0504)	(1.2903)	(0.1304)	(0.3049)
Loans to Deposits	0.0569***	0.0764***	0.0497***	0.0438*	0.0508***	0.0435**
	(0.0067)	(0.0101)	(0.0136)	(0.0193)	(0.0071)	(0.0133)
GDP Growth	0.00001	−0.0009*	−0.0001	−0.0013	−0.0010	0.0007
	(0.0005)	(0.0003)	(0.0010)	(0.0035)	(0.0005)	(0.0013)
Inflation	0.0003	−0.0010***	0.0021**	0.0015	−0.0002	0.0016
	(0.0003)	(0.0003)	(0.0007)	(0.0017)	(0.0003)	(0.0008)
Constant	0.1998***	0.4612***	0.1502**	−1.2330	−0.5167***	0.1229
	(0.0392)	(0.0974)	(0.0521)	(1.2007)	(0.1218)	(0.2858)
Equation (8) Dependent variable is efficiency						
Z-score	0.0321	0.0796**	0.0592	−0.0158	−0.0578	0.1599
	(0.0310)	(0.0251)	(0.1267)	(0.0217)	(0.0323)	(0.1235)
Equity to total assets	−1.4088***	−2.2261***	−1.4126***	0.4463**	2.4934**	0.1005
	(0.1541)	(0.6505)	(0.2904)	(0.1584)	(0.8629)	(0.2560)
Revenue diversification	−0.2636***	0.0220	−0.4081***	−0.0036	0.0241	−0.1410
	(0.0353)	(0.0350)	(0.0828)	(0.0138)	(0.0511)	(0.0799)
Loans to total assets	0.1338***	0.1495***	0.1434*	−0.0319***	−0.0964**	−0.0796
	(0.0229)	(0.0264)	(0.0656)	(0.0078)	(0.0353)	(0.0615)
GDP growth	−0.0027***	−0.0010	−0.0062***	0.0017*	0.0002	0.0038**
	(0.0007)	(0.0007)	(0.0018)	(0.0007)	(0.0008)	(0.0014)
Inflation	−0.0004	−0.0015**	0.0029	−0.0011*	0.0005	−0.0033*
	(0.0005)	(0.0005)	(0.0015)	(0.0005)	(0.0007)	(0.0013)
Constant	0.9127***	0.7445***	0.8390*	0.9747***	1.0442***	0.4479
	(0.0902)	(0.0629)	(0.3820)	(0.0625)	(0.0814)	(0.3706)
χ^2 for Equation (1)	230.1263	139.1742	54.3503	264.4973	125.6213	36.9606
χ^2 for Equation (2)	136.4323	69.7912	44.7499	9.0442	67.3049	20.5772
χ^2 for Equation (3)	297.1047	54.1641	175.1209	57.2339	13.7683	16.8237
Observations	720	450	270	720	450	270

Notes: Standard errors in parentheses. *,**,***10, 5, 1 per cent level of significance, respectively

Table IV. The relationships between risk, capital and efficiency that when inflation grows, public banks – under the influence of the government policies – may still expand lending for the purpose of improving the economy, while private banks can reduce lending (a main source of denominator of capital ratio) due to the higher probability of loan default.

Results for Equation 8 show that *Z*-score creates positive and significant impacts on the cost efficiency of public banks. Since *Z*-scores as the reverse interpretation of risk (i.e. lower *Z*-score means more risk), the positive parameter of *Z*-score in Equation 8 suggests that public banks face bad luck regarding the cost management. However, this finding is not significant for private banks or when a profit function is analysed (i.e. bad lucks seem to avoid private banks and do not affect profits). An increase in capital ratio is found to precede a decrease in cost efficiency, but a reverse sign incurs at the profit aspect. Banks which raise equity as a funding source for loans usually involve higher costs, but they generate higher revenue than those relying on income from deposits (Berger and Mester, 1997). Revenue diversification is found to have a negative effect on cost efficiency of private banks. This could be because the expenses for non-lending products are greater than those for lending-products, and private banks tend to intensify revenue diversification more than public banks.

The ratio of loans to total assets is found to be associated positively with cost efficiency, but negatively with profit efficiency. One possible explanation is that loans are increased by lowering both deposit and lending interest rates, but the decreased interest expenses (paid to depositors) do not offset the reduced interest income (received from borrowers).

We test the moral hazard hypothesis by re-estimating the system of Equations 6–8 for the subsample of banks with a capital ratio below the sample median. Results from Equation 6 show that the capital ratio (equity to total assets) creates a positive effect on *Z*-scores in both cost and profit efficiency measurement (see Table V). In other words, a decrease in capital leads to an increase in the risk of insolvency, thus supporting the moral hazard hypothesis.

	Cost efficiency	Profit efficiency
Equation (6) Dependent variable is risk (Z-score)		
Efficiency	1.3620	−1.5357
	(0.9112)	(1.1366)
Equity to total assets	13.0781***	13.0321***
	(2.8710)	(2.9475)
Ln(total assets)	−0.0582	−0.0752
	(0.0492)	(0.0517)
Ln(total assets)^2	0.0047	0.0057
	(0.0032)	(0.0033)
Revenue diversification	1.0322***	0.8581***
	(0.1955)	(0.1881)
Inflation	0.0028	0.0007
	(0.0024)	(0.0026)
Constant	1.4074	4.2467***
	(0.8732)	(1.1883)

Notes: Standard errors in parentheses; Low capitalized banks: banks have capital ratio below than the sample median ($n = 360$). ***1 per cent level of significance

Table V. Testing moral hazard behaviour (Equation 6)

Robust tests of management behaviour hypotheses by other risk measures. In order to make robust inferences on the management behaviour of Indian banks, we re-estimate Equations 6-8 using the two alternative measures of risk: the volatility of ROA and the volatility of ROE. The key results of these re-estimations, together with extract of the original results (risk = Z-scores) for the ease of comparison, are presented in Table VI. Note that a higher Z-score indicates that the bank is more stable while a higher volatility of ROA or ROE indicates that the bank is less stable. Thus, we expect to see parameter estimates using the volatilities of ROA and ROE having opposite signs of those using Z-scores. It can be seen that findings remain robust when risk is measured by the volatility of ROA and volatility of ROE, especially for public banks and in the test for moral hazard.

In general, the findings on management behaviour in Indian banks are similar to those of Berger and DeYoung (1997) and Kwan and Eisenbeis (1997) for US commercial

Model	Cost efficiency Risk = Z-score	Risk = ROA Volatility	Risk = ROE Volatility	Profit efficiency Risk = Z-score	Risk = ROA Volatility	Risk = ROE volatility
A. Robust test on hypotheses bad management, bad luck and skimping						
A.1 In Indian banks (sample of all banks: $n = 720$)						
Equation (6) Dependent variable is risk						
Efficiency	2.6035***	−0.0177	−0.6302	−3.5804**	0.0548	3.4430*
	(0.4943)	(0.0118)	(0.5580)	(1.2824)	(0.0295)	(1.4561)
Equation (8) Dependent variable is efficiency						
Risk	0.0321	−2.7984	−0.0613	−0.0158	0.7102	0.0318
	(0.0310)	(2.7767)	(0.0737)	(0.0217)	(2.2685)	(0.0606)
A.2 In public banks (sample of public banks: $n = 450$)						
Equation (6) Dependent variable is risk						
Efficiency	4.7340***	−0.1617***	−7.5598***	−7.2236***	0.1811***	9.2551**
	(1.1350)	(0.0330)	(1.7903)	(1.6365)	(0.0513)	(2.9023)
Equation (8) Dependent variable is efficiency						
Risk	0.0796**	−6.4946***	−0.1571***	−0.0578	4.9585***	0.1192***
	(0.0251)	(1.2455)	(0.0268)	(0.0323)	(1.1096)	(0.0188)
A.3 In private banks (sample of private banks: $n = 270$)						
Equation (6) Dependent variable is risk						
Efficiency	1.6269**	−0.0143**	0.0059	−3.2190	0.0243	0.2822
	(0.5537)	(0.0052)	(0.1097)	(1.8147)	(0.0154)	(0.3317)
Equation (8) Dependent variable is efficiency						
Risk	0.0592	−9.7461	0.3918*	0.1599	−13.8083*	−0.2933**
	(0.1267)	(8.4124)	(0.1929)	(0.1235)	(5.8871)	(0.0894)
B. Robust test on hypothesis moral hazard						
Sample of low capitalized banks ($n = 360$)						
Equation (6) Dependent variable is risk						
Equity to total assets	13.0781***	−0.2804***	−17.9074**	13.0321***	−0.3049***	−19.9204***
	(2.8710)	(0.0829)	(5.6229)	(2.9475)	(0.0846)	(5.7273)

Notes: Standard errors in parentheses; Low capitalized banks: banks have capital ratio lower than the median. *,**,***10, 5 and 1 per cent level of significance, respectively

Table VI. Robust tests

banks which were found to exhibit bad management, bad luck, skimping and moral hazard behaviour; those of Williams (2004) and Fiordelisi *et al.* (2011) for European banks which were found to be affected by bad management; those of Deelchand and Padgett (2010) for Japanese cooperative banks which were found to exhibit bad management, bad luck and skimping; and those of Das and Ghosh (2004) for Indian public banks which were found to show bad luck.

5. Conclusion and policy implication

We used stochastic cost and profit frontier models to comprehensively assess the efficiency of 40 Indian banks during the 1994-2011 period. We found that, on average, Indian banks can reduce costs by 5 per cent and increase profits by 6.6 per cent if they adopt the best practices. Public banks are more cost-efficient, but slightly less profit-efficient than private banks. Indian banks benefit from technological change and scale expansion in reducing costs and increasing profits. Further, we employed three-stage least square estimation for the system of three simultaneous equations to investigate the relationships between risk, capital and efficiency. We found that in both public and private banks, a decline in cost efficiency is generally followed by an increase in insolvency risk ("bad management"), and a decrease in capital ratio is generally followed by an increase in insolvency risk ("moral hazard"). In public banks, a rise in insolvency risk is generally followed by a decline in cost efficiency ("bad luck") while an increase in profit efficiency precedes an increase in the insolvency risk ("skimping"). Better capitalized banks suffer lower insolvency risk and achieve higher profit efficiency. Each of these results have a small impact on banks on average, but may have a considerable impact on individual banks that are most subject to bad luck, bad management, skimping and/or moral hazard.

These findings may have some policy implications. The bad management evidence in both public and private banks suggests that bank regulators and supervisors should consider cost efficiency as a good predictor of banks at risk. The bad luck in public banks evidence implies that bank regulators and supervisors should limit public banks' exposures to external shocks by diversifying income streams or restricting the loan to assets ratio. The skimping hypothesis in public banks suggests that bank regulators and supervisors should consider profit efficiency as a proxy for insolvency risk in public banks. The moral hazard hypothesis implies that bank regulators and supervisors should carefully monitor capital ratio in the low capitalized banks in order to require them to quickly raise this capital ratio when it declines. The finding that capital ratio has a negative effect on the risk of insolvency, but a positive effect on profit efficiency suggests that capital ratio could be an efficient tool to reduce the insolvency risk and improve the profit performance.

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