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Risk management and managerial efficiency in Chinese banks: A network DEA framework ☆

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ABSTRACT

Risk management in Chinese banks has traditionally been the Cinderella of its internal functions. Political stricture and developmental imperative have often overridden standard practice of risk management resulting in large non-performing loan (NPL) ratios. The training and practice of risk managers remain second class compared with foreign banks operating in China. This paper surveys Chinese bank risk managers and constructs metrics of risk management practice and risk management organisation. The metrics are used as intermediate inputs in a Network DEA framework to produce a measure of income efficiency. A statistical test is carried out to assess the importance of the risk metrics in evaluating bank income efficiency.

1. Introduction

In recent years the Chinese banking system has made enormous strides in reform and deregulation. They have emerged relatively unscathed from the global banking epidemic that has infected the developed economies and the largest of them stand alongside the giants of global banking as first among equals[1]. However, despite the relative strength of the large listed Chinese banks in world banking, lingering doubts remain about the inherent fragility of the banking system in China. The past decade has seen a large volume of academic and professional papers expressing concerns about the safety and soundness of the Chinese banking system and their medium term viability in the face of increasing competition from foreign banks in the post WTO years. The common thread in many reviews of Chinese banking are: the large number of non-performing loans, the dominance of lending to state-owned enterprises, and the influence of local government and Communist Party officials in lending decisions.

A particular area of concern for the regulatory authorities and strategic investors in the Chinese banks has been the quality of training of risk managers, the organisational culture and the misalignment of incentives associated with bureaucracy rather than commercialism [7]. The process of converting Chinese banks from state dominated bureaucracies to modern profit oriented banking institutions involves not just the training of decision makers in modern banking but also the transformation of the organisation. This transformation has been occurring but on an evolutionary rather than a revolutionary pace. With the encouragement of the regulatory authorities, Chinese banks have in recent years, had to restructure their balance sheet, develop modern risk management methods, improve capitalization, diversify earnings, reduce costs and improve corporate governance and disclosure[2].

This paper aims to evaluate the performance of the risk management function of Chinese banks in terms of its contribution to profitability. There are four parts to the research. The first part collects qualitative data on risk management practice and risk management organisation through a semi-structured questionnaire. The second part quantifies the qualitative data by constructing a metric of risk management practice, and risk management organisation in Chinese banks, using the foreign banks operating in China as a yardstick of best practice. The metric will measure how good the practice of risk management is in a Chinese bank and how well the risk management function organisation is relative to best practice. The third part uses the

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[1] According to 1000 top bank survey in the July 2009 issue of the Bankers Magazine, the Industrial and Commercial Bank of China is the 8th largest in the world and Bank of China is 11th largest. For a statement of the development of the banking market see Yang and Kuhn [20] Ch 3.

[2] CBRC Annual Report 2006 http://www.cbrc.gov.cn/english/home/jsp/index.jsp.

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Table 1

Bank number	Mnemonic	Bank name	Number of interviewees
1	ICB	Industrial Bank of China (Joint-stock commercial bank)	1
2	GDB	Guangdong Development Bank (Jointstock commercial bank)	1
3	CMBCL	China Merchant Bank Co Ltd (Jointstock commercial bank)	2
4 (Big-4)	ABOC	Agricultural Bank of China (State-owned bank)	1
5 (Big-4)	CCB	China Construction Bank (State-owned bank)	1
6	CMB	China Minsheng Bank (Joint-stock commercial bank)	1
7	HUAXIA	Huaxia Bank (Joint-stock commercial bank)	1
8	EVERBRT	Everbright Bank of China (Joint-stock commercial bank)	2
9 (Big-4)	ICBC	Industrial and Commercial Bank of China (State-owned bank)	2
10	(Big-4)	BOC Bank of China (State-owned bank)	1
11	SPD	Shanghai Pudong Development Bank (Joint-stock commercial bank)	1
12	SDB	Shenzhen Development Bank (Jointstock commercial bank)	1
13	SPAN	Shenzhen Ping An Bank (City commercial bank)	3
14	BOB	Bank of Beijing (City commercial bank)	1
15	CITIC	China CITIC Bank (Joint-stock commercial bank)	1
Foreign agencies			
1	Citi	Citibank (China)	2
2	HSBC	Hong Kong Shanghai Banking Corporation	1
3	BEA	Bank of East Asia (Hong Kong)	1
4	EXP	Experian (China)	1

constructed metrics of risk management in a network DEA framework to evaluate bank income efficiency. The fourth part tests the hypothesis that the inclusion of the risk metrics in the network DEA improves the measurement of income efficiency and its link to bank profitability.

The paper is organised in the following way. The next section outlines the results of interviews. Section 3 describes how the interview responses are converted into a relative score compared with two of the major foreign banks operating in China (HSBC and Citibank). Section 4 describes the method of performance evaluation based on Data Envelopment Analysis (DEA) and the use of network DEA to think of risk management and organisation as an intermediate output/input in the process. Section 5 tests the hypothesis that the use of the risk metrics in the network DEA improves the measurement of efficiency and its correlation with bank profitability. Section 6 summarises the results and concludes.

2. Qualitative analysis

Twenty five bank executives involved in the area of lending and risk management were interviewed over the period 2007–2008. The banks included three foreign banks, the big 4, nine joint-stock commercial banks and two city commercial banks. The criteria for choosing interviewees were that they were involved in the risk management function and the lending decision with several years experience. The aim was to get middle ranking managers who could explain existing risk management practice and provide subjective evaluation of staffing, training and recruitment issues.

The interviews were conducted in a semi-structured format in which interviewee responses were recorded and respondents recorded their own scores (1–5 Likert scale) with respect to specific questions about risk management functions. Interviews were conducted in Beijing, Shanghai, Tianjin, Dalian, Guangzhou and Shenzhen. Table 1 lists the banks that were involved in the research.

The questionnaire was divided into two areas of the risk management operation. The first area was concerned with the importance of particular characteristics regarding the loan approval decision to specific sectors (large enterprises, Small and Medium size Enterprises (SME) and consumers). The second area covered the organisation, training and staffing of the risk management section of the bank. This section dealt with issues relating to performance evaluation, training, recruitment, and retention, and work organisation. A shortened version of the questionnaire dealing with the factors that make up the construction of the risk metrics is included in the appendix.

The single largest factor in the granting of a loan was cash flow (70%)[3], which biases bank lending to established enterprises. Record of repayments (good credit record) was cited by 30% of respondents. A preference for lending to State-owned Enterprises (SOE) (65%) reflects the political reality of state and local government relevance in the lending decision as well as implicit government guarantees. Collateral was not an issue except in the case of lending to SMEs. Less than 20% of interviewees considered collateral and guarantees as important in the lending decision reflecting the dominance of SOEs in the bank's loan portfolio. Collateral was a more important feature for the two foreign banks reflecting the stronger focus of these banks in the SME sector. In the case of mortgage lending, there was no common formula relating loan size to annual income. The most common cited reason for approval of a mortgage was the type of job the borrower had. Government officials, civil servants and employees in large SOEs were viewed as having the safest jobs and lowest risk (65%). Income levels, ability to pay and volatility of income was cited as the second main factor in determining mortgage approval (25%). Loan-to-Value of mortgages does not exceed 80% and typically are in the region 60–65% with normal upper bound of 70%.

The reasons for a loan refusal had a greater variation in the response. The single main reason for a loan refusal to a SOE was weak financial projections (36%) which, was also linked to any history of delinquency (18%). However, the second single factor was state policy. Even if an enterprise is state owned, it may be classified as belonging to a declining industry with weak state guarantees (27%). In contrast, the foreign banks saw independence of SOE management from the state as strength and cited poor management quality as the principal reason for loan refusal to a SOE.

In the case of SMEs, the principal reason for loan refusal was the lack of collateral or third party guarantee (36%). One respondent stated that collateral substituted for post-loan monitoring

[3] The percentages are of the total number of respondents of the domestic banks and not the number of banks surveyed. The number of respondents per bank is shown in Table 2 of the appendix.

and was viewed as the price for the loan. Weak financial and cash projections were the second most cited reason (27%) and poor credit record or lack of credit record was the third most cited reason (22%). The response of the domestic bank risk managers highlights the conservativeness of the lending decision to SMEs. Start up companies would be considered high risk and only established SMEs with good collateral and financial history stand much chance of a loan approval. The foreign banks also viewed start ups as risky but even with good financial projections and solid third party guarantees, the strength of the company's management was a determining factor in loan refusal. Only one of the domestic bank's respondents stated that the quality of management was a significant factor in loan refusal to SMEs.

The policy on remuneration, incentives and performance evaluation varied widely. One of the big-4 had no formal performance related compensation system. Bonuses were determined by the Chief Risk Officer at headquarter, but there was a recognition that risk managers that recovered Non Performing Loans (NPL) were worthy of special reward. For this particular bank, the quantity or frequency of approvals was not a factor in determining the final bonus. Under-performance led to transfer. Except in the case of fraud, redundancy was not a policy option. With two other big-4 banks, profit from the loan was the principal factor in performance evaluation and NPL recovery was the next important factor. While the frequency or number of approvals did not affect the evaluation, the overall profit of the unit was the main factor. With one of these big-4 banks, poor performance led to transfer or payment of basic salary (zero bonus). With the third bank in the big-4 group, the risk manager received 50% of compensation as basic and 50% as bonus but the evaluation was done by the General Manager rather than an independent Risk Manager, giving rise to the potential of moral hazard and adverse incentives.

With the interviewees of the joint-stock banks (JSB), the frequency and size of approvals was cited as many times as the profitability of the loan book. Only one interviewee of a JSB mentioned moral hazard as a reason for separating the bonus package for risk staff from the approvals decision making process. But in contrast, one other interviewee of a JSB specifically stated that the principle of a separation between the Sales/Business side of bank operations and the risk management function was impractical. As each branch is its own Profit & Loss centre, the political and business pressure on the approvals process detracted from any attempt of independence. The local bank president had considerable influence over the local risk management team. A second interviewee of a JSB stated that the Sales/Business side of the bank was an important consideration for the determination of bonuses to risk management. A third interviewee said that the local bank president has considerable influence on the local risk management team although the governance structure is changing. In the case of one small city commercial bank the risk personnel were evaluated in exactly the same way as non-risk staff and the bonus was based on position rather than performance.

Interviewees were asked to score the training of risk managers in their institution from a scale of [5] being excellent to [1] being useless. The underlying assumption is that the scores of the foreign banks risk managers represents 'best practice' in the sense that risk management training and organisation draws from a global experience. The 'best practice' score obtained from interviewing four managers from the two foreign banks was [5].[4] The median response from the Chinese bank managers was a score of [3] which was described as *adequate* with one-third of the sample scoring [2] as *inadequate*. Yet when asked to weight an incentive scheme against training to get the best performance from the risk team, the median response was 60% in favour of incentives and 40% for training. The 'best practice' defined by the interviewees of HSBC and Citibank weighted training as 70% and incentives 30%.

A similar question relating to staffing levels in the risk team where the 'best practice' response was a score of [4], which is described as 'good' but not excellent ([5]) produced the following results. Three banks matched the 'best practice' and one exceeded it, but most recorded a score of [3] or [2]. The median score was [3]. There appeared to be no relationship between the perception of 'good' or 'excellent' and the position of the bank in the industry. The risk manager from the Industrial and Commercial Bank of China, one of the largest in the world, gave a score of [2] (inadequate) for staffing levels in the risk management field. In contrast four JSBs gave 'best practice' scores with the remaining big-4 SOB interviewees giving a score of [3].

The interviews also revealed information about recruitment and skills of bank personnel that were not covered in the questionnaire. One respondent of the big-4 said that 'many heads of sub-branches are not professional bankers but are retired army officers of 10–15 years experience. They tend to be appointed to high levels even as President or Head of Human Resource Management and even on the credit committee. While the chief risk manager is usually a professional and can veto a lending decision, the non-professionals wield influence and can affect decisions at the margin'. Another manager described his staff as principally 'government officials' that are procedurally driven rather than professional in the business of loan approvals.

3. Quantitative analysis

This section describes the translation of the individual scores into a single relative metric. The interviewee provided scores relating to individual factors in the approvals process and factors relating to the training, staffing, reward, recruitment, and retention of risk staff. A test for independence of the distribution of the scores from the 'best practice' values is shown in Table 2 below. A standard small sample test would be a '*t*' test but depends on the assumption of an asymptotic normal distribution. Since normality may not be an appropriate assumption, we employ a non-parametric test that is less restrictive in its assumption and only requires symmetry in the distribution. The Wilcoxon signed rank test, tests the median differences in paired data where one of the pairs is defined as the 'best practice' score.

The results of Table 2 suggest important differences in the attitudes of Chinese domestic bank risk managers and Chinese foreign bank risk managers. For domestic risk managers the credit record and cash flow of the borrower (SOE and SME) are less important than for foreign banks. Similarly knowing your customer is much more important to the foreign bank risk manager than the domestic. A possible reason is that domestic banks concentrate their lending on SOEs that are implicitly guaranteed by the central and local government and have less of a focus on SMEs. Therefore rules about credit record, cash flow or knowing your customer regulations were historically less relevant to them.

A significant difference in importance of a person's credit record and credit score for a mortgage loan (X11) indicates the prevalent attitude that the type of job a person has is a better

[4] Interviews with four risk management personnel from Citi Bank, HSBC and Bank of East Asia were conducted but only the responses from Citi and HSBC were used in defining the benchmark. The respondent from the Bank of East Asia was a recent employee and could not give answers to all the questions. The 'best practice' was defined as the 'envelope' (maximum) of scores of the response of the three risk managers.

(*footnote continued*)

Table 2
Statistical significance of individual factors.

Individual factor	Wilcoxon* ($p < .05$)
X1—Credit record (SOE	.014*
X2—Cash flow (SOE)	.022*
X3—Account profitability (SOE)	.059
X4—Collateral or guarantee (SOE)	.078
X5—Know your customer (SOE)	.006*
X6—Credit record (SME)	.022*
X7—Cash flow (SME)	.008*
X8—Account profitability (SME)	.227
X9—Collateral or guarantee	.008*
X10—Know your customer (SME)	.022*
X11—Credit record (Mortgage)	.036*
X12—Personal income (Consumer loan)	.170
X13—Credit score (personal loans)	.003*
X14—Net worth of borrower (personal loan)	.754
X15—deposit account (personal loan)	.002*
X17—Risk management training	.001*
X18—Staffing levels	.002*
X19—Organisation of workloads	.036*
X20—Internal recruitment	.177
X21—External recruitment	.001*
X22—University background	.286
X23—Foreign University Training	.530
X24—Experience	.100
X25—Professional qualification	.009*
X26—Higher degree	.038*
X27—Retention policy	.834

indicator of creditworthiness than income. A frequent response was that a government official was considered a good risk and a credit score or credit record was inappropriate.

A strong difference was noted in the scoring of the risk management training (X17) provided in domestic banks. The median response was a score of [3] against a 'best practice' score of [5]. Staffing levels were only *adequate* [3] or *inadequate* [2] against a 'best practice' score of *good* [4]. External recruitment was also an important difference in the preferences between Risk Managers in domestic banks and foreign banks. Foreign banks were more used to using Head-Hunters and agencies to recruit from outside the bank whereas this was not typical of Chinese banks which had a preference for recruitment within the bank.

Using the foreign bank scores as the measure of best practice, the individual 5-point Likert scores of the domestic risk managers were measured relative to the scores of the foreign bank. The measuring principle is that negative scores (when the domestic bank score is less than the 'best practice' score) were heavily penalised but positive scores (domestic bank score greater than the 'best practice') were lightly penalised. The argument is that negative scores are indicative of downside risk whereas positive scores are overcautious but do not warrant an equivalent penalty. For example if the 'best practice' is that a certain factor is '*important*' (4) a score of '*not important*' (3) is given a heavier penalty than a score of '*very important*' (5). An asymmetric translation function on the lines of Surico [17] produces the desirable properties. A translation function of the following type was used.

$$f(x) = \left\{1 + \frac{\frac{3}{2}x^2 - \frac{1}{2}x^3}{\gamma}\right\}^{-1} 100 \tag{1}$$

where $x = response\ score - best\ practice\ score$ and γ is an arbitrary scaling parameter. The function described by Eq. (1) has the property of having a score of 100 when the respondents score equals the 'best practice' score but remains in the neighbourhood of 100 with a slight penalty for up to the value $x=2$ (point of inflexion) when it starts to rise towards 100.

The deviation of the different scores of each question from the respective 'best practice' score were first transformed by Eq. (1) and then combined using a principal components analysis (PCA) to construct a single metric for each bank[5]. The scores from the fifteen questions (factors X1–X15 appendix) relating to the approvals function (denoted risk) were first transformed by Eq. (1) and then subjected to the PCA and the first principal component[6] (denoted RISKMAN) was retained out of a possible five as a potential metric of risk management practice for each bank.

The next step was to test the veracity of the principal component vector against an objective measure of risk. Following Hannan and Hanweck [8], a risk index based on the probability of insolvency is defined as below;

$$\frac{E(\mathrm{ROA}) + \frac{\mathrm{CAP}}{A}}{\sigma_{\mathrm{ROA}}} \tag{2}$$

ROA is the return on assets, *E(*ROA*)* is the mean of ROA over the 5 years to 2007 for each bank, CAP is the bank's capital, A is its assets and σ_{ROA} is the standard deviation of ROA over the 5 years to 2007 for each bank. Eq. (2) is a risk index, measured in terms of units of the standard deviation of ROA. The index can be used to measure the probability of a decline in the bank's accounting earnings so that it has a negative book value and measures the thickness of the capital cushion relative to profit so that a higher measure indicates a safer bank[7]. The index can be interpreted as a measure of the probability of technical insolvency and used as an indicator of the riskiness of the bank. For example the correlation between the risk index defined by Eq. (2) and the NPL ratio[8] of the bank in 2007 is -.8860. A higher index score indicates a safer bank which correlates significantly with a lower NPL ratio. The risk index (denoted *RI*–07) was therefore used as a test of the veracity of the combination of the 15 factors. The Spearman's Rank correlation between *RI* and 07 and RISKMAN was 0.6321 ($p > |t| = .0115$), suggesting that the largest principal component was an appropriate indicator of risk practice.

Similar to the construction of the risk management practice metric, a metric of risk management organisation was constructed from the transformed raw scores relating to training, staffing, recruitment and retention (factors X18–X27 appendix) and was the first principal component of a PCA analysis (RISKORG). However, there was no significant correlation between this measure and an objective measure of risk or bank performance such as cost-income ratio or Return on Assets (ROA).

4. Network data envelopment analysis

In this section the metrics of risk practice and organisational performance are treated as inputs in a multi-stage production process of the bank in a Data Envelopment Analysis (DEA) framework to transform primary inputs of operational expenses and fixed assets into the outputs of net-interest income and non-interest income.

The traditional DEA method is a linear programming method for measuring the relative efficiency of DMUs that have multiple

[5] It is important to note that most mathematical operations including PCA may not be valid for Likert scaled variables being ordinal rather than ratio-scaled. However, Ochieng Owuor and Zumbo [12] show that in the context of regression models, a fewer number of Likert scale points result in larger biases and that four or more Likert scale points should be used. The data we use in the PCA has been differenced from the benchmark value and transformed by an asymmetric loss function. For a full discussion of the use of Likert scale variables in PCA see Kolenikov and Angeles [11].

[6] Based on the Eigen-vector of the largest Eigen-value.

[7] See for example Sinkey [16] p. 140.

[8] Ratio of NPLs to total loans.

inputs and outputs. It is a technique that has been used as a benchmarking process in evaluating the efficiency of management to transform input resources into outputs relative to 'best practice'. In the traditional DEA model, performance measurement is based on a 'black box' process [6]. Inputs are transformed into outputs but the transformation process is implicit and unknown. Indeed the advantage of DEA is that it does not impose a specific structure. However, researchers impose some structure when applying DEA to specific problems.

A common structure is the two-stage DEA. The two-stage method has been applied to numerous cases. For example in the case of a bank, labour and fixed capital can be used to generate deposits, which in turn is used to generate interest earning assets. The deposits can be viewed as an intermediate output which is an intermediate input to produce interest bearing assets in the second stage of production. Recent expositions can be found in Chen and Zhu [2], Kao and Hwang [10], Chen, Liang and Zhu [3] and Cook, Liang and Zhu [4].

However, the two-stage DEA model is only one of a family of DEA models that comes under the notion of a network DEA framework. Färe and Grosskopf [6] develop a general formulation of the network DEA which attempts to provide deeper structure to the 'black box' transformation of the conventional DEA. We develop a network DEA that utilises the risk and organisational metrics we construct as intermediate inputs in the production process.

Traditionally, the application of DEA to banking has followed one of two methods. The most popular method is known as the *intermediation approach* [15] which recognises the intermediation role of the bank by transforming the traditional factors of production such as labour and capital into outputs relating to stocks of earning assets. However, deposits and borrowed funds are seen as part of the intermediation process of taking in deposits and transforming them into loans. Consequently deposits are also classified as an input. The alternative method is the *production approach* that is closer to the neo-classical production function which uses the traditional factors of production of capital and labour and uses these to produce the number of accounts of loan and deposit services. A proxy measure would be final output of the bank, namely its revenue streams [5]. Between these two approaches have been a number of studies that have treated deposits as both inputs and outputs. Demand deposits are seen as an output as the bank produces deposit related services to customers (billing, fund transfers, payments mechanism etc) while time deposits are maturity based and used as an input in the intermediation process. The advantage of the network framework is that deposits may be seen as an input at an intermediate stage.

However, the link between the two risk metrics and the production of bank revenue streams requires further elaboration. The principal revenue stream for Chinese banks is interest earned from loans. Loan decisions are initially approved by risk managers. The reliability of the loan granting decision to generate interest earnings will be a function of the organisation and training of the risk management department and the risk culture that derives from political and social pressure.

To appreciate the value added from the risk and organisational metrics constructed for the sample set of banks, we examine two cases of network DEA, excluding and including the risk practice index and risk organisation index as external an internal inputs in the intermediate stage of production. It can be argued that organisation of the risk function is a management activity generated within the bank but risk practice is part of a culture that is imposed on the bank based on social and political imperatives. The first is a three-stage network DEA that excludes the risk practice index and risk organisation index in the intermediate stage, but as China has historically had a large non-performing loan (NPL) problem, taking the lead from Berger and De Young [1] that NPLs will affect bank efficiency, we treat NPLs as a separable bad output. The second case replicates the first case, where NPL is treated as a bad output, but including the measure of risk practice and risk organisation as internal and external intermediate inputs/outputs in the production chain.

Specifically, we conduct a three-stage network DEA with one undesirable output using the software *DEA-Solver-PRO Version 6*[9]. The notation and description of the process follows closely that of Tone and Tsutsui [19].[10] There are n DMUs ($j=1\ldots n$) consisting of P stages ($p=1\ldots P$). Let m_p and r_p be the number of inputs and outputs to stage p, respectively. The link leading from stage p to stage h is denoted by (p,h) and the set of links by L. The observed data are $x_j^p \in R_+^{m_p} \quad (j=1,\cdots n),(p=1,\cdots P)$ (inputs to DMU_j at stage p), $y_j^p \in R_+^{r_p} \quad (j=1,\cdots n),(p=1,\cdots P)$ (outputs from DMU_j at stage p) and $z_j^{(p,h)} \in R_+^{(p,h)} \quad (j=1,\cdots n);(p,h)\in L)$ (linking intermediate outputs from stage p to stage h) where $t_{(p,h)}$is the number of items in Link (p,h).

Following Tone and Tsutsui [19], the production set $(x^p,y^p,z^{(p,h)})$is given by;

$$x^p \geq \sum_{j=1}^{n} x_j^p \gamma_j^p (p=1,\cdots P),$$

$$y^p \leq \sum_{j=1}^{n} y_j^p \gamma_j^p (p=1,\cdots P),$$

$$z^{(p,h)} = \sum_{j=1}^{n} z_j^{(p,h)} \gamma_j^p (\forall (p,h)) \text{ as outputs from stage } p,$$

$$z^{(p,h)} = \sum_{j=1}^{n} z_j^{(p,h)} \gamma_j^h (\forall (p,h)) \text{ as inputs to stage } h,$$

$\sum_{j=1}^{n} \gamma_j^p = 1(\forall p), \gamma_j^p \geq 0\ (\forall j,p)$ is binding in the case of VRS, where $\gamma^p \in R_+^n$ is the intensity vector corresponding to stage p ($p=1,\ldots P$).

Any DMUo can be represented by

$$x_o^p = X^p \gamma^p + s^{p-} (p=1,\cdots P) \tag{3}$$

$$y_o^p = Y^p \gamma^p - s^{p+} (p=1,\cdots P) \tag{4}$$

$$e\gamma^p = 1\ (p=1,\cdots P) \tag{5}$$

$$\gamma^p \geq 0, s^{p-} \geq 0, s^{p+} \geq 0$$

where $X^p = (x_1^p,\cdots x_n^p) \in R^{m_p \times n}, \quad Y^p = (y_1^p,\cdots y_n^p) \in R^{r_p \times n}$.

The link constraints are either 'freely determined' or 'fixed' (see Tone and Tsutsui [19]. In this paper we adopt the fixed link restriction shown as;

$$z_0^{(p,h)} = Z^{(p,h)} \lambda^h (\forall (p,h)) \tag{6}$$

where $Z^{(p,h)} = (z_1^{(p,h)},\cdots z_n^{(p,h)}) \in R^{t_{(p,h)} \times n}$

There are three primary inputs and two final outputs. The primary inputs are operational costs (OC), fixed assets (FA) and deposits (DEP). In the first stage OC and FA are used to create labour time and materials (computers, buildings, electricity etc.). These are proxied respectively by personnel cost (PERS) and other operational costs (OTHER—non personnel costs) which are intermediate outputs in the first stage of production and intermediate inputs in the second stage of production. The intermediate inputs PERS and OTHER are combined with Deposits (DEP) which is a primary input in the second stage of production to create interest costs (INTCOST) and number of branches (BR). A bank needs labour, materials and deposits as primary inputs to make profits from loans and bank services. Interest on deposits is the means by

[9] The software DEA-Solver-PRO Version 6, www.saitech-inc.com was used.

[10] An alternative exposition can be found in Hua and Bian [9].

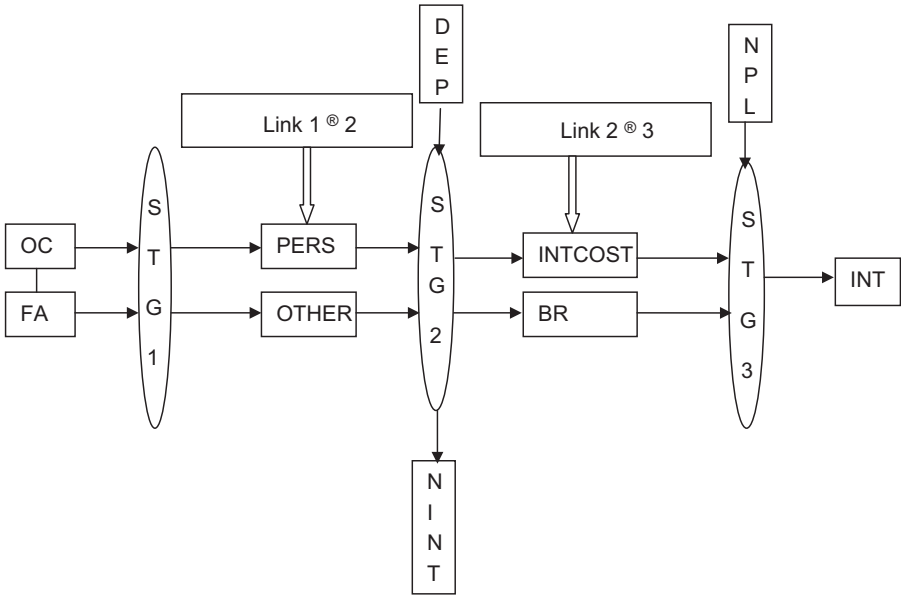

Fig. 1

which banks attract deposits and is therefore viewed as an output in the second stage. Bank branches are located in areas that will attract business from customers for fee paying banking services and deposit and loan services. In combination with the primary and intermediate inputs in the second stage of production, banks charge their customers fees for financial services. These fees are non-interest earnings (NINT) which are produced as a final output[11]. The main product of a bank is loans from which loan interest emerges from the type and quality of the credit. In China, non-performing loans have been a serious problem in the past and bundled in with the loan portfolio. However, interest earnings from loans will depend on the proportion of non-performing loans in the portfolio. Therefore in stage three, INTCOST and BR are intermediate inputs to the production of interest earnings (INT), which is the second final output. The undesirable output, non-performing loans (NPL) is included as a primary input in the final stage of production[12]. Fig. 1 describes the three-stage process. Each stage of production is shown by the elliptical figure. In stage 2, DEP enters as a primary input and NINT is produced as a final output. NPL enters as a primary input in stage 3 as a way of treating it as a bad final output. The summary statistics of the data is presented in the appendix.

The software employs a weighted network slacks based model (NSBM) assuming non-orientation[13]. To summarise, there are 4 inputs (three primary inputs and one undesirable output), 2 primary outputs and 4 internal inputs which are also 4 internal outputs. The objective function for the DMU is shown below.

$$\rho_o^* = \min \frac{\sum_{p=1}^{3} w_p \left[1 - \frac{1}{3}\left(\sum_{j=1}^{3} \frac{s_j^{p-}}{x_{io}^p}\right)\right]}{\sum_{p=1}^{3} w_p \left[1 + \frac{1}{3}\left(\sum_{i=1}^{3} \frac{s_r^{p+}}{y_{ro}^p}\right)\right]} \tag{7}$$

subject to (3)–(6) and $\sum_{i=1}^{P} w_p = 1$, $w_p \geq 0$ and w_p is the relative weight of stage p and represents the importance of each stage in the process.

Efficiency at each stage of production is given by Eq. (8) below.

$$\rho_p = \frac{1-(1/3)(\sum_{r=1}^{3}(s_i^{p-*}/x_{io}^p))}{1+(1/3)(\sum_{r=1}^{3}(s_i^{p+*}/x_{ro}^p))} \quad (p=1,2,3) \tag{8}$$

where s^{p-*} and s^{p+*} are the optimal input- and output-slacks for (7). The overall score is a function of the divisional scores [19].

Case 1

The optimisation exercise is to maximise the desirable outputs and minimise the undesirable outputs within each sub-DMU. Separating the stages of the creation of balance sheet items is more consistent with the intermediation approach. Operational costs and fixed assets are used to separate personnel costs from other costs. Deposits is a primary input but enters the production chain at a stage once the primary factor inputs of OC and FA have been deployed. The combination of personnel and other costs with deposits generate interest costs—the reward to depositors and the maintenance of the branch network. Non-interest earnings are generated as a final output at the second stage of production[14].

Table 3 shows the results. The network results provide a wider menu of benchmark banks at each stage for the manager to emulate. At stage 1, no bank is 100% efficient but the big-4 can use CCB as the closest to 'best practice' and the other banks can learn from CMBCL and SPAN. A number of banks are 100% efficient at stage 2, but at stage 3 only CMBCL and SPAN are on the best practice frontier.

Case 2

Table 4 below shows the implications of extending the network process to include our measures of risk practice and organisation in the production chain. This exercise utilises the measure of risk practice as a primary input in stage 3 and risk organisation as an intermediate output in stage 2 and an

[11] The implicit assumption is that fee income is largely generated in association with deposits which is dominated by households. In reality fee income will also be associated with corporate loans but to some extent this is captured by the creation of corporate deposits that match the marginal corporate loan account.

[12] This approximates the treatment of NPL as a separable bad output (Thanassoulis et al., [18]).

[13] Non-orientation was used because it can accommodate the simultaneous contraction of inputs and expansion of outputs.

[14] The summary statistics of the input and output data used in the NDEA exercises are described in Appendix III. The constructed risk and organisational metrics from the Principal Component Analysis is presented in Table III.2.

Table 3
Three stage network with NPL as bad output.

No.	DMU	Overall Score	Overall Rank	Stage1 Score	Stage2 Score	Stage3 Score
1	ICB	0.5481	4	0.4943	0.6292	0.5207
2	GDB	0.4123	6	0.5124	0.5912	0.1333
3	CMBCL	0.9505	1	0.8516	1	1
4	ABOC	0.2547	13	0.5528	1	0.0145
5	CCB	0.5653	2	0.7874	1	0.1985
6	CMB	0.0609	14	0.749	0.9309	0.0238
7	HUAXIA	0.0237	15	0.2254	0.3835	0.0064
8	EVERBRT	0.484	5	0.5167	0.7806	0.1548
9	ICBC	0.5497	3	0.6367	1	0.1898
10	BOC	0.3817	9	0.2978	0.6722	0.1751
11	SPD	0.3393	11	0.2947	0.4388	0.2845
12	SDB	0.3242	12	0.4244	0.4622	0.0859
13	SPAN	0.3859	8	0.9078	0.1725	1
14	BOB	0.3905	7	0.3078	0.6085	0.2282
15	CITIC	0.3446	10	0.7709	0.0084	0.2637
	Average	0.401027		0.555313	0.6452	0.28528
	Std Dev	0.219209		0.221206	0.314219	0.317234

Table 4
Network DEA incorporating risk and organisational input measures.

No.	DMU	Overall Score	Overall Rank	Stage1 Score	Stage2 Score	Stage3 Score
1	ICB	0.7376	5	0.8483	0.5372	1
2	GDB	0.5241	10	0.5278	0.6033	0.4412
3	CMBCL	0.9493	4	0.8478	1	1
4	ABOC	0.5361	8	0.6415	0.6939	0.323
5	CCB	1	1	1	1	1
6	CMB	0.1173	14	0.5949	0.6918	0.0572
7	HUAXIA	0.0356	15	0.2421	0.3993	0.0178
8	EVERBRT	0.6816	7	0.7026	0.6385	0.7281
9	ICBC	0.9535	3	0.8604	1	1
10	BOC	0.717	6	0.2869	0.9608	0.9034
11	SPD	0.4637	12	0.7772	0.2726	0.8516
12	SDB	0.4156	13	0.4486	0.4798	0.3182
13	SPAN	1	1	1	1	1
14	BOB	0.4794	11	0.454	0.4787	0.506
15	CITIC	0.5309	9	0.8296	0.0096	0.7534
	Average	0.609447	0.67078	0.651033	0.659993	
	Std Dev	0.297394	0.240191	0.302253	0.355074	

intermediate input in stage 3. As in case 1, in the first stage of the process, the primary inputs are used to produce PERS and OTHER. Deposits are a primary input in the second stage and NINT is a final output. In stage 2 INTCOST, BR, and risk organisation (RISKORG) are intermediate outputs and also inputs to stage 3.

The organisation of the risk management function acts as an intermediate input to the third stage of production in combination with branches and interest costs and the external input of risk management practice (RISKMAN). It is also an intermediate output in the second stage of production. The risk management practice measure is treated as an exogenous cultural input in the production of interest earnings in the third and final stage. It can be argued that different banks have different risk practice cultures that have evolved from their short history. State-owned banks may have a different risk practice to joint-stock banks because of their history of directed lending to state-owned enterprises. City Commercial banks may have to deal with local government pressures that impinge on lending decisions and so on. Additionally non-performing loans are produced as a bad output in the final stage. Following Thanassoulis et al. [18], the bad output is treated as an input in the final stage of production. The complete process is shown graphically in Fig. 2 below.

The difference between Figs. 1 and 2 is that RISKORG is a second stage output and a third stage input and RISKMAN is an exogenous third-stage input. The link between the second and third stages is the appropriate point of entry for the risk metric RISKORG as the organisation of the risk management function is a specialised derivative of operational costs, which measures the variable costs of the bank. The metric RISKMAN measures a culture that is externally imposed rather than internally derived.

Table 4 shows only two banks are 100% efficient overall, China Construction Bank and Shenzhen Ping An. However, ICBC and China Merchant are fully efficient in stages 2 and 3 and China Industrial is fully efficient at stage 3. It can be seen from Table 4 that the mean efficiency score is higher and the relative dispersion is lower at each stage of the production process. The inclusion of the risk management metric as a primary input in the third stage of production and the risk management practice as an intermediate output in the second stage of production and an intermediate input in the third stage of production, has improved the overall measure of relative efficiency scores by pushing all of the banks on or closer to the frontier.

The reason for this is twofold. First, the overall score is a function of the score at each stage of production and the inclusion of an extra output–input in the intermediation stage exerts an influence on the efficiency at each stage. We can see from Table 4 that efficiency has increased in each stage but most markedly in stage 3, where the output has remained the same between the two exercises but the menu of inputs has increased in the second exercise. We argue that the exclusion of the risk metrics in the third stage produces misleading measures of efficiency. It can be seen from Table 3 that the number of benchmark banks is two but from Table 4 this increases to five.

Second, the efficiency scores have increased due to the dimensionality problem in DEA. A common problem in the application of DEA is that the average efficiency score increases with the increase in inputs. The next section addresses both these issues.

5. The value-added of the risk metrics.

This section tests the hypothesis that the improvement in the efficiency measure from the inclusion of the risk metrics in the network DEA is significant and has systematic value. Pastor et al. [13] suggest a statistical test to evaluate the marginal role of an additional input (or output) in the production process as in a nested DEA model[15]. Since the DEA model applied in Table 3 is nested within the DEA model applied in Table 4, Pastor et al. [13] show that the ratio of the scores from the nested DEA to the full model represents the 'efficiency contribution measure' of additional inputs. We define a given marginal improvement in efficiency from the addition of the risk management practice and risk management organisation inputs as $\overline{\theta}$. This is the hypothesised increase in efficiency arising from the utilisation of the two risk metrics as inputs in intermediate stage of production. The actual efficiency gains is defined as $\tilde{\theta}_i$ for the $i=1\ldots15$ banks (ratio of efficiency score from case 2 to case 1). The marginal impact of the two risk metrics can be evaluated as;

$$p[\tilde{\theta}_i > \overline{\theta}] > p_0 \tag{9}$$

Eq. (9) is the probability that the actual gain in efficiency is greater than the hypothesised gain in efficiency. For a given probabilityp_0, the test is a conventional binomial where Tao (Γ_i)

[15] See also Pastor et al. [14].

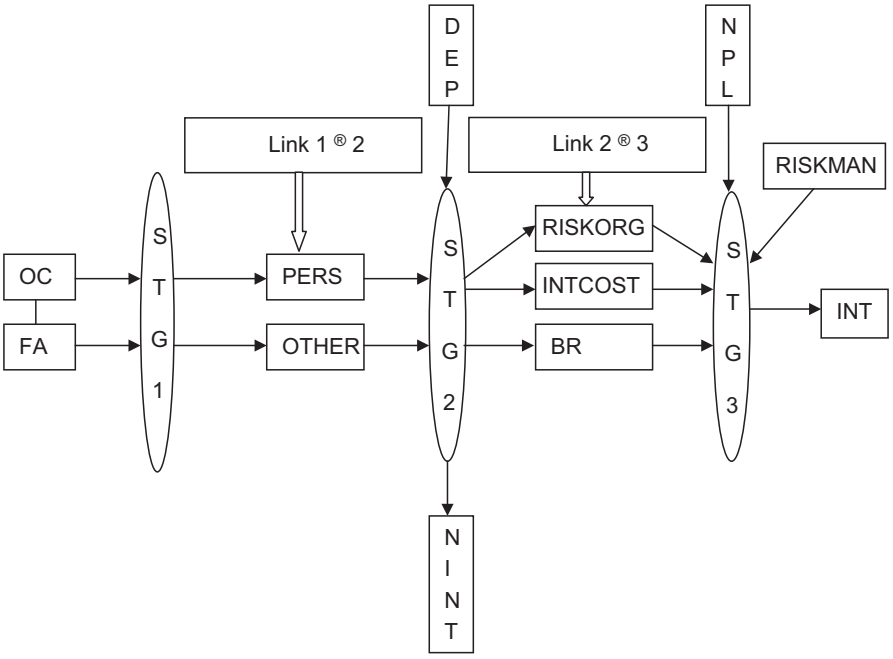

Fig. 2

Table 5
Efficiency contribution measure.

Tao(Γi)	$\overline{\theta}=10\%$	$\overline{\theta}=20\%$	$\overline{\theta}=25\%$	$\overline{\theta}=26\%$
1	14	13	12	10
0	1	2	3	5
p value	.000977***	.00739***	.0352**	.302

** Significant at the 5%.
*** Significant at the 1%.

is given by expression (10);

$$\Gamma_i = \begin{cases} 1, \cdots \text{if } \tilde{\theta}_i > \overline{\theta} \\ 0 \cdots \text{otherwise} \end{cases} i = 1,2, \cdots 15 \tag{10}$$

Table 5 shows the results of implementing the efficiency contribution test. Column 2 of Table 5 shows that 14 banks that have a 10% gain in efficiency as a result of the inclusion of the two risk metrics. Row three of the table is the '*p*' value which indicates that the gain in efficiency is not random. Column 3 shows the number of banks that have a 20% efficiency improvement and column 4 shows the number of banks that have a 25% efficiency improvement. Only at a 26% efficiency gain can we not reject a random improvement. The Table shows that evaluating the efficiency contribution at various levels of efficiency gain, the contribution of the risk metrics is in the region 20–25% at the conventional level of significance.

A further indication of the value-added is obtained by comparing the overall score from Tables 3 and 4 with ROA for significance of association. The simple and Spearman's rank correlation is shown in Table 6. For purposes of comparison a standard DEA score is correlated with ROA.

The results from Table 6 can only be interpreted as indicative. However, as an indicator it is clear that the DEA score obtained from the inclusion of the risk practice and risk organisation functions of the bank have a closer association with the objective measure of performance. The importance of the exercise is that the manager has an indication of the areas improvement can be made by examining the ranking in each stage of production.

Table 6
Correlation of DEA score with ROA; *p* values in parenthesis.

	Standard DEA score	Network DEA excluding risk indices	Network DEA including risk indices
Correlation coefficient	.5444 (.0359)**	.6638 (.0070)***	.6867 (.0047)***
Spearman's rank correlation	.4257 (.1136)	.6643 (.0069)***	.7080 (.0031)***

** Significant at the 5%.
*** Significant at the1%.

6. Conclusion

This paper has demonstrated an innovative application of utilising qualitative data in the efficiency evaluation of firms operating in the same market. Specifically we have constructed an index of risk management practice and risk organisational practice for a sample of Chinese banks from qualitative information. Risk management practice and risk organisational practice was confined to the classic retail banking functions. The metrics were constructed from scores provided by risk managers in domestic Chinese banks in responses to a semi-structured questionnaire. Scores on a Likert scale of 1–5 were translated into an index of practice from an asymmetric function that penalised downside deviations from best-practice more than up-side deviations. Best practice was defined from the interviews of four managers from two foreign banks operating in China. An aggregate score was constructed using principal components analysis.

The metrics of risk management practice and risk management organisation obtained from questionnaire analysis may be used as a measure of performance however, organisation of the risk function is a management function and the risk management practice can be thought of as part of a culture of loan approval determined by a mixture of political as well as commercial interest. The organisation of the risk function metric can therefore be thought of as an internal intermediate input along with risk management practice as an external input, to produce interest earnings (as well as non-performing loans). The risk organisation

and risk management metrics are a link in the production chain of revenue streams in Chinese banking.

We found no significant direct relationship between the two constructed measures of risk management practice and risk management organisation and an objective measure of performance of the bank such as ROA. However, the input of these measures within a DEA network framework produced efficiency scores that explained ROA better than efficiency scores that excluded them. We have addressed the dimensionality problem in DEA and demonstrated that the improvement in average efficiency as a result of using the two risk measures as intermediate inputs is a valid exercise. We argue that the information content of the risk management practice and risk management organisation measures is indirect and is better revealed within a network DEA framework.

The risk management practice and risk management organisational metrics constructed from interviews provide insight into the risk function in Chinese banks relative to best practice. The link between the two measures of risk management and that of bank revenue efficiency works only if the results from the qualitative analysis are representative of the organisation as a whole. There is no reason to believe that this is not the case. But, it is the combination of the risk practice and risk organisation with the other inputs and outputs of the banks that matter for final performance. Provided that the results from the interviews of risk managers for each bank are representative of broad practice nationwide, the metrics can be used as inputs in the intermediate stage of production.

Appendix A. Supplementary Information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.omega.2012.06.003.

References

[1] Berger AN, De Young R. Problem loans and cost efficiency in commercial banks. Journal of Banking and Finance 1997;21:849–870.
[2] Chen Y, Zhu J. Measuring information technology's indirect impact on firm's performance'. Information Technology and Management Journal 2004;5(1-2):9–22.
[3] Chen Y, Liang L, Zhu J. Equivalence in two-stage DEA approaches. European Journal of Operational Research 2009;193:600–604.
[4] Cook WD, Liang L, Zhu J. Measuring performance of two-stage network structures by DEA: A review and future perspective. Omega 2010;38(6):423–430.
[5] Drake L. Costs and efficiency in banking: a survey of the evidence from the US, the UK and Japan. In: Mullineaux AW, Murinde V, editors. Handbook of international banking. Cheltenham: Edward Elgar; 2003.
[6] Färe R, Grosskopf S. Network DEA. Socio-Economic Planning Sciences 2000;34:35–49.
[7] Hamid J, Tenev S. Transforming China's banks: the IFC experience. Journal of Contemporary China 2008;17(56):449–468.
[8] Hannan TH, Hanweck GA. Bank insolvency risk and the market for large certificates of deposits. Journal of Money, Credit and Banking 1988;20(2) 203–211.
[9] Hua Z, Bian Y. Performance measurement for network DEA with undesirable factors. International Journal of Management and Decision Making 2008;9(2) 141–153.
[10] Kao C, Hwang S-N. Efficiency decomposition in two-stage data envelope analysis: an application to non-life insurance companies in Taiwan. European Journal of Operational Research 2008;185(1):418–429.
[11] Kolenikov S, Angeles G. Socioeconomic status measurement with discrete proxy variables: is principal component analysis a reliable answer? Review of Income and Wealth 2009;55(1):128–165.
[12] Ochieng Owuor C, Zumbo BD. 'Implications of ordinal scale categorization on regression models under different distributions and conditions' Paper presented to the National Council on Measurement in Education, Seattle; 12 April, 2001.
[13] Pastor J, Ruiz J, Sirvent I. A statistical test for nested radial DEA models. Operations Research 2002;50(4):728–735.
[14] Pastor J, Ruiz J, Sirvent I. A statistical test for detecting influential observations in DEA. European Journal of Operational Research 1999;115:542–554.
[15] Sealey CW, Lindley JT. Inputs, outputs and the theory of production and costs at depository financial institutions. Journal of Finance 1977;32(4):1251–1265.
[16] Sinkey JF. Commercial bank financial management. 6th ed.Prentice Hall; 2002.
[17] Surico P. Measuring time inconsistency of US monetary policy. Economica 2008;75:22–38.
[18] Thanassoulis E, Portela M, Despić O. Data envelope analysis: the mathematical programming approach to efficiency analysis'. In: Fried H, Knox-Lovell CA, Schmidt S, editors. The measurement of productive efficiency and productivity growth. Oxford: Oxford University Press; 2008.
[19] Tone K, Tsutsui M. Network DEA: a slacks-based measure approach. European Journal of Operational Research 2009;197:243–252.
[20] Yang L, Kuhn RL. China's Banking and financial markets: the internal research report of the Chinese government. John Wiley and Sons (Asia); 2007.