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

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A B S T R A C T
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.

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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 equals1. 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 mis-alignment 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 disclosure2.

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.

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, 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 independent SOE management from the state as strength and cited government guarantees. Collateral was not an issue except in the case of SMEs. 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%.

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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

### Table 1

<table>
<thead>
<tr>
<th>Bank number</th>
<th>Mnemonic</th>
<th>Bank name</th>
<th>Number of interviewees</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ICB</td>
<td>Industrial Bank of China (Joint-stock commercial bank)</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>GDB</td>
<td>Guangdong Development Bank (Joint-stock commercial bank)</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>CMBC</td>
<td>China Merchant Bank Co Ltd (Joint-stock commercial bank)</td>
<td>2</td>
</tr>
<tr>
<td>4 (Big-4)</td>
<td>ABOC</td>
<td>Agricultural Bank of China (State-owned bank)</td>
<td>1</td>
</tr>
<tr>
<td>5 (Big-4)</td>
<td>CCB</td>
<td>China Construction Bank (State-owned bank)</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>CMIB</td>
<td>China Minsheng Bank (Joint-stock commercial bank)</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>HUXIAIX</td>
<td>Huaxia Bank (Joint-stock commercial bank)</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>EvertB</td>
<td>Everbright Bank of China (Joint-stock commercial bank)</td>
<td>2</td>
</tr>
<tr>
<td>9 (Big-4)</td>
<td>ICRC</td>
<td>Industrial and Commercial Bank of China (State-owned bank)</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>BOC</td>
<td>BOC Bank of China (State-owned bank)</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>SPD</td>
<td>Shanghai Pudong Development Bank (Joint-stock commercial bank)</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>SDR</td>
<td>Shenzhen Development Bank (Joint-stock commercial bank)</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>SPAN</td>
<td>Shenzhen Ping An Bank (City commercial bank)</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>BOB</td>
<td>Bank of Beijing (City commercial bank)</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>CITIC</td>
<td>China CITIC Bank (Joint-stock commercial bank)</td>
<td>1</td>
</tr>
</tbody>
</table>

**Foreign agencies**

<table>
<thead>
<tr>
<th>Bank number</th>
<th>Mnemonic</th>
<th>Bank name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Citi</td>
<td>Citibank (China)</td>
</tr>
<tr>
<td>2</td>
<td>HSBC</td>
<td>Hong Kong Shanghai Banking Corporation</td>
</tr>
<tr>
<td>3</td>
<td>BEA</td>
<td>Bank of East Asia (Hong Kong)</td>
</tr>
<tr>
<td>4</td>
<td>EXP</td>
<td>Experian (China)</td>
</tr>
</tbody>
</table>

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\(^3\) 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 headquarters, 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

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(footnote continued)

practice’ was defined as the ‘envelope’ (maximum) of scores of the response of the three risk managers.
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.² 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 component⁶ (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:

\[ E(\text{ROA}) + \frac{\text{CAP}}{\sigma_{\text{ROA}}} \]  

(2)

ROA is the return on assets, \( E(\text{ROA}) \) is the mean of ROA over the 5 years to 2007 for each bank, \( \text{CAP} \) is the bank's capital, \( A \) is its assets and \( \sigma_{\text{ROA}} \) 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 ratio⁸ of the bank in 2007 is -.8680. 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 (RISKCOR). 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

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² It is important to note that most mathematical operations including PCA may not be valid for Likert scaled variables being ordinal rather than scale. 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 Angles [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 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\textsuperscript{9}. The notation and description of the process follows closely that of Tone and Tsutsui [19]\textsuperscript{10}. There are n DMUs (j = 1...n) consisting of P stages (p = 1...P). Let m\textsubscript{p} and r\textsubscript{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 \( x_{p}^{j} \in R^{m_{p}} \) \( (j = 1,\ldots,n) \) \( (p = 1,\ldots,P) \) (inputs to DMU\textsubscript{j} at stage p), \( y_{p}^{j} \in R^{r_{p}} \) \( (j = 1,\ldots,n) \) \( (p = 1,\ldots,P) \) (outputs from DMU\textsubscript{j} at stage p) and \( z_{p,h}^{j} \in R^{o_{p,h}} \) \( (j = 1,\ldots,n) \) \( (p,h) \in L \) (linking intermediate outputs from stage p to stage h) where \( o_{p,h} \) 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:

\[
x_{p}^{j} \geq \sum_{j=1}^{n} x_{p}^{j} r_{j}^{p} (p = 1,\ldots,P),
\]

\[
y_{p}^{j} \leq \sum_{j=1}^{n} y_{p}^{j} r_{j}^{p} (p = 1,\ldots,P),
\]

\[
z_{p,h}^{j} = \sum_{j=1}^{n} z_{p,h}^{j} r_{j}^{p} (\psi(p,h)) \text{ as outputs from stage p},
\]

\[
z_{p,h}^{j} = \sum_{j=1}^{n} z_{p,h}^{j} r_{j}^{p} \psi(p,h) \text{ as inputs to stage h},
\]

\[
\sum_{p=1}^{P} z_{p,h}^{j} = 1(\psi(p,h)) r_{p}^{j} \geq 0 \text{ (VJP)} \] is binding in the case of VRS, where \( r_{p}^{j} \) \( = R^{p} \) is the intensity vector corresponding to stage p \( (p=1,\ldots,P) \).

Any DMU\textsubscript{o} can be represented by

\[
x_{p}^{o} = x_{p}^{o} + x_{p}^{o} \quad (p = 1,\ldots,P) \tag{3}
\]

\[
y_{p}^{o} = y_{p}^{o} - y_{p}^{o} \quad (p = 1,\ldots,P) \tag{4}
\]

\[
e_{p}^{o} = 1 \quad (p = 1,\ldots,P) \tag{5}
\]

\[
r_{p}^{o} \geq 0, s_{p}^{o} \geq 0, s_{p}^{o} \geq 0 \tag{5}
\]

where \( x_{p}^{o} = (x_{1}^{o},\ldots,x_{P}^{o}) \in R^{m_{o}}, y_{p}^{o} = Y_{1}^{o},\ldots,y_{P}^{o} \in R^{r_{o}} \).

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:

\[
z_{p,h}^{o} = \sum_{j=1}^{n} z_{p,h}^{j} \psi(p,h) \tag{6}
\]

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

\textsuperscript{9} The software DEA-Solver-PRO Version 6, www.saitech-inc.com was used.

\textsuperscript{10} An alternative exposition can be found in Hua and Biau [9].
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$^{13}$. The main product of a bank is loans from which loan interest earns 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.

$$\rho_i^e = \min \frac{\sum_{p=1}^3 w_p \left[ 1 - \frac{1}{3} \sum_{r=1}^3 \frac{y_{ir}}{x_{ir}} \right]}{\sum_{p=1}^3 w_p \left[ 1 + \frac{1}{3} \sum_{r=1}^3 \frac{y_{ir}}{x_{ir}} \right]}$$  \hspace{1cm} (7)

$^{11}$ 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.

subject to (3)–(6) and $\sum_{p=1}^3 w_p = 1$. $w_p \geq 0$ 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.

$$\rho_p = \frac{1 - (1/3)\sum_{r=1}^3 [(x_{ir} - \bar{x}_{ir})/\bar{x}_{ir}]}{1 + (1/3)\sum_{r=1}^3 [(x_{ir} - \bar{x}_{ir})/\bar{x}_{ir}]} \quad (p = 1, 2, 3)$$  \hspace{1cm} (8)

where $x_{i-p}$ and $x_{i+}$ 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 learn from CMBCL and SPAN. A number of banks are 100% efficient at stage 2, but at stage 3 only CMBC 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

$^{14}$ 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.
The complete process is shown graphically in Fig. 2 below.

Following Thanassoulis et al. [18], the organisation of the risk management function acts as 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 intermediate 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 intermediate 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.

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.

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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. 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 general marginal improvement in efficiency from the addition of the risk management practice and risk management organisation inputs as \( \theta_i \). 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 \( i = 1 \ldots 15 \) banks (ratio of efficiency score from case 2 to case 1). The marginal impact of the two risk metrics can be evaluated as:

\[
 p(\tilde{\theta}_i > \theta) > p_0
\]  

Eq. (9) is the probability that the actual gain in efficiency is greater than the hypothesised gain in efficiency. For a given probability \( p_0 \), the test is a conventional binomial where \( \text{Tao}(I_i) \)

15 See also Pastor et al. [14].
is given by expression (10);

\[
\Gamma_i = \begin{cases} 
1, \ldots, \text{if } \hat{\Psi}_i > \Psi & \text{for } i = 1, 2, \ldots, 15 \\
0, \ldots, \text{otherwise} & 
\end{cases}
\]  \hspace{1cm} (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.

**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