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A fuzzy multi-objective two-stage DEA model for evaluating the performance of US bank holding companies

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ABSTRACT

This paper investigates the association between the performance of bank holding companies (BHCs) and their intellectual capital (IC). We start from constructing an innovation ratio two-stage DEA model and then applies fuzzy multiple objective programming approaches to calculate the efficiency score. This model provides a common scale for comparing performance, increases the discriminating power, and simplifies the calculation process. The links between IC and the BHCs' performance are also investigated by means of the truncated-regression model, and a positive relationship between them is found. The decision-making matrix combined with an efficiency improvement map proposed in this study can clearly define the benchmark that can be emulated by inefficient BHCs and help BHC managers to develop appropriate strategies needed to enhance their overall efficiency.

1. Introduction

Bank holding companies (BHCs) have developed new operational styles in the banking industry, and through these approaches, most financial institutions can be improved in terms of scale economies and achieve company synergy. While there are several reasons for the rapid increase in the number of BHCs, the primary one is that compared with banking firms, BHCs have easier access to capital markets and greater levels of debt capital. According to the Global Competitiveness Report published by the World Economic Forum, as far back as the 1990s, almost 6000 BHCs controlled banks that held over 90% of the industry assets. In 2002, approximately 6300 banks were affiliated with BHCs. In 2009, a total of 5635 top-tier US BHCs were in operation, controlling 6710 insured commercial banks and holding approximately 88.5 percent of all insured commercial bank assets in the US. The establishment of BHCs has increased diversity in the expanding financial industry and also led to reform of the global financial system.

Despite the fact that BHCs have constituted a diversified system in the financial sector, the US economy has faced financial market turmoil in recent years. The "sub-prime mortgage crisis" in 2007 and the collapse of Lehman Brothers in 2008 resulted in a large decline in capital, bankruptcy of many banks, and the writing-off by BHCs of more assets and credit costs. The crisis, which exposed pervasive weaknesses in both financial industry regulation and global financial system regulation, has created an enormous debt burden for US financial institutions. Clearly, there is a critical need at this time for performance management tools which can improve the efficiency of BHCs and enhance their competitiveness.

In recent decades, data envelopment analysis (DEA) has been widely used as a performance measurement tool in the banking industry (Fare, Grosskopf, & Weber, 2004; Barth, Lin, Ma, Seade, & Song, 2013; Halkos & Tzeremes, 2013; Paradi, Zhu, & Edelstein, 2012). But, unfortunately, most studies have flaws on model setting. For examples, first, most of prior studies trying to capture the banks' complex production processes with the conventional DEA models, which consider the system as a single-process black box, it does not provide sufficient details to identify the specific sources of inefficiency embedded within the interacting divisions of a bank. Second, applying with traditional DEA model in banking industry, each BHC's efficiency ratio is calculated by means of its own best multipliers, which might produce a relatively large proportion of efficient DMUs, leading to weak discriminating power. Third, according to Cooper, Seiford, and Tone (2007), when the input and output variables simultaneously take the form of percentiles (e.g., EPS, ROE, ROI) and raw data (e.g., revenues, assets, employees, profits), the efficiency score will be misjudged.

To overcome aforementioned shortcomings, this study made some breakthroughs in order to improve the estimation bias caused by model misspecification. We constructed a two-stage DEA model with ratio variables to assess the efficiency of BHCs. This innovational model is able to fully reflect the operating units'

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multi-functional nature and the linkage of the two sub-processes with the whole process. Furthermore, this study also adopts Zimmermann's (1978) multi-objective linear programming approach, in which the efficiency evaluation of all DMUs is viewed as one objective function to be maximized. It provides a common scale for comparing performances and increases discriminating power in order to more accurately measure the performance of BHCs. This approach deals directly with the measurement flaws of conventional DEA models and simplifies the calculation process. Consequently, it provides a common scale for comparing performance and increases discriminating power in order to more accurately measure the performance of BHCs.

Following with the coming of knowledge economy and globalization, knowledge-intensive industries will replace the traditional labor and capital-intensive base industries and will enter the economic mainstream (Whittington, Owen-Smith, & Powell, 2009). As a result, accurately evaluate the performance for the banking industry is more important than before. No matter tangible or intangible assets, i.e., knowledge, human resources, or customer resource, is need to be value comprehensively. But, as indicated by Dedman, Mouselli, Shen, and Stark (2009), the value of intangible assets has frequently been ignored despite the fact that an entity's value is the sum of both tangible and intangible assets. In order to avoid underestimating the true value of a BHC's total assets, the impact of IC on the BHC's performance needs to be clarified. We follow Simar and Wilson's (2007) bootstrapped truncated-regression to investigate the relationship between intellectual capital (IC) and a BHC's performance. A positive relationship between them is found, and it means that IC to be significantly related to the performance of the BHCs.

In summary, our findings make several important contributions to the literature as well as contribute to the intense debate of operation efficiency in banking industry. First, improving prior researches, this study employs an innovative ratio two-stage production process model, which includes profitability and value creativity performance, to assess the efficiency of BHCs in the US bank industry. Second, the two-stage DEA model, combined with the fuzzy multi-objective programming approach, is used to investigate not only the operating performance of BHCs but also how BHCs make strategic decisions, especially regarding operational styles in an intensely competitive environment. Finally, the links between IC and a BHC's performance are investigated with a bootstrapped truncated-regression model, and found that IC has been deem as the key to increasing a bank's value, and this result is never take account in the past.

The rest of the paper is arranged as follows. The next section presents the financial ratios which are employed to construct the two-stage process model and samples, and also describes the proposed non-parametric technique. In Section 3, empirical analysis and results are presented. Lastly, Section 4 presents conclusions drawn from the results obtained and outline further research.

2. Research design

2.1. Sample description

We examined 56 listed bank holding companies (BHCs) in the US. Each BHC was treated as a decision making unit (DMU). Despite the difficulty of obtaining a homogeneous sample of banks in terms of specialization, all products and services were similar in the sample. We primarily obtained input and output data from the COMPUSTAT database and from proxy statements published in 2006 and 2007. We opted for outputs and inputs that adequately described bank operations. The descriptive statistics of all inputs and outputs are listed in Table 1. One point to be noted is that a very high mean-of-liability ratio results in the high leverage ratio. Perhaps we could through the data in this study reveal that the occurrence of financial crisis in 2008 is not accidental but already have tracks to follow.

2.2. Two-stage production process

Comparing with traditional DEA models, the production process is deemed as a black-box, where the inputs and outputs are the focus of inquiry and what goes on inside the box is typically ignored. In contrast to the black-box production technology, some production systems have a connect structure, such as when production by one division or sub-process results in an intermediate output that is an input to another sub-process. In addition, according to Favero and Papi (1995) study, there are three approaches can be used to the input and output specification, namely production approach, intermediation approach and the asset approach. Different methods are applied to different conditions, so it is essential to carefully analyze the characteristics of measurement object.

It is worth mentioning that BHCs' operation system is not as simple as commercial banks, because they are a comprehensive institution providing a variety of services for people. BHCs not only paly an intermediate role which transform and transfer financial resources from units in surplus to units in deficit, but also practice most activities consist of turning large deposits and funds purchased from other financial institutions into loans and financial investments (Favero & Papi, 1995). After considering the BHC characteristics and following prior researches (Favero & Papi, 1995; Berger and Humphrey, 1991), we adopt the intermediation approach and construct a two-stage DEA model, differ from the traditional one, to analyze the performance of BHCs. We believe that it is more appropriate to take into account the performance of the

Table 1
Descriptive statistics.

Variables	Mean	S.D	Median	Maximum	Minimum
Panel A: Inputs (X), intermediate products (Y) and outputs (Z) of the 56 BHCs in the US					
(I)X_1 Total liability ratio	0.903	0.024	0.906	0.936	0.812
(I)X_2 Total equity ratio	0.097	0.024	0.094	0.188	0.064
(I)X_3 Unit employee cost	70.004	18.194	67.026	122.212	40.002
Y_1 Profit ratio	29.511	12.647	29.935	58.390	1.150
Y_2 ROA	1.355	0.650	1.340	3.060	0.040
Y_3 ROE	14.855	7.902	15.360	37.930	0.380
(O)Z_1 B/M ratio	7.728	3.243	7.291	18.607	0.005
(O)Z_2 E/P ratio	82.511	11.421	86.070	92.480	28.290
Panel B: Ratio of IC to operating performance of the 56 BHCs in the US					
Independent variables					
HC (%)	2.977	0.672	2.869	4.885	0.764
SC (%)	1.621	0.284	1.591	2.605	1.094
RC (%)	2.047	0.737	1.932	4.500	0.531

sub-processes, and could provide more accurate information for investors to make a wise decision.

This study adapts Seiford and Zhu's (1999) two-stage transformation process framework and constructs a more accurate innovation ratio two-stage model by replacing marketability with value creativity in the second stage and by also replacing variables with a united ratio. As seen in Fig. 1, the sustainable operation process of BHCs can be decomposed into two sub-processes, namely, profitability performance and value creativity performance, so as to identify the BHCs' operation status and potential for future growth. Obviously, the performance of a BHC will be misjudged if an incorrect variable is used. Because equity is the complement of an asset, it is inappropriate to consider the two variables together. More importantly, decomposing assets into equity and liability helps companies identify the costs that cause inefficiency, and provides decision makers with a direction for improving the efficiency of their companies.

In each stage, input and output variables are chosen based on the prior researches. Financial ratios are accounting tools that allow stakeholders to review a company's performance. Different ratio categories exist for testing specific financial information. In the first stage, there are three inputs (X_1: total liability ratio; X_2: total equity ratio; X_3: unit cost of employee) from the year of 2006 to produce three outputs (Y_1: profit ratio; Y_2: return on asset (ROA); Y_3: return on equity (ROE)), which are deem as inputs to the second stage to produce two outputs, also named as intermediate variables. Both inputs and outputs are introduced in the first stage to assess the efficiency of asset usage as well as to resolve the problem of overlap between assets and equities.

Profitability performance is measured in this stage. The total liability ratio (X_1) is the ratio of total debt (the sum of current liabilities and long-term liabilities) divided by total assets, and indicates the percentage of a company's assets that are provided via debt. The total equity ratio (X_2) is the ratio of shareholders' equity divided by total assets. The Equity ratio measures the proportion of the total assets that are financed by stockholders and not creditors. A low equity ratio will produce good results for stockholders as long as the company earns a rate of return on assets that is greater than the interest rate paid to creditors. In the last input variable, unit employee cost (X_3) is calculus by personal expenses to the number of employee. Through investigate three variables to measure the efficiency on usage of assets.

In the second stage, the value creativity performance model measures a BHC's attractiveness in the stock market and its ability to continue as a going concern. This stage adopts a framework compose of three-inputs (Y_1: profit ratio; Y_2: ROA; Y_3: ROE) and two-outputs (Z_1: book-to-market equity ratio (B/M); Z_2: earnings to price ratio (E/P)) to reflect a company's future growth. The data of both inputs and outputs are all from the year of 2007. The profit margin ratios (Y_1) state how much profit the company makes for every dollar spent on each business, thus providing clues to the BHC's cost structure and production efficiency. Two other measures used in assessing earning ability are returns on assets (Y_2) and return on equity (Y_3). As a matter of fact, Y_1, Y_2 and Y_3 together play an intermediate role between the first stage and second stage; that is, the outputs of the first stage are inputs for the second stage.

In general, the whole value of a company is composed of its ability to generate profit and its attractiveness in the stock market, which reflects the company's potential for future growth. Those companies having high ratios of earnings to price (E/P), book-to-market equity (B/M), or cash flow to price (C/P) have been defined as value stocks and others as growth stocks (Fama & French, 1992). Stattman (1980) indicated that companies with high B/M equity ratios outperform those that have low B/M equity ratios. Basu (1977) also found that there is a positive relationship between a company's E/P ratio and future returns. Accordingly, the two outputs (i.e., B/M ratio and E/P ratio) in this study can properly reflect the linkage of the two variables with BHC future growth in a tighter way.

2.3. The fuzzy multi-objective two-stage model

DEA is widely used to evaluate the relative effectiveness and efficiency of operating units, especially in the banking industry, with the same organizational objectives by measuring the relationship between multiple inputs and outputs. Seiford and Zhu's (1999) two-stage model calculates the first stage, second stage, and the whole production process independently. However, Kao and Hwang (2008) asserted that it is inappropriate to calculate the two sub-processes independently since a production process is composed of a series of two sub-processes and the intermediate products play an interactive role in both processes. Agreeing with Kao's argument, we adopt the concept of the relational two-stage DEA model, together with the fuzzy multi-objective approach, to evaluate the efficiency of BHCs in the US. The mathematically sound fuzzy multi-objective two-stage DEA model reflects the complex operational phenomena in BHCs and deals directly with the drawbacks of the solution process in the conventional DEA model.

In the relational two-stage DEA model, the production process is composed of a series of two sub-processes. For any DMU$_j$($j = 1, \ldots, n$), m inputs $x_{ij}(i = 1, \ldots, m)$ are used to produce

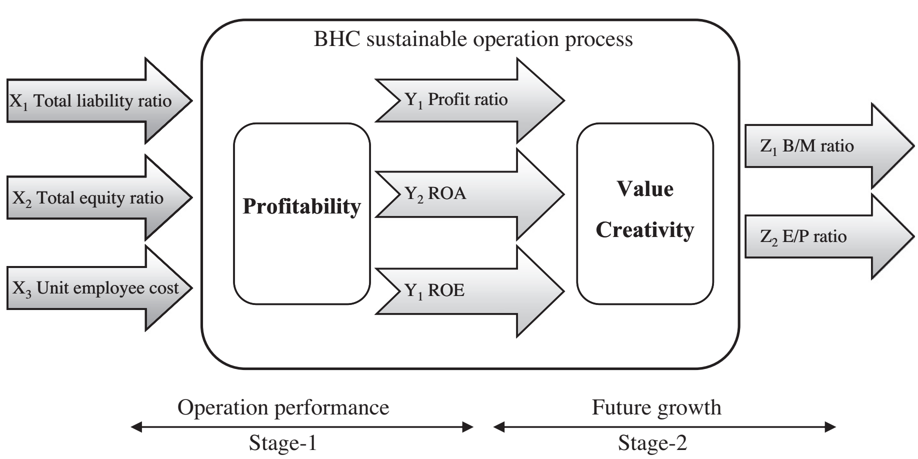

Fig. 1. Bank production process.

intermediate products $z_{pj}(p = 1,\ldots,q)$ in the first process and are then consumed in the second process to generate outputs y_{rj} $(r = 1,\ldots,s)$. For this study, we transformed the relational two-stage DEA model into the multiple objectives network DEA model, called Model (1):

$$
\begin{aligned}
&\theta_1 = \max \frac{\sum_{r=1}^{s} u_r y_{r1}}{\sum_{i=1}^{m} v_i x_{i1}}\\
&\theta_2 = \max \frac{\sum_{r=1}^{s} u_r y_{r2}}{\sum_{i=1}^{m} v_i x_{i2}}\\
&\vdots\\
&\theta_n = \max \frac{\sum_{r=1}^{s} u_r y_{rn}}{\sum_{i=1}^{m} v_i x_{in}}\\
&\text{s.t. } \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leqslant 1, \quad j = 1,\ldots,n\\
&\frac{\sum_{p=1}^{q} \eta_p z_{pj}}{\sum_{i=1}^{m} v_i x_{ij}} \leqslant 1 \quad j = 1,\ldots,n\\
&\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{p=1}^{q} \eta_p z_{pj}} \leqslant 1, \quad j = 1,\ldots,n\\
&u_r, \eta_p, v_i \geqslant \varepsilon > 0 \quad r = 1,\ldots,s; \quad i = 1,\ldots,m; \quad p = 1,\ldots,q
\end{aligned}
\tag{1}
$$

We adopt Zimmermann's (1978) fuzzy approach to determine the solution of Model (1). In this way, we solve multi-objective problems, provide an efficient solution, and acquire less additional prior or extraneous information than other approaches do. In addition, for each DMU, the single objective network DEA may have fuzzy goals. In the maximization problem for each single objective function, the fuzzy goal stated by the decision maker may be to achieve "an objective function θ_k that is substantially larger than or equal to some value of p" and can be quantified by the corresponding membership function.

The fuzzy approach utilizes the membership function to transform multi-objective programming into one objective programming. By the means of the membership function, each DMU expresses its degree of achievement with respect to the value of its objective function. Therefore, the related membership function is defined as:

$$
f_j(\theta_j) = \begin{cases} 0 & \text{if} \quad \theta_j \leqslant \theta_j^l \\ \frac{\theta_j - \theta_j^l}{\theta_j^u - \theta_j^l} & \text{if} \quad \theta_j^l \leqslant \theta_j \leqslant \theta_j^u \\ 1 & \text{if} \quad \theta_j \geqslant \theta_j^u \end{cases}
\tag{2}
$$

where θ_j is the efficiency value of Model (1), and θ_j^u and θ_j^l denote the maximum and minimum of the objective functions, respectively. $f_j(\theta_j)$ is the membership function of θ_j, which refers to the level of achievement of the efficiency ratio for the DMU$_j$. Since the efficiency ratio of the objective functions in Model (1) is between 0 and 1, the degree of the membership function will also be located within this interval. Based on transformation of the membership function, $f_j(\theta_j) = 1$ is defined the highest achievement and $f_j(\theta_j) = 0$ as the lowest. It is well known that the best approach to solving the conjunction of a fuzzy set is to maximize the minimum of the membership functions, which can be expressed as Model (3):

$$
\max_{u,v,\eta} \quad \min_{j}^{n} f_j(\theta_j)
\tag{3}
$$

Therefore, Model (1) can be rewritten as max–min form, shown below as Model (4):

$$
\begin{aligned}
&\max_{u,v,\eta} \quad \min_{j}^{n} f_j(\theta_j)\\
&\text{s.t. } \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \quad j = 1,\ldots,n\\
&\frac{\sum_{p=1}^{q} \eta_p z_{pj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \quad j = 1,\ldots,n\\
&\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{p=1}^{q} \eta_p z_{pj}} \leq 1, \quad j = 1,\ldots,n\\
&u_r, \eta_p, v_i \geq \varepsilon > 0, \quad r = 1,\ldots,s; \quad i = 1,\ldots,m; \quad p = 1,\ldots,q
\end{aligned}
\tag{4}
$$

Since $\theta_j \in [0,1]$ for any DMU, the membership function of Model (4) can be simplified as $f_j(\theta_j) = \theta_j$. Then, by introducing an auxiliary variable λ, we obtain the equivalent Model (5):

$$
\begin{aligned}
&\max_{u,v,\eta} \lambda\\
&\text{s.t. } \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \quad j = 1,\ldots,n\\
&\frac{\sum_{p=1}^{q} \eta_p z_{pj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \quad j = 1,\ldots,n\\
&\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{p=1}^{q} \eta_p z_{pj}} \leq 1, \quad j = 1,\ldots,n\\
&\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \geq \lambda, \quad j = 1,\ldots,n\\
&u_r, \eta_p, v_i \geq \varepsilon > 0, \quad r = 1,\ldots,s; \quad i = 1,\ldots,m; \quad p = 1,\ldots,q
\end{aligned}
\tag{5}
$$

Through simple transformation, Model (5) can be rewritten as the following equivalent conventional mathematical programming problem:

$$
\begin{aligned}
&\max_{u,v,\eta} \lambda\\
&\text{s.t. } \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \quad j = 1,\ldots,n\\
&\sum_{p=1}^{q} \eta_p z_{pj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \quad j = 1,\ldots,n\\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{p=1}^{q} \eta_p z_{pj} \leq 0, \quad j = 1,\ldots,n\\
&\sum_{r=1}^{s} u_r y_{rj} - \lambda \sum_{i=1}^{m} v_i x_{ij} \geq 0 \quad j = 1,\ldots,n\\
&u_r, \eta_p, v_i \geq \varepsilon > 0, \quad r = 1,\ldots,s; \quad i = 1,\ldots,m; \quad p = 1,\ldots,q
\end{aligned}
\tag{6}
$$

The bisection method (Sakawa & Yumine, 1983) can be applied to solve the nonlinear programming problem of Model (6) and find the common multipliers (u_r^*, η_p^*, v_i^*) needed to calculate the efficiency score of each DMU. The efficiency can be measured by model (7):

$$
\theta_j^F = \frac{\sum_{r=1}^{s} u_r^* y_{rj}}{\sum_{i=1}^{m} v_i^* x_{ij}} = \frac{\sum_{p=1}^{q} \eta_p^* z_{pj}}{\sum_{i=1}^{m} v_i^* x_{ij}} \times \frac{\sum_{r=1}^{s} u_r^* y_{rj}}{\sum_{p=1}^{q} \eta_p^* z_{pj}} = \theta_j^{F1} \times \theta_j^{F2}
\tag{7}
$$

where θ_j^F, θ_j^{F1} and θ_j^{F2} of Model (7) represent the overall efficiency and corresponding process efficiencies calculated using the fuzzy multi-objective two-stage approach. Consequently, the fuzzy multi-objective two-stage DEA model provides a common scale for comparing performance, while increasing the discriminating power and simplifying the calculation process.

2.4. Truncated regression

Instead of applying Tobit regression to investigate exogenous factors that affect a BHC's performance, we use truncated regression:

$$\theta_j^F = \alpha + Z_j\delta + \varepsilon_j, \quad j = 1, \ldots, n \tag{8}$$

In Eq. (8), α is the intercept, ε_j is the residual value and Z_j is a vector of observation-specific variables for banks that we expect it is related to the banks overall efficiency score which is proxy by θ_j^F. Since the distribution of ε_j is restricted by the condition $\varepsilon_j \geqslant 1 - \alpha - Z_j\ \delta$, Eq. (8) is modified to get Eq. (9), which assumes that the distribution before truncation is truncated with zero mean, unknown variance and a truncation point, which are determined by different conditions:

$$\begin{aligned} &\widehat{\theta}_j^F \approx \alpha + Z_j\delta + \varepsilon_j, \quad j = 1, \ldots, n \\ &\text{where} \\ &\varepsilon_j : N(0, \sigma_\varepsilon^2), \text{ such that } \varepsilon_j \geq 1 - \alpha - Z_j\delta, \quad j = 1, \ldots, n. \end{aligned} \tag{9}$$

The regression process of parametric bootstrapping is used to construct the bootstrap confidence intervals for the estimates of parameters $(\delta, \sigma_\varepsilon^2)$, and to estimate Eq. (9) by maximizing the corresponding likelihood function, and give heed to the $(\delta, \sigma_\varepsilon^2)$.

3. Research analysis and results

3.1. Measuring profitability and value creativity performance

The two-stage DEA-based evaluation model, together with the fuzzy multi-objective programming approach, will be used here to assess the BHCs' performance. Table 2 shows the efficiency score of the two sub-processes (θ_j^{F1} and θ_j^{F2}) and the efficiency of the whole process (θ_j^F); the last row shows the mean of all the BHCs' measures. The mean of θ_j^{F1} is greater than that of θ_j^{F2}, and the overall efficiency is not 1. The overall efficiency does not reach 1 due to the inefficiency embedded in one of the two sub-processes. On the whole, these US BHCs are relatively efficient in terms of profit making, but they need to recheck their policies of further growth in order to increase the efficiency of value creativity. In this way, sustainable development can be put into practice.

Obviously, none of the BHCs achieves optimal efficiency in both sub-processes, and their overall efficiency does not reach 1. To find out the reason for the overall inefficiency and provide some useful information for managers, we analyzed the efficiency scores of 9 BHCs. We found that they applied and transformed resources effectively enough to achieve a maximum performance outcome in stage one or stage two, respectively, but were not located on the efficient frontier in terms of overall efficiency. In stage 1 (θ_j^{F1}), five BHCs performed efficiently, but their efficiency in the second stage was relatively poorer than that of their counterparts. The other four BHCs, i.e., NY Community Bancorp, the Bank of Hawaii Corporation, Westamerica Bancorp and First South Bancorp, performed efficiently in stage 2 (θ_j^{F2}), but not in the first stage. The results imply that the reason for the overall inefficiency was inefficiency embedded in one of the two sub-processes.

The above findings demonstrate that the fuzzy multi-objective two-stage DEA model is capable of opening the black-box in order to identify the causes of inefficiency, and that it provides a common scale for comparing performance, thereby potentially increasing discriminating power and yielding greater managerial insights into the performance of BHCs so that further improvements can be made.

3.2. Relationship between IC and performance variations

We adopt three variables (i.e., human capital, structural capital and relational capital) and truncate regression in order to explore the relationship between intellectual capital and BHC performance. We estimate the following truncated-regression model:

$$\theta_j^F = \alpha + \beta_1 \mathrm{HC}_i + \beta_2 \mathrm{SC}_i + \beta_3 \mathrm{RC}_i + \varepsilon_i, \tag{7}$$

where θ_j^F is the empirical result of the operating performance from the fuzzy multi-objective two-stage model.

HC is human capital, which is the sum of the individual capabilities, knowledge, skill and experience of an organization's employees and managers (Edvinsson & Malone, 1997). Thus, we use the ratio of operating income to the number of employees as the human capital proxy to measure the contribution an employee makes to operating income, so as to assess a bank's efficiency based on human capital use. SC is structure capital, which is composed of a bank's patents, copyrights, trademarks, and management philosophy and infrastructure assets. Structure capital arises from a bank's processes and organizational value; thus, it reflects the external and internal focuses of the company, plus renewal and development value in the future (Edvinsson & Malone, 1997; Petty & Guthrie, 2000). We use the ratio of operating income to administrative expense as the structural capital proxy to measure how much administrative expense is incurred to create operating income. RC is relationship capital. Bontis (1998) proposed that customer capital represents the potential an organization has due to ex-bank intangibles. The main customer of a BHC is the general populace; therefore, developing relationships with new customers and solidifying relationships with old customers are important objectives. Interest income and expenses may represent the relationship between a customer and a bank, so we use the net interest income to operating income ratio as the proxy variable of RC to assess a bank's ability to maintain customer relationships. Gujarati (1995) suggested that multicollinearity is unlikely to be problematic if the VIFs are below 10.0. For the regression estimate used in this study, all of the VIFs fall below 10.0, and the results remain qualitatively unchanged.

The results of truncated-regression model analysis are displayed in Table 3. All of the independent variables are significantly related to the BHCs' operating performance. It is evident that all of the variables are consistent with the prediction that they have a positive effect on a BHC's performance. HC allows managers to see where all these investments are paying off in the short term. Thus, a BHC's managers must do all they can to retain their "good" employees before they can turn human capital into value creation. SC reflects the external and internal foci of a BHC, forcing it to create the highest value-add capabilities possible and compelling differentiation in order to maximize profits. RC can force a BHC to focus its strategies and management attention on what customers need, not only to achieve financial success in the short run but also to help the BHC weather storms in the long run. Our findings can serve as a guide for the financial service industry and assist it in increasing operating efficiency. The suggestions can give managers invaluable new insights, at relatively low cost in terms of financial expenditure and effort, so that they can compete effectively.

3.3. Managerial conceptual map

By combining the efficiency results of the two sub-processes, this study constructed a decision-making matrix, in which the

Table 2
Efficiency results of the 56 BHC in the US.

Bank name	Code	Two-stage model			Bank name	Code	Two-stage model		
		θ_j^F	θ_j^{F1}	θ_j^{F2}			θ_j^F	θ_j^{F1}	θ_j^{F2}
BANK AMERICA CORP.	BAC	0.516	0.945	0.546	FIRSTMERIT CORP.	FC	0.553	0.928	0.596
CITIGROUP INC.	CI-1	0.035	0.677	0.051	STERLING FINANCIAL CORP.	SFC	0.497	1	0.497
JP MORGAN & CO.	JPM&C	0.541	0.975	0.555	UCBH HOLDINGS, INC	UI	0.744	0.939	0.792
WACHOVIA CORP.	WC	0.46	0.963	0.478	UMB FINANCIAL CORP.	UFC	0.352	0.849	0.414
WELLS FARGO & CO.	WF&C	0.66	0.947	0.697	BANK OF HAWAII CORP.	BHC	0.971	0.971	1
SUNTRUST BANKS, INC.	SBI	0.456	0.939	0.485	CATHAY GENERAL BANCORP, INC.	CGBI	0.96	0.992	0.968
NATIONAL CITY CORP.	NCC	0.089	0.743	0.119	TRUSTMARK CORP.	TC	0.603	0.92	0.656
REGIONS FINANCIAL CORP.	RFC	0.47	0.992	0.474	OLD NATIONAL BANCORP	ONB	0.414	0.94	0.441
FIFTH THIRD BANCORP.	FTB	0.486	0.949	0.512	FIRST MIDWEST BANCORP, INC	FMBI	0.513	0.889	0.578
KEY CORP.	KC	0.429	0.976	0.44	CHITTENDEN CORP.	CC	0.67	0.915	0.732
STATE STREET CORP.	SSC	0.462	0.896	0.515	CENTRAL PACIFIC FINANCIAL CORP.	CPFC	0.516	1	0.516
COMERICA INCORP.	CI-2	0.575	0.963	0.597	PACIFIC CAPITAL BANCORP	PCB	0.669	0.985	0.679
UNIONBANCAL CORP.	UC	0.58	0.964	0.602	PROVIDENT BANKSHARES CORP.	PBC	0.225	0.858	0.262
ZIONS BANCORP.	ZB	0.526	0.983	0.536	CVB FINANCIAL CORP	CFC	0.721	1	0.721
HUNTINGTON BANCSHARES,INC.	HBI	0.019	0.307	0.06	AMCORE FINANCIAL, INC.	AFI-1	0.285	0.851	0.336
NY COMMUNITY BANCORP, INC.	NYCBI	0.903	0.903	1	COMMUNITY BANK SYSTEM, INC.	CBSI	0.398	0.952	0.418
COLONIAL BANCGROUP, INC.	CBI	0.459	0.953	0.482	WESTAMERICA BANCORP.	WB	0.906	0.906	1
ASSOCIATED BANC-CORP.	ABC	0.715	0.961	0.744	INDEPENDENT BANK CORP.	IBC	0.491	0.929	0.529
BOK FINANCIAL CORP.	BFC	0.588	0.917	0.642	TOMPKINS FINANCIAL CORP	TFC-2	0.562	0.934	0.601
WEBSTER FINANCIAL CORP.	WFC	0.338	0.895	0.377	DEARBORN BANCORP INC	DBI	0.249	1	0.249
CITY NATIONAL CORP.	CNC	0.694	0.948	0.732	ENTERPRISE FINANCIAL SERVICES	EFS	0.542	0.901	0.602
SOUTH FINANCIAL GROUP, INC.	SFGI	0.351	0.931	0.377	FIRST M & F CORP.	FM&FC	0.477	0.978	0.487
CULLEN/FROST BANKERS, INC.	C/FBI	0.72	0.96	0.75	AMERISERV FINANCIAL, INC	AFI-2	0.167	0.871	0.191
FULTON FINANCIAL CORP.	FFC	0.565	0.965	0.586	ENTERPRISE BANCORP INC	EBI	0.5	0.982	0.509
VALLEY NATIONAL BANCORP.	VNB	0.726	0.925	0.785	LINCOLN BANCORP	LB	0.079	0.616	0.129
TCF FINANCIAL CORP.	TFC-1	0.85	1	0.85	EVERGREENBANCORP, INC.	EI	0.207	0.839	0.247
NEWALLIANCE BANCSHARES INC.	NBI	0.323	0.512	0.63	BANK OF NEW YORK MELLON CORP.	BNYMC	0.497	0.922	0.539
WHITNEY HOLDING CORP.	WHC	0.663	0.971	0.682	FIRST SOUTH BANCORP INC	FSBI	0.949	0.949	1
					Average		**0.516**	**0.909**	**0.553**

θ_j^F is the overall efficiency.
θ_j^{F1} is the efficiency score obtained from the two-stage model at the first stage of profitability.
θ_j^{F2} is the efficiency score obtained from the two-stage model at the second stage of value creativity.

Table 3
Results of truncate-regression models. $\theta_j^F = \alpha + \beta_1 \mathrm{HC}_i + \beta_2 \mathrm{SC}_i + \beta_3 \mathrm{RC}_i$.

Variables	Coefficient	Std. Error	Z-statistic	P-value
INTERCEPT	−6.0790	1.1688	−5.20087	0.0000
HC	0.0741*	0.0511	1.45024	0.0735
SC	5.2729***	1.6344	3.22630	0.0006
RC	0.5826**	0.1994	2.92124	0.0017
R^2	0.17			

θ_j^F is the overall efficiency.
* indicate that the significance level of the p-value $\leqslant 0.1$.
** indicate that the significance level of the p-value $\leqslant 0.05$.
*** indicate that the significance level of the p-value $\leqslant 0.01$.

vertical axis represents the efficiency of profitability (θ_j^{F1}) and the horizontal axis represents the efficiency of value creativity (θ_j^{F2}). Furthermore, we assigned each of the BHCs to one of the four zones, based on the scores calculated using the two-stage DEA model in order to identify the relative positions of the BHCs so that managers can understand their relative competitiveness. For example, the BHCs located in the first zone have the best performance, that is, effective resource utilization, excellent managerial efficiency and strong developmental potential for further growth. With the decision-making matrix proposed in this study, we can clearly define the benchmark to be emulated by inefficient BHCs and help BHC managers to develop appropriate strategies for enhancing their overall efficiency.

The aim of efficiency measurement is to detect the weak areas of an organization so that appropriate effort can be devoted to improving performance. In addition, most entrepreneurs and banks have had little or no understanding of the importance of IC or of the IC management techniques and strategies needed to achieve a competitive advantage and greater earnings. We apply the decision-making matrix, combined with the concepts of IC, to construct a conceptual map which can be used to improve managerial efficiency. No matter which zone a BHC is located in, its managers can effectively use this map to make the strategic decisions needed to improve efficiency. Below, we describe the characteristics of BHCs located in each of the four zones.

Zone I: eight of the BHCs were located in zone 1 because they achieved outstanding managerial efficiency and exhibited better efficiency than the BHCS in the other zones. The most important tasks for these 8 BHCs in order to keep their leading positions in the industry are to maintain their relationships with customers and to dedicate themselves to Corporate Social Responsibility (CSR). Customer satisfaction is the key to maintaining good relationships with customers. In addition, a BHC's reputation is an important asset which it can leverage to maintain its status within the industry. The companies were also assessed based not only on the financial outcome of their decisions but also on how they measured up to a boarder set of societal expectations. As a result, sustainable development will be the first and foremost business objective of these BHCs.

Zone II: twenty-one BHCs belonged to this zone because they had lower value creativity, while their profitability was relatively efficient. Therefore, it is suggested that these 21 BHCs should make use of their comparative advantages in the profitability dimension. On the other hand, they should also improve their ability to expand their business territory. The best way to take advantage of the many opportunities available to BHCs is to establish knowledge centers and embrace global collaboration. With established knowledge pools and knowledge sharing, these BHCs can further expand their development of brand value to make them irreplaceable. Then, prosperity will be just around the corner.

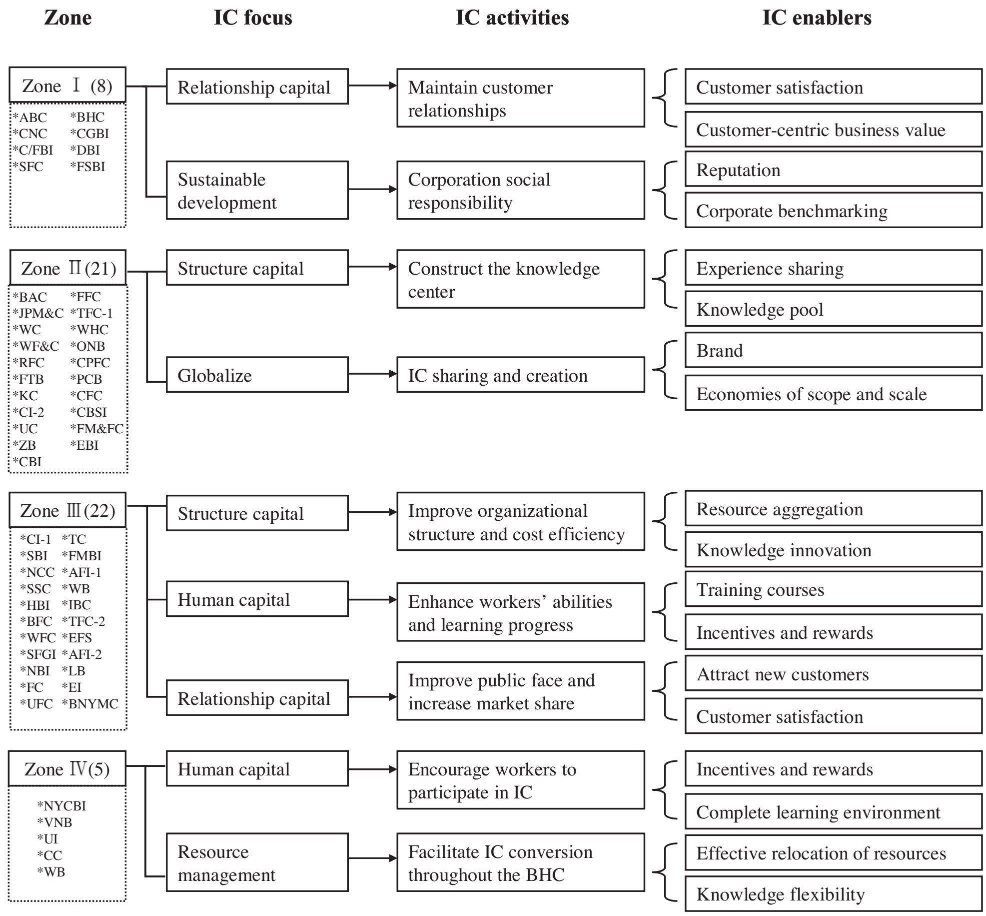

Fig. 2. Conceptual map of using IC to improve managerial efficiency.

Zone III: twenty-two of the BHCs were located in this zone is due to inefficiencies in operations or because the available resources had not been efficiently allocated, resulting in the worst performance in the two dimensions. The first priority of these BHCs should be to comprehensively review and reform themselves in order to improve both profitability and value creativity. Thus, we recommend that these BHCs begin by focusing on three dimensions of IC: improving cost efficiency and organization structure, and integrating resources. In order to increase overall efficiency, these BHCs should place more emphasis on employee training and education. Employees need to learn how to provide better services that meet current customers' needs and attract new customers, thereby improving their company's competitive advantage.

Zone IV: five BHCs belonged to this zone because they had better efficiency in value creativity, but poorer efficiency in profitability. We suggest that reforms at these BHCs begin with human resources and resource management. Encouraging workers to participate in IC and facilitating IC conversion throughout their organizations should be top priorities of these BHCs. They should also increase their pace of integration and utilize their group resources to keep their operations up-to-date; in addition, they should use the fruit of their growing competitiveness to provide a complete learning environment for their staff. Then, the efficiency of their organizations will match that of benchmarking BHCs, and they will move up to Zone 1 (See Fig. 2).

4. Conclusions

Using a sample of 56 US BHCs in 2006 and 2007, this paper analyzed the relationship between BHCs performance and IC. We focus on BHCs' current profitability and its potential for future growth. The primary reason for the analyses in this paper is that we can find from a significant number of researchers that the issue of operating efficiency in the financial industry has grown in importance in the last decade. An innovative two-stage DEA approach combined with fuzzy multi-objective programming has been used to calculate efficiency scores and to provide an easily interpretable efficiency index for benchmarking the BHCs. In addition, a bootstrapped truncated-regression model was adopted to investigate the relationship between performance and IC. Via the management decision-making matrix along with the IC map of efficiency improvement, improvements can be achieved more easily. The main finding supports our predictions that IC is significantly related to the performance of the BHCs.

Our findings make several important contributions to the literature as well as contribute to the intense debate of operation efficiency in banking industry. First, this paper improve some shortcomings in prior researches; in other words, this study employs an innovative ratio two-stage production process model, which includes profitability and value creativity performance, to assess the efficiency of BHCs in the US. bank industry. Second, the two-stage DEA model, combined with the fuzzy multi-objective programming approach can thereby increasing discriminating power and simplifying the calculation process. More important, this approach can more accurately identify sources of inefficiency in BHCs. Finally, the links between IC and a BHC's performance are investigated with a bootstrapped truncated-regression model, and found that IC has been deem as the key to increasing a bank's value, and this result is never take account in the past.

To summarize, this paper can provide some innovation viewpoints for the managers to understand the importance of IC.

Decision-making matrix not only can provide guidelines for companies to integrate IC into company's business model, but also can clearly define the benchmark that can be emulated by inefficient BHCs and help BHC managers to develop appropriate strategies needed to enhance their overall efficiency. Future research could further explore the relationship between a BHC's efficiency and IC performance in the US via Malmquist productivity change index techniques. It could avoid the results being affected by external, short-term factors. Such an approach would allow a dynamic view of the multidimensional performance of banks. Hopefully, the innovation model and the IC concept map proposed in this study will also be applied in other industries.

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