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# USING A HYBRID SYSTEMS DEA MODEL TO ANALYZE THE INFLUENCE OF AUTOMATIC BANKING SERVICE ON COMMERCIAL BANKS' EFFICIENCY

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*Abstract* This study develops a Hybrid Systems DEA model to analyze the influence of automatic service on bank performance. There are two assumptions seldom used in prior banking studies that are introduced into the DEA model. The first assumes that automatic service inputs do not change proportionally with branch service inputs. The second assumes banks that employ different operating types have different frontier technologies. The inefficiency sourced from excess inputs in automatic and branch service is evaluated through the empirical model.

Results show that the excess input in automatic service is the cause of lower efficiency in financial holding banks when compared to independent banks. On the other hand, increasing inputs in automatic services do not result in a negative impact on independent banks. The finding also indicates that the cross-learning initiatives between the two groups is effective in reducing the inefficiency caused from excess automatic service but ineffective for excess branch service.

**Keywords**: DEA, efficiency, bank, ATM, automatic service

## 1. Introduction

Since the internationalization and liberalization of global banking, the finance sector and banking industry has expanded rapidly within the past two decades. To confront this competitive environment, many bank operators and academic researchers have invested in finding ways to enhance the performance of commercial banks. As a way to increase performance, banks utilized information technology into core operations, thereby enabling business processes to be reengineered in a rapidly changing business environment [31]. Automatic banking services provided by information technology gradually replaced traditional services offered at brick and mortar locations, which effectively decreased labor costs and fixed assets [37]. Automatic teller machines (ATMs), a novelty when first introduced, are now mainstream and a daily necessity for modern citizens [21, 49]. The use of automatic banking services to reduce costs and enhance competitive advantage has become an inevitable trend for bankers [50, 76]. Meredith [44] indicated that the branch service of banking will eventually be replaced by non-branch services, while the scale of financial transactions is expected to increase.

There is great potential for automatic banking services to create customer value, such as cost and time savings, better controlled services, convenient banking options, and smart alternative solutions through information technology, etc [20, 22, 38, 45]. While automated banking services add customer value, there are also shortfalls to its usage. Users, especially the elderly, may experience trepidation at having to operate new technology, and as a result, reject outright the benefits offered by automatic services [58]. To that end, previous studies have to an extent verified that older adults show more resistance to using ATMs than those from a younger generation [21, 28, 39, 53–55, 62]. Other barriers take form in the security of transactions and privacy. With improvements in technology also comes more inventive ways for fraud and scams to occur, which naturally creates cautionary distrust in consumers [32, 48]. Nevertheless, relative to the benefits and value added to customers, the hurdles from using automated banking services have an inconsequential impact on performance.

Some major approaches to research on bank efficiency include the Stochastic Frontier Approach (SFA) and DEA. The SFA measures efficiency by estimating the production function with econometrics. However, the pattern of production functions found in the banking industry can be uncertain and assumed to be various forms, such as Cobb-Douglas, Translog, etc., by different researchers. The DEA computes an efficiency score without needing to set the functional form for the production function. In addition, DEA uses multiple outputs to evaluate efficiency that differs from the SFA model, which uses a single input.

The aim of this study is to develop a DEA model to evaluate the influence of automatic service on bank performance through the viewpoint of technical efficiency. There are two assumptions which are seldom emphasized in prior studies but are conducted in the developed DEA model.

The first assumption is that automatic service inputs do not change proportionally with branch service inputs. Most researches assess bank efficiency by assuming change to be fully proportional between input factors [60,70,73]. This implies that automatic service inputs are increased or decreased proportionally with branch service inputs. The operations of banks may not adhere to these assumptions, in which automatic service inputs and branch service inputs (i.e., counters, tellers, branches, etc) can be substituted with each other. Branch service inputs can be reduced while automatic service inputs can be increased. Therefore, the assumption that automatic service inputs change proportionally to branch service inputs is not comprehensive. In empirical evaluation, the automatic service input, which is defined as non-radial input, is assumed to not increase or decrease proportionally with other inputs which are defined as radial inputs. In addition to bank efficiencies, the inefficiency which results from excess automatic or branch service inputs can be revealed by the empirical model.

The second assumption is that banks employ different operating types and are measured with the premise that they have different frontier technologies. Many researches investigate the difference between various banking types and assume the technology set used to evaluate efficiency frontier as being single, even though banks under evaluation are characterized by different technology types, such as Chen [11], Chen and Yen [12], Isik [35], Ray and Das [51], Ariff and Can [2], Vennet [72], Yamori et al. [75], etc. Financial holding banks have advantages such as economies of scale, diversification, and cross-selling, They have the ability to target financial product sales and personal financial planning. This in turn allows them to seize market share through increased service positions and product types. Conversely, independent banks can only perform the traditional banking model due to resource limitations and regulatory restrictions. These hurdles have pushed some to merge into groups in the name of financial reform. Many independent banks aim at service quality and cost saving to enhance their competitiveness. Some researches illustrate that while a firm may employ one kind of technology, another firm may utilize a different technology, and therefore one cannot reasonably assume there to be any technology set between them [19, 67]. The empirical model of this study evaluates the efficiencies of financial holding and independent banks based on different technology sets.

This study is organized as follows: Section 2 illustrates the previous studies on banks' efficiency. Section 3 introduces the empirical model. Empirical results and analysis are described in Section 4. Finally, the conclusions are offered in Section 5.

## 2. Literature

### 2.1. Black box technology

In early studies, DEA models evaluating the operating performance of banks are treated as a black box. Performance in areas such as technical, cost, profit efficiencies, and productivity, were computed with the assumption that inputs are consumed to generate outputs, such as [1,6,9,16,25,30,43] etc.

In order to explore the sources of inefficiency, bank efficiency was decomposed into technical, scale, and allocated divisions by Miller and Noulas [46], Taylor et al. [63], and Thompson et al. [64]. Some researches attempted to look for external effects on efficiency, such as post financial deregulation [9,16], market conditions [8], asset size [17,24,36,47], and operational risks [3,10,15,29].

Differences between various operating types were also regarded as a significant external influence on bank performance. Commercial banks were categorized as public- and privately-owned types by Chen [11] and Chen and Yen [12], Isik [35] Ray and Das [51], and Ariff and Can [2]. Isik and Hassan [36] distinguished banks by domestic and foreign types. Comparisons between financial holding and independent banks were discussed by investigators. Benston [5] and Saunders and Walter [59] expressed that independent banks would be beneficial to the financial services sector from the perspective of financial system risks. Grabowski et al. [30] compared performance between financial holding companies and branch banking. Vennet [72] analyzed the difference in cost and profit efficiency between financial conglomerates and independent banks. Yamori et al. [75] verified that financial holding banks were more efficient and profitable than independent banks.

The non-radial DEA models, which considered the possibility of simultaneous input decreases as well as output increases, evaluated efficiency based on output deficits and excess input utilization. Chiu and Chen [14] and Drake et al. [23] employed a SBM model to estimate bank efficiency and explored internal influences on efficiency. Hsiao et al. [33] proposed a Fuzzy SBM model to treat inputs and outputs that were fuzzy-numbered. Hu et al. [34] analyzed human resource performance with the SBM model. Sahoo and Tone [56] used non-radial decompositions of profit change to evaluate the Indian banking sector. Sahoo and Tone [57] proposed a non-radial model to decompose capacity utilization into various components.

The DEA analysis with black-box technology only performs the efficiency for the whole process. The performance of various sub-processes and valued-added systems in production cannot be mirrored by the single indicator. In order to evaluate the performance of sub-processes and find the inefficiency resulting from individual divisions, the multi-stage and network DEA models were applied to banking industry researches.

### 2.2. Network technology

Black-box technology investigated influences on inefficiency through internal and external factors. In order to analyze the performance of sub-processes in production and the source of inefficiency, some studies structurally decomposed overall efficiency into components.

Researchers applied the framework of a value-added chain in order to analyze the performance of banks and evaluated multiple performance indicators through DEA models.

Manandhar and Tang [42] considered that the dimensions of a bank's performance included internal service quality, operating efficiency, and profitability. Seiford and Zhu [61] and Luo [41] examined the performance of banks via a two-stage process that separated profitability and marketability. Lo and Lu [40] explored the influence of operating size on a bank's profitability and marketability. Chen and Zhu [13] measured information technology's indirect impact on bank performance through the two-stage frame.

The multiple stages framework further extends to a network form, in which stages in the production process are separated into various divisions. Network DEA technology provides more information through sub-processes, or divisional efficiency measures. Cook et al. [18] evaluated the performance of Canadian banks by using a multi-component efficiency model to distinguish between sales and service divisions. Wu et al. [74] applied a neural network DEA to examine the relative efficiency of Canadian banks. Avkiran [4] used a slacks-based network DEA to identify the specific sources of inefficiency of commercial banks. Fukuyama and Weber [26, 27] also used the network DEA models to estimate inefficiency in the Japanese banking industry and introduced the undesirable output (i.e., nonperforming loans) into methodology.

## 3. Methodology and Data

### Systems DEA model

Suppose there is a $J$ dimension DMU set denoted as $j$ and $DMU_j \in J$. The input and output denote $x \in R_+^M$ and $y \in R_+^R$, respectively. The production technology is defined as $T\{(x, y) : \sum_{j=1}^{J} \lambda_j x_{mj} \leq x_m,\ m = 1, \ldots, M,\ \sum_{j=1}^{J} \lambda_j y_{rj} \geq y_r,\ r = 1, \ldots, R,\ \lambda_j \geq 0\}$, where $\lambda_j \in R^J$ is a nonnegative intensity variable and indicates the extent to which DMUs act as an efficient reference set for a particular DMU under evaluation. Some constraints can be imposed on $\lambda_j$, such as $\sum_{j=1}^{J} \lambda_j = 1$ (the BCC model), if it is needed to modify the assumption of returns to scale for production technology. Tone [65] proposed a method, named the systems model, in which the technology set consists of two systems. Let the $J\ (= J_A + J_B)$ dimension set of DMUs in two systems be $A = \{a_j, j = 1, \ldots, J_A\}$ and $B = \{b_j, j = 1, \ldots, J_B\}$. The technology sets of system $A$ and $B$ are respectively defined as:

$$
\begin{aligned}
T_A\{(x, y) : \quad & \sum_{j \in J_A} \lambda_j^A x_{mj} \leq x_m,\ m = 1, \ldots, M, \\
& \sum_{j \in J_A} \lambda_j^A y_{rj} \geq y_r,\ r = 1, \ldots, R,\ \lambda_j^A \geq 0\}
\end{aligned}
\tag{3.1}
$$

and

$$
\begin{aligned}
T_B\{(x, y) : \quad & \sum_{j \in J_B} \lambda_j^B x_{mj} \leq x_m,\ m = 1, \ldots, M, \\
& \sum_{j \in J_B} \lambda_j^B y_{rj} \geq y_r,\ r = 1, \ldots, R,\ \lambda_j^B \geq 0\}.
\end{aligned}
\tag{3.2}
$$

The technology set formed by the union of two systems $(T_A \cup T_B)$, can be depicted as:

$$
\begin{aligned}
T_{sys}\{(x, y) : \quad & \sum_{j \in J_A} \lambda_j^A x_{mj} + \sum_{j \in J_B} \lambda_j^B x_{mj} \leq x_m,\ m = 1, \ldots, M, \\
& \sum_{j \in J_A} \lambda_j^A y_{rj} + \sum_{j \in J_B} \lambda_j^B y_{rj} \geq y_r,\ r = 1, \ldots, R, \\
& \lambda_j^A,\ \lambda_j^B \geq 0\}.
\end{aligned}
\tag{3.3}
$$

Let the DMU under evaluation be represented as $DMU_o$ of which its $m$th input and $r$th output respectively denote $x_{mo}$ and $y_{mo}$. The optimal objective value ($\theta^*$) can be solved through a radial programming problem with $z^A$, $z^B$ as binary variables: The mathematical expression is given in the following:

$$\begin{aligned} \min \quad & \theta \\ \text{s.t.} \quad & \sum_{j\in J_A} \lambda_j^A x_{mj} + \sum_{j\in J_B} \lambda_j^B x_{mj} \le \theta \cdot x_m,\ m = 1,\ldots,M; \\ & \sum_{j\in J_A} \lambda_j^A y_{rj} + \sum_{j\in J_B} \lambda_j^B y_{rj} \ge y_r,\ r = 1,\ldots,R; \\ & \sum_{j\in J_A} \lambda_j^A = z^A, \sum_{j\in J_B} \lambda_j^B = z^B,\ \lambda_j^A, \lambda_j^B \ge 0; \\ & z^A + z^B = 1, z^A, z^B = 0 \text{ or } 1. \end{aligned} \tag{3.4}$$

If the model assumes $z^A = 1$ and $z^B = 0$, then the optimal objective value ($\theta^A$) can be computed. If the model assumes $z^A = 0$ and $z^B = 1$, then the optimal objective value ($\theta^B$) can be computed. The input-oriented efficiency score ($E$) can then be obtained by Formula (3.5).

$$\theta^* = \min\{\theta^A, \theta^B\}. \tag{3.5}$$

When the efficiency is obtained as $\theta^* = \theta^A$, in order to achieve the best practice, the $DMU_o$ should refer to system $A$ as benchmark. When the efficiency is obtained as $\theta^* = \theta^B$, the $DMU_o$ should refer to system $B$ as benchmark to achieve the best practice.

**Hybrid Systems DEA model**

The input-oriented Systems DEA model assumes proportional improvement of inputs, in which the target improvement values are obtained for all of the inputs. In order to become efficient, $DMU_o$ must change proportionally to realize the target values of inputs. In some cases, it may be impossible for a DMU to improve all of the inputs with proportional reduction. That is, some inputs are subject to change proportionally while other inputs are subject to change disproportionably. These differences should be reflected in the evaluation of efficiency [66, 71].

The System DEA model, which evaluates efficiency through a radial measure, can be modified for (radial and non-radial) hybrid measure based on Tone [66] as follows. Assume that the set of all inputs ($x \in R_+^M$) are decomposed into a radial part that changes proportionally and a non-radial part which changes disproportionably. The radial and non-radial inputs are labeled $x^R \in R_+^{M^R}$ and $x^{NR} \in R_+^{M^{NR}}$, respectively, with $M = M^R + M^{MR}$. The outputs $y \in R_+^R$ are assumed as changing proportionally. The technology sets of system $A$ and $B$ are respectively re-defined as:

$$\begin{aligned} T_A^H\{(x,y): \quad & \sum_{j\in J_A} \lambda_j^A x_{mj}^R \le x_m^R,\ m = 1,\ldots,M^R, \\ & \sum_{j\in J_A} \lambda_j^A x_{mj}^{NR} = x_m^{NR} - s_m^-,\ m = 1,\ldots,M^{NR}, \\ & \sum_{j\in J_A} \lambda_j^A y_{rj} \ge y_r,\ r = 1,\ldots,R,\ \lambda_j^A, s_m^- \ge 0\} \end{aligned} \tag{3.6}$$

and

$$T_B^H\{(x,y): \quad \sum_{j\in J_B} \lambda_j^B x_{mj}^R \le x_m^R,\ m=1,\dots,M^R,$$
$$\sum_{j\in J_B} \lambda_j^A x_{mj}^{NR} = x_m^{NR} - s_m^-,\ m=1,\dots,M^{NR},$$
$$\sum_{j\in J_B} \lambda_j^B y_{rj} \ge y_r,\ r=1,\dots,R,\ \lambda_j^B, s_m^- \ge 0\}. \tag{3.7}$$

Then, the technology set of the union of two systems ($T_A^H \cup T_B^H$) can be depicted as:

$$T_{sys}^H\{(x,y): \quad \sum_{j\in J_A} \lambda_j^A x_{mj}^R + \sum_{j\in J_B} \lambda_j^B x_{mj}^R \le x_m^R,\ m=1,\dots,M^R,$$
$$\sum_{j\in J_A} \lambda_j^A x_{mj}^{NR} + \sum_{j\in J_B} \lambda_j^B x_{mj}^{NR} = x_m^{NR} - s_m^-,\ m=1,\dots,M^{NR},$$
$$\sum_{j\in J_A} \lambda_j^A y_{rj} + \sum_{j\in J_B} \lambda_j^B y_{rj} \ge y_r,\ r=1,\dots,R,$$
$$\lambda_j^A, \lambda_j^B, s_m^- \ge 0\}. \tag{3.8}$$

The optimal objective value ($\phi^*$) can be solved through a (radial and non-radial) hybrid programming problem with $z^A$, $z^B$ as binary variables. The mathematical expression is given in the following:

$$\min \quad 1 - \frac{M^R}{M}(1-\phi) - \frac{1}{M}\left(\sum_{m=1}^{M^{NR}} \frac{s_-^m}{x_{mo}^{NR}}\right)$$
$$\text{s.t.} \quad \sum_{j\in J_A} \lambda_j^A x_{mj}^R + \sum_{j\in J_B} \lambda_j^B x_{mj}^R \le \phi \cdot x_{mo}^R,\ m=1,\dots,M^R,$$
$$\sum_{j\in J_A} \lambda_j^A x_{mj}^{NR} + \sum_{j\in J_B} \lambda_j^B x_{mj}^{NR} = x_{mo}^{NR} - s_m^-,\ m=1,\dots,M^{NR},$$
$$\sum_{j\in J_A} \lambda_j^A y_{rj} + \sum_{j\in J_B} \lambda_j^B y_{rj} \ge y_{ro},\ r=1,\dots,R,$$
$$\sum_{j\in J_A} \lambda_j^A = z^A, \sum_{j\in J_B} \lambda_j^B = z^B,\ \lambda_j^A, \lambda_j^B \ge 0$$
$$z^A + z^B = 1, z^A, z^B = 0 \text{ or } 1. \tag{3.9}$$

Here, $s_m^-$ denotes the slack of the $m$th non-radial input that is the excess input utilization. The efficiency score ($\rho$) measured in $s_m^-$ and $\phi$ is defined as:

$$\rho = 1 - \frac{M^R}{M}(1-\phi) - \frac{1}{M}\left(\sum_{m=1}^{M^{NR}} \frac{s_-^m}{x_{mo}^{NR}}\right). \tag{3.10}$$

If the model of Formula (3.9) assumes $z^A = 1$ and $z^B = 0$, which implies that the $DMU_o$ is evaluated based on the technology set of system $A$ ($T_A^H\{x,y\}$), then the optimal objective value of radial inputs ($\phi^A$) and slacks of non-radial inputs ($s_-^{mA}$, $m = 1,\dots,M$) will be computed. If the model of Formula (3.9) assumes $z^A = 0$ and $z^B = 1$ which implies that the

$DMU_o$ is evaluated based on the technology set of system $B$ ($T_B^H\{x,y\}$), then the optimal objective value of radial inputs ($\phi^B$) and slacks of non-radial inputs ($s_-^{mB},\ m = 1,\ldots,M$) will be computed. The optimal objective value ($\rho^*$) and slacks ($s_-^{m^*},\ m = 1,\ldots,M$), which are evaluated based on the technology set of a union of two systems, ($T_{sys}^H\{x,y\}$) can be measured by the following fractional programs.

$$\phi^* = \min\{\phi^A, \phi^B\} \tag{3.11}$$

$$s_-^{m^*} = \max\{s_-^{mA}, s_-^{mB}\},\ m = 1,\ldots,M. \tag{3.12}$$

The input-oriented efficiency score ($\rho^*$) can then be obtained by Formula (3.13).

$$\rho^* = 1 - \frac{M^R}{M}(1-\phi^*) - \frac{1}{M}\left(\sum_{m=1}^{M^{NR}} \frac{s^{m*}}{x_{mo}^{NR}}\right). \tag{3.13}$$

Using the solutions ($\phi^*$ and $s_-^{m^*}$), the inefficiency indicator $(1-\rho^*)$ can be deconstructed into two parts as follows:

Inefficiency resulting from excess radial input:

$$\alpha^R = \frac{M^R}{M}(1-\phi^*). \tag{3.14}$$

Inefficiency resulting from excess non-radial input:

$$\alpha^{NR} = \frac{1}{M}\left(\sum_{m=1}^{M^{NR}} \frac{s^{m*}}{x_{mo}^{NR}}\right). \tag{3.15}$$

The input-oriented efficiency score ($\rho^*$) also can be expressed as:

$$\rho^* = 1 - \alpha^R - \alpha^{NR}. \tag{3.16}$$

This expression is useful in finding the influence of inefficiency sources on the efficiency score. The inefficiency of radial input evaluated based on system $A$ and $B$ are labeled as $\alpha_A^R$ and $\alpha_B^R$, respectively; the inefficiency of non-radial input evaluated based on system $A$ and $B$ are labeled as $\alpha_A^{NR}$ and $\alpha_B^{NR}$, respectively. If $\alpha_A^R > \alpha_B^R$ ($\alpha_A^R < \alpha_B^R$), this represents that the $DMU_o$ takes system $A$ ($B$) as a reference set to decrease excess radial inputs. If $\alpha_A^{NR} > \alpha_B^{NR}$ ($\alpha_A^{NR} < \alpha_B^{NR}$), this represents that the $DMU_o$ takes system $A$ ($B$) as a reference to decrease excess non-radial inputs.

**Data**

Many previous bank researches adopted the intermediation approach to define inputs and outputs of banking operations and to evaluate efficiency. Under the intermediation approach, financial intermediaries are institutions that convert and transfer financial assets between surplus units and deficit units [58]. This approach has been found to be more relevant for financial institutions as it is inclusive of interest expenses [6]. In empirical evaluations of this study, referring to [52,68,69], outputs are the dollar value of deposits, loans, and non-interest income while inputs include employees, fixed assets (excluding dollar value of ATM), and ATM.

The annual banking data is aggregated from reports published by the Taiwan Banking Bureau in 2010, which contains 38 of Taiwan's commercial banks. The descriptive statistics

Table 1: Descriptive statistics

| | Employee ($x_1^R$) | Fixed asset ($x_2^R$) | ATM ($x^{NR}$) | Deposit ($y_1$) | Loan ($y_2$) | Non-interest income ($y_3$) |
|---|---|---|---|---|---|---|
| *Financial holding type:* | | | | | | |
| Mean | 2,685 | 18,737 | 1,097 | 848,281 | 755,267 | 4,086 |
| Std. Dev. | 1,613 | 19,000 | 1,154 | 663,537 | 516,686 | 2,954 |
| Max. | 5,617 | 76,360 | 4,386 | 2,697,431 | 1,977,707 | 12,696 |
| Min. | 506 | 1,283 | 118 | 31,314 | 65,483 | 804 |
| *Independent type:* | | | | | | |
| Mean | 1,243 | 7,356 | 268 | 368,131 | 343,242 | 1,596 |
| Std. Dev. | 1,293 | 8,429 | 282 | 465,737 | 479,508 | 1,780 |
| Max. | 5,333 | 33,840 | 1,197 | 1,818,940 | 1,762,078 | 6,882 |
| Min. | 144 | 846 | 26 | 33,202 | 26,506 | 74 |

Table 2: Results of the Rank-Sum-Test

| | Statistic |
|---|---|
| Mann-Whitney $U$-value | 99.5 |
| Wilcoxon $W$-value | 204.5 |
| $Z$-value | −2.67572 |
| Asy. $\sigma$ | 0.007 |
| $P$-value | >0.01 |

are reported in Table 1. The means of outputs in financial holding type are higher than independent type, which reveals financial holding banks generally have larger operation scales. On average, the financial holding type is 2 to 2.5 times the size of the independent type in employee and fixed asset utilizations. The number of ATMs of financial holding type is more than 4 times that of independent type. This shows that, relative to other inputs, the financial holding banks place more emphasis on their ATMs setting.

## 4. Empirical Results

Because the statistical distribution of the efficiency score evaluated from the DEA model is unknown, the differences between efficiencies for various groups must be examined with non-parametric statistics, which are independent of the distribution of the efficiency score [19]. We refer to Brockett and Golany [7] and confirm firstly whether the frontiers of two types belong to different systems with the Rank-Sum-Test (Wilcoxon-Mann-Whitney test).

The null hypothesis of a test model is that "the 2 samples come from identical populations." The result reported in Table 2 shows that the null hypothesis is rejected at the 1% significance level. This indicates that the financial-holding and independent banks belong significantly to different frontier systems.

Secondly, in order to confirm whether a proportional change correlation exists within the radial and non-radial inputs, we use a multiple regression model to examine the empirical dataset and list the results in Table 3. The Regression model 1 assumes non-radial input (ATM) as dependent variable and radial inputs (employee and fixed asset) as independent variables. The estimated coefficient of employee is significant but fixed asset is insignificant. The statistic of R2-value is estimated as 0.317, which represents the validity for the estimated coefficients. The results show that a high degree of correlation does not

Table 3: The verification of correlation between radial and non-radial inputs

| Regression model 1 | | | Regression model 2 | | |
|---|---|---|---|---|---|
| | Coefficient | Standard Error | | Coefficient | Standard Error |
| Constant | −33.867 | 160.3 | Constant | 781.818 | 208.7 |
| Employee | 0.362 | 0.108 | Fixed asset | 0.086 | 0.011 |
| Fixed asset | −0.003 | 0.012 | | | |
| Dependent variable: ATM | | | Dependent variable: Employee | | |
| F-value: | 12.59 | | F-value: | 55.96 | |
| R2-value: | 0.317 | | R2-value: | 0.806 | |

exist between the radial and non-radial inputs. We also evidence the correlation between the two radial inputs by using the Regression model 2 which assumes employee as the dependent variable and fixed asset as the independent variable. The results (reported in Table 3) show that the fixed asset is closely related to employee. Therefore, it is verified that the radial inputs (employee and fixed asset) are subject to change proportionally while the non-radial input (ATM) is subject to change non-proportionally.

In Table 4, the first column reveals the number code of each bank, in which "F" and "I" denote whether the bank belongs to a financial-holding or independent type, respectively.

The results of the operational efficiency score and rank calculated from the hybrid systems DEA model are reported in the part under the heading "Operational efficiency." There are 8 units ranked first, which perform efficiently and have a score equal to one. Among the efficient units, 2 banks (F05 and F14) belong to the financial holding type and the remaining 6 banks (I3, I6, I15, I19, I21, and I23) belong to the independent type.

The radial inefficiency indicators (i.e., $\alpha^R$) and their reference set (benchmark) for improving the excess radial inputs utilization are reported in the left half under the heading "Inefficiency" in Table 3. The 8 banks (F05, F14, I03, I06, I15, I19, I21, and I23), which performed efficiently, consequently do not have any radial or non-radial inputs inefficiency. One bank (F09) has an efficiency score lower than one and has zero radial input inefficiency. This indicates that the inefficiency of the unit is entirely sourced from having excess non-radial input utilization.

Among those financial holding banks which have a positive radial input inefficiency indicator, there are 4 banks (F01, F02, F10, and F11) that take the independent type as a reference set and 6 banks (F04, F06, F07, F08, F12, and F13) that are of the financial holding type. This implies that, in order to remedy the inefficiency caused from the excess radial inputs, the 4 banks should refer to their opposite type in their method of radial inputs utilization and that the other 6 banks should refer to an identical type. Among those independent banks which have a non-zero radial inefficiency indicator, there are 15 banks (I01, I02, I04, I05, I07, I08, I09, I10, I12, I13, I14, I18, I20, I22, and I24) that take the independent type as a reference set and 3 banks (I11, I16, and I17) that take the financial holding type. This implies that, in order to remedy the radial inputs inefficiency, the 3 banks should refer to their opposite type in their method of radial inputs utilization and that the other 15 banks should refer to an identical type.

The non-radial inefficiency indicators (i.e., $\alpha^{NR}$) and their reference set (benchmark) for improving the excess non-radial inputs utilization are reported in the right half under the heading "Inefficiency" in Table 3. One bank (I13) has an efficiency score lower than one and has zero non-radial input inefficiency. This indicates that the inefficiency of the unit is entirely sourced from having excess non-radial inputs utilization.

Among those financial-holding banks which have a positive non-radial input inefficiency indicator, there are 10 banks that take the independent type as a reference set and 2 banks that take the financial holding type. This implies that, in order to remedy the inefficiency caused from the excess radial inputs, the 10 financial holding banks (F01, F02, F03, F04, F07, F08, F09, F11, F12, and F13) should refer to their opposite type in their method of radial inputs utilization while the 2 banks (F06 and F10) should refer to an identical type. Among those independent banks which have a non-zero radial inefficiency indicator, there are 17 banks (I01, I02, I04, I05, I07, I08, I09, I10, I11, I12, I13, I14, I16, I17, I20, I22, and I24) that take the independent type as reference set and one bank (I18) that takes the financial holding type. This implies that, in order to remedy the inefficiency caused from the excess radial inputs, the one independent bank should refer to their opposite type in their method of radial inputs utilization while the 17 banks should refer to an identical type.

The comparison of averages between financial holding and independent type, which are evaluated through a Rank-Sum-Test (Wilcoxon-Mann-Whitney test), are reported in Table 5. The average operational efficiency of independent type at 0.792 is significantly greater than that of the financial holding type at 0.668. The difference of radial input inefficiency between the two types is not significant. The average of non-radial input inefficiency for independent type at 0.054 is significantly lower than that of the financial holding type at 0.179.

Through the results of average comparisons, we evaluate that the financial holding banks perform with lower efficiencies than independent banks, which is caused by their non-radial input inefficiency.

## 5. Conclusions

This study develops an empirical model which is extended from Tone [65,66] to analyze the influence of automatic service on bank performance, where two assumptions are different from previous banking studies. The first assumes that automatic service inputs do not change proportionally with branch service inputs. The second assumes that banks which employ different operating types to have different frontier technologies. The inefficiency sourced from excess inputs in automatic and non- automatic service is evaluated through the empirical model.

The empirical results of this study verify that the operational efficiency of financial holding banks is less than independent banks. Results further indicate that the excess input in automatic service is a cause for financial holding banks to have lower efficiency than independent banks. In the case of Taiwan, the three major components of a financial holding company comprises of the bank, an insurance arm, and securities companies. Financial holding banks generally set ATMs in insurance and securities companies as well as in banks that belong to the same financial holding group. They also install a large number of ATMs in convenience stores, department stores, supermarkets, shopping malls, etc, which provide readily available financial services to customers in an effort to extend market scale for their financial holding group. By employing a larger number of ATMs than independent type, financial holding banks are not effectively utilizing their resources, and as a result, generate waste and operational inefficiency.

Conversely, our empirical results show that the independent banks perform greater than

Table 4: Result of operational efficiency and inefficiency indicator

| | Operational efficiency | | Inefficiency | | | |
|---|---|---|---|---|---|---|
| DMU | Score | Rank | Radial input | Reference set | Non-radial input | Reference set |
| F01 | 0.310 | 38 | 0.394 | *I* | 0.296 | *I* |
| F02 | 0.476 | 36 | 0.211 | *I* | 0.314 | *I* |
| F03 | 0.787 | 18 | - | | 0.213 | *I* |
| F04 | 0.647 | 29 | 0.250 | *F* | 0.103 | *I* |
| F05 | 1 | 1 | - | | - | |
| F06 | 0.313 | 37 | 0.390 | *F* | 0.298 | *F* |
| F07 | 0.597 | 30 | 0.021 | *F* | 0.382 | *I* |
| F08 | 0.770 | 19 | 0.144 | *F* | 0.086 | *I* |
| F09 | 0.789 | 17 | 0 | | 0.211 | *I* |
| F10 | 0.563 | 31 | 0.193 | *I* | 0.244 | *F* |
| F11 | 0.803 | 15 | 0.134 | *I* | 0.063 | *I* |
| F12 | 0.797 | 16 | 0.144 | *F* | 0.059 | *I* |
| F13 | 0.506 | 34 | 0.250 | *F* | 0.244 | *I* |
| F14 | 1 | 1 | - | | - | |
| I01 | 0.860 | 11 | 0.089 | *I* | 0.050 | *I* |
| I02 | 0.705 | 24 | 0.202 | *I* | 0.093 | *I* |
| I03 | 1 | 1 | - | | - | |
| I04 | 0.814 | 14 | 0.162 | *I* | 0.024 | *I* |
| I05 | 0.735 | 21 | 0.176 | *I* | 0.089 | *I* |
| I06 | 1 | 1 | - | | - | |
| I07 | 0.889 | 9 | 0.102 | *I* | 0.009 | *I* |
| I08 | 0.732 | 22 | 0.146 | *I* | 0.122 | *I* |
| I09 | 0.697 | 25 | 0.172 | *I* | 0.131 | *I* |
| I10 | 0.479 | 35 | 0.455 | *I* | 0.067 | *I* |
| I11 | 0.758 | 20 | 0.192 | *F* | 0.050 | *I* |
| I12 | 0.536 | 32 | 0.322 | *I* | 0.141 | *I* |
| I13 | 0.878 | 10 | 0.122 | *I* | 0 | *I* |
| I14 | 0.687 | 26 | 0.185 | *I* | 0.128 | *I* |
| I15 | 1 | 1 | - | | - | |
| I16 | 0.726 | 23 | 0.253 | *F* | 0.021 | *I* |
| I17 | 0.523 | 33 | 0.462 | *F* | 0.015 | *I* |
| I18 | 0.672 | 28 | 0.218 | *I* | 0.110 | *F* |
| I19 | 1 | 1 | - | | - | |
| I20 | 0.674 | 27 | 0.150 | *I* | 0.176 | *I* |
| I21 | 1 | 1 | - | | - | |
| I22 | 0.832 | 13 | 0.103 | *I* | 0.066 | *I* |
| I23 | 1 | 1 | - | | - | |
| I24 | 0.833 | 12 | 0.155 | *I* | 0.012 | *I* |

Note: "$F$" denotes the reference set belongs to the financial holding type; "$I$" denotes the reference set belongs to the independent group.

Table 5: Averages of efficiency and inefficiency indicators

| | | Mean | Std. Dev. | $Z$-statistic |
|---|---|---|---|---|
| Operational efficiency | Financial holding | 0.668 | 0.212 | $-1.702^{*}$ |
| | Independent | 0.792 | 0.160 | (0.089) |
| Radial input inefficiency | Financial holding | 0.152 | 0.139 | $-0.031$ |
| | Independent | 0.153 | 0.129 | (0.976) |
| Non-radial input inefficiency | Financial holding | 0.179 | 0.125 | $-2.833^{**}$ |
| | Independent | 0.054 | 0.056 | (0.005) |

Note: $*$ denotes significance at the 0.1 level, $**$ denotes significance at the 0.01 level.

financial holding banks in operational efficiency and that increasing inputs in automatic services do not result in a negative impact on efficiency. Because of the smaller scale in operation, many independent banks strategically place their ATMs directly in the branches and positions where they have a great usage rate, which improves efficiency by marketing financial services directly to the target audience. This study suggests that, in the development of automatic banking service, bank operators should focus on the quality of service, such as diversity, security, convenience, and simple user interfaces. These improvements, rather than boosting the quantity of ATMs, are more effective for increasing consumer confidence in using automatic services.

The empirical model also provides a mechanism to examine whether the cross-learning initiative is advisable for decreasing inefficiency sourced from excess inputs in branch and automatic services. The evidence suggests that cross-learning initiatives between the two groups can be effective for reducing inefficiency of excess automatic service but ineffective for branch service.

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