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Benchmarking the Bank Branch Efficiency Through a New Dynamic Network DEA Model

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Abstract: Evaluating the effectiveness and productivity of financial institutions has been a focal point of research for scholars, professionals, and government regulators. Considering the limited number of existing literature and the availability of segregated data from the Taiwanese banking industry, this paper enhances and uncovers how the efficiency of bank branches varies based on several characteristics, including region and location of the branch. This study proposes a new model by incorporating a carry-over input and segregating the branch production process into operational and investment divisions. Using a dataset of 121 Taiwanese branches, the findings were as follows: First, the overall efficiencies of bank branches are not on par regardless of investment or operational efficiencies. In other words, the result reveals that banking branches in Taiwan are not only far away from reaching unity in efficiency but that there are also rooms for further improvement for both types of efficiency, particularly investment efficiency. Second, the operational efficiencies of branches do not differ statistically between regions, although investment efficiencies do. Third, clustering the efficiency of branches based on characteristics provided evidence that branches located in industrial areas have a higher level of operational efficiency (and second highest investment efficiency) compared to other locations. Overall, our results emphasize that operational efficiency exhibits statistical variations across diverse locations, while there is no corresponding variability in investment efficiency within the Taiwanese banking industry. The findings contribute to a foundational understanding for researchers, practitioners, and stakeholders, paving the way for further exploration and practical applications in the dynamic landscape of financial institutions.

Keywords: Dynamic Modelling, Data Envelopment Analysis, Operational Efficiency, Investment Efficiency, Bank Branches, Taiwan

1. Introduction

The importance of the banking industry in the overall development of a country is undeniable. One of the crucial tasks that banks perform is matchmaking between savers and borrowers to ensure the flow of financial resources from surplus households to deficit households. Accordingly, many countries have liberalized the banking sector to promote efficiency in the industry [1]. In recent years, globalization, digitalization, and a dynamic environment have also enhanced competition among financial service providers across the world, particularly in the banking industry. To survive and remain competitive, banks and financial institutions must attain efficiency in their operations [2]. Ample studies have investigated the efficiency of banks and their sources of inefficiencies through diverse methods and techniques. Although the number of literature related to banking efficiency has been increasing rapidly in recent years, there is still no consensus on the stages of the production process and input/output used owing to the multidimensionality of banking activities [3]. This situation provides the researcher with opportunities to explore various production possibilities to estimate the efficiency of banks in line with the ongoing issues and challenges facing the overall banking industry. Nonetheless, efficiency analysis at the branch level has also gained more attention in recent years for various reasons.

For example, institutional-level versus branch-level efficiency evaluations are substantially different in their objectives. At the institutional level, an analyst explores the bigger picture from an institutional perspective to identify the internal and external factors that might affect bank efficiency as a whole [3]. By contrast, at the branch level, the aim is to determine the factors influencing managerial efficiency in a secondary operational hierarchy (i.e., a branch). This is an important area to investigate if the purpose is to provide managerial implications. Exploring branch-level efficiency resembles breaking a larger problem into smaller pieces in order to provide a more comprehensive and specific solution. Undeniably, even in today's digitalized world, the majority of bank expenses are related to the branches [4]. Hence, an analysis of branch-level efficiency will provide useful and directive recommendations tailored for individual branches, through which, ultimately, the performance of banking institutions as a whole can be improved [5].

For various reasons, the focus of Taiwan banks in recent years has been somewhat different, and it is envisaged that managing the risks of banks is on the core agenda for regulators and practitioners. The trade war, the Chinese debt crisis, and geopolitical issues surrounding Taiwan are credible external threats to the sustainability of the financial industry. A financially efficient bank is widely understood to be more capable of handling its management or business risks than otherwise. Nonetheless, it is also understood that the banking industry promotes overall efficiency and growth in an economy [6]. However, how efficient these banks are remains a crucial aspect of banking literature. Without understanding the efficiency levels of the bank branches, how they contribute to the overall banking industry and the economy of a country would be impossible to understand. Thus, the main purpose of this study is to evaluate the efficiency of a business bank branch in Taiwan by utilizing a comprehensive production process and a two-stage dynamic data envelopment analysis (DEA) technique.

One of the uniqueness of this study is the proposed efficiency framework by considering two stages of efficiency, namely, operational and investment efficiency at the branch level. Given the lack of access to branch-level data, it is not surprising to find a limited number of studies investigating the efficiency of bank branches, yet the importance of branch-level efficiency is crucial [7]. For example, branches are considered foot soldiers, and their role involves crucial modern banking practices such as cost management, risk management, governance, and recovery management [7]. Analyzing branch-level efficiency will also help the bank determine the level of supervision and control in a bid to increase their efficiency.

Second, the regulatory and supervisory changes in the Taiwanese banking industry in recent years provide an intriguing environment to analyze efficiency in both dimensions, and analyzing it at the branch level makes the study interesting for managers and practitioners [8, 9]. For example, the recent amendments to anti-money laundering laws that took effect on June 2017 and the "Directions Governing Internal Control Systems of Anti-Money Laundering and Countering Terrorism Financing of Banking Business, Electronic Payment Institutions and Electronic Stored Value Card Issuers" were amended in June 2017 [10]. These two amendments are expected to affect the overall businesses of banks and have a cost implication due to compliance cost. As a result of the increasing compliance cost, the overall efficiency is expected to be relatively lower since the input/operating cost has increased. Third, the study covers a very recent and large-scale dataset that ranges from 2011 to 2018 and covers 121 business bank branches.

The remainder of this paper is organized as follows. Section 2 presents the review of bank branch efficiency based on existing literature. Sections 3 and 4 comprehensively discuss the research design and efficiency results, respectively. Section 5 sets out the conclusion with limitations and guidance for future research.

2. A Review of Bank Branch Efficiency

Since the introduction of DEA by Charnes, Cooper [11] studies on banking efficiency have stood on the top of all application-centered articles [12]. The popularity of efficiency studies in the banking sector is due to the data availability of public listed banks, high demand, and strong journal support [13]. The availability of data is a key factor because publicly traded banks are required to disclose their quarterly and annual financial reports, but this is not the case for bank branches [4]. Branch-level data are usually reported in aggregates embedded in the annual reports of the parent entity. Nevertheless, in the last decade, efficiency studies at the branch level appear to come into existence as opposed to the bank level, which has been around for three decades.

The latest survey on bank branch efficiency goes back to 2013, when Paradi and Zhu [14] reviewed 275 banking studies published between 1985 and 2011, in which only 80 papers explored bank branches. The majority of existing branch-level studies used two main approaches to measure the efficiency via DEA. First, in the intermediation approach [15, 16], branches are viewed as intermediary operators, channeling funds between savers and borrowers. Second, in the production approach [17, 18], branches are viewed as production units using the available resources to produce outputs. To explain further, measuring how efficiently a branch generates transaction services (outputs) from the resources (inputs) describes the production approach, and measuring how a branch operates the loan provision and investment capacities (outputs) from monetary liabilities (inputs) defines the intermediation approach [3]. Given that a branch's choice of production mechanism depends on the objective of the study, we assumed the intermediation approach to define the branch operational activities.

The current literature on branch efficiency evaluation and the complex production process of the banking system has been overlooked. Generally, the majority of studies assume branches have a single production process for transforming inputs to outputs. For example, Tsolas, Charles [19] proposed a DEA approach integrated with an artificial neural network to measure the efficiency of 160 bank branches in Greece. They used a one-stage model that takes personnel expenses, rents and depreciation, and operational expenses as inputs and net interest income and non-interest income as outputs. In another study in the Greek context covering the period of

2006–2016, Aggelopoulos and Georgopoulos [20] used a bootstrap input-oriented profit DEA approach to evaluate the efficiency of branches, with direct operating expenses and loan loss provisions as inputs and non-interest income and net interest income as outputs. Exploring the branch network of one of Canada's top five banks, LaPlante and Paradi [4] proposed five output-oriented DEA models in a single-stage context.

A quick search on the Internet reveals a number of highly cited studies exploring branch efficiency in a single stage, with the input and output combinations rotated depending on the objective of their studies For example, [15-18, 21, 22-32]. While the abovementioned articles offered grounding works for branch efficiency, they commonly studied branches as black boxes transforming inputs to outputs in a one-stage scenario. However, the production process of an entity, for example a bank branch, involves multiple stages; hence, a multilayer conceptual framework has the ability to capture a true production mechanism [33]. Viewing a branch as an intermediary unit requires an efficiency analysis to measure how monetary liabilities are transformed into loan provision and investment. Therefore, in the particular case of bank branch, at least two stages are involved, namely, operational stage and investment stage.

The multistage production process of banking institutions as a whole has been adequately studied in the literature for example, [13, 33, 34, 35-39]. However, as outlined above, due to data availability, multistage evaluation at the branch level is still in its nascent stage. In their review of 80 articles on branch efficiency analysis, Paradi and Zhu [14] did not find any studies to evaluate the multistage efficiency of bank branches. Avkiran [35] emphasized the necessity of proposing multistage branch efficiency frameworks as opposed to conventional models. To this end, the present study attempts to propose a two-stage efficiency framework for the production process of bank branches to fill the existing research gap.

3. Research Design

3.1. Dynamic Network Slacks-Based Measure

Among the types of DEA analyses in stages, researchers should employ the two-stage DEA model with a unified execution to evaluate two stages of DEA efficiencies [40, 41]. Readers are encouraged to read Cook, Liang [42] for more details. Among all the categories, the SBM network DEA introduced by Tone and Tsutsui [43] is a suitable tool to assess each stage and the overall efficiencies of decision-making units. Moreover, the SBM approach handles slacks in bank branches and recognizes the non-proportional nature of apparently worsening bank branch performance. Other desirable properties of the SBM model are the following: (i) unit invariant—the measure is invariant relating to the unit of measurement of DEA inputs and outputs; (ii) monotone—the measure monotonically decreases as each slack in inputs and outputs increases [44].

For these reasons, the present study integrates the two-stage SBM DEA and dynamic SBM or the two-stage DEA with consideration of dynamism [45] to gauge the operational performance and wealth-creation efficiency over long-term periods. The SBM network DEA [43] can precisely evaluate the inner operation of companies' network structures. We can also divide the resources of a bank branch's efficiency into operational performance and wealth-creation efficiency by analyzing the main resources of efficiency contribution and building the evaluation mechanism of the inner network production structure of a bank branch. This approach involves the use of a two-stage DEA model with consideration of the dynamic effects. This model simultaneously incorporates various performance indicators in evaluating bank branch efficiencies and revealing the "black box" of bank branch efficiencies across time.

With regard to bank branches' dynamic framework of operational and investment efficiencies in Figure 1, it must be assumed that n bank branches ($j = 1,\dots,n$) with two stages $(k=1,2)$ over T periods ($t=1,\dots,T$) are available. At each period, bank branches employ m inputs ($i=1,...,m$) to generate D outputs ($d=1,...,\mathrm{D}$) for the first stage. These D outputs, which are referred to as link indicators, become the inputs to the second stage. Bank branches use D link indicators to produce s outputs ($r = 1,\dots,s$) for the second stage. H carryover indicator ($h=1,...,H$) at Stage 1 from time t to time $t+1$ is also considered.

$x_{ij}^{t}\left(i=1,...,m; j=1,...,n; t=1,...,T\right)$ is input i to the jth bank branch for Stage 1 in time t, and $y_{rj}^{t}\left(r=1,...,s; j=1,...,n; t=1,...,T\right)$ is output r to the jth bank branch for Stage 2 in time t. $z_{dj}^{t}\left(d=1,...,D; j=1,...,n; t=1,...,T\right)$ links the intermediate products of the jth bank branch from Stage 1 to Stage 2 in time t. $c_{hj}^{(t,t+1)}\left(h=1,...,H; j=1,...,n; t=1,...,T\right)$ is the carryover of the jth bank branch at Stage 1 from time t to time $t+1$. x_{ij}^{t}, y_{rj}^{t}, and z_{dj}^{t} must indicate the input, output, and connector from the Stages 1 to 2 values of the jth bank branch consisting of two stages at period t, respectively. The $c_{hj}^{(t,t+1)}$ signifies carryover from t to $t+1$ for Stage 1.

Following Kao [46], the present study applies the concepts of cooperative constraints into the bank branch evaluation model for two reasons. First, the carryover carried forward from $t+1$ is required to be equal to that carried forward into t to satisfy the continuity between the two periods. Second, while managers in charge of Stage 1 will want to maximize the intermediate products from Stage 1, managers handling Stage 2 will want to use the minimum possible intermediate products from Stage 1. In short, the present study indicates that the identified two stages of the efficiency model work together in handling the intermediate. Specifically, it derives the efficiency under the assumption of variable returns to scale (VRS) by answering the non-oriented function as follows:

$$\phi_o = Min \frac{\frac{1}{T}\sum_{t=1}^{T}\left[1-\frac{1}{2}\left[1-\frac{1}{m+D+H}\left(\sum_{i=1}^{m}\frac{s_{io}^{t^-}}{x_{io}^t}+\sum_{d=1}^{D}\frac{s_{do}^{t^-}}{z_{do}^t}+\sum_{h=1}^{H}\frac{s_{ho}^{-,(t,t+1)}}{c_{ho}^{t,t+1}}\right)\right]\right]}{\frac{1}{T}\sum_{t=1}^{T}\left[1+\frac{1}{2}\left[1+\frac{1}{s+D+H}\left(\sum_{r=1}^{s}\frac{s_{ro}^{t^+}}{y_{ro}^t}+\sum_{d=1}^{D}\frac{s_{do}^{t^+}}{z_{do}^t}+\sum_{h=1}^{H}\frac{s_{ho}^{+,(t,t+1)}}{c_{ho}^{t,t+1}}\right)\right]\right]} \tag{1}$$

s. t.

$$x_{io}^t = \sum_{j=1}^{n} x_{ij}^t \lambda_{j1}^t + s_{io}^{t^-}, \ (i = 1,...,m;\ t = 1,\ldots,T), \tag{2}$$

$$y_{ro}^t = \sum_{j=1}^{n} y_{rj}^t \lambda_{j2}^t - s_{ro}^{t^+}, \ (r = 1,...,s;\ t = 1,\ldots,T), \tag{3}$$

$$\sum_{j=1}^{n} \lambda_{jk}^t = 1, \quad (k = 1,2;\ t = 1,\ldots,T), \tag{4}$$

$$\sum_{j=1}^{n} z_{dj}^t \lambda_{j1}^t = \sum_{j=1}^{n} z_{dj}^t \lambda_{j2}^t, \ (t = 1,\ldots,T), \tag{5}$$

$$z_{do}^t = \sum_{j=1}^{n} z_{dj}^t \lambda_{j1}^t - s_{do}^{t^+}, \ (d = 1,...,D; t = 1,\ldots,T), \tag{6}$$

$$z_{do}^t = \sum_{j=1}^{n} z_{dj}^t \lambda_{j2}^t + s_{do}^{t^-}, \ (d = 1,...,D; t = 1,\ldots,T), \tag{7}$$

$$\sum_{j=1}^{n} c_{hj}^{(t,t+1)} \lambda_{j1}^t = \sum_{j=1}^{n} c_{hj}^{(t,t+1)} \lambda_{j1}^{t+1}, \ (t = 1,\ldots,T-1), \tag{8}$$

$$c_{ho}^{(t,t+1)} = \sum_{j=1}^{n} c_{hj}^{(t,t+1)} \lambda_{j1}^t - s_{ho}^{+,(t,t+1)}, \ (h = 1,...,H; t = 1,\ldots,T-1). \tag{9}$$

$$c_{ho}^{(t,t+1)} = \sum_{j=1}^{n} c_{hj}^{(t,t+1)} \lambda_{j1}^{t+1} + s_{ho}^{-,(t,t+1)}, \ (h = 1,...,H; t = 1,\ldots,T-1). \tag{10}$$

$$\lambda_{jk}^t,\ s_{io}^{t^-},\ s_{ro}^{t^+},\ s_{do}^{t^-}, s_{do}^{t^+}, s_{ho}^{-,(t,t+1)},\ s_{ho}^{+,(t,t+1)} \geq 0.$$

where $s_{ro}^{t^+}$ and $s_{io}^{t^-}$ are the input/output slacks, respectively; $s_{do}^{t^+}$ and $s_{do}^{t^-}$ are the slacks of the free link value; $s_{ho}^{-,(t,t+1)}$ and $s_{ho}^{+,(t,t+1)}$ are the carryover deviations; and λ_{j1}^t is the intensity of bank branch j corresponding to Stage 1 at period t. Equations (2) and (3) are the input and output constraints. Equation (4) suggests the assumption of VRS. Equations (5) to (7) suggest that the linking activities are freely determined while keeping continuity between inputs and outputs. Equations (8) to (10) indicate that the current link flow corresponds to carryover that bank branches can handle freely. Its value can be increased or decreased from the observed one. Equations (5) and (8) show that the two stages work together to use and generate the same amount. Equations (2) to (10) designate the production possibility set for the objective bank branch $(o = 1,...,n)$. Accounting for Equations (2) to (10) in an optimum solution of Equation (1) leads to the following:

$$\left\{\begin{matrix} \lambda_{jk}^{t*}, j = 1,...,n;\ s_{io}^{t^-*}, i = 1,...,m;\ s_{ro}^{t^+*}, r = 1,...,s;\ s_{do}^{t^{+*}}, s_{do}^{t^{-*}}, d = 1,...,D\ ; \\ s_{ho}^{-*,(t,t+1)}, s_{ho}^{+*,(t,t+1)}, h = 1,...,H;\ \ t = 1,...,T; k = 1,2 \end{matrix}\right\}$$

The present study derives the overall dynamic efficiency, which ranges from zero to unity, by answering the non-oriented function during term *T* for the objective bank branch as follows:

$$\phi_o^* = \frac{\frac{1}{T}\sum_{t=1}^{T}\left[1-\frac{1}{2}\left[1-\frac{1}{m+D+H}\left(\sum_{i=1}^{m}\frac{s_{io}^{t^{-*}}}{x_{io}^{t}}+\sum_{d=1}^{D}\frac{s_{do}^{t^{-*}}}{z_{do}^{t}}+\sum_{h=1}^{H}\frac{s_{ho}^{-*,(t,t+1)}}{c_{ho}^{t,t+1}}\right)\right]\right]}{\frac{1}{T}\sum_{t=1}^{T}\left[1+\frac{1}{2}\left[1+\frac{1}{s+D+H}\left(\sum_{r=1}^{s}\frac{s_{ro}^{t^{+*}}}{y_{ro}^{t}}+\sum_{d=1}^{D}\frac{s_{do}^{t^{+*}}}{z_{do}^{t}}+\sum_{h=1}^{H}\frac{s_{ho}^{+*,(t,t+1)}}{c_{ho}^{t,t+1}}\right)\right]\right]} \tag{11}$$

Equation (11) is an extended SBM model [47] under a non-oriented function, which accounts for superfluous inputs and carryovers. The dividend of the fraction is the input-related efficiency on average while the divisor is the inverted output-related efficiency on average.

This study derives the periodic efficiency for the objective bank branch as follows:

$$\pi_o^{t*} = \frac{\left[1-\frac{1}{2}\left[1-\frac{1}{m+D+H}\left(\sum_{i=1}^{m}\frac{s_{io}^{t^{-*}}}{x_{io}^{t}}+\sum_{d=1}^{D}\frac{s_{do}^{t^{-*}}}{z_{do}^{t}}+\sum_{h=1}^{H}\frac{s_{ho}^{-*,(t,t+1)}}{c_{ho}^{t,t+1}}\right)\right]\right]}{\left[1+\frac{1}{2}\left[1+\frac{1}{s+D+H}\left(\sum_{r=1}^{s}\frac{s_{ro}^{t^{+*}}}{y_{ro}^{t}}+\sum_{d=1}^{D}\frac{s_{do}^{t^{+*}}}{z_{do}^{t}}+\sum_{h=1}^{H}\frac{s_{ho}^{+*,(t,t+1)}}{c_{ho}^{t,t+1}}\right)\right]\right]}. (\forall t) \tag{12}$$

It then derives the staged efficiency for the objective bank branch as follows:

$$\eta_o^{k=1*} = \frac{\frac{1}{T}\sum_{t=1}^{T}\left[1-\frac{1}{m}\left(\sum_{i=1}^{m}\frac{s_{io}^{t^{-*}}}{x_{io}^{t}}\right)\right]}{\frac{1}{T}\sum_{t=1}^{T}\left[1+\frac{1}{D+H}\left(\sum_{d=1}^{D}\frac{s_{do}^{t^{+*}}}{z_{do}^{t}}+\sum_{h=1}^{H}\frac{s_{ho}^{+*,(t,t+1)}}{c_{ho}^{t,t+1}}\right)\right]}. \tag{13}$$

$$\eta_o^{k=2*} = \frac{\frac{1}{T}\sum_{t=1}^{T}\left[1-\frac{1}{D+H}\left(\sum_{d=1}^{D}\frac{s_{do}^{t^{-*}}}{z_{do}^{t}}+\sum_{h=1}^{H}\frac{s_{ho}^{-*,(t,t+1)}}{c_{ho}^{t,t+1}}\right)\right]}{\frac{1}{T}\sum_{t=1}^{T}\left[1+\frac{1}{s}\left(\sum_{r=1}^{s}\frac{s_{ro}^{t^{+*}}}{y_{ro}^{t}}\right)\right]}. \tag{14}$$

Finally, it derives the periodic-staged efficiency for the objective bank branch as follows:

$$\varphi_{ot}^{k=1*} = \frac{1-\frac{1}{m}\left(\sum_{i=1}^{m}\frac{s_{io}^{t^{-*}}}{x_{io}^{t}}\right)}{1+\frac{1}{D+H}\left(\sum_{d=1}^{D}\frac{s_{do}^{t^{+*}}}{z_{do}^{t}}+\sum_{h=1}^{H}\frac{s_{ho}^{+*,(t,t+1)}}{c_{ho}^{t,t+1}}\right)}. (\forall t) \tag{15}$$

$$\varphi_{ot}^{k=2*} = \frac{1-\frac{1}{D+H}\left(\sum_{d=1}^{D}\frac{s_{do}^{t^{-*}}}{z_{do}^{t}}+\sum_{h=1}^{H}\frac{s_{ho}^{-*,(t,t+1)}}{c_{ho}^{t,t+1}}\right)}{1+\frac{1}{s}\left(\sum_{r=1}^{s}\frac{s_{ro}^{t^{+*}}}{y_{ro}^{t}}\right)}. (\forall t) \tag{16}$$

Using the two-stage dynamic DEA model will produce plural branches with a full efficient status denoted by unity. A number of the branches might be possible to lead on the frontier. To discriminate between these efficient branches, the reference-share measure (Zhu, 2000) defines a ranking measure by first combining the factor-specific measure and two-stage dynamic DEA model. This study can then identify the inputs/intermediates/outputs that are most important or distinguish those branches that can be treated as benchmarks. Table 1 provides the definition of each variable.

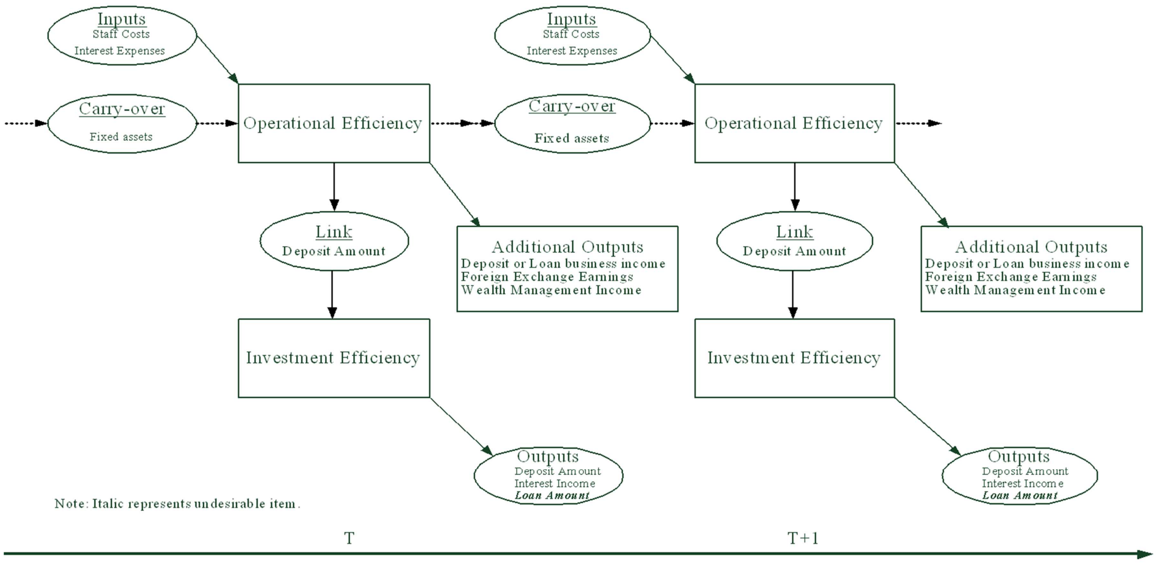

Figure 1. *Dynamic two-stage network production process of bank branches.*

Table 1. *Definitions of Variables.*

Variables	Definitions
Inputs	
Staff Costs	The actual amount paid for all employee wages and benefits. This includes wages, salaries, commissions, employer match of taxes such as social security and Medicare, employer paid insurance premiums and pension deposits, and the cost of all other fringe benefits.
Fixed Assets	The book value of the branch's place of business and the estimated present value (including the book value of the land and building of the self-owned house or the current value of the leased house using the discount rate).
Interest Expenses	The deposits deposited by the depositor in the Bank (excluding check deposits) and the interest charges paid by the Bank.
Additional Outputs	
Deposit or Loan Business Income	Receiving fees and charges related to deposit, lending, import, export and foreign exchange business, property and casualty insurance, life insurance, and fund or gold passbook business
Foreign Exchange Earnings	To undertake import and export billing business and collect operating fees for the loan business
Wealth Management Income	Tailor-made financial planning for customers; regularly review customer assets, adjust configuration in a timely manner, and assist customers to increase the value of their assets and collect the fee income.
Intermediate	
Deposit Amount	Accepting the annual average amount of deposits of customers in different periods
Outputs	
Interest Income	Collecting interest income from corporate or individual households who handle the loan
Loan Amount	Annual average amount of funds lending to corporate or individual households that need financing
Loan Loss	The credit risk that the lending financier may generate in the future and the estimated amount of loan loss.

3.2. Descriptive Analysis

The descriptive analysis of our sample data, which was hand collected from 121 non-public financial reports of the bank branches of Taiwan Business Bank Co., Ltd. over the period of 2011–2018 (Table 2). To ensure the sample satisfies the DEA's basic assumption of the "variables match non-normal distribution" under production technology frontiers, this study conducted a normality test to check the validity. Results of the normality test (Kolmogorov–Smirnov test) are significant, supporting the first assumption that sample variables should not be normally distributed in addition to wealth management income variable. With non-normal distributed samples, median values are a better description of the central tendency (Farnum, 1996). In this research, there are 121 bank branches, which is greater than triple the number of 10 factors selected, $121 > 3(3+4+3) = 30$. As a result, a high validity is expected in this developed DEA model. This result validates the basic assumption of the two-stage dynamic DEA model and validates the adoption of this approach.

Table 2. *Descriptive Statistical Summary of All Bank Branches.*

Variables	Valid N	Mean	Median	Quartile	Std.Dev.	Normality test
Staff Costs	968	36,197,656	34,712,681	6,998,371	6,945,803	p-value<0.00
Fixed Assets	968	93,462,181	65,762,758	71,543,454	97,929,523	p-value<0.00
Interest Expenses	968	48,769,688	41,445,368	28,044,888	27,520,754	p-value<0.00
Deposit or Loan Business Income	968	5,612,620	4,245,856	3,607,563	4,502,681	p-value<0.00
Foreign Exchange Earnings	968	12,809,888	9,494,575	10,991,376	10,561,705	p-value<0.00

Variables	Valid N	Mean	Median	Quartile	Std.Dev.	Normality test
Wealth Management Income	968	10,489,069	9,283,994	7,637,944	5,733,810	p-value<0.00
Deposit Amount	968	7,663,913,357	6,467,952,266	4,076,482,445	4,331,251,731	p-value<0.00
Interest Income	968	147,960,605	129,935,420	58,958,710	65,252,166	p-value<0.00
Loan Amount	968	6,353,365,774	5,004,101,000	2,732,625,000	5,359,698,609	p-value<0.00
Loan Loss	968	10,257,195	2,726,500	5,974,500	49,985,554	p-value<0.00

Note: Shapiro–Wilk is used to test Normality.

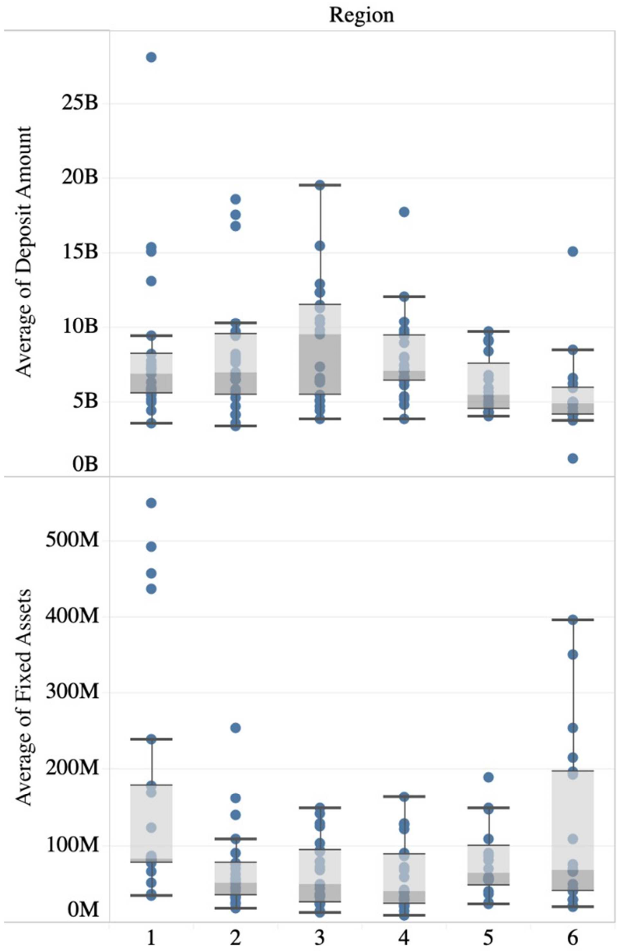

Figure 2. *Average annual carryovers by region.*

We also present the data dispersion of the carryover fixed assets and the intermediate deposit amount in boxplots. Figure 2, which depicts the average annual changes by region, shows that our sample bank branches in different regions have different levels of deposit amount and fixed assets. Such discrepancies imply the importance of comparing the efficiency scores of the bank branches by region. Moreover, Figure 2 corroborates the non-normality of our dataset. In our undepicted boxplots of other variables, we observe the same widely dispersed data distribution in the different regions.

4. Efficiency Analysis

In Tables 3 and 4, we reported the operational efficiency (TE1) and investment efficiency (TE2) of 121 branches for the period of 2011–2018 on a yearly average basis, segregated into six regions, three in the north area, namely, Region 1 (21 branches), Region 2 (23 branches), and Region 3 (21 branches); one in the central area, namely, Region 4 (22 branches); and two in the south area, namely, Region 5 (16 branches) and Region 6 (18 branches). A comparison of the results of Tables 4 and 5 clearly reveals that branches are more efficient in their operational activities than their investment activities in all years and all regions. The yearly trends of regional efficiencies in both stages are not promising, with decreasing trends observed in general and a few regions experiencing fluctuations in their yearly efficiency scores throughout the sample period. In the operational efficiency stage, Region 1 appeared to be more efficient compared to other regions while Region 5 scored the least. However, the results of the Kruskal–Wallis test did not support the significance of the differences observed between the efficiency of regions in TE1. This was not the case for TE2, where we observed a p-value of 0.0134 denoting the significant differences between regional efficiencies. While the branches performed poorly in TE2, Region 1 showed better performance comparatively, similar to the first stage. Regions 3 and 5 were the weakest among the regions in the investment stage.

Table 3. *Operational Efficiency and Nonparametric Statistical Analysis by Regions.*

TE1 Efficiency		2011	2012	2013	2014	2015	2016	2017	2018	Kruskal–Wallis test
Overall	Mean	0.697	0.626	0.656	0.674	0.509	0.637	0.598	0.533	
	Std.Dev.	0.232	0.259	0.256	0.260	0.315	0.273	0.306	0.314	
Region 1	Mean	0.767	0.732	0.743	0.781	0.624	0.746	0.734	0.623	
	Std.Dev.	0.215	0.257	0.245	0.249	0.356	0.258	0.297	0.327	
Region 2	Mean	0.742	0.671	0.680	0.727	0.537	0.651	0.607	0.568	
	Std.Dev.	0.251	0.263	0.267	0.275	0.351	0.287	0.348	0.352	p-value<0.6487
Region 3	Mean	0.670	0.648	0.710	0.709	0.555	0.693	0.624	0.583	
	Std.Dev.	0.177	0.207	0.233	0.245	0.321	0.247	0.307	0.326	
Region 4	Mean	0.700	0.565	0.661	0.655	0.437	0.541	0.477	0.447	
	Std.Dev.	0.228	0.251	0.260	0.241	0.256	0.244	0.273	0.288	
Region 5	Mean	0.647	0.528	0.548	0.550	0.424	0.515	0.488	0.378	

TE1 Efficiency		2011	2012	2013	2014	2015	2016	2017	2018	Kruskal–Wallis test
	Std.Dev.	0.260	0.262	0.223	0.249	0.279	0.235	0.236	0.203	
Region 6	Mean	0.632	0.579	0.554	0.573	0.445	0.651	0.641	0.566	
	Std.Dev.	0.259	0.288	0.268	0.253	0.291	0.318	0.303	0.317	

Table 4. *Investment Efficiency and Nonparametric Statistical Analysis by Regions.*

TE2 Efficiency		2011	2012	2013	2014	2015	2016	2017	2018	Kruskal–Wallis test
Overall	Mean	0.094	0.192	0.201	0.216	0.121	0.242	0.188	0.149	p-value<0.0134
	Std.Dev.	0.247	0.317	0.343	0.321	0.231	0.334	0.300	0.271	
Region 1	Mean	0.284	0.269	0.269	0.270	0.176	0.306	0.233	0.232	
	Std.Dev.	0.423	0.391	0.390	0.371	0.282	0.380	0.341	0.383	
Region 2	Mean	0.067	0.262	0.230	0.278	0.169	0.332	0.240	0.191	
	Std.Dev.	0.206	0.365	0.362	0.352	0.332	0.383	0.361	0.331	
Region 3	Mean	0.108	0.173	0.243	0.294	0.098	0.218	0.158	0.069	
	Std.Dev.	0.280	0.324	0.387	0.369	0.100	0.299	0.283	0.057	
Region 4	Mean	0.025	0.175	0.190	0.166	0.052	0.278	0.154	0.114	
	Std.Dev.	0.031	0.293	0.330	0.276	0.072	0.362	0.299	0.211	
Region 5	Mean	0.018	0.064	0.093	0.084	0.056	0.051	0.116	0.092	
	Std.Dev.	0.024	0.065	0.243	0.133	0.035	0.030	0.108	0.122	
Region 6	Mean	0.040	0.170	0.147	0.161	0.167	0.207	0.210	0.185	
	Std.Dev.	0.096	0.305	0.311	0.309	0.318	0.324	0.320	0.327	

Since the location of the branches are important in their efficiency performance, we further categorized the operational efficiency (TE1) and investment efficiency (TE2) into five grouping characteristics: Characteristic 1 (15 branches in the industrial area), Characteristic 2 (30 branches near the industrial area), Characteristic 3 (49 branches in the metropolitan area), Characteristic 4 (12 branches in a semi-city type), and Characteristic 5 (15 branches in a rural type). The results of TE1 and TE2 are reported in a yearly average basis in Tables 5 and 6, respectively. The findings reveal that branches in the industrial area ranked at the top in TE1 and second in TE2. Branches near the industrial area follow in TE1 but not in TE2. The rural area with 15 branches performed poorly in both stages. Similarly, semi-city branches ranked the least among others in TE1. The statistical analysis of the differences between the efficiency of the five characteristics showed that branches have significant differences between their efficiency scores in operational efficiency only.

Table 5. *Operational Efficiency and Nonparametric Statistical Analysis by Characteristics.*

TE1 Efficiency		2011	2012	2013	2014	2015	2016	2017	2018	Kruskal–Wallis test
Overall	Mean	0.697	0.626	0.656	0.674	0.509	0.637	0.598	0.533	p-value<0.0020
	Std.Dev.	0.232	0.259	0.256	0.260	0.315	0.273	0.306	0.314	
Characteristic 1	Mean	0.825	0.840	0.831	0.870	0.804	0.849	0.810	0.765	
	Std.Dev.	0.203	0.205	0.231	0.196	0.264	0.200	0.264	0.281	
Characteristic 2	Mean	0.678	0.639	0.693	0.705	0.525	0.660	0.643	0.602	
	Std.Dev.	0.210	0.225	0.244	0.260	0.302	0.272	0.317	0.330	
Characteristic 3	Mean	0.744	0.665	0.668	0.685	0.513	0.662	0.626	0.541	
	Std.Dev.	0.228	0.255	0.235	0.239	0.315	0.258	0.285	0.293	
Characteristic 4	Mean	0.672	0.467	0.503	0.525	0.305	0.424	0.324	0.284	
	Std.Dev.	0.203	0.180	0.192	0.204	0.093	0.118	0.122	0.091	
Characteristic 5	Mean	0.475	0.384	0.495	0.500	0.328	0.467	0.421	0.332	
	Std.Dev.	0.199	0.199	0.287	0.281	0.284	0.290	0.286	0.277	

Table 6. *Investment Efficiency and Nonparametric Statistical Analysis by Characteristics.*

TE2 Efficiency		2011	2012	2013	2014	2015	2016	2017	2018	Kruskal–Wallis test
Overall	Mean	0.094	0.192	0.201	0.216	0.121	0.242	0.188	0.149	p-value< 0.1672
	Std.Dev.	0.247	0.317	0.343	0.321	0.231	0.334	0.300	0.271	
Characteristic 1	Mean	0.084	0.379	0.358	0.364	0.144	0.389	0.419	0.158	
	Std.Dev.	0.225	0.446	0.463	0.402	0.252	0.450	0.490	0.248	
Characteristic 2	Mean	0.052	0.182	0.212	0.225	0.100	0.204	0.133	0.110	
	Std.Dev.	0.182	0.289	0.366	0.323	0.183	0.306	0.242	0.187	
Characteristic 3	Mean	0.164	0.194	0.234	0.244	0.165	0.298	0.196	0.198	
	Std.Dev.	0.328	0.333	0.357	0.349	0.294	0.366	0.293	0.342	
Characteristic 4	Mean	0.018	0.117	0.046	0.115	0.033	0.142	0.115	0.165	
	Std.Dev.	0.017	0.210	0.033	0.150	0.035	0.136	0.184	0.294	
Characteristic 5	Mean	0.018	0.078	0.040	0.038	0.067	0.070	0.100	0.044	
	Std.Dev.	0.021	0.136	0.029	0.030	0.090	0.077	0.122	0.054	

5. Discussion

Data from a total of 121 bank branches in Taiwan spanning 2011 to 2018 were evaluated by utilizing a recent and popular non-parametric technique known as dynamic network slacks-based measures. Our findings are promising and reveal several interesting facts about the branch efficiency of banks that were largely unknown in past studies.

First, in terms of operational and investment efficiency, we could see a huge gap between the two types of efficiency estimates. For example, overall operational efficiency (TE1 in Table 4) was around four times higher than the overall investment efficiency (TE2 in Table 5). This finding highlights that banking branches in Taiwan are not only far away from reaching unity in efficiency but that there are also rooms for further improvement for both types of efficiency, particularly investment efficiency. Second, clustering regional efficiencies also reveal that there are differences in efficiency scores for both operational and investment efficiencies. For example, Region 1 has the highest level of operational efficiency while Region 5 has the lowest, despite the differences not being statistically significant based on the Kruskal–Wallis test. By contrast, for investment efficiency, we could see statistically significant differences in the efficiency of branches based on region. Region 3 had the lowest level of investment efficiency and region 6 had the highest. A similar study by Paradi, Rouatt [34] also found strong differences in the efficiency performance between bank branches in Canada by utilizing a similar Kruskal–Wallis test and t-test. The differences in efficiency estimates of the bank branches between various regions could result from the diseconomies of distance, whereby operating cost in general increases with respect to distance from the natural market [48]. Third, the overall branch-level efficiencies (both operational and investment) of Taiwanese banks either declined over the years or fluctuated throughout the study period, raising concerns about the efficacy of the mixed inputs and outputs used in the production process.

Next, clustering of the efficiency of bank branches was furthered by grouping them based on the exact location of the branch. Our results found strong evidence that branches located in industrial areas have higher levels of operational efficiency (second highest for investment efficiency) compared to those in other locations. Locating a branch in an industrial area provides a locational advantage to the branch as it is relatively easier to target clients for different banking products and services that ultimately help achieve economies of scale. By contrast, our study documented that branches in rural areas have performed very poorly both in operational and investment efficiency. However, Paradi, Rouatt [34] findings reveal otherwise. For example, they found that branches in the rural market performed better than those in major urban and small urban markets owing to the following reasons: less staff specialization (they could all do everything needed), long-term relationship banking with clients that helped reduce bad loans and increase productivity, and a lower staff turnover rate (helps minimize the overall operating cost).

6. Conclusion

For the past few decades, analyzing the efficiency and/or productivity of financial institutions has been a central research agenda among academicians, practitioners, and government regulators. However, the institutional analysis of the efficiency of banks at an aggregate level does not provide a true picture. One of the limitations behind the limited number of literature on the investing efficiency of bank branches is the unavailability of segregated branch-level data. Motivated by the limited number of existing literature and the availability of segregated data from the Taiwanese banking industry, we wanted to dig deeper and uncover how the efficiency of bank branches varies based on several characteristics, including region and location of the branch. Overall, our findings highlight that operational efficiency statistically varies among different locations (characteristics) but not for investment efficiency in the Taiwanese banking industry.

Despite analyzing branch-level efficiency in the Taiwanese banking industry with a dynamic DEA, our study is not devoid of limitations. For example, as we found that operational and investment efficiency levels are far away from unity, a second-stage regression analysis incorporating environmental variables to better understand the inefficiencies could be one of the genuine contributions in existing banking and efficiency literature. In this aspect, the characteristics of branch managers, including gender, educational level, and experience, could generate interesting findings. How the legal environment and the overall socio-economic conditions of Taiwan affect branch-level efficiency could be explored in future studies.

Conflicts of Interest

The authors declare no conflicts of interest.

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