

## **Discussion on Banking Efficiency and Determinants in the Digital Finance Environment - Evidence in Taiwan**

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### **ABSTRACT**

This study aims to examine the determinants of banking efficiency in the digital finance environment using data from 35 banks in Taiwan. We use a two-stage DEA model to measure service penetration efficiency and profit creation efficiency. Then, we adopt Tobit regression to evaluate how the key factors affect banking efficiency. Our results show that 13 banks (out of 20 high profit-creating banks) are profit creators but not service penetrators, suggesting that financial inclusion can generate profits, but it is not a necessity. Although IT infrastructure of ATMs and e-banking plays a crucial role in fostering financial inclusion, ATMs are still the backbone of efficient banking, while digital banking in Taiwan is merely a strategic necessity rather than strategic advantage. Further, although financial holding banks are more efficient than their nonfinancial holding counterparts, our research suggests that banks should still specialize in a few products rather than diversify too widely.

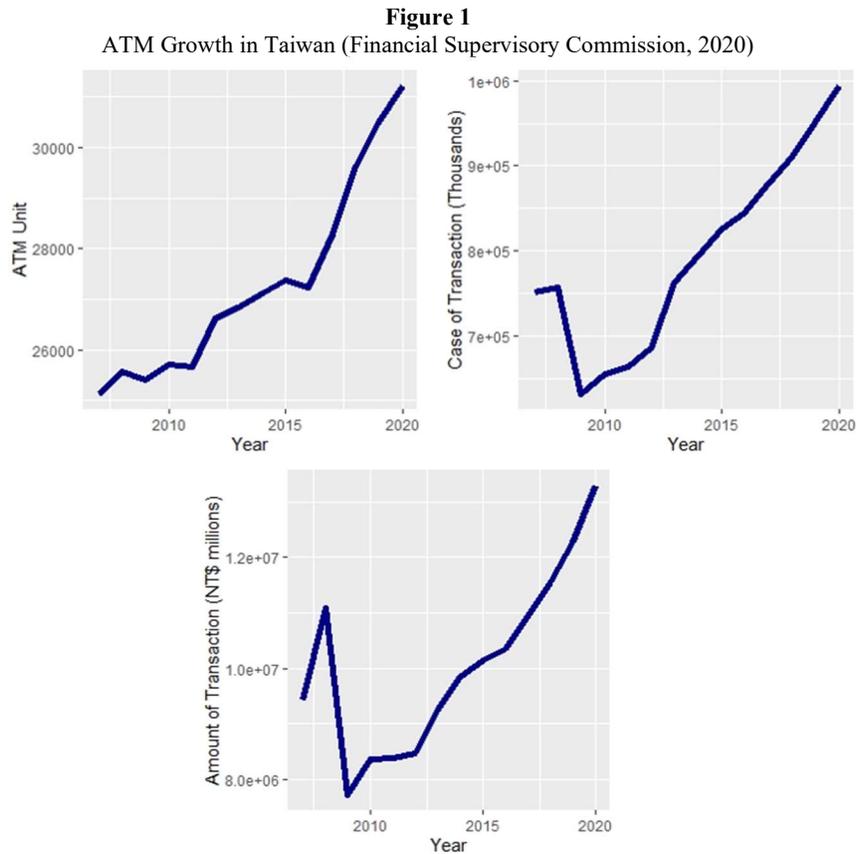
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*Keywords: financial inclusion, digital finance, two stage DEA, efficiency*

## I. INTRODUCTION

Taiwan's early banks mostly conducted transactions at counters. Later, the bank industry dramatically invested in the automatic teller machine (ATM), which significantly shortened the money flow. As ATMs facilitate customer transactions, the number of ATMs and transactions increase every year. Figure 1.1 shows that the number of ATM units in Taiwan expanded by 24.2% from 2007 to 2020, while the number of transactions using ATMs increased by over one-third during the same period. Global financial crisis impacted almost every country in the world in 2008, which caused the decline.

In recent years, smartphones have become increasingly popular thanks to rapid technological advancements. The government will create technological changes that will reform the future banking industry to supervise and upgrade the domestic financial industry. As the banking system develops, cross-industry alliances will become more prevalent. A significant change has taken place. According to Lin et al. (2019), digital banking also contributes to a decline in bank branches. In Europe, we can see from statistics that bank branches do not have the same importance as they once did because of the high growth of virtual banking and remote transactions.



"Building a Digital Financial Environment 3.0" was opened in 2015. Network and mobile equipment technology has improved dramatically over the past few years, and biometric technology is also becoming more mature. The landscape of digital finance was revolutionized in 2018. This time, the trademark is: "Banking Everywhere, Never at a Bank." 4.0 is about "Embedded Banking". Aside from that, the FSC (Financial Supervisory Commission) approved the establishment of three pure online banks in July of next year, namely Future Bank, Rakuten Bank, and LINE Bank. FSC suggests that the entry of pure online banking can propel the "catfish effect" of domestic banks to speed up the transition. In management, this allusion is used to introduce threatening competitors into a stagnant organization or industry in order to motivate the original members to work harder. According to the overall cost structure, traditional banking costs represent 60% of revenues, while online banking represents 10%. Cost differentials are substantial. Because of pure online banking competition in the future, Taiwan's number of bankers will decline and the number of branches will also decrease, which may solve Taiwan's banking crisis. This will have a direct effect on small and medium-sized banks, but will be beneficial to the expansion of inclusive finance.

The impact of digital finance on banking efficiency has long been a topic of discussion in Taiwan and various countries in the world. Research conducted by Wirdiyanti (2018) uses a sample of 95 banks in Indonesia and adopts the nonparametric DEA, revealing that digital banking technology adoption (DBTA) encourages the relative efficiency of banks in Indonesia. The study also found a trade-off between bank efficiency performance and bank market range generated by DBTA. Aside from affecting banking efficiency, digital banking also positively reshapes efforts to encourage financial inclusion, such as the results of a study conducted by Ozili (2018). Further, a recent study from Wang et al. (2020) adopts DEA to study banking data in China and based on spatial data between provinces show that digital finance has slightly increased the efficiency of the financial sector but has a significantly different impact on each province in China. It reveals that the spatial factor is quite an essential factor in determining the efficiency of the banking sector.

Chen et al. (2011) examines the operating efficiency of domestic banks in Taiwan, using the two-stage DEA to evaluate their operating efficiency, and analyse from the perspective of profitability and marketability. They find that most banks in Taiwan are not operating at the most appropriate scale in terms of profitability and marketability in 2008. Taiwan's banking technology (TE) is inefficient for several reasons, including: The profitability primarily results from the inefficiency of pure technology (PTE). Marketability is largely influenced by inefficiency of scale (SE). In their study, however, efficiency values of each stage are measured separately, ignoring the role of intermediary in the performance of the different stages. Most of the time, credit cards are used as a digital account intermediary for making payments on smart phones. Therefore, we introduce the credit card as the bridge between our profit and service stages to illustrate the digital story of our study. we adopt a two stage DEA approach and the Tobit regression to measure the banking efficiency in Taiwan banking sector. By establishing a link between the service penetration and the profit creation perspectives on two relevant issues in banking, this research contributes to the field by addressing deposit and credit cards as critical intermediate outputs. Besides, this study also makes contributions in its empirical application to Taiwanese banking: different contextual variables (bank type, size, diversification, foreign ownership and public ownership) are tested as factors

influencing the increases in efficiency levels in two stage analyses.

This paper further consists of the following sections: Section 2 - Literature review; Section 3 - Data and model; Section 4 - Empirical results, discussed in terms of policy implications; and Section 5 – Conclusions

## II. LITERATURE REVIEW

### A. Performance Evaluation

Szilagyí (1981) refers to "performance" as the extent to which an enterprise or organization achieves its set goals or performance. It relates to the business execution results of the enterprise, and its importance to the enterprise is beyond doubt. The two levels of efficiency and effectiveness are essential factors that constitute performance. Drucker and Fluri (1974) believe that efficiency is the right way to complete the current task, which is equivalent to "do the thing right"; the effect (Effectiveness) is to choose the right direction to move towards the goal, that is, "do the right thing". The difference between them is that efficiency refers to the degree of relevance between the input resources and the output results, while the effect refers to the degree to which the expected goal is achieved. McClure (1986) believes that performance evaluation investigates and analyses the current status of the organization and uses the results of the evaluation to check the organization's original mission and goals, and strengthen improvements, where performance is poor, in order to effectively achieve resource allocation and achieve the organization's mission and goals.

### B. Two Stage DEA and Tobit Regression

According to Cook et al. (2010), all the DEA approaches utilized to measure the efficiency of DMUs with two stages can be classified as non-cooperative (leader-follower) or cooperative game approaches. When both stages are considered simultaneously in performance optimization, the models used are often referred to as centralized efficiency models (Zhu, 2011). In Liang et al. (2008), the global efficiency level is computed as the product of the individual efficiencies of each stage.

DEA is a nonparametric approach in frontier analysis. One of the advantages of the nonparametric method is that it has more statistical power when there is a violation of the parametric assumptions. Apart from DEA, a prevalent nonparametric approach is the artificial neural network (Adha and Hong, 2021). The DEA is the primary method that has been widely adopted in analysing the level of efficiency of banking (Wirdiyanti, 2018). Based on Paradi et al. (2018), more than 15 thousand articles use DEA in their analysis, and most of them discuss the banking and health sectors.

Further, Wang et al. (2007) demonstrates that through the analysis of DEA and Tobit regression, they investigate the influence of the number of branches, the degree of diversification of operations, the age of financial holdings, and the size of the bank on the efficiency value. They also uses the Max Productivity Index to analyse the changes in bank productivity. Jinbiao et al. (2010) uses DEA and Tobit regression analysis to measure the operating efficiency of 35 banks in Taiwan from 2005 to 2007 and the influence of credit card-related variables. Indeed, the credit card variables were internalized into the model. Their study shows that credit cards do affect the operating

efficiency of banks. Non-financial holdings are better than financial holdings, and listed counters are better than unlisted counters.

Han (2015) uses DEA and Tobit regression to analyse the efficiency of technology and finance integration in Henan Province, China, over the past ten years. He shows a trend of first increasing and then declining, and there are noticeable regional differences; cities with relatively high technology and finance integration efficiency should pay attention to the scale to improve efficiency, cities with relatively low integration efficiency should increase investment in technology and finance. Technology funding and technology finance integration efficiency are significantly negatively correlated, and the size of the financial market, the overall scale of high-tech enterprises, and technology finance integration efficiency are significantly positively correlated.

Aside from the banking sector, other financial sectors such as insurance also use the DEA and Tobit methods to analyse the level of efficiency, and this is like a study conducted by Grmanová and Strunz (2017), who direct a study with 15 insurance companies in Slovakia during the period 2013-2015. They indicate that the relationship between technical efficiency and all groups formed based on ROA and ROE is unconfirmed and significant at a confidence level of less than 1%. Wang et al. (2014) adopt the two-stage network DEA to explore the measurement and improvement in the Chinese commercial banks. The entire banking operation is divided into two sub-processes (deposit generation and profit earning). An evaluation of the sub-process efficiencies could assist in identifying the sources of inefficiency in the entire banking system.

Moreover, Wanke et al. (2019) investigate the Middle East and North Africa (MENA) countries using the DEA dynamic network and Tobit regression and show that banking efficiency performance is determined by the type of bank, Islamic or conventional banking. Banks with Islamic principles have a better efficiency score than conventional banks as long as they can present loan activities with less leverage than conventional banks.

The spatial aspect of geography is also an essential factor in efficiency studies, and it is shown by a study conducted by Banna et al. (2019), who researched the importance of geographical aspects for banking efficiency. Their study uses 407 banks in 6 ASEAN countries and China by adopting DEA, Tobit regression, bootstrapping, and Simar and Wilson double bootstrapping regression. Their study results show that the banking market has a substantial and significant influence on banking efficiency. Their study results also reveal that banks in China are better in efficiency than banks in ASEAN countries. The importance of the spatial aspect is also explained by Wang et al. (2020) in their research. He also explained the importance of the spatial aspect in influencing the level of banking efficiency.

Moutinho et al., (2021) show that banks can be significantly more efficient by improving their resources management practices. Their results indicate that the performance of Iberian banks is mainly determined by their human capital. Intellectual capital measurement can assist bank managers in making decisions more effectively. Xu and Zhou (2020) evaluate the efficiency of the loan supply chain for Chinese commercial banks using a two-stage AR-DEA model based on different non-performing loans. In addition, they distinguish different types of commercial banks (state-owned commercial banks, joint-stock commercial banks, and city commercial banks) as well as different stages of their operation (deposit-producing sub-stage, profit-making sub-stage, and

overall stage). Berger et al. (2007) uses data from 38 banks in China during the period 1994-2003, and explains that minority foreign ownership can increase the efficiency of Chinese banks. Their findings also indicate that foreign minority ownership can significantly improve performance from the big four Chinese banks. Hutama and Prasetyo (2016), who study nine foreign banks and 11 domestic banks in Indonesia, show no significant difference between the efficiency level of foreign banks and domestic banks in Indonesia. It means that both types of banks operate at the same level during the study period.

As for digital finance, digitalization in banking is the process of ensuring that digital technologies are used to simplify banking operations and reducing costs. (Bhutani and Paliwal, 2015). Kahveci and Wolfs (2018) shows that the banks invest in digital banking (DB) services in order to maintain their competitiveness. Simply put, they view them as a strategic necessity. DB services do not provide any strategic advantage to any banks in terms of financial performance or efficiency since the banks are already efficient. Investing in DB only help to preserve their strategic positions. Chen et al. (2011) uses two stage DEA to examine the influence of financial development and operating scale on bank efficiency in Taiwan. They find pure technical efficiency is positively associated with financial development, and enlargement of operating scale improves bank efficiency.

Based on the description previously explained, it appears that banking efficiency studies using two stage DEA and Tobit regression have been carried out by many researchers. However, ownership and digital finance variables are still not widely discussed. Therefore, our study explores the ownership aspect, such as a foreign bank and nonforeign (i.e. domestic) bank, public and private bank and financial holding and non-holding banks. Meanwhile, we include the number of digital accounts in Taiwan to serve as the proxy variable of digital finance.

### III. METHODOLOGY

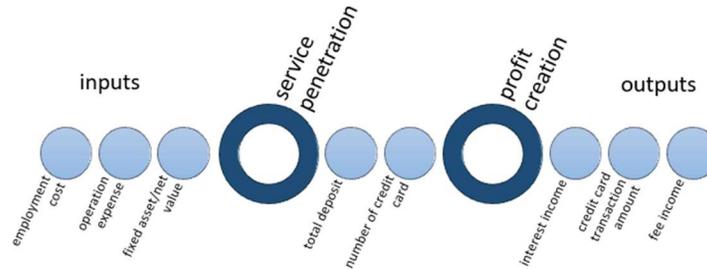
#### A. Two-Stage DEA Model

It's common to use data envelopment analysis in research to improve bank efficiency. However, the production process of the decision-making unit is a black box, and the production activities and structure within the DMU are not considered. Therefore, following Wanke and Barros's (2014) Two-stage DEA, we disassemble the business process of the bank into two concepts of "service penetration" and "profit creation" and treats labour and capital equipment as inputs, deposits and credit cards as intermediary items, and interest and commission as output items. Fig. 2 and Table 1 illustrate the two-stage process considered in this study.

##### 1. The First Stage Service Penetration

We examine service penetration from two different perspectives. In terms of a bank's perspective, digital banking aims to increase the use of people's accounts (such as digital account inquiries) while increasing the convenience of people using financial services. From the customer's perspective, the simple functions of remittance and balance inquiry in online banking are often used, and the investment part is still under observation. As a result of investment in digital banking through the first stage, we can examine how many consumers have accounts and credit cards currently.

**Figure 2**  
Two stage of DEA



## 2. The Second Stage Is a Profit Creation

From a bank's perspective, digital banking allows them to increase revenue by providing transaction-oriented financial and non-financial services, such as third-party payment, borrowing, fund trading, stock trading, and credit card spending. From the customer's perspective, they are able to conduct money transactions through online banking's two-stage function when they become accustomed to it.

**Table 1**  
Comparison of Two-Stage DEA Model

Classification	Stage 1-Service penetration	Stage 2-Profit creation
Core value	User friendly, paper saver	Increase revenue, net value
Purpose	Increase account usage	Increase transaction number and transaction amounts
Bank respect	Role	Intermediary, value added provider
	Input	Deposits, credit cards
	output	Interest income, credit card payment, fee income
Customer respect	Function	Transaction-oriented finance service and non-finance service
	Attitude	Get used to using actively
	Attribute	High risk

The two-stage DEA model is used to determine if the relationship between their input and output is appropriate for institutions that provide similar services. In the measure of efficiency, the total input is divided by the total output. So, we know how efficient the planned program is, and at the same time under the weight settings, since DEA is defined as the most appropriate combination of planned programs. Profit-making businesses are aiming to maximize efficiency, hoping to get the maximum output with the least amount of input. By using the two-stage DEA method, companies can combine their inputs and outputs to figure out which components of input and output are problematic, and which components of input and output should be improved to reach leadership levels. With our approach, we can not only determine the efficiency status of a DMU, but also provide a good benchmark for the DMU, thereby reducing the gap between the benchmarks of the intermediate measures set by the two stages separately.

As compared to traditional DEA models, a two-stage network DEA model, first proposed by Liang et al. (2008), includes intermediate measurements. Assumedly, DMU<sub>j</sub> (j = 1, 2, ..., n) has D intermediate measures Z<sub>dj</sub> (d = 1, 2, ..., D), in addition to the initial inputs X<sub>i</sub> (i = 1, ..., m) and the final outputs Y<sub>r</sub> (r = 1, ..., s). As a two-stage network DEA model, the linear equations for the o<sup>th</sup> DMU are given in the following: (1) (2) (3) (4):

$$\begin{aligned}
 \text{Max} \quad & \vartheta^{overall} = \sum_{j=1}^s u_r Y_{r_o} \\
 \text{s.t.} \quad & \sum_{i=1}^m v_i X_{i_o} = 1 \\
 & \sum_{r=1}^s u_r Y_{r_j} - \sum_{d=1}^D w_d Z_{dj} \leq 0, \quad j = 1, 2, \dots, n \\
 & \sum_{d=1}^D w_d Z_{dj} - \sum_{i=1}^m v_i X_{ij} \leq 0, \quad j = 1, 2, \dots, n \\
 & u_r \geq 0, \quad r = 1, 2, \dots, s; \quad v_i \geq 0, \quad i = 1, 2, \dots, m; \quad w_d \geq 0, \quad d = 1, 2, \dots, D
 \end{aligned} \tag{1}$$

$\vartheta^{overall}$ : The total efficiency value of the o<sup>th</sup> DMU

$Y_{rj}$ : The r<sup>th</sup> kind of output of the j<sup>th</sup> DMU

$u_r$ : The weighted value of the r<sup>th</sup> kind of output

$Z_{dj}$ : The d<sup>th</sup> kind of intermediate measures of the j<sup>th</sup> DMU

$w_d$ : The weighted value of the d<sup>th</sup> kind of intermediate output

$X_{ij}$ : The i<sup>th</sup> kind of output of the j<sup>th</sup> DMU

$v_i$ : The weighted value of the i<sup>th</sup> kind of input

$$\vartheta^{service\ penetration} = \sum_{d=1}^D w_d^* Z_{do} \tag{2}$$

$$\vartheta^{profit\ creation} = \sum_{r=1}^s u_r^* Y_{r_o} / \sum_{d=1}^D w_d^* Z_{do} \tag{3}$$

$$\vartheta^{overall} = \vartheta^{service\ penetration} * \vartheta^{profit\ creation} \tag{4}$$

$$\vartheta^{service\ penetration} = \sum_{d=1}^D w_d^* Z_{do} \tag{5}$$

The overall efficiency is equal to the product of the service penetration efficiency and profit creation efficiency as expressed above equation.

Variables

(1) Input items

- a. Employee expenses: all expenses such as salary, welfare, bonus, or other grants for the employment of the enterprise belong to it.
- b. Operating expenses: Operating expenses refer to the expenses derived during the company's operation.
- c. Fixed assets/net value: the ratio of the fixed assets to the owner equity of the firms.

(2) Intermediary items

- a. Deposits and remittances: including savings, checks, current deposits, fixed deposits, and remittance amounts.
- b. Valid number of credit cards: the number of credit cards that have been swiped for consumption in the past six months.

(3) Output items

- a. Interest income: the revenue generated from a bank's interest-bearing assets. A typical bank's assets consist of all forms of personal and commercial loans, mortgages, and securities.

- b. Credit card transaction amount: the credit card holder's consumption amount in the current year.
- c. Commission income: refers to the fee income collected by the banks for various businesses.

### 3. Tobit Regression Model

Tobit regression is a model proposed by Nobel Prize winner James Tobin in 1958. It assumes that the independent and dependent variables have a functional relationship, using statistical methods to find the regression line of the causal relationship. In 1964, it was developed by the economist Goldberger, who were first adopted in the research report. This study uses the Tobit regression model to evaluate the main influencing determinants of digital financialization on the operating efficiency of each bank. Since the DEA efficiency value is between 0 and 1, if the ordinary least squares method (OLS) is used for regression analysis, it will cause that the average of error term is not equal to zero, it produces an inconsistent phenomenon with the assumptions of ordinary regression. It also causes deviation and inconsistency of parameter estimates (Cummins et al., 1997). Therefore, this research adopts the Tobit regression model, and the following Tobit regression model established in this research is as follows:

$$\begin{aligned}
 Y_{ij}^* &= X_{ij} - B_{ij} + \varepsilon_{ij} & i = 1, 2, \dots, m; j = 1, 2, \dots, n \\
 Y_{ij} &= Y_{ij}^* & \text{if } Y_{ij}^* > 0 \\
 Y_{ij} &= 0 & \text{if } Y_{ij}^* \leq 0
 \end{aligned} \tag{6}$$

#### (1) Dependent variables

- a. Overall efficiency value (TE0)  
After inputting employment expenses, operating expenses, and fixed assets/net value, the efficiency value of interest income, credit card transaction amount, and fee income will be output.
- b. The first stage efficiency value (TE1)-service penetration  
After inputting employment expenses, operating expenses, and fixed assets/net value, the efficiency value of the adequate number of deposits and credit cards will be output.
- c. The second stage efficiency value (TE2)-profit creation  
After depositing deposits and valid credit cards, the efficiency value of interest income, credit card transaction amount, and fee income will be generated.

#### (2) Independent variables

- a. Dummy FHC : Financial holding and nonfinancial holding institution  
Whether a bank joins the financial holding institution or not has the most significant impact on the efficiency since the financial holding institutions have more channels, products, and sources of funds, and their scales are larger than nonfinancial holding banks. Songyu et al. (2006) explored whether the operating efficiency of the banking industry in Taiwan has been improved after joining a "financial holding company". The empirical results show that the subsidiary banks under the financial holding structure are better than the independent banks under the nonfinancial holding institution. When FHC=0, it

represents the nonfinancial holding sector; when  $FHC=1$ , it represents the financial holding sector.

- b. Number of branches  
When most banks expand their business, the primary method is to increase the number of branches. As the number of branches increases, the efficiency of the people in handling financial-related projects and convenient banks will increase. Xiuling and Yushuo (2000) believe that the greater the bank's efficiency, the higher it is. However,
- c. Transaction amount of ATM  
ATM can solve some business conveniently and efficiently for bank customers, so it is usually regarded as a weapon for banks to obtain or protect deposit market share (Wang et al., 1997). However, the large number of ATM transactions does not mean that the amount is high, but a relatively low transaction amount due to frequent transactions. Therefore, this study uses the transaction amount of ATM as a finance inclusion indicator, and believes that the high frequency of ATM transactions determines the efficiency of bank operations
- d. The number of ATMs  
IT infrastructure refers primarily to payment and settlement systems. The effective operation of these systems ensures that money flows easily among financial institutions. In order for the financial system to function efficiently, a secure, reliable, and effective payment clearing system is essential. A variety of payment methods are used including cash, checks, debit cards, credit cards, online payments, third party payments, and ATMs. The World Bank and G20 group use the number of ATM as Finance Inclusion indicator as mentioned in Hao (2017). Therefore, we use ATM number as another indicator of finance inclusion in each bank.
- e. The number of Digital accounts  
As mentioned by Guibaud (2016), developing APIs and Open Banking services are part of the profitable and customer-centric digital strategy in Europe's Payment Services. As such, we adopt digital banking accounts as another indicator of digital banking.
- f. Dummy PP : Private and Public Bank  
Bhattacharyya et al. (1997) shows that the difference in equity affects operation efficiency. The efficiency of the public sector is the highest, followed by foreign companies, and the private sector is the worst. Mukherjee et al. (2002) found that public banks are more efficient than private and foreign banks. Therefore, they believe that public banks have a large number of customers all over the country, and it is easy to expand their operations. Following the above literatures, we divide our banks as two groups. When  $PP=0$ , it represents the public sector; when  $PP=1$ , it represents the private sector.
- g. Dummy FB : Foreign and Local Bank  
Foreign financial institutions in Taiwan expect to have a relatively strong management team through the internationalization and group management of the parent company.

We believe that local banks and foreign banks operating in Taiwan are different. Thus, we classify banks as two groups. When  $FB=0$ , it represents the foreign sector; when  $FB=1$ , it represents the local sector.

h. Age

Banks have been established for a long time and have accumulated more customers. However, their employees have a longer service age, resulting in higher labour input than new banks. Therefore, the operating efficiency of new banks is usually better than that of old banks.

i. Diversification

In Aly et al. (1990) diversification degree method (where  $S_i$  is the proportion of each bank's  $i$ th business revenue to its total revenue).

$$Diversity = -\ln \sum_{i=1}^n s_i^2 \quad (7)$$

#### 4. Data Sources and Period

We adopted the annual data of the banks in Taiwan and selected 35 banks from 2013 to 2018 from Taiwan Economic Journal (TEJ) database. Table 2 shows the list of banks in our study.

**Table 2**  
Decision-making units

Category	Bank name	Category	Bank name
Public	Land Bank of Taiwan	Private	O-Bank
Public	Bank of Taiwan	Private	Hwatai Bank
Mixed	Chang Hwa Bank	Private	COTA Bank
Mixed	Hua Nan Bank	Private	Cathay United Bank
Mixed	Mega International Commercial Bank	Private	Taipei Fubon Bank
Mixed	First Commercial Bank	Private	ChinaTrust Bank
Mixed	Taiwan Cooperative Bank	Private	E.SUN BANK
Mixed	Taiwan Business Bank	Private	Taishin International Bank
Private	Agricultural Bank of Taiwan	Private	Wing Fung Commercial Bank
Private	Standard Chartered Bank (Taiwan) Limited	Private	JIH SUN INTERNATIONAL BANK
Private	King's Town Bank	Private	Yuanta Bank
Private	Bank of Kaohsiung	Private	Bank Of Panshin
Private	KGI Bank	Private	Taipei Star Bank
Private	Union Bank of Taiwan	Private	Citibank Taiwan
Private	Far Eastern International Bank	Private	HSBC Bank (Taiwan)
Private	EnTie Bank	Private	DBS Bank
Private	Shin Kong Bank	Private	The Shanghai Commercial and Savings Bank
Private	Sunny Bank		

Note: Public banks account for 6% of the total, mixed private-public account for 14% of the total, and private banks account for 80% of the total

## IV. EMPIRICAL RESULTS

Table 3 shows the maximum, minimum, average, and standard deviation of the input and output items of 35 banks from 2013 to 2018.

**Table 3**  
Summary Statistic

Unit: NT\$ thousand

Year /Variables	Salary	Input Operation expenses	Fixed asset/ Net value	Credit card payment	Output Interest income	Fee income	
2	MAX	20,295,443	35,931,793	65.78	29,337	59,252,283	26,326,013
0	MIN	268,852	598,371	0.41	0	1,003,045	70,936
1	AVG	5,772,693	9,779,314	20.07	3,727	18,826,381	4,678,989
3	S D	4,807,195	7,884,656	14.43	7,370	15,703,517	5,021,593
2	MAX	24,138,685	45,153,569	59.69	31,714	65,232,885	30,137,222
0	MIN	304,510	650,684	0.31	0	1,148,439	93,127
1	AVG	6,146,587	10,782,109	18.45	4,171	21,685,127	5,300,685
4	S D	5,284,524	9,208,424	13.18	8,184	18,664,447	5,831,147
2	MAX	26,359,037	51,502,379	50.82	35,023	64,758,332	37,811,816
0	MIN	304,510	684,497	0.31	0	1,233,673	97,695
1	AVG	6,439,588	11,539,138	16.58	4,430	22,413,959	6,000,016
5	S D	5,598,673	10,216,994	11.67	8,690	18,984,443	7,126,309
2	MAX	28,130,690	53,179,414	49.47	38,956	65,265,705	35,518,902
0	MIN	304,510	694,142	0.31	0	1,169,628	95,829
1	AVG	6,563,110	11,680,580	15.62	4,732	21,517,152	6,177,576
6	S D	5,803,174	10,513,275	11.08	9,458	18,447,771	6,985,756
2	MAX	29,971,528	54,554,422	44.59	40,305	67,347,690	35,163,741
0	MIN	304,510	704,456	0.31	0	1,175,141	88,716
1	AVG	6,933,779	12,117,687	14.44	5,212	22,758,064	6,121,287
7	S D	6,173,011	10,822,840	10.04	10,420	19,166,020	6,892,953
2	MAX	29,652,544	54,905,097	46.69	47,164	78,042,305	34,342,828
0	MIN	406,593	731,941	0.73	0	1,317,750	91,725
1	AVG	7,204,945	12,602,317	13.77	5,660	25,759,140	6,292,209
8	S D	6,328,373	11,144,284	9.84	11,399	21,928,656	6,891,764

Note: MAX indicates maximum; MIN represent minimum; AVG indicate average, SD represent standard deviation

Table 3 shows the maximum input and small value are increasing year by year, as well as the output part. The trend also shows that people have become more dependent on banks in recent years. Further, it can be seen that average salaries in Taiwan's banking industry have increased year after year. Operations expenditures in the banking sector increased by 28.8% in 2018 compared to 2013. However, banks' average fixed assets decreased by 31.4% from 2013 to 2018. In terms of output, bank interest income increased by 36.8% in 2018, as compared to 2013, resulting in a higher fee income increase, namely around 48%.

#### A. Efficiency Analysis

We followed the two-stage DEA method to evaluate service penetration efficiency in the first stage, profit creation efficiency in the second stage, and overall digital bank production efficiency. A “fully efficient” DMU is one that could be the benchmark for other DMUs. The results indicate that among the 35 banks, three banks are benchmarks in the service penetration stage, four banks are benchmarks in the profit creation stage, and two banks are benchmarks in both stages. Taken together, these results suggest that

about one-eleventh banks have good performance in the service penetration stage; one-eighth of the banks have good performance in the profit creation stage; as for the two stages, there are two banks with “full efficiency” value, that is, Cathay United Bank, HSBC Taiwan accounted for only 5% of the total. Since there are still large numbers of inefficient banks at each stage, the benchmarks for the banks prove that our approach is very useful for the banks to reduce the gap between their intermediate measures set in two stages. That is, the results can provide a good alternative for coordinating the activities of the two stages to reduce resource waste. The results are shown in Appendix A to F.

**Table 4**  
Service Penetration Efficiency

Category	Average Per-Year						t-Stat (Mean Difference)
	2013	2014	2015	2016	2017	2018	
Foreign banks	0.3120	0.3208	0.3149	0.3145	0.4073	0.4228	-0.76
Domestic banks	0.3123	0.3267	0.3273	0.3224	0.3150	0.3699	0.18
Public banks	0.0206	0.0291	0.0272	0.0268	0.0283	0.0551	-28.73***
Private banks	0.3754	0.3896	0.3865	0.3808	0.3846	0.4470	+4.42***
Mixed private- public banks	0.1252	0.1391	0.1530	0.1530	0.1591	0.1631	-16.8***
Financial holding company	0.4766	0.4657	0.4843	0.4787	0.4671	0.4760	+14.88***
Non-financial holding company	0.2027	0.2330	0.2204	0.2167	0.2312	0.3092	-5.33***
Annual mean	0.3122	0.3238	0.3211	0.3185	0.3612	0.3964	

Note: \*\*\*denote 1% levels of significance

If we look at the results of the t-stat and significance level in Table 4, we can see there are significant differences between the efficiency values and the average value of each year, except for foreign and nonforeign bank category. Foreign banks have an even efficiency value compared to local banks; the difference between the years 2013 and 2016 is quite small. It is not until 2017 that there is a significant difference between foreign and local banks. From the average value between the several types of banks, when compared between foreign and domestic banks, foreign banks have a higher level of efficiency. The possible reason is that these four foreign banks have drastically replaced their senior management in the takeover and changes in their internal business operating policies. Furthermore, the service penetration efficiency of private banks is higher than that of public and mixed banks since the ATM numbers of private banks are higher than the public and mixed banks. Private banks usually cooperate with convenience stores and install ATM machines in each chain store. Private banks pay more attention to finance inclusion for individual convenience. As a result, people will prefer private banks with more ATMs, such as China Trust Bank, Taishin Bank, and Cathay United Bank. In addition, financial holding banks are twice more efficient than nonfinancial holding banks on average. One possible explanation for this is that they have normally high level of assets and high scale of customer base. The reason may well be that there are only four foreign banks and they have merged domestic banks around year 2008.

**Table 5**  
Profit Creation Efficiency

Category	Average per-Year						t-Stat (Mean Difference)
	2013	2014	2015	2016	2017	2018	
Foreign banks	0.9205	0.8901	0.7886	0.7938	0.7413	0.8940	+8.7***
Local banks	0.5435	0.5439	0.5493	0.5572	0.5448	0.5294	-6.83***
Public banks	0.8511	0.832	0.8375	0.852	0.8675	0.881	+33.82***
Private banks	0.5353	0.5311	0.5136	0.5226	0.5000	0.5056	-9.14***
Mixed private- public banks	0.7293	0.7363	0.7734	0.7723	0.7698	0.7622	+20.91***
Financial holding	0.8196	0.8200	0.8081	0.8076	0.7856	0.7508	+19.5***
Non-financial holding	0.4313	0.4258	0.4224	0.4354	0.4217	0.4512	-26.48***
Annual mean	0.58659	0.58345	0.57667	0.58427	0.56723	0.57105	

Note: \*\*\*denote 1% levels of significance

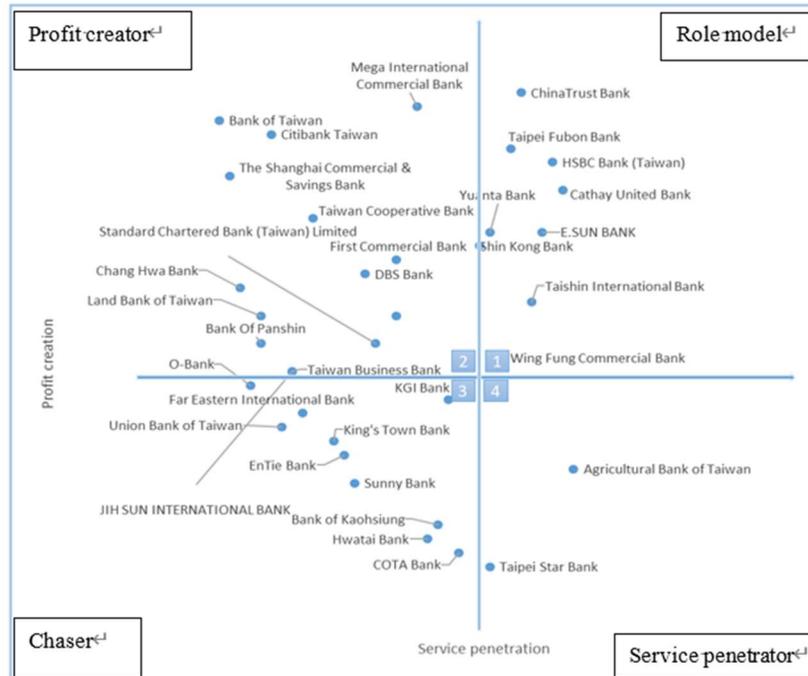
Based on the t-Stat and significance level from all types of banks, we can see that there is a significant difference between the efficiency values and the average value for each year in terms of profit creation efficiency. In Table 5, we find that foreign banks have a higher efficient value of profit creation than local banks. The introduction of new IT technology in the 2007-2008 takeover and changes in their internal business operating policies would be the main reason. Moreover, the profit creation efficiency of private banks are lower than those of public banks and mixed banks, and public banks are higher than mixed banks. The reason is that public banks usually have long age, high level of assets and high scale of customer base, which might result in more traditional interest income.

Furthermore, Table5 shows that average finance holding bank is double that of nonfinancial holding banks. The main reason is that financial holding subsidiaries benefit from standard business promotion, interactive use of information, and the use of common business equipment and facilities. It is common for subsidiaries of financial holding companies to engage in cross-industry marketing and to offer consumers one-stop shopping services. As a result, financial holding banks are more efficient.

#### 1. Efficiency Matrix

The service penetration on the horizontal axis represents the essential source of profit. The stability of profit results from the high operating efficiency of deposits and credit cards; the profit creation on the vertical axis denotes the actual performance of profits. The higher the loan amount and credit card transaction, the more profit growth and earning. Figure 3 further represents the different bank development strategies in the four quadrants:

**Figure 3**  
Efficiency matrix diagram



- (1) The first quadrant I  
A total of 9 banks are the **role models** (both profit penetrators and service penetrators) in the banking sector: China Trust Bank, Taipei Fubon Bank, HSBC Taiwan, Cathay Pacific, Yuanta Bank, Taishin Bank, Wing Fung Bank, Shin Kong Bank and E Sun Bank. Their service penetration efficiency and profit creation efficiency are the highest. It points out that these role models fully play as producers, effectively using resources to attract consumers to deposit and use credit card services, which are intermediaries for creating bank profits. In terms of the development of digital banking, if customers can be familiar with and accustomed to the functions of digital banking, they will have the opportunity to increase the market share and profitability by fully utilizing deposits and credit cards.
- (2) The second quadrant II  
A total of 13 banks are **profit creators** (but not service penetrators) in the banking sector: Bank of Taiwan, Mega Bank, Citibank Taiwan, Shanghai Commercial Bank, Taiwan Cooperative Bank, First Bank, DBS Taiwan, Changhwa Bank, Land Bank, Taiwan Business Bank, Standard Chartered Bank, Taiwan Enterprise Bank and Bank of Panshin have high profit creation efficiency but low service penetration efficiency, which explains that although banks can effectively create value and profit, the efficiency of essential services still needs to be strengthened to expand the profit creation niche. In terms of the

development strategy of digital banking, attention should be paid to the operational efficiency of the first stage, the cost of controlling the input of resources, and the expansion of deposits and the number of valid credit cards to penetrate the service to consumers. However, the large number of profit creators but not service penetrator suggests that service penetration or widespread financial inclusion is not a necessity for creating profits.

(3) The third quadrant III

A total of 11 banks are **chasers** in the banking sector: Union Bank, KGI Bank, Far Eastern Bank, Kings Town Bank, EnTie Bank, Sunny Bank, Jih Sun Bank, Cota Bank, O-Bank, Kaohsiung Bank, and Hwatai Bank. They have low service penetration efficiency and low-profit creation efficiency, which means that there is a capacity for improvement in the input and output of each stage of the process. In terms of the development strategy of digital banking, it is advisable to identify benchmark banks with comparable nature in the industry to imitate and learn and encourage the strengths of internal processes or improve the weaknesses of internal processes to increase the efficiency of service penetration and profit creation, and give play to the effect of di banking.

(4) The fourth quadrant IV

A total of 2 banks are **service penetrators** (but not profit creators) in the banking sector: National Agricultural Bank and Taipei Star Bank. Their service penetration efficiency is high, but the profit creation efficiency is low. It explains that banks have effectively used resources to produce essential financial services—deposits and credit cards. Service penetration, how to effectively use deposits and credit cards to create value and make profits, still needs to be improved and learned. In the minds of Taiwanese, banks that are more localized have not invested in digital banking. When developing a digital banking strategy, it is crucial to utilize the efficient penetration of services so that consumers are familiar with and accustomed to using it. If it is to create value and profit further, it is necessary to improve the efficiency of the second stage of the process as soon as possible.

## 2. Tobit Regression Results

Table 6 presents the overall efficiency analysis of Tobit regression. From this table, it can be found that except for branch numbers and age, all control variables including financial inclusion variable, diversification and total assets are significant in P value. Foreign versus domestic, financial versus non-financial, and private versus public dummy variables are significantly associated with total efficiency, indicating there are significant differences between our three categories. In terms of the coefficients, the number of digital accounts are negatively associated with total efficiency, implying the more digital account numbers, the less total efficiency. One possible explanation could be that Taiwan's digital finance is still in the investing(construction) stage, it has not yet been harvested. The coefficient of diversification is also negative, indicating that the more diversified the products are, the worse the overall efficiency. This may indicate that banks should focus on their own specialized products, rather than too many diversified ones. In addition, positive coefficients for the ATM number of ATMs are not surprising since more ATMs in a digital environment will result in greater efficiency for the banks.

It might be because most digital account holders are young people who prefer not to use branches for transactions and have skills in running ATMs and internet banking. This will reinforce the usage of ATMs and internet banking. Despite this, the number of digital accounts in Taiwan, that reflects digital finance practices, is negatively related to total efficiency. It is likely that Taiwan's digital finance environment is still in the investing phase, resulting in high infrastructure costs and low profits.

**Table 6**  
Total efficiency

Independent variables	coefficient	P value.
# of Digital accounts	-3.65E-07	0.0521**
# of ATMs	4.32E-05	0.0159**
Transaction amounts of ATMs	-1.33E-07	0.3195
# of Branches	-0.000732	0.1338
Diversification	-0.255977	0.0000***
Foreign/Local	0.455305	0.0000***
Holding/non-holding	0.088342	0.0137**
Age	-0.000178	0.6753
Private/public	0.234158	0.0000***
Total assets	1.00E-10	0.0001***
C	0.374134	0.0065

**Table 7**  
Service penetration efficiency

Independent variables	coefficient	P value.
# of Digital accounts	-1.42E-07	0.6030
# of ATMs	6.54E-05	0.0312***
Transaction amount of ATMs	7.81E-07	0.0000***
# of Branches	-0.00577	0.0000***
Diversification	-0.130084	0.0000***
Foreign/Local	0.150274	0.0720**
Holding/non-holding	0.263907	0.0002***
Age	0.001312	0.0604**
Private/public	0.183228	0.0066***
Total assets	8.51E-11	0.0424**
C	0.198374	0.3874

Table 7 shows the results of the efficiency of service penetration stage. In terms of the P-value, the digital account numbers are the only insignificant variable. The main reason might be that the digital accounts have not yet become popular throughout the entire financial system, so it has not had much impacts. The dummy variables including foreign and domestic, financial and nonfinancial, and private and public are positively associated with service penetration efficiency significantly, which again indicates there are significant differences between different groups. In terms of the coefficient, the number of ATMs are positively associated with service penetration efficiency, implying the more the number and transaction amount of ATMs, the more service penetration

efficiency. The mature ATM infrastructure and bank branches in Taiwan enable individuals and businesses to easily obtain financial services that meet their needs, which may include transactions, payments, savings, credit, and insurance, which is what financial inclusion is about. As indicated in Figure 1, the number of ATMs distributed in Taiwan increased by 24.2% from 2007 to 2020, along with the number of transactions made at ATMs, which grew by over a third in the same period. However, the coefficient of diversification is negative, meaning the greater the number of branches, the lower the service penetration efficiency. This may suggest that the high costs of branch establishment reduce service efficiency and performance, the same result as Lin et al. (2019). Therefore, the banks should focus on their own unique service products, not put their efforts into too much diversified products.

**Table 8**  
Profit creation efficiency

Independent variables	coefficient	P value.
# of Digital accounts	-3.91E-07	0.0369**
# of ATMs	1.11E-05	0.5260
Transaction amount of ATMs	-2.69E-07	0.0323**
# of Branches	0.000578	0.2746
Diversification	-0.140043	0.0000***
Foreign/Local	0.611798	0.0000***
Holding/non-holding	0.248512	0.0000***
Age	-0.000121	0.7270
Private/public	0.100908	0.0104***
Total assets	2.10E-10	0.0000***
C	0.222764	0.1526

Table 8 provides the result of profit creation performance. There was no evidence that the number of ATMs and the number of branches had an influence on profit creation efficiency. Although the number of ATMs can create total efficiency as mentioned earlier, this variable is not significant at the profit creation stage. This reflects that the number of ATMs is highly associated with service penetration. When it comes to profit creation efficiency, both the great number of ATMs and branches is not helpful for transferring the total deposits and number of credit cards into interest income, fee income, and credit card transaction amounts. It is possible that some banks with more branches are conservative with their loans. Meanwhile, some private banks with many ATMs also issue a great deal of credit cards, but a lot of them do not generate revenue from transactions and fees. In addition, the number of digital accounts, the transaction amount of ATMs, total assets and the degree of diversification reveal a strong association with profit creation efficiency. However, diversification and number of digital accounts are negatively associated with profit creation efficiency. The main reason may be that digital finance in Taiwan is in the investing stage, which means high infrastructure costs and lower profits. In terms of the dummy variables including foreign and domestic, financial and nonfinancial, and private and public, these variables are positively associated with profit creation efficiency significantly, which again indicates there are significant differences between our three categories.

## V. CONCLUSION

In this paper, we use a two-stage DEA model to measure service penetration efficiency and profit creation efficiency, and adopts Tobit regression to determine the factors that affect banking efficiency and evaluate how they affect banking performance. We emphasize the importance of digital finance and finance inclusion on banking efficiency, though some of the variables are not so mature. It is essential that the financial market is an industry that relies heavily on efficiency to drive company profitability. Our results show that foreign banks have a higher profit creation efficiency than local banks. The introduction of new IT technology in the 2007-2008 takeover and changes in their internal business operating policies may be the main reason. Further, the service penetration efficiency of private banks will be higher than that of public and mixed banks since the number of private banks' ATMs are higher than the public and mixed banks. In addition, financial holding banks are twice more efficient than nonfinancial holding banks on average. One possible explanation for this is that they typically have a high level of assets and a high scale of customer base. This also confirms our results that higher level of assets can bring higher service penetration and profit creation efficiency, the same results as Sukmana, et al. (2020).

From our efficiency matrix, the most striking observation to emerge from the analysis is that about 25% of the banks have good performance in the service penetration stage; 57% of the banks have good performance in the profit creation stage. As for the efficiency in both stages, there are seven banks which are role models for others, such as China Trust Bank, Taipei Fubon Bank, Yunta Bank, Taishin international Bank, Cathay United Bank, HSBC Taiwan, and E.Sun Bank, which accounted for 77.8% (7 in 9 banks) of the penetrators. This means most service penetrators have also higher profit creation efficiency. These seven banks are all private banks with higher IT infrastructure, which means that the introduction of IT financial technology can improve the deficiencies in the service process. These findings confirm those of earlier studies, such as Banker and Kauffman (1991), who mention that IT investments not only increase the operation process but also increase the productivity and expand the market share. However, there are 13 banks (out of 20 banks that have high profit creation) which are profit creators, but not service penetrators. Taking into account both of these facts, we conclude that financial inclusion may generate profits, but it is not a necessity for creating profits.

In addition, the higher the number of ATMs, the better the service penetration and overall efficiency, which implies that IT infrastructure can help banks effectively utilize their resources, as mentioned by Wang et al. (1997) and Chen and Zue (2004). Financial inclusion in Taiwan is well achieved, since people can use financial services through ubiquitous ATMs. Financial inclusion can help to increase service penetration efficiency, but it may not necessarily lead to higher profit creation efficiency. However, the number of digital accounts is not helpful to both stages, since digital finance is still in its infancy. Therefore, we can also infer that digital banking in Taiwan is strategic necessity rather than strategic advantage in terms of efficiency as suggested by Kahveci and Wolfs (2018). As for the other factors influencing the efficiency, it can be found that the in terms of profit creation efficiency and service penetration efficiency, financial holding banks outperform nonfinancial holding banks since they typically possess high levels of assets and a large customer base. Our evidence also shows that higher asset generally brings higher efficiency. However, higher number of branches leads to poor performance in

service penetration efficiency due to the heavy burden of rental costs. Further, we also find that diversified products have a negative impact on the overall efficiency. Banks would be better off focusing on specialized products, not as many diversified products. The findings of this study have several implications for banking management. First, despite that IT infrastructure of ATMs and e-banking plays a crucial role in fostering financial inclusion, ATMs are still the backbone of efficient banking in the digital finance environment, while digital banking in Taiwan is merely a strategic necessity rather than strategic advantage. Meanwhile, traditional branches of banks may even hinder efficiency. As a result, banks should focus on inclusive finance in order to expand the scope of customer services and transform the main source of profits in the digital finance environment. Second, although financial holding banks are more efficient than their nonfinancial holding counterparts, and cross-selling is undoubtedly attractive, our research suggests that banks should still specialize in a few products rather than diversify too widely.

## VI. Research limitations and recommendations

Apps are the main methods used for mobile payments, but we are not able to retrieve the app's download number, so we have to use other public data from TEJ. For further research, we recommend that researchers interested in the performance of mobile banks monitor the number of users downloading apps. Besides reducing costs and increasing revenue, mobile banking also seeks to improve the bank's image and increase consumer satisfaction. Thus, future research can consider variables such as "customer satisfaction" and "brand image" when evaluating the performance of mobile banking. When electronic payments, offered by several financial institutions, are used more widely, specific financial institutions or customer groups can be determined for deeper consideration and study. When banks introduce another new technological service in the future, they can still use this research method to evaluate performance.

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## APPENDIX

## A. Service penetration (Foreign companies and non- foreign companies)

Category	Bank name	Average Value					
		2013	2014	2015	2016	2017	2018
Foreign company	Standard Chartered Bank (Taiwan) Limited	0.1733	0.1884	0.1788	0.1722	0.1651	0.2036
Foreign company	Citibank Taiwan	0.0205	0.0201	0.0235	0.0235	0.0234	0.1565
Foreign company	HSBC Bank (Taiwan)	1	1	1	1	1	1
Foreign company	DBS Bank	0.0541	0.0748	0.0574	0.0624	0.4408	0.3309
	Average	0.3120	0.3208	0.3149	0.3145	0.4073	0.4228
Non-foreign company	Agricultural Bank of Taiwan	1	1	1	1	1	1
Non-foreign company	Chang Hwa Bank	0.0184	0.0254	0.0237	0.0232	0.0226	0.057
Non-foreign company	King's Town Bank	0.0858	0.1125	0.1146	0.0896	0.0807	0.1618
Non-foreign company	Taiwan Business Bank	0.0363	0.0518	0.0488	0.0464	0.0449	0.0652
Non-foreign company	Bank of Kaohsiung	0.1854	0.2947	0.2609	0.2442	0.2275	0.3628
Non-foreign company	KGI Bank	0.3535	0.3254	0.2894	0.2498	0.2384	0.2469
Non-foreign company	Union Bank of Taiwan	0.0415	0.0493	0.0466	0.0433	0.0331	0.0658
Non-foreign company	Far Eastern International Bank	0.0474	0.0558	0.0545	0.0529	0.0535	0.1322
Non-foreign company	EnTie Bank	0.075	0.0893	0.0759	0.0834	0.085	0.2611
Non-foreign company	Shin Kong Bank	0.452	0.4639	0.4615	0.44	0.4271	0.4185
Non-foreign company	Sunny Bank	0.1272	0.1524	0.1412	0.1295	0.1277	0.199
Non-foreign company	O-Bank	0.0196	0.033	0.038	0.0353	0.0319	0.0631
Non-foreign company	Hwatai Bank	0.1843	0.2471	0.2335	0.2335	0.2521	0.4379
Non-foreign company	COTA Bank	0.2503	0.3406	0.2708	0.2727	0.2228	0.3898
Non-foreign company	Cathay United Bank	1	1	1	1	1	1
Non-foreign company	Taipei Fubon Bank	0.999	0.6246	0.6381	0.6148	0.5614	0.5369
Non-foreign company	Hua Nan Bank	0.1623	0.2077	0.2395	0.2536	0.2875	0.2501
Non-foreign company	ChinaTrust Bank	0.7945	0.7422	0.7588	0.7598	0.7654	0.6865
Non-foreign company	Mega International Commercial Bank	0.2568	0.2446	0.2872	0.2723	0.2553	0.2409

Non-foreign company	First Commercial Bank	0.1944	0.2128	0.2272	0.2276	0.2409	0.2449
Non-foreign company	E.SUN BANK	1	1	1	0.9121	1	1
Non-foreign company	Taishin International Bank	0.822	0.9103	0.9503	0.9566	1	1
Non-foreign company	Wing Fung Commercial Bank	0.666	0.6589	0.6816	0.6304	0.5329	0.5251
Non-foreign company	JIH SUN INTERNATIONAL BANK	0.0696	0.1041	0.1008	0.1063	0.0947	0.1633
Non-foreign company	Yuanta Bank	0.1567	0.2361	0.32	0.4121	0.2502	0.4442
Non-foreign company	Taiwan Cooperative Bank	0.0827	0.0922	0.0915	0.0946	0.1034	0.1202
Non-foreign company	Land Bank of Taiwan	0.0254	0.0358	0.0313	0.0317	0.0355	0.0763
Non-foreign company	Bank of Taiwan	0.0157	0.0224	0.0231	0.0218	0.021	0.0338
Non-foreign company	Bank Of Panshin	0.1567	0.2059	0.1654	0.1817	0.1755	0.2837
Non-foreign company	Taipei Star Bank	0.3838	0.5654	0.5511	0.5541	0.5728	0.9487
Non-foreign company	The Shanghai Commercial and Savings Bank	0.0182	0.025	0.0224	0.0205	0.021	0.0502
	Average	0.3123	0.3267	0.3273	0.3224	0.3150	0.3699

#### B. Service penetration (Public, Private and Mixed; Private-public )

Category	Bank name	2013	2014	2015	2016	2017	2018
Public	Land Bank of Taiwan	0.0254	0.0358	0.0313	0.0317	0.0355	0.0763
Public	Bank of Taiwan	0.0157	0.0224	0.0231	0.0218	0.021	0.0338
Average		0.0206	0.0291	0.0272	0.0268	0.0283	0.0551
Private	Agricultural Bank of Taiwan	1	1	1	1	1	1
Private	Standard Chartered Bank (Taiwan) Limited	0.1733	0.1884	0.1788	0.1722	0.1651	0.2036
Private	King's Town Bank	0.0858	0.1125	0.1146	0.0896	0.0807	0.1618
Private	Bank of Kaohsiung	0.1854	0.2947	0.2609	0.2442	0.2275	0.3628
Private	KGI Bank	0.3535	0.3254	0.2894	0.2498	0.2384	0.2469
Private	Union Bank of Taiwan	0.0415	0.0493	0.0466	0.0433	0.0331	0.0658
Private	Far Eastern International Bank	0.0474	0.0558	0.0545	0.0529	0.0535	0.1322
Private	EnTie Bank	0.075	0.0893	0.0759	0.0834	0.085	0.2611
Private	Shin Kong Bank	0.452	0.4639	0.4615	0.44	0.4271	0.4185
Private	Sunny Bank	0.1272	0.1524	0.1412	0.1295	0.1277	0.199
Private	O-Bank	0.0196	0.033	0.038	0.0353	0.0319	0.0631
Private	Hwatai Bank	0.1843	0.2471	0.2335	0.2335	0.2521	0.4379
Private	COTA Bank	0.2503	0.3406	0.2708	0.2727	0.2228	0.3898
Private	Cathay United Bank	1	1	1	1	1	1

Private	Taipei Fubon Bank	0.999	0.6246	0.6381	0.6148	0.5614	0.5369
Private	ChinaTrust Bank	0.7945	0.7422	0.7588	0.7598	0.7654	0.6865
Private	E.SUN BANK	1	1	1	0.9121	1	1
Private	Taishin International Bank	0.822	0.9103	0.9503	0.9566	1	1
Private	Wing Fung Commercial Bank	0.666	0.6589	0.6816	0.6304	0.5329	0.5251
Private	JIH SUN INTERNATIONAL BANK	0.0696	0.1041	0.1008	0.1063	0.0947	0.1633
Private	Yuanta Bank	0.1567	0.2361	0.32	0.4121	0.2502	0.4442
Private	Bank Of Panshin	0.1567	0.2059	0.1654	0.1817	0.1755	0.2837
Private	Taipei Star Bank	0.3838	0.5654	0.5511	0.5541	0.5728	0.9487
Private	Citibank Taiwan	0.0205	0.0201	0.0235	0.0235	0.0234	0.1565
Private	HSBC Bank (Taiwan)	1	1	1	1	1	1
Private	DBS Bank The Shanghai Commercial and Savings Bank	0.0541	0.0748	0.0574	0.0624	0.4408	0.3309
Private		0.0182	0.025	0.0224	0.0205	0.021	0.0502
Average		0.3754	0.3896	0.3865	0.3808	0.3846	0.4470
Mixed	Chang Hwa Bank	0.0184	0.0254	0.0237	0.0232	0.0226	0.057
Mixed	Taiwan Business Bank	0.0363	0.0518	0.0488	0.0464	0.0449	0.0652
Mixed	Hua Nan Bank	0.1623	0.2077	0.2395	0.2536	0.2875	0.2501
Mixed	Mega International Commercial Bank	0.2568	0.2446	0.2872	0.2723	0.2553	0.2409
Mixed	First Commercial Bank	0.1944	0.2128	0.2272	0.2276	0.2409	0.2449
Mixed	Taiwan Cooperative Bank	0.0827	0.0922	0.0915	0.0946	0.1034	0.1202
Average		0.1252	0.1391	0.1530	0.1530	0.1591	0.1631

## C. Service penetration (Financial holding and Non-financial holding)

Category	Bank name	2013	2014	2015	2016	2017	2018
Financial holding	Shin Kong Bank	0.452	0.4639	0.4615	0.44	0.4271	0.4185
Financial holding	Cathay United Bank	1	1	1	1	1	1
Financial holding	Taipei Fubon Bank	0.999	0.6246	0.6381	0.6148	0.5614	0.5369
Financial holding	Hua Nan Bank	0.1623	0.2077	0.2395	0.2536	0.2875	0.2501
Financial holding	ChinaTrust Bank	0.7945	0.7422	0.7588	0.7598	0.7654	0.6865
Financial holding	Mega International Commercial Bank	0.2568	0.2446	0.2872	0.2723	0.2553	0.2409
Financial holding	First Commercial Bank	0.1944	0.2128	0.2272	0.2276	0.2409	0.2449
Financial holding	E.SUN BANK	1	1	1	0.9121	1	1
Financial holding	Taishin International Bank	0.822	0.9103	0.9503	0.9566	1	1
Financial holding	Wing Fung Commercial Bank	0.666	0.6589	0.6816	0.6304	0.5329	0.5251
Financial holding	JIH SUN INTERNATIONAL BANK	0.0696	0.1041	0.1008	0.1063	0.0947	0.1633
Financial holding	Yuanta Bank	0.1567	0.2361	0.32	0.4121	0.2502	0.4442
Financial holding	Taiwan Cooperative	0.0827	0.0922	0.0915	0.0946	0.1034	0.1202

		Bank					
Financial holding	Bank of Taiwan	0.0157	0.0224	0.0231	0.0218	0.021	0.0338
	Average	0.4766	0.4657	0.4843	0.4787	0.4671	0.4760
Non-financial holding	Agricultural Bank of Taiwan	1	1	1	1	1	1
Non-financial holding	Chang Hwa Bank	0.0184	0.0254	0.0237	0.0232	0.0226	0.057
Non-financial holding	Standard Chartered Bank (Taiwan) Limited	0.1733	0.1884	0.1788	0.1722	0.1651	0.2036
Non-financial holding	King's Town Bank	0.0858	0.1125	0.1146	0.0896	0.0807	0.1618
Non-financial holding	Taiwan Business Bank	0.0363	0.0518	0.0488	0.0464	0.0449	0.0652
Non-financial holding	Bank of Kaohsiung	0.1854	0.2947	0.2609	0.2442	0.2275	0.3628
Non-financial holding	KGI Bank	0.3535	0.3254	0.2894	0.2498	0.2384	0.2469
Non-financial holding	Union Bank of Taiwan	0.0415	0.0493	0.0466	0.0433	0.0331	0.0658
Non-financial holding	Far Eastern International Bank	0.0474	0.0558	0.0545	0.0529	0.0535	0.1322
Non-financial holding	EnTie Bank	0.075	0.0893	0.0759	0.0834	0.085	0.2611
Non-financial holding	Sunny Bank	0.1272	0.1524	0.1412	0.1295	0.1277	0.199
Non-financial holding	O-Bank	0.0196	0.033	0.038	0.0353	0.0319	0.0631
Non-financial holding	Hwatai Bank	0.1843	0.2471	0.2335	0.2335	0.2521	0.4379
Non-financial holding	COTA Bank	0.2503	0.3406	0.2708	0.2727	0.2228	0.3898
Non-financial holding	Land Bank of Taiwan	0.0254	0.0358	0.0313	0.0317	0.0355	0.0763
Non-financial holding	Bank Of Panshin	0.1567	0.2059	0.1654	0.1817	0.1755	0.2837
Non-financial holding	Taipei Star Bank	0.3838	0.5654	0.5511	0.5541	0.5728	0.9487
Non-financial holding	Citibank Taiwan	0.0205	0.0201	0.0235	0.0235	0.0234	0.1565
Non-financial holding	HSBC Bank (Taiwan)	1	1	1	1	1	1
Non-financial holding	DBS Bank	0.0541	0.0748	0.0574	0.0624	0.4408	0.3309
Non-financial holding	The Shanghai Commercial and Savings Bank	0.0182	0.025	0.0224	0.0205	0.021	0.0502
	Average	0.2027	0.2330	0.2204	0.2167	0.2312	0.3092

#### D. Profit Creation (Foreign companies and non-foreign companies)

Category	Bank name	2013	2014	2015	2016	2017	2018
Foreign	Standard Chartered	0.7559	0.6164	0.5591	0.5244	0.5266	0.7835

company	Bank (Taiwan) Limited						
Foreign company	Citibank Taiwan	1	1	1	1	1	1
Foreign company	HSBC Bank (Taiwan)	1	1	0.9122	0.9291	1	1
Foreign company	DBS Bank	0.926	0.9441	0.6829	0.7215	0.4384	0.7924
	Average	0.9205	0.8901	0.7886	0.7938	0.7413	0.8940
Non- foreign company	Agricultural Bank of Taiwan	0.1712	0.1624	0.1636	0.1783	0.1792	0.159
Non- foreign company	Chang Hwa Bank	0.6667	0.7018	0.7165	0.7741	0.7652	0.8004
Non- foreign company	King's Town Bank	0.2537	0.2877	0.308	0.3395	0.3496	0.311
Non- foreign company	Taiwan Business Bank	0.4478	0.4494	0.5019	0.5299	0.5395	0.5605
Non- foreign company	Bank of Kaohsiung	0.0789	0.0811	0.0843	0.0862	0.0804	0.0856
Non- foreign company	KGI Bank	0.4236	0.4095	0.4985	0.5172	0.4614	0.4431
Non- foreign company	Union Bank of Taiwan	0.2838	0.2948	0.3002	0.3348	0.3308	0.3605
Non- foreign company	Far Eastern International Bank	0.4211	0.3798	0.365	0.3849	0.3899	0.4231
Non- foreign company	EnTie Bank	0.2903	0.2749	0.2767	0.2265	0.1995	0.2077
Non- foreign company	Shin Kong Bank	1	0.9794	0.7554	0.6552	0.6312	0.6175
Non- foreign company	Sunny Bank	0.1434	0.1447	0.1572	0.171	0.1711	0.1725
Non- foreign company	O-Bank	0.4835	0.4431	0.4751	0.4985	0.4724	0.3863
Non- foreign company	Hwatai Bank	0.0605	0.0629	0.0612	0.0635	0.0539	0.0487
Non- foreign company	COTA Bank	0.0529	0.0503	0.0554	0.0575	0.0592	0.056
Non- foreign company	Cathay United Bank	0.9813	1	1	1	0.8232	0.7787
Non- foreign company	Taipei Fubon Bank	0.9459	1	1	1	1	0.98
Non- foreign company	Hua Nan Bank	0.6585	0.6685	0.697	0.6501	0.6264	0.5905
Non- foreign company	ChinaTrust Bank	1	1	1	1	1	1
Non- foreign company	Mega International Commercial Bank	1	1	1	1	1	1
Non- foreign company	First Commercial Bank	0.7633	0.7707	0.8017	0.7775	0.7863	0.698
Non- foreign company	E.SUN BANK	0.7998	0.7604	0.7615	0.9166	0.8543	0.7936
Non- foreign company	Taishin International Bank	0.7574	0.7162	0.6874	0.7739	0.7206	0.6918

Non- foreign company	Wing Fung Commercial Bank	0.6664	0.6373	0.567	0.5123	0.5973	0.5886
Non- foreign company	JIH SUN INTERNATIONAL BANK	0.1484	0.1199	0.1198	0.1185	0.1188	0.1232
Non- foreign company	Yuanta Bank	0.9138	1	1	1	0.9385	0.7248
Non- foreign company	Taiwan Cooperative Bank	0.8393	0.8272	0.9233	0.9021	0.9016	0.924
Non- foreign company	Land Bank of Taiwan	0.7022	0.664	0.6751	0.7044	0.7351	0.7621
Non- foreign company	Bank of Taiwan	1	1	1	1	1	1
Non- foreign company	Bank Of Panshin	0.0681	0.0738	0.0703	0.1066	0.0981	0.1029
Non- foreign company	Taipei Star Bank	0.0203	0.0207	0.0236	0.0224	0.0208	0.0208
Non- foreign company	The Shanghai Commercial and Savings Bank	0.8065	0.8796	0.9834	0.9729	0.9836	1
	Average	0.5435	0.5439	0.5493	0.5572	0.5448	0.5294

## E. Profit Creation (Public, Private and Mixed Private-public )

Category	Bank name	2013	2014	2015	2016	2017	2018
Public	Land Bank of Taiwan	0.7022	0.664	0.6751	0.7044	0.7351	0.7621
Public	Bank of Taiwan	1	1	1	1	1	1
	Average	0.8511	0.832	0.8375	0.852	0.8675	0.881
Private	Agricultural Bank of Taiwan	0.1712	0.1624	0.1636	0.1783	0.1792	0.159
Private	Standard Chartered Bank (Taiwan) Limited	0.7559	0.6164	0.5591	0.5244	0.5266	0.7835
Private	King's Town Bank	0.2537	0.2877	0.308	0.3395	0.3496	0.311
Private	Bank of Kaohsiung	0.0789	0.0811	0.0843	0.0862	0.0804	0.0856
Private	KGI Bank	0.4236	0.4095	0.4985	0.5172	0.4614	0.4431
Private	Union Bank of Taiwan	0.2838	0.2948	0.3002	0.3348	0.3308	0.3605
Private	Far Eastern International Bank	0.4211	0.3798	0.365	0.3849	0.3899	0.4231
Private	EnTie Bank	0.2903	0.2749	0.2767	0.2265	0.1995	0.2077
Private	Shin Kong Bank	1	0.9794	0.7554	0.6552	0.6312	0.6175
Private	Sunny Bank	0.1434	0.1447	0.1572	0.171	0.1711	0.1725
Private	O-Bank	0.4835	0.4431	0.4751	0.4985	0.4724	0.3863
Private	Hwatai Bank	0.0605	0.0629	0.0612	0.0635	0.0539	0.0487
Private	COTA Bank	0.0529	0.0503	0.0554	0.0575	0.0592	0.056
Private	Cathay United Bank	0.9813	1	1	1	0.8232	0.7787
Private	Taipei Fubon Bank	0.9459	1	1	1	1	0.98
Private	ChinaTrust Bank	1	1	1	1	1	1
Private	E.SUN BANK	0.7998	0.7604	0.7615	0.9166	0.8543	0.7936
Private	Taishin International Bank	0.7574	0.7162	0.6874	0.7739	0.7206	0.6918
Private	Wing Fung Commercial Bank	0.6664	0.6373	0.567	0.5123	0.5973	0.5886
Private	JIH SUN INTERNATIONAL BANK	0.1484	0.1199	0.1198	0.1185	0.1188	0.1232
Private	Yuanta Bank	0.9138	1	1	1	0.9385	0.7248

Private	Bank Of Panshin	0.0681	0.0738	0.0703	0.1066	0.0981	0.1029
Private	Taipei Star Bank	0.0203	0.0207	0.0236	0.0224	0.0208	0.0208
Private	Citibank Taiwan	1	1	1	1	1	1
Private	HSBC Bank (Taiwan)	1	1	0.9122	0.9291	1	1
Private	DBS Bank	0.926	0.9441	0.6829	0.7215	0.4384	0.7924
Private	The Shanghai Commercial and Savings Bank	0.8065	0.8796	0.9834	0.9729	0.9836	1
	Average	0.5353	0.5311	0.5136	0.5226	0.5000	0.5056
Mixed Private-public	Chang Hwa Bank	0.6667	0.7018	0.7165	0.7741	0.7652	0.8004
Mixed Private-public	Taiwan Business Bank	0.4478	0.4494	0.5019	0.5299	0.5395	0.5605
Mixed Private-public	Hua Nan Bank	0.6585	0.6685	0.697	0.6501	0.6264	0.5905
Mixed Private-public	Mega International Commercial Bank	1	1	1	1	1	1
Mixed Private-public	First Commercial Bank	0.7633	0.7707	0.8017	0.7775	0.7863	0.698
Mixed Private-public	Taiwan Cooperative Bank	0.8393	0.8272	0.9233	0.9021	0.9016	0.924
	Average	0.7293	0.7363	0.7734	0.7723	0.7698	0.7622

## F. Profit Creation (Financial holding and Non-financial holding )

Category	Bank name	2013	2014	2015	2016	2017	2018
Financial holding	Shin Kong Bank	1	0.9794	0.7554	0.6552	0.6312	0.6175
Financial holding	Cathay United Bank	0.9813	1	1	1	0.8232	0.7787
Financial holding	Taipei Fubon Bank	0.9459	1	1	1	1	0.9800
Financial holding	Hua Nan Bank	0.6585	0.6685	0.6970	0.6501	0.6264	0.5905
Financial holding	ChinaTrust Bank	1	1	1	1	1	1
Financial holding	Mega International Commercial Bank	1	1	1	1	1	1
Financial holding	First Commercial Bank	0.7633	0.7707	0.8017	0.7775	0.7863	0.6980
Financial holding	E.SUN BANK	0.7998	0.7604	0.7615	0.9166	0.8543	0.7936
Financial holding	Taishin International Bank	0.7574	0.7162	0.6874	0.7739	0.7206	0.6918
Financial holding	Wing Fung Commercial Bank	0.6664	0.6373	0.567	0.5123	0.5973	0.5886
Financial holding	JIH SUN INTERNATIONAL BANK	0.1484	0.1199	0.1198	0.1185	0.1188	0.1232
Financial holding	Yuanta Bank	0.9138	1	1	1	0.9385	0.7248
Financial holding	Taiwan Cooperative Bank	0.8393	0.8272	0.9233	0.9021	0.9016	0.924
Financial holding	Bank of Taiwan	1	1	1	1	1	1
	Average	0.8196	0.8200	0.8081	0.8076	0.7856	0.7508
Non-financial holding	Agricultural Bank of Taiwan	0.1712	0.1624	0.1636	0.1783	0.1792	0.1590
Non-financial holding	Chang Hwa Bank	0.6667	0.7018	0.7165	0.7741	0.7652	0.8004
Non-financial holding	Standard Chartered Bank (Taiwan) Limited	0.7559	0.6164	0.5591	0.5244	0.5266	0.7835

Non-financial holding	King's Town Bank	0.2537	0.2877	0.308	0.3395	0.3496	0.311
Non-financial holding	Taiwan Business Bank	0.4478	0.4494	0.5019	0.5299	0.5395	0.5605
Non-financial holding	Bank of Kaohsiung	0.0789	0.0811	0.0843	0.0862	0.0804	0.0856
Non-financial holding	KGI Bank	0.4236	0.4095	0.4985	0.5172	0.4614	0.4431
Non-financial holding	Union Bank of Taiwan	0.2838	0.2948	0.3002	0.3348	0.3308	0.3605
Non-financial holding	Far Eastern International Bank	0.4211	0.3798	0.365	0.3849	0.3899	0.4231
Non-financial holding	EnTie Bank	0.2903	0.2749	0.2767	0.2265	0.1995	0.2077
Non-financial holding	Sunny Bank	0.1434	0.1447	0.1572	0.171	0.1711	0.1725
Non-financial holding	O-Bank	0.4835	0.4431	0.4751	0.4985	0.4724	0.3863
Non-financial holding	Hwatai Bank	0.0605	0.0629	0.0612	0.0635	0.0539	0.0487
Non-financial holding	COTA Bank	0.0529	0.0503	0.0554	0.0575	0.0592	0.056
Non-financial holding	Land Bank of Taiwan	0.7022	0.664	0.6751	0.7044	0.7351	0.7621
Non-financial holding	Bank Of Panshin	0.0681	0.0738	0.0703	0.1066	0.0981	0.1029
Non-financial holding	Taipei Star Bank	0.0203	0.0207	0.0236	0.0224	0.0208	0.0208
Non-financial holding	Citibank Taiwan	1	1	1	1	1	1
Non-financial holding	HSBC Bank (Taiwan)	1	1	0.9122	0.9291	1	1
Non-financial holding	DBS Bank	0.926	0.9441	0.6829	0.7215	0.4384	0.7924
Non-financial holding	The Shanghai Commercial and Savings Bank	0.8065	0.8796	0.9834	0.9729	0.9836	1
	Average	0.4313	0.4258	0.4224	0.4354	0.4217	0.4512