Clicks business of deposit-taking institutions: an efficiency analysis

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Abstract

Purpose – The purpose of this paper is to empirically examine the direct and indirect effects of automated teller machines (ATMs) on the performance and scope economies of the Japanese financial institutions.
Design/methodology/approach – Stochastic frontier approach is adopted to estimate banks' cost and profit efficiency indices and to examine the relationship between inefficiency scores and the number of ATMs.
Findings – The study concludes that the banks not only minimize costs and save money by using ATMs, but also spend the saved funds on hiring highly skilled staff to introduce a better product mix which allows the banks to observe scope economies.
Originality/value – The findings suggest that although branches would remain a crucial interaction point for relationship banking, but given their high fixed cost, shifting routine banking transactions from the branch to low-cost electronic channels can significantly reduce costs and enhance efficiency of the financial institutions.

Keywords Stochastic frontier approach, Profit efficiency, Cost efficiency, Automated teller machines, Deposit-taking institutions

Paper type Research paper

1. Introduction

During the past two decades, information and communication technology (ICT) has changed the landscape of international financial markets remarkably and have received significant attention from the researchers (see Frame and White, 2012 for a survey). In this context, the utilization of ICT for retail payment services have positive effects on banks' efficiency and customers' convenience (Hasan *et al.*, 2012; Fung *et al.*, 2014). In Japan, although banks have weathered various problems of non-performing loans but they are facing new challenges such as massive holdings of government bonds (IMF, 2012), longer term decline in domestic demand and changing customer expectations (PWC, 2014) and more stringent prudential supervision (Basel III) requirements which may further reduce degrees of freedom in searching profits. For sustainable gains, banks have to think of a right mix of automated and branch services.

The financial sector contribution in the total output and the labor force of the Japanese economy is 5 and 3 percent, respectively. Since the government is supporting debt over security, the banking units dominate the financial sector along with government postal savings and insurance companies. Japan's banking system is segmented into clearly defined components: commercial banks (6 city banks, 64 regional banks and 48 sub-regional banks), long-term credit banks (2), trust banks (5), foreign banks (61) and various specialized financial institutions such as Shinkin Banks, Credit Cooperatives, Agricultural Cooperatives, Fishery Cooperatives and their National Federations. These institutions have combined assets of 912 trillion Japanese yen[1] (JPY), total deposits of JPY641 trillion and an overall loan-to-deposit ratio of 70 percent[2].

Since the introduction of automated teller machines (ATMs) in 1970, the banking operations in Japan have changed a lot and most of the deposits and withdrawals take place

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using ATMs. The technology is so advanced that the notes received through ATMs are steam cleaned and ironed before their recirculation. In addition, ATMs can now check balances, transfers to the savings accounts of others, and issue card loans (revolving consumer credit). It has also become possible to obtain small amount, short-term loans by using the credit cards of credit card companies affiliated with particular banks. Initially, cash withdrawal could only be done through the ATMs of the bank with which one had an account. Further, in 1999 ATM networks are formed and shared by the member banks. The cardholders are allowed to perform transactions at any terminal of the member banks.

Convenience stores started installing ATMs at their premises in 1999 and since convenient stores are open 24/7 and located everywhere in Japan, banks are able to extend transaction services to its customers around the clock without recruiting more staff or machines. It helps banks to reduce their operating costs which consequently enhance their profitability.

The efficiency study of the banking sector in the era of modern technology has important research interest and policy relevance as described below.

First, Sathye (1997) reports that for an Australian economy a 10 percent increase in banking efficiency leads to $4 billion cost savings, which emphasis its importance in the banking business. Albertazzi and Gambacorta (2009) suggest that banks' cost to income ratio (operational efficiency) is lower due to incorporating ICT in their businesses. Schmiedel *et al.* (2012) claim that the average unit cost of traditional payment instruments (i.e. paper-based credit transfers, checks, collecting items) is almost three times that of straight to processing orders. The efficiency studies should be updated once and a while.

Second, there are a number of studies which observe various factors affecting the profitability of banks such as Lloyd-Williams and Molyneux (1994), Molyneux and Forbes (1995), Garcia-Herrero *et al.* (2009), Hakenes and Schnabel (2011) and Du and Sim (2016) analyze the effect of capitalization on bank profits; Naceur and Goaied (2001) find the effect of capital and labor productivity, portfolio composition and capitalization on banks efficiency; Berger *et al.* (2000), Claessens *et al.* (2002), Hasan and Hunter (1996), Lin and Zhang (2009), Malik *et al.* (2016), etc. interrogate the effect of ownership on bank performance; Hasan and Marton (2000), Laeven (1999), Barros *et al.* (2007), Athanasoglou *et al.* (2008), Feng and Serilitis (2009), Giordano and Lopes (2009), etc. find the effects of bank size on its performance. Some studies have discussed IT investments as a determinant of banks profitability such as Holden and El-Bannany (2004), Porter and Millar (1985), Chen *et al.* (2006), Isizoh *et al.* (2012).

Very few studies are related to ours such as Haynes and Thompson (2000) study adoption of ATMs by 93 UK building societies for the period of 1981-1993 using augmented Cobb-Douglas production function. Ou *et al.* (2009) estimate cost efficiency with respect to ATMs per employee in a cross-section of 264 banks in Taiwan using OLS method. Ardizzi *et al.* (2015) provide an evidence on the positive link between ATMs and overall operating costs of Italian banks during the period 2006-2010 by applying nonparametric estimation techniques.

Furthermore, since Japan is the world's second biggest banking market (assets-wise) several studies have conducted efficiency analysis of the Japanese banking sector such as Ohsato and Takahashi (2015), Assaf *et al.* (2011), Uchida and Satake (2009), Drake *et al.* (2009), etc. However, to the best of our knowledge, Kondo (2010) is the only study which investigates whether ATMs increase ROA following Holden and El-Bannany (2004) method for the period 2000-2004. Our study deviates from theirs in the model, data coverage and findings. Since Japan is a high-tech leader and its banking sector is technologically intense, it is relevant to explore how its focus on using technology improves its efficiency.

Third, while other studies conduct banks surveys (in Malaysia, Abdullah, 1985; in Japan, Katagiri, 1989; in the USA, Shawkey, 1995 and Gupta, 1998) or relate IT investment to the bank's efficiency or use nonparametric methods to perform efficiency analyses (Berg *et al.*, 1993;

Feith and Pasiouras, 2010), our study uses stochastic frontier approach (SFA) to interrogate the number of ATMs and the banks' performance. Due to increasingly complex banking environment, it is challenging to specify a suitable methodology for bank efficiency. In this context, two approaches are commonly used: SFA and data envelopment analysis (DEA) with its extensions to super efficiency DEA (SDEA) and bootstrapping DEA. SFA is considered as a superior approach especially for the studies of the banking sector due to two factors. Nonparametric methods such as DEA estimates give only an upper bound to efficiency measures so that it is difficult to use DEA to compare efficiency among firms (Schmidt, 1985). In order to overcome this problem, Andersen and Petersen (1993) proposed SDEA model which has better discriminating power than DEA but it is likely that a specific set of DMUs are ranked too high (Balf *et al.*, 2012). DEA does not assume statistical noise which means that all the error term in the estimation is attributed to inefficiency. This means that DEA will account for the influence of factors such as regional factor price differences, luck, bad data and extreme observations as "inefficiency" (Greene, 1993). Parametric methods allow us to distinguish between inefficiency and other stochastic shocks. Studies such as Silva *et al.* (2017) report lower efficiency means on average with greater variation with nonparametric methods than those using parametric techniques – an average of 72 percent with 17 percent variation vs 84 percent with 6 percent deviation (Berger and Humphrey, 1997). Simar and Wilson (2000, 2007) addressed this problem and introduced bootstrap approach to DEA. However, this method is based on strong assumptions, which seem to be practically implausible (see Tziogkidis, 2012).

Furthermore, in SFA no bank can be used as a benchmark because benchmarking is not explicit in SFA. Here, efficiency is generally defined relative to the true minimum costs lying on the frontier. We investigate whether banks with more exposure to electronic banking vs banks with less exposure are more efficient, which requires only comparisons to a consistent frontier.

Forth, since Japan like other developed nations is facing a shrinking working age population, it is important for its banking sector to use technology to rationalize processes, allowing the fewer staff available to concentrate on more value-added tasks (PWC, 2014). Fifth, although most of the researchers agree on the importance of technology in the development of the banking sector, some of them do not find a proportional relationship between the technology and banks efficiency (Thakor and Olazabal, 2002; Kondo, 2010).

Sixth, financial institutions are appraised by the integrated analysis using both cost and profit efficiencies and scope economy[3] jointly. This is especially true when the SFA applies to a multi-product industry such as banks (Lan and Lin, 2006). There is a possibility that a bank may rise superior to other banks in one indicator but inferior in the other indicator. However, a careful review of the literature has led us to conclude that only a few studies (e.g. Aly *et al.*, 1990; Grabowski *et al.*, 1993; Shao and Lin, 2002; Delgado *et al.*, 2015) have formulated scope economy and cost efficiency. We study that the funds saved using ATMs might be applied to hire staff with better analytical skills to introduce a better product mix which allows the banks to observe scope economies.

In this paper, we interrogate direct and indirect effects of the usage of technology and conclude that firms not only save money and minimize cost by using ATMs, they spend these saved money on hiring knowledgeable staff to offer a better output mix and earn scope economies. We address the following questions. How efficient the banking sector is in the era of ICT? Which banks category (big or small) is more efficient? Whether scope economies are observed in the technology-driven banking business?

Current study utilizes unbalanced panel data from the Japanese banks for the pre-financial crisis period of 14 years and estimates bank-specific efficiency relative to the predictive cost and profit functions of the efficient banks by employing stochastic frontier method. We first estimate the average cost and profit efficiency levels for 124 banks over the study period in which, following Battese and Coelli (1995), the parameters of the stochastic frontier and the inefficiency model are estimated simultaneously, given appropriate

distributional assumptions associated with cross-sectional data on the sample banks. In this simultaneous equation model, the inefficiency term is dependent upon variables, which represent virtual banking such as ATMs.

We also estimate scope economy from the estimated cost function which indicates whether a bank that is minimizing the cost of producing a particular output bundle could further lower costs by changing its product mix. Lastly, we rank all banks on the basis of their profit and cost efficiency scores as well as scope values.

The scale economy measure that has been widely adopted in the literature on the management of financial institutions is excluded in this study. Actually the importance of the scale economy decreases when the application of e-finance prevails. That is, the use of e-finance technology enables smaller institutions to access remote clients as easily as the major players in the industry, thereby scale economies play a less significant role in the exploration of e-finance (Claessens *et al.*, 2002; Furst *et al.*, 2002).

This paper is organized as follows: Section 2 describes the variables and database and Section 3 discusses the methodology used in this study. Section 4 presents the estimates of cost and profit efficiencies while Section 5 summarizes estimated efficiency indices and scope economies and the final section summarizes research findings.

2. Description of variables and the database

This research is based upon "intermediate approach" where banks are treated as multi-product firms which use three inputs: labor (X1), capital (X2) and borrowed funds (X3) to produce two outputs: loans and bills discounted (Y1) and investments (Y2). Loans and bills discounted (Y1) are the sum of all loan accounts and bills discounted whereas investments (Y2) are measured as the sum of securities, equities and other investments. The price of labor (P1) is measured as personal expenses divided by total number of employees. The price of physical capital (P2) is calculated as depreciation and rent divided by the value of premises and equipment. The price of borrowed funds (P3) is measured as interest expenses divided by total deposits.

The capital adequacy ratio (RISK) is included in the inefficiency equation due to the fact that it determines managerial risk preferences. It is possible that risk-averse managers hold higher level of equity than that of cost minimizing level to absorb financial shocks. Therefore, an efficient bank might be labeled as inefficient due to its risk preference (Mester, 1996).

Along with the capital adequacy ratio (RISK), other variables, which affect inefficiency, are related to the virtual banking. Specifically, number of ATMs (ATM) and number of branches (BR) along with a dummy variable ATMNET showing shared ATMs by all banks which takes value 1 for the years in which ATM network is widely used and 0 for the rest of the periods. It represents networking among all banks and between banks and convenience stores and among banks, post offices and convenience stores.

The banks in our sample constitute a fairly large proportion of the banks over the period of 1992-2005. Due to data availability constraints, we used data prior to the 2008 financial crisis. Nonetheless, data period is really not a point of concern since data from any time period could interrogate the questions addressed in this study. The data consist of balance sheets and income statements for 5 of the city banks, 64 largest regional banks[4], 48 members of second association of banks[5], 5 trust banks and 2 long-term credit banks. Although all of these types of banks were used to function differently but since the Financial System Reform Law of 1992[6] city banks, regional and trust banks businesses are becoming similar, therefore, we use various types of banks in our study.

Since there are many mergers and acquisitions take place during the time of study, here we explain their treatment in the data by taking the example of Mitsubishi bank, which was merged with Bank of Tokyo in 1996 to form the Bank of Tokyo-Mitsubishi, Ltd. Following database Nikkei Kinyu Zaimu treatment of mergers, for the years 1992-1996 Mitsubishi bank's data are used while for the period 1997-2005, merged bank's data (Bank of Tokyo-Mitsubishi) are used.

Other city banks such as Mizuho Bank, Mizuho Corporate Bank, UFJ Bank, etc. are treated in the same manner. We include only those banks in the study whose data are available for almost all the sample period.

Banks' financial statement data are taken from Nikkei Kinyu Zaimu CD-Rom and the rest is extracted from Nikkin Shirio Nenpo and Analysis of Financial Statements of all banks. The data are based upon 1,722 observations belonging to 124 banks for 14 years for cost stochastic frontier model and 1,440 observations for profit function.

Table I captures descriptive statistics for all the variables used in this study.

Table I shows that Japanese banking industry is well presented in our analyses, as there are huge discrepancies between minimum and maximum values. For example, bank A's total assets are JPY135 million while bank B holds almost JPY82 billion worth of assets. Some are earning good profits while others are running in lose. Further, the data suggest that there are some limitations in using this data set. For example, the minimum and maximum numbers of ATMs are unbelievably apart from each other (4 and 16,482, respectively). There is a possibility that banks took different approaches when reporting number of ATMs. Some banks have just reported ATM machines installed by that bank while others have reported ATM machines that can be used by its customers, which mean they have included shared ATMs too. At this point, it was difficult to clarify this point therefore, we use the numbers as found on the pages of Nikkin Shirio Nenpo. Before reporting capital adequacy ratios, we drop outliers in the data. The RISK data show that the Japanese banks are cautious in lending money and many banks maintain capital adequacy ratio higher than the minimum international requirement (8 percent).

The data for each banks category are reported in Table II. The table shows that the major banks are holding more than 60 percent of the assets, and the sub-local banks are holding only 1 percent of the total. Furthermore, only regional banks are earning profits and all other categories are running in losses. Average costs are highest for the long-term banks and lowest for the local banks. It seems as if only local banks are most efficient banks. Loans and securities are covering more than 75 percent of the total assets, on average. Labor is highly paid in the long-term credit banks and lowest paid in the second tier regional banks (sub-regional banks). Numbers of branches are limited; however, the numbers of ATMs are very high for city banks[7].

An overall look of the Table II shows that local (regional) banks are placed at an average position in all aspects. The asset size of these banks is not very large but they appear more efficient as compared to other banks with respect to their profit and cost structure and number of ATMs.

Table III presents a year-by-year summary of all variables. Data show that total assets of the Japanese banking sector were lowest in 2000. The growth rate of total assets was highest

	n	Minimum	Maximum	Mean	SD
Assets (billion yen)	1,727	0.1352	81.9462	4.7891	10.6531
Total cost (billion yen)	1,727	0.0051	4.5600	0.2033	0.5113
Profit (billion yen)	1,727	−3.5607	0.5416	−0.0070	0.1258
Loans and bills discounted (billion yen)	1,727	0.0939	43.7519	2.9538	6.0845
Investment securities (billion yen)	1,728	0.0227	22.8027	0.8999	2.0307
Price of labor (million yen)	1,723	4.2211	16.4167	8.4791	1.3997
Price of capital (million yen)	1,722	0.0328	0.5057	0.1488	0.0574
Price of funds (million yen)	1,727	0.0025	2.9682	0.2865	0.3769
No. of branches (BR)	1,722	17	658	109.88	74.31
No. of ATMs (ATM)	1,722	4	16.842	511.36	1,035.87
Capital adequacy ratio (RISK)	1,722	0.45	22.13	8.37	2.51

Table I. Summary of data

Table II.
Summary data for each category of banks (on average)

	City banks	Long-term banks	Trust banks	Local banks	Sub-local banks
No. of banks	5	2	5	64	48
Assets (billion yen)	50.4965	15.9116	11.3052	3.1411	1.0486
Total vost (billion yen)	2.1560	1.1851	0.6582	0.1072	0.0381
Profit (billion yen)	−0.1171	−0.1955	−0.0244	0.0036	0.0002
Loans and bills discounted (billion yen)	29.2862	9.6582	5.8165	2.0918	0.7631
Investment securities (billion yen)	8.3923	2.7942	3.0213	0.6376	0.1635
Price of labor (million yen)	10.1316	11.2474	9.7844	8.8477	7.5781
Price of capital (million yen)	0.1927	0.2178	0.1877	0.1469	0.1400
Price of funds (million yen)	0.1183	0.0850	0.1133	0.2681	0.3552
No. of branches (BR)	383.20	27.71	68.77	121.05	73.54
No. of ATMs (ATM)	4,087.56	46.08	288.67	496.09	196.56
Capital adequacy ratio (RISK)	9.94	11.72	10.62	9.21	6.73

in year 2003 (5.8 percent) and negative in the years 1998-2000. Total operating expenses were higher in the years 1996, 1999 and 2003. Average cost of the banks, obtained by dividing total cost to total assets of the bank, is the highest for the last four years and increasing. It is probably due to huge investment in IT sector in this time period. Profit is negative in the years 1996-1999 and then in 2002-2003, which means for 6 out of 14 years banks were running in losses. This scenario makes it difficult to measure and compare profit efficiencies of the banks.

The value of loans and bills discounted is lower in the last two years of the study while investment securities have increased faster. This phenomenon explains that the banks are diversifying the products and more banks are interested in investment securities rather than loans and bills discounted (Y1). Also bad debt is lower in recent years, which reduce the size of Y1 in balance sheet.

There is not much reduction in branches in last two years, however, ATM's have reduced to some extent. Banks start using joint ATM machines and also internet and phone banking gained momentum, ATMs have closed down. However, our study is still relevant because Japan is a cash loving society and ATMs are still popular. Capital adequacy ratio becomes higher than 8 percent in and after 1998, which is a minimum requirement imposed by the Bank for International Settlements, which means that before the financial crisis of 1998, Japanese banks were very risky.

Due to expansion in businesses in year 2002 the prices of labor and capital are increased in the later periods of the study, however, cost of labor has been decreased in year 2005 while cost of capital is still higher. As expected, cost of borrowed funds has been decreased in recent years quite significantly as interest rate on deposits is almost nil.

3. Methodology

As mentioned earlier, our study uses SFA to interrogate the effect of technology on the banks' performance. SFA requires the specification of a functional form for the frontier. Transcendental Logarithm (translog) and Cobb-Douglas are the most used functional forms. Among them, translog function, which is a generalization of Cobb-Douglas function, is more flexible in nature and applied more frequently in the studies of financial sector for multi-inputs and outputs[8] such as Lozano-Vivas and Pasiouras (2010), Silva *et al.* (2017), Berger *et al.* (2009), Alhassan and Biekpe (2016). Following the literature, in our study, we employ the multi-product translog model to estimate the cost and alternative profit stochastic frontiers.

The cost and profit efficiencies are derived from a cost and a profit function, respectively, in which costs and profits depend on the prices of variable inputs, the quantities of variable

Table III. Average of the variables (year-wise distribution)

	Assets (billion yen)	Total cost (billion yen)	Profit (billion yen)	Loans and bills discounted (billion yen)	Investment securities (billion yen)	Price of labor (million yen)	Price of capital (million yen)	Price of funds (million yen)	No. of branches	No. of ATMs	Shared ATM network	Capital adequacy ratio
1992	4.8837	0.3195	0.0159	2.8683	0.7228	7.6152	0.1788	0.9708	108.58	316.61	0	6.9
1993	4.6237	0.2545	0.0139	2.926	0.7063	7.756	0.1801	0.7582	110.66	348.44	0	7.43
1994	4.5759	0.2331	0.0094	2.9243	0.7042	7.8501	0.1776	0.5802	111.79	379.93	0	7.67
1995	4.5955	0.2329	0.0087	2.932	0.7224	7.9818	0.1768	0.4598	112.1	409.05	0	7.43
1996	4.6251	0.2655	−0.0123	3.0413	0.742	8.2441	0.1744	0.3689	112.02	437.99	0	7.64
1997	4.8412	0.2399	−0.0002	3.1736	0.7786	8.3853	0.1753	0.2159	112.02	446.47	0	7.41
1998	4.8324	0.2305	−0.0252	3.0782	0.7575	8.6337	0.1312	0.1978	111.11	481.77	0	8.25
1999	4.611	0.2488	−0.0757	2.9587	0.7183	8.4084	0.1273	0.156	110.77	511.4	1	8.28
2000	4.4017	0.1574	0.0109	2.8254	0.8183	8.5202	0.1274	0.0911	109.38	527.8	1	9.22
2001	4.7543	0.1356	0.0025	2.8524	1.0386	8.774	0.1249	0.0988	110.99	541.64	1	9.44
2002	4.7971	0.1562	−0.0322	2.9242	1.013	9.0552	0.1259	0.0385	111.07	638.26	1	9.16
2003	5.0762	0.1502	−0.0333	2.9979	1.131	9.1957	0.126	0.0209	107.65	810.95	1	9.01
2004	5.1637	0.1129	0.007	2.9226	1.3325	9.3117	0.126	0.0188	104.8	654.99	1	9.52
2005	5.3	0.1026	0.0149	2.9258	1.4471	9.0298	0.1284	0.0157	104.95	667.44	1	9.96

outputs and any fixed inputs or outputs, random error and efficiency. Before computing efficiency estimates (Coelli, 1996), profit and output variables are normalized by total assets which makes return on assets a dependant variable in profit function, a usual performance indicator. The normalization further controls for heteroscedasticity, scale biases, and other estimation biases. Furthermore, cost, profit and input prices are normalized[9] by the price of borrowed funds before taking logarithms to impose linear input price homogeneity.

Cost efficiency measures how close a bank is to produce at a minimum possible cost as best-practice financial institution on the frontier for given levels of input prices and outputs and other exogenous market variables. The cost frontier function is represented by:

$$\ln TC_{it} = \beta_0 + \sum_{k=1}^{3} \beta_{1k} \ln p_{kit} + \sum_{s=1}^{2} \beta_{2s} \ln y_{sit} + \frac{1}{2} \sum_{k=1}^{3} \sum_{k'=1}^{3} \beta_{3kk'} \ln p_{kit} \ln p_{k'it}$$

$$+ \frac{1}{2} \sum_{s=1}^{2} \sum_{s'=1}^{2} \beta_{4ss'} \ln y_{sit} \ln y_{s'it} + \sum_{k=1}^{3} \sum_{s=1}^{2} \beta_{5ks} \ln p_{kit} \ln y_{sit} + U_{it} + V_{it} \quad (1)$$

where p_i and y_i are input prices and output amounts. The dependent variable, total cost, is the sum of interest expenses, personnel expenses and other operating expenses. The inefficiency term U_{it} is regressed on three variables; number of branches (BR), number of ATMs (ATM) and a dummy variable (ATMNET) to represent shared ATMs. Capital adequacy ratio (RISK) is also included as a control variable. As a requirement of SFA model with multiple outputs and inputs (Coelli and Perelman, 2000), we impose the regular restrictions of symmetry and linear homogeneity in estimating the above equation.

Scholars are not agreed upon the definition of efficiency estimated by a cost frontier. For instance, Coelli (1996) defined efficiency as the ratio of actual cost to the optimally minimized cost while Kumbhakar and Lovell (2000) described it as the ratio of the optimally minimized cost to the actual cost (reversal of Coelli's definition). This study adopts the efficiency defined by Kumbhakar and Lovell (2000) because the efficiency values are limited to less than one and comparable with the efficiency estimated by the production function. That is, we inverse the efficiency estimates to obtain the efficiency scores.

The cost efficiency ratio is measured by the ratio between the actual cost of a bank and the minimum possible cost that is achievable on the frontier. For example, a bank with cost efficiency of 0.75 is 75 percent efficient and incurring 25 percent higher costs relative to cost frontier.

Profit efficiency gives a measure of how close a bank is to what a best-practice bank's profit would be for producing the same output bundle under the same exogenous conditions. Following Berger and Mester (1997)[10], we estimate alternative profit frontier which uses the same specification in cost equation with minor changes such as in the estimation of profit frontier the dependent variable is profit and the inefficiency term is $-U$:

$$\ln TP_{it} = \beta_0 + \sum_{k=1}^{3} \beta_{1k} \ln p_{kit} + \sum_{s=1}^{2} \beta_{2s} \ln y_{sit} + \frac{1}{2} \sum_{k=1}^{3} \sum_{k'=1}^{3} \beta_{3kk'} \ln p_{kit} \ln p_{k'it}$$

$$+ \frac{1}{2} \sum_{s=1}^{2} \sum_{s'=1}^{2} \beta_{4ss'} \ln y_{sit} \ln y_{s'it} + \sum_{k=1}^{3} \sum_{s=1}^{2} \beta_{5ks} \ln p_{kit} \ln y_{sit} - U_{it} + V_{it} \quad (2)$$

where TP stands for total profit of bank at time t and all other variables are the same as are explained in cost function. The rest of the variables are the same as discussed in Equation (1).

Profit efficiency is defined as the estimated profit which is the maximum if the bank is operating on the frontier. For example, 70 percent profit efficiency score of a bank means

that the bank could secure 30 percent more profit by choosing optimum input quantities and outputs prices.

The economies of scope are measured using Willig's (1979) measurement method. Using the parameter estimates based on the translog cost functions in last section, the economy of scope is calculated. Suppose that we have a cost function and two outputs: y_1, y_2. According to Willig's formula, the measurement scope economies are described by the following equation:

$$\text{Scope} = \frac{C(y_1,0)+C(y_2,0)-C(y_1,y_2)}{C(y_1,y_2)} \quad (3)$$

The numerator represents the cost saving caused by two outputs while the denominator is the real cost. Therefore, Equation (3) means the ratio of the total cost saving caused by the multi-product production to the real cost. For example, if the measurement of SCOPE is 3, then the cost saving is three time as much as the real cost. The results obtained from Equation (3) may be positive, zero or negative.

4. Empirical findings

The estimated coefficients of the cost and profit functions are reported in the Table IV (panels A, B, C).

Table IV (panel A, second column) shows that there is a significantly negative relationship between loans and bills discounted and average total cost. In other words, if loans increase by one unit, average cost will decrease by 3.17 units and this reduction in average cost occurs with less speed with each increase in loan because square term appears with negative sign.

	Cost function	Profit function
Panel A: Estimated results of the stochastic cost and profit frontiers		
Constant	−5.2827* (0.8277)	−0.7835* (0.3518)
Lny1	−3.1758* (0.7483)	0.8125* (0.3577)
Lny2	−0.7588*** (0.3798)	0.1830 (0.1690)
Lnp1	0.2238 (0.1275)	−0.1710** (0.0939)
Lnp2	0.3903 (0.3058)	−0.1287 (0.0942)
lnp1sq	0.1289* (0.0552)	0.0867* (0.0151)
lnp1lnp2	−0.0958 (0.1144)	0.0540** (0.0297)
lnp2sq	−0.0157 (0.0627)	−0.0327** (0.0167)
lny1sq	−0.8974 (0.7875)	−0.3183 (0.2257)
lny1lny2	0.5845 (0.4170)	−0.2355 (0.1603)
lny2sq	−0.2597** (0.1305)	−0.0669 (0.0491)
Lnp1lny1	0.5120* (0.1510)	0.1231** (0.0652)
Lnp1lny2	−0.0333 (0.0585)	0.0085 (0.0232)
Lnp2lny1	−0.2633 (0.1588)	−0.1209** (0.0648)
Lnp2lny2	0.0602 (0.0638)	0.0085 (0.0241)
Panel B: Estimated results of the cost and profit inefficiency		
Branch	−0.0003 (0.0005)	0.0055* (0.0005)
Atm	−0.0001* (0.0000)	−0.0001* (0.0000)
Atmnet	−4.7424* (0.1557)	0.3168* (0.0633)
Risk	−0.0483* (0.0162)	−0.0435* (0.0094)
Panel C: Variance parameters in cost and profit functions		
σ^2	0.1621* (0.0211)	0.4422* (0.027938)
γ	0.8352* (0.0340)	0.9992* (0.000173)
	LR test = 220.199	LR test = 3,091.7891

Notes: Standard errors are presented in parentheses. *,**,***Significant at 1, 5 and 10 percent level, respectively

Table IV. Efficiency determinants

Putting it differently, average cost is lower with the increase in loan shares in bank's portfolio but too much of loans might not lead to larger reduction in operating expenses. It happens with investment securities too as its coefficient appears significantly negative along with significantly negative square term. This means that with the increase in investment securities, average cost is decreasing with decreasing rate. Therefore, for Japanese banks suitable combination of both outputs is very important in order to reduce operating cost.

The input factors – price of labor (lnp1) and price of capital (lnp2) – show positive relationships with average total cost, which is in line with previous studies. That is, if price of labor increases by one unit, average cost will increase by 0.224 points. However, the coefficient of price of capital is not significant. The positive square term of p1 significantly explains that with more usage of labor, total cost will increase with an increasing rate while negative coefficient of the square of p2 (though insignificant) tells that usage of physical capital increases average cost with decreasing rate. This is in line with current situation in Japanese economy in general and Japanese banks in specific that they have adopted a downsizing policy.

The estimated coefficients in the inefficiency model are of particular interest to this study. Coefficients related to cost inefficiency equation are arranged in Table IV (panel B, column 2) and following behavior is observed. There is a significantly negative relationship between the number of ATMs installed by bank and cost inefficiency. That is, the cost inefficiency will decrease by 0.01 percent if bank increases ATM installments. On the contrary, we see a significantly positive relationship between number of branches and cost inefficiency. The cost inefficiency will increase by 0.55 percent if number of branches is increased. We can conclude that increase in ATMs will enhance the cost efficiency while more branches will lead to inefficient cost structure. Our findings contradict with Harimaya and Kondo (2016) study of regional banks. Perhaps regional banks should maintain good number of branches to conduct relationship banking but, according to our findings, it is not cost efficient for all the participating institutions in the Japanese banking industry.

Variable ATMNET, which represents the existence of more ATMs outside the bank branches could not reduce inefficiency component of banking cost structure as the sign of the coefficient appears significantly positive. One possible explanation of this phenomenon is that with the introduction of usage of ATM networking machines imply new, significant cost charges, contract signing expenditures for instance. This means, widening the networking may lead to an increase of its processing cost. The coefficient of capital adequacy ratio is significantly and negatively related with the cost inefficiency showing that higher capital adequacy ratio, lower risk and higher the cost efficiency.

Table IV (panel C, second column) presents significant values of σ^2 and γ. Thus, these results indicate that vast majority of residual variation is due to the inefficiency effect, u_{it} and that the random error, v_{it} is 0.165. We also observe that the one-sided generalized likelihood ratio test of $\gamma = 0$ provides a statistic of 220.199, which is significant at 1 percent level, showing that the proxies used to measure electronic banking are satisfactory.

Now we describe the pattern of profit functions for Japanese banks. The outcome is displayed in Table IV (panel A, column 3).

Regression results indicate that y1, which represents the loans and bills discounted of the banks depicts a significantly positive relationship with the profit of the bank. Specifically, if loans and bills discounted increase in a bank's balance sheet, profit will increase by 81 percent on average. However, there is no significant proof that this increase in profit is temporary as the square term of y1 is insignificant. The coefficient of y2 (marketable securities) is also insignificant though positive.

Further, both input prices contribute to profit negatively. The coefficient of cost of labor is significant but not that of the cost of capital. The coefficients of square terms of both inputs appear significantly though their signs are different from each other. Coefficient of square of labor is positive and highly significant, meaning that the increase in labor will

decrease profit with an increasing rate. Therefore, banks should think twice before hiring more personnel. Fixed assets such as buildings and machinery measured as price of capital (p2) are negatively related with the profit and coefficient is not significant. Its square term holds negative sign, which shows that increase in capital will decrease profit but not much reduction in profit takes place with each addition in machinery.

From the comparison of the columns 2 and 3 in the Table IV (panel A), it is revealed that human capital is an important determinant of banks' cost and profit structure. It also shows that manpower is costly and fully exhausted in Japanese banks, that is why average cost increases and profit decreases with the increase in the usage of manpower. Fixed assets such as buildings and machinery measured as price of capital (p2) appear insignificantly in both tables.

Coefficients related to the inefficiency equation are displayed in Table IV (panel B, column 3). Major findings are as follows. There is a significantly negative relationship between the number of ATMs installed by bank and profit inefficiency. That is, the profit inefficiency will decrease by 0.0001 points if bank increases ATM installments. Our findings contradict that of Kondo (2010) in which he did not find a direct relationship between number of ATMs and ROA. The coefficient of number of branches is not significant. The variable of networking in using ATMs is highly significant and its negative sign proves that higher usage of ATMs brings more efficiency in banking sector.

Comparing the columns 2 and 3 of Table IV (panel B) reveals that ATM network increases profit efficiency but could not help in increasing cost efficiency. These results indicate that introduction of usage of ATM networking machines, on one hand, generate additional revenues, but, on the other hand, imply new, significant cost charges, for example, contract signing expenditures. This means, widening the networking may lead an increase of cost of their processing, however, it will increase shareholders' wealth, which is the basic purpose of any banking activity. The coefficient of capital adequacy ratio is significant and its negative sign repeats that higher capital adequacy ratio lead to more efficient functions of the banks.

Table IV (panel C, third column) shows significant values of σ and γ. This justifies the identification of error terms in the stochastic frontier equation. The value of log likelihood ratio test significantly indicates that the proxy used to measure electronic banking is acceptable.

Now, we analyze two extreme groups, ten best-cost efficient banks and ten least-cost efficient banks, under the umbrella of number of ATMs. Although some researchers (Berger and Mester, 1997) believe that the profit efficiency score better evaluate the overall performance of the firm as compared to cost efficiency, since majority of Japanese banks report negative profits for many years in last decade we prefer cost efficiency estimates.

Table V lists the number of ATMs in ten banks, which are cost efficient and inefficient in each column. Figures show that majority of cost efficient banks operate more than 500 ATMs while group of inefficient banks have less than 500 ATMs.

	Number of ATMs	
	Cost efficient banks	Cost inefficient banks
1	759	130
2	3,670	117
3	1,054	206
4	5,735	158
5	374	54
6	590	27
7	628	831
8	2,953	68
9	365	75
10	210	52

Table V.
Cost efficient/ inefficient banks and virtual banking

5. Efficiency indices and scope economy

The empirical evidence strongly suggests that it may be misleading if commercial banks are evaluated and ranked based solely on either cost efficiency or profit efficiency. The two performance measures must be used jointly, rather than independently, along with scope economy to provide a reliable judgment on how a bank performs.

A summary of the predicted cost and profit efficiencies and values of scope (measured using Equation (3)) of the banks are reported in Table VI. An overview of efficiency

	City banks	Long-term credit banks	Trust banks	Regional banks	Sub-regional banks
Cost efficiency scores					
1992	0.93	0.65	0.59	0.85	0.77
1993	0.93	0.6	0.56	0.86	0.8
1994	0.92	0.53	0.51	0.88	0.84
1995	0.91	0.54	0.5	0.89	0.85
1996	0.89	0.42	0.41	0.88	0.85
1997	0.92	0.46	0.49	0.89	0.85
1998	0.92	0.68	0.64	0.87	0.84
1999	0.9	0.22	0.52	0.82	0.8
2000	0.9	0.75	0.55	0.85	0.79
2001	0.94	0.86	0.75	0.86	0.81
2002	0.84	0.94	0.59	0.81	0.72
2003	0.83	0.95	0.64	0.81	0.7
2004	0.85	0.96	0.86	0.84	0.75
2005	0.88	0.97	0.78	0.84	0.76
Profit efficiency scores					
1992	0.68	0.7	0.62	0.66	0.58
1993	0.55	0.4	0.5	0.71	0.66
1994	0.32	0.3	0.36	0.62	0.56
1995	0.21	0.17	0.29	0.68	0.61
1996	0.59			0.75	0.68
1997	0.15	0.16	0.38	0.57	0.46
1998		0.29	0.36	0.6	0.6
1999				0.52	0.44
2000	0.73		0.79	0.56	0.58
2001	0.58	0.94	0.62	0.62	0.56
2002		0.43		0.42	0.46
2003		0.42		0.43	0.53
2004	0.54	0.45	0.8	0.65	0.58
2005	0.51	0.82	0.89	0.73	0.69
Scope scores					
1992	1.59	1.94	1.9	1.53	1.53
1993	1.5	2	1.79	1.49	1.5
1994	1.5	2	1.79	1.51	1.52
1995	1.49	2.19	1.81	1.52	1.53
1996	1.47	1.77	1.72	1.52	1.53
1997	1.46	1.89	1.68	1.56	1.61
1998	1.56	2.19	1.74	1.61	1.7
1999	1.6	5.68	1.92	1.79	1.92
2000	1.58	9.15	2.09	1.88	1.96
2001	1.57	−5.57	1.83	1.84	1.88
2002	1.76	−3.03	2.62	2.04	2.06
2003	2.7	3.45	2.98	0.52	−4.21
2004	2.13	3.52	2.28	145.69	−0.09
2005	1.91	1.9	2.92	3.4	2.71

Table VI.
Cost and profit efficiency and scope scores

estimates of profit[11], cost and scope economy tells that some banks are efficient but others are not. Further, it is very difficult to decide which bank is most efficient because their efficiency level varies with respect to their profit, cost or scope. One bank is performing at lower costs but at the same time not earning higher profits or it is unable to choose right combination of outputs, as a result it represents diseconomies of scope (with negative scope value). For example, long-term credit banks in year 2002 were highly cost efficient (estimate = 0.94) but profit efficiency was marginal (estimate = 0.43) and showed diseconomies of scale (value = −3.03).

Furthermore, Table VI shows that profit efficiency scores are difficult to explain because for many years, data are missing and/or scores are relatively smaller. However, city banks appeared cost efficient in the last century but long-term credit banks become more cost efficient in the beginning of this century. Moreover, two things are noticed for the scope economies. First, regional and sub-regional banks outperform city banks. Second, long-term credit banks score highest in scope economies followed by trust banks. However, they are the most vulnerable as well (with negative scope economies in 2001 and 2002).

Estimates reveal that profit efficiencies differ from cost efficiencies in magnitude. The profit efficiency scores are lower than the cost efficiency scores. It seems as if more Japanese banks are cost efficient, which shows their better debt management and cost control skills but unable to maintain their efficiency at profit levels.

Regarding profit efficiency estimates on average, long-term credit banks attains highest score for the year 2001 while city banks are the least efficient in year 1997. Regarding cost efficiency estimates, again long-term credit banks are at the top in current years while Trust banks were least efficient in the year 1996. As per the economies of scope is concerned, long-term credit banks were the worst in the selection of outputs in the year 2001, and regional banks are among the best in output selection in year 2004. Regarding economies of scope, an interesting observation is that banks are least able to choose best combination of outputs in current years as all negative scope values appear for and after 2001. These findings should be explained with caution. Although scope measures show lack of Japanese banks' ability to diversify their products in early years of twenty-first century, there could be revenue advantages, which are not grasped in the scope as they are estimated from the cost function. This is the limitation of the study which will be interrogated in the future research.

Of course, not all banks appear average. The frequency distribution of the cost and profit efficiency estimates is displayed in the figure below. Number of cases on the vertical axis represents number of banks in years 1992-2005, which make 1,722 and 1,440 total cases for cost and profit functions, respectively. Figure 1 shows that majority of Japanese banks are cost efficient but they are not highly efficient with respect to their profits. When compared with results of other studies of the US banks, Japanese financial institutions seem to

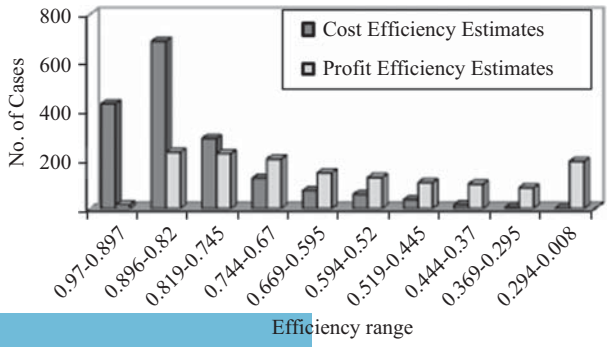

Figure 1.
Frequency distribution of efficiency estimates

outperform US banks for cost efficiency estimates. Nonetheless, as in any financial market many Japanese banks have room for improvement.

Cost and profit efficiencies and scope economy for each category of the banks are obtained by taking simple average of time series data and are listed in Table VII along with their rankings[12]. Ranking 1 denotes the most economical or higher efficiency followed by 2, 3, … *n*. Average ranking is also tabulated in the last column of the Table, where average ranking is the summation of these three rankings divided by three.

It is worth noting that except very few banks, others report economies of scope, as their estimates of SCOPE variable are larger than zero. That means that majority of Japanese banks enjoy scope economy. Among big banks such as city banks, long-term credit banks, and trust banks, none of them report diseconomies of scope, on average.

Cost efficiency ranking shows that majority of mega banks are cost efficient. Among them, Mizuho Bank and Bank of Tokyo-Mitsubishi appear highly cost efficient banks (ranked at 2nd and 4th number, respectively), however, they are unable to maintain their profit efficiency (ranked at 92nd and 90th number, respectively). That explains their ability to manage debt and to control their costs. Further, their high-cost efficiency score could result from their offshore operations. Trust banks did not show any sign of efficiency as they are the last in cost-based rankings and lie in the middle in profit-based rankings.

Regional banks lead other banks in Japan in terms of their best performance in saving costs, securing high profits and diversifying their products. Long-term credit banks are less cost and profit efficient but they rank higher in scope measures. One possible explanation is that their expenditure on IT mitigates their cost efficiency but increase their scope economy. This result is in line with Shamim and Anjum (2013) in which they found that saving banks were more likely to adopt internet banking because they aim at diversifying their products and offering innovative services to their customers.

According to our average ranking (average of cost, profit and scope rankings), regional (local) banks secure first position followed by city banks, second tier regional bank and other banks. This means that holding large assets never mean that they are efficient too. Probably, diseconomies of scale are larger than scale benefits when it comes to Japanese financial industry. This evidence is consistent with the previous studies such as Tadesse (2005).

6. Conclusion

Despite the importance of virtual banking and efficiency studies, the literature on virtual banking is limited. Our study fills this gap in the literature. The study interrogates the effect of ATMs on banks' performance. SFA was used to estimate banks' cost and profit efficiency indices and to examine the relationship between the number of ATMs and the cost and profit inefficiencies. We then estimated scope economy based on the estimated cost function and then ranked all banks on the basis of their profit and cost efficiency scores as well as scope values. Unbalanced panel data covered 124 banks for the period of 14 years prior to the crisis of 2008.

Table VII.
Ranking of cost and profit efficiencies and scope economy

	Cost efficiency estimates	Cost ranking	Profit efficiency estimates	Profit ranking	Scope	Scope ranking	Average ranking
City banks	0.90	1	0.48	4	1.70	4	2
Long-term credit banks	0.68	4	0.47	5	2.15	2	5
Trust banks	0.60	5	0.56	3	2.08	3	4
Regional banks	0.85	2	0.61	1	11.67	1	1
Sub-regional banks	0.79	3	0.57	2	1.21	5	3

The estimated coefficients in the inefficiency model showed that there was a significantly negative relationship between the number of ATMs used by the banks and their cost/profit inefficiencies. A negative sign of the ATMNET reiterated that the banks efficiency enhanced with the provision of banks services through electronic devices. We observed a significantly positive relationship between number of branches and cost/profit inefficiency which helped us to conclude that virtual banking helped banks to lower their costs and in turn increased their profits.

Further, as in most previous studies of bank efficiency, we found that the average bank performed below the best-practice frontier. The managerial inefficiencies in Japanese banking sector were found to be significant, with average cost and profit efficiency levels 89 and 59 percent, respectively. However, on average Japanese banks were good at diversifying their products as it was shown by higher average scope value (= 6.72). The technological progress, which mainly comprised of computerization and automation of financial transactions, had significantly reduced the cost of banking industry during the sample period. These average estimates suggested that an average bank would have incurred 11 percent less of its actual costs had it matched its performance with the best-practiced frontier.

According to our average ranking (average of cost, profit and scope rankings), regional (local) banks secured top ten positions and other banks (mega banks, trust banks, long-term credit banks) surprisingly could not secure any top position. This means that holding large assets never meant that they are efficient. Probably, diseconomies of scale were larger than scale benefits when it comes to Japanese financial industry.

Moreover, our analysis of two extreme groups, ten best-cost efficient banks and ten least-cost efficient banks, under the umbrella of number of ATMs proved that efficient banks possessed more ATMs. We conclude that there is a scope of cost saving and profit maximizing in the banking industry which could be achieved through adopting corrective measures in technological progress, optimal diversification of asset portfolio and of course administrative management.

The information obtained from this study is useful for bank managers, investors and government regulators. Managerial performance can be improved by identifying "best practice" and "worst practice" associated with high and low efficiency banks, respectively. Success in competing markets demands achieving the highest levels of performance through continuous improvement and learning.

From this study, we can conclude that although branches would remain a crucial interaction point to sell complex products and build strong relationships with the customers, but given their high fixed cost, shifting routine banking transactions from the branch to low-cost electronic channels can significantly reduce costs and enhance efficiency of the financial institutions.

Notes

1. 1 Japanese yen = US$0.0087.
2. Japanese Banking Association website January 2014.
3. Scope economies exist between outputs when the cost of producing them together in a single firm is less than the cost of producing them in different firms.
4. Regional Banks Association of Japan website www.chiginkyo.or.jp/
5. The Second Association of Regional Banks website www.dainichiginkyo.or.jp/en/index.html
6. EIU (1999/2000) Country Finance Report Japan (p. 12).
7. City banks have more ATMs machines outside the banks' premises and there is a possibility that they have reported joint ATM machines too.

8. A more detailed discussion of the evolution of the use of the translog functional form can be found in Goddard *et al.* (2001).
9. For detailed discussions of this normalization see Berger and Mester (1997, 1999) and Berger *et al.* (2000).
10. Since profit efficiencies include errors from both the output and input side with a possibility of output side inefficiencies larger than that of the input side (Berger *et al.*, 1993), Berger and Mester (1997) consider profit efficiency concept superior to cost efficiency concept for evaluating the overall performance of the bank. Moreover, Berger and Mester (1997) prefer an alternative profit specification over standard profit efficiency because of the differences in the quality of banking services and the markets are not perfectly competitive so that banks might have some market power in pricing their outputs; and output prices are not available.
11. Please note that in years when some banks were not observed, values of profit efficiencies are not calculated nor scope of those banks are measured.
12. Detailed results for each bank can be provided upon request.

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