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Efficiency frontier on Japanese banking system

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Introduction

The Japanese banking system could be described as a system that hasn't yet found its equilibrium after the burst of the late 80's economic bubble, with a large effect on stock prices and on the real estate segment of loans. Also, after the prices reached a nadir in 2003 and experienced a slow growth, the onset of the financial crisis made them drop even lower.

Like many other countries, Japan must deal with foreign competition in the banking sector, especially US banks that succeeded in changing the local banking market segmentation. Another special characteristic of the Japanese banking system is the presence of large financial institutions that play an important role in the local and international financial systems. These institutions are known as keiretsu. The main role of a keiretsu is to act as intermediary between local firms and the economic environment, helping the firms with loans for investment projects. In accordance with the 1977 Anti-Monopoly Law, a keiretsu bank could have shares at one of the partner firms, but not more than 5%. The structure of this network resembles in some way the structure of a virtual enterprise, the main difference being that, unlike virtual enterprises, keiretsu maintain reciprocal relations with the firm for an unlimited period of time.

Lately, a large number of keiretsu banks started to merge into huge financial institutions. The most representative case is the merger of the Bank of Tokyo with the Mitsubishi Banking conglomerate, the result being the second largest bank worldwide, when taking into consideration the dimension of assets.

The main problem that is to be discussed over the following pages revolves around the term of financial efficiency of the Japanese Banking system. The subject

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is interesting, mainly because of the Japanese Banking system's particularities, such as the presence of keiretsu and the effect they have on efficiency scores, inter and intraregional banks and also efficiency analysis in the context of the present financial crisis.

So far, there haven't been many studies that center on the efficiency of the banks in Japan, with the exception of foreign banks. Some research has been done, using Data Envelopment Analysis (DEA) estimates of efficiency, the most notable article being the one written by Fukuyama in 1993. Nowadays, new data are available, also data that include the effect of the financial crisis. This paper will focus on this new data, extracted from the main local banks' income statement, for the 2012 fiscal year. Also, unlike Fukuyama's decomposition of efficiency scores into pure technical efficiency and scale efficiency, this paper will relax the convexity restriction of the DEA program and will present the Free Disposal Hull (FDH) scores. At the same time, the banks will be analyzed from the super-efficiency perspective, giving a classification of the efficient banks.

The main findings of this paper revolve around the comparison between efficiency scores obtained through DEA and FDH models and also using the terms of super-efficiency and input/output aggregation.

The article is structured as follows. The second section positions this paper within the specialty literature. Section 3 gives the necessary theoretical means for a better understanding of the application. Section 4 presents an application of a DEA and FDH model, the super-efficiency measures for the fully efficient banks and the effect of input and output aggregation over the efficiency scores. Section 5 summarizes our findings.

Literature review

The non-parametric efficiency measurement started from the concept of convex hull proposed by Farrell (1957) in "The measurement of productive efficiency". Practically speaking, in economic theory, a firm's inputs and outputs are represented graphically using a production function. The convex hull represents the smallest convex subset in a Euclidian space, which contains the cloud of points (representation of firms). The convex hull envelops the data, and the efficiency measures are calculated relative to this surface.

For almost 20 years, the work of Farrell passed unnoticed, until 1978, when Charnes, Cooper and Rhodes introduced the term of data envelopment analysis in the paper "Measuring the efficiency of decision making unit". The model proposed by Charnes, Cooper and Rhodes was an input orientated one, with constant returns to scale. The model was constructed as a linear programming problem that maximizes the ratio of output to input (with associated weights) following sign restriction of weights and the constraint that seeks to radially contract the input

vector, while still remaining in the feasible input set (Coelli, Prasada 2005). The model is suitable when all the analyzed firms are operating at an optimal scale (which is almost impossible, due to microeconomic issues – imperfect competition, tax regulations, government laws). When this model is used and the firms are not operating at an optimal scale, scale efficiency cannot be calculated (it is included in technical efficiency).

Several years later, the DEA methodology moved to a model with variable returns to scale (Färe, Grosskopf and Logan – in 1983; Banker, Cooper and Charnes – in 1984) by introducing a convexity constraint. Also, this model is capable of finding the scales where a firm is operating.

Other works in this domain include the way the orientation of the model is chosen, environmental variables, input congestion or slacks treatment.

In the case of model orientation, Coelli states in his 1999 work together with Perelman, that the orientation of the model doesn't have a major influence upon the scores obtained following the DEA implementation.

Over time, a lot of articles have dealt with the DEA method of estimating efficiency scores – Thanassoulis in his paper "Assessing police forces in England and Wales using data envelopment analysis", or Thrall in "Recent Developments in DEA: The Mathematical Programming Approach to Frontier Analysis". Today, some authors try to solve the remaining disadvantages of DEA implementations (e.g. Leopold Simar – the way outlier variables affect the obtained results).

As stated in the introduction, the main research article applied on the Japanese Banking system belongs to Fukuyama (1993). In his article, he applied a DEA model to calculate the scores of technical efficiency, finding an overall score of approximately 0.865, meaning the banks could diminish their inputs by 13,5% and still produce the same output.

Another article focusing on Japanese credit banks – Hosono et al. (2006) – studied the effect of credit banks' consolidation over the efficiency scores. Drake et al. (2009) made a study on technical efficiency level using more recent data than Fukuyama (1993), obtaining an overall score of efficiency equal with 0,72, thus observing a drop in Japanese efficiency levels.

Methodology

The main purpose of the article is to analyze, from an efficiency point of view, the main banks of Japan, using data envelopment analysis and free disposability hull analysis, non-parametric tools. DEA provides an analysis of technical efficiency using an input orientation approach, since for a bank's management it is easier to have control over inputs rather than outputs. The technical efficiency measures are calculated relative to a surface that envelops the considered data. FDH relaxes the convexity constraint and provides a biased estimator of efficiency measures.

The approach from Farrell's "The Measurement of Productive Efficiency" (1957) and Charnes et al., considers a constant returns to scale (CRS) methodology, but lacks a scale efficiency measurement. Charnes and Cooper solve this problem by considering a variable returns to scale (VRS) methodology, which focuses on scale efficiency rather than pure technical efficiency.

Firstly, I will define some notations. Considering data on n inputs and m outputs, summarized in an NxB matrix of inputs and an MxB matrix of outputs, where B represents the number of banks taken for analysis, I define the column vectors x_i (input values for i-th bank) and q_i (output values for the i-th bank).

The data set is described by a production process that defines the data cloud production set Ψ, defined as follows, according to Wilson and Simar (2008):

$\Psi = \{(x,y) \in R_+^{N+M} \mid x$ can produce $y\}$ where x is a strictly positive N-dimensional vector of inputs and y a strictly positive M-dimensional vector of outputs.

The production function is described by the following properties:
1. is finite, non-negative and real valued;
2. weakly essential – to produce one unit of output at least one input must be used;
3. increasing in inputs – first differential positive and equal with the marginal productivity; an increase in input leads to an increase in output (not necessarily equal);
4. everywhere continuous; twice-continuously differentiable;
5. concave in inputs – law of diminishing marginal productivity.

In Coelli (2005), the next model for CRS DEA is defined:

$$
\begin{aligned}
&\min \theta \\
&\quad \theta\,\lambda \\
&-q_i + Q\,\lambda \geq 0 \qquad\qquad \text{(LP 1)}\\
&\theta x_i - X\,\lambda \geq 0 \\
&\qquad \lambda \geq 0
\end{aligned}
$$

where the following notations are used: θ – scalar, Q – output matrix, X – input matrix and λ – vector of constants. θ represents the efficiency score of the i-th bank. The constraints ensure that, after the radial contraction of inputs, the projected point on the frontier still remains in the feasible region of production (Coelli, 2005).

The LP 1 model is summarized in Wilson and Simar (2008) as follows:

$\partial \Psi = \{(x,y) \in \Psi \mid (\theta x,y) \notin \Psi, \forall 0 < \theta < 1, (x, \lambda y)) \notin \Psi, \forall \lambda > 1\}^2$

This relation defines the production frontier used to calculate the efficiency scores. Basically, the inefficient banks are found in the interior of Ψ, while the efficient ones lies on the frontier defined by $\partial\Psi$. Wilson and Simar (2008) continue with the definitions of θ as an input measure of efficiency and λ as an output measure of efficiency.

$$
\begin{aligned}
\theta(x,y) &= \inf\{\theta \mid (\theta x,y) \in \Psi\} \\
\lambda(x,y) &= \sup\{\lambda \mid (x,\lambda y) \in \Psi\}
\end{aligned}
$$

The main problem with CRS DEA is the existence of slacks, both in input or output. For example, an input slack can be defined as the radial contraction of an inefficient point where a bank produces the same amount of output using more input than is used another efficient point. In practice, after the radial contraction, the inefficient point moves on the CRS frontier in a zone where the frontier is parallel with the axes. In a similar way the output slack is defined as the point where a bank produces less output, using the same amount of input as another bank. The output and input slacks are equal to zero when both the first and second constraints of LP1 are equal to zero.

Later, Charnes et al. found a way to differentiate between pure technical efficiency and scale efficiency, by introducing a new constraint to LP1 $- I_1'\lambda = 1$ (where I_1 is a vector with elements equal to 1). This construct ensures the formation of a convex hull[1] that envelops better the data than the conical hull from LP1. The new formulation of the CRS DEA will be considered in the following pages as VRS DEA or LP2.

Solving both CRS DEA and VRS DEA, the scale efficiency can be easily calculated as the ratio between CRS technical efficiency and VRS technical efficiency. Thus, the following notation represents scale efficiency $SE = \frac{TE_{CRS}}{TE_{VRS}}$.

Technical efficiency is measured using the distance concept, proposed by Malmquist and Shepard (1953) in order to calculate the efficiency of a firm. Considering the input vector $\Psi(y)$, Malmquist and Shepard define the input based distance function as a maximal contraction in inputs, given the output vector:

$$d_i(x,y) = max\ [\omega, under - \epsilon\ \Psi(y)]$$

For a better understanding of the concept, I considered the representation of the output vector through an isoquant (Figure 1).

The input based distance function calculated for firm A (which uses $\times 1$ and $\times 2$ inputs to produce y output) is equal to $d = \frac{OA}{OB}$.

Figure 1. Representation of output vector
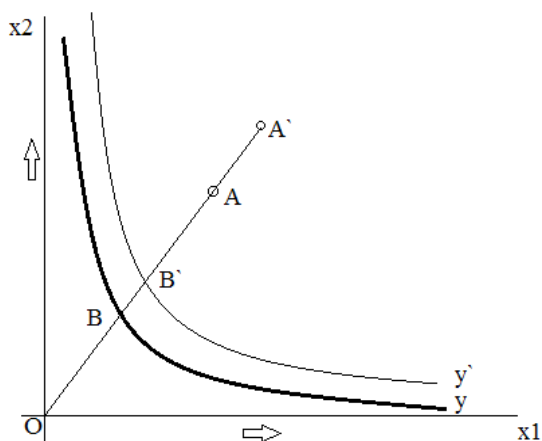
Source: own elaboration.

[1] The convex hull of a set Y of points in a Euclidian space is the smallest convex set that contains Y.

The distance function has the following properties:

1. increasing in inputs – it can be observed that if an equal increase in inputs is to be considered, the firm moves to A' and the new associated distance is bigger d' = — ;

2. decreasing in outputs – at an increase in the output vector, the isoquant will shift upward to y'. The new distance will equal d" = $\frac{OA}{OB'}$, which is smaller than d;

3. if x $\epsilon \Psi(y)$, than $d_i(x,y) \geq 1$;

4. if the firm lies on the isoquant, the associated distance is equal to 1.

Based on the distance concept, Farrell (1957) proved that the technical efficiency equals the inverse of the firm's associated input orientated distance.

After calculating the scale efficiency, the presumption whether the studied banks are situated in the increasing returns to scale or decreasing returns to scale region of the production frontier would be the first thing to question. To find out the answer to this question, a new linear programming model (LP3) is considered, which replaces the VRS constraint with $I_1'\lambda \leq 1$. To find out the region where a bank is situated on the production frontier, technical efficiency is calculated in accordance with LP2 and LP3. If $TE_{LP3} \neq TE_{VRS}$ the bank is situated in the increasing returns to scale region. In the contrary case, the bank is situated in the decreasing returns to scale region.

For the DEA model, Wilson and Simar (2008) define seven assumptions for the data generating process. One of them is the disposability assumption, stating that for any x' $\geq$ x and y' $\leq$ y, (x',y') belongs to Ψ. Generally, this assumption states the possibility of producing less using more input.

Deprins (1984) formulates a model based on this assumption and based on a non-convex production set, formulated by Wilson and Simar (2008) as follows:

$$\Psi_{FDH} = \{(x,y) \epsilon R_+^{N+M} \mid y \leq y_i, x \geq x_i, (x_i, y_i) \epsilon B\}$$

Analyzing the environment where the banks operate, it is observed that some of them act in a different way than normal commercial banks. This is the case of the "keiretsu banks". These banks represent the core of a union of companies that operate in different sectors of the Japanese economy. They act as the main financial link of these firms with the economic environment, so they also have a great influence over Japan's economic and financial environment. For example, the bankruptcy of such a bank could lead to a small financial crisis in Japan.

In this paper I will also use the term super efficiency model defined by Wilson (1995), as a modified DEA purposed by Petersen and Andersen (1993). The super efficiency scores are calculated based on a reduced set of data, B-1, since in calculating scores for the *b*-th bank, the *b*-th bank can't use itself as a peer. Thus, the super-efficiency score could be greater than 1.

Empirical results

In choosing the input and output variables, I use the profit approach defined in Fethi and Pasiouras (2009), which treats revenues from the income statement as output variables and the cost components from the income statement as input variables. Following this approach, I choose to study the efficiency of the Japanese banking system using costs with provisions, fees and commissioning expenses and interest paid as inputs and net income, fees and commissioning revenues and interest revenues as outputs.

I have selected these inputs and outputs since they successfully succeed in describing the main characteristics of the banking system (deposits – interest costs, loans – interest paid and fees and commissioning for banks services). Also, the provisions costs could engulf the ability of the banks to deal with the risk of non-performing loans. The net income variable encapsulates banks' general performance over a given period of time.

The data set is selected from the official site of the Bank of Japan, the National Bank of Japan, covering the 2010–2012 period and 99 banks, including the four Japanese megabanks (financial groups), named further as shikin banks.

The data are summarized in Table 1.

Table 1. Variable summary (trillion yen)

	Fee cost	Interest cost	Provision cost	Net income	Fee reven	Interest reven
Min.	0,30	0,38	0	(9,00)	0,60	0,30
1st Qu.	1,00	1,00	0,47	1,00	3,00	18,00
Median	2,00	3,00	1,00	4,00	7,00	35,00
Mean	8,48	17,25	11,14	29,89	38,91	106,00
3rd Qu.	5,00	7,00	4,00	10,00	15,00	76,00
Max.	165,00	508,00	750,00	981,00	1100,00	2300,00

Source: own elaboration.

The effect of taking into account the shikin banks can be observed; the gap between minimum, mean and maximum values could support the idea of outlier values or super-efficient banks. Further in the analysis, I will work with normalized variables, since this change doesn't have any effect on the efficiency scores (Simar and Daraio, 2007).

In the following section, I describe the outlier problem and try to identify the outliers from the data cloud. The outlier problem is very well documented in Bogetoftand Otto (2010). They use the data cloud method in finding the outliers from a set of data.

Considering the data represented in anMxNdimension (Minputs and Noutputs – M-input matrix, N-output matrix) and the data cloud, defined as all the

observations represented in the MxN dimension, Bogetoft and Otto (2010) define the volume of the data cloud as being approximately equal to the determinant of the [MN]`[MN] matrix. By removing outliers from the analysis, the volume of the data cloud decreases.. If the observations linked to a bank are in the middle of the data cloud, by removing this bank, the volume of the data cloud remains unchanged. Bogetoft and Otto (2010) define the following ratio:

$$R^{(i)} = \frac{D^{(i)}}{D}$$

where $D^{(i)}$ represents the determinant calculated after the removal of the bank and D – the determinant before the removal of the bank.

The ratio will tend to 1, if the analyzed bank is not an outlier (the volume of the data cloud doesn't change much). Similarly, when the ratio tends to 0, clearly the bank being analyzed is an outlier.

Using R software, I performed the outlier analysis. The results are summarized in the below table.

Table 2. Outlier detection results

Deleted observations												R
1												5.80E-03
97	1											5.50E-04
4	2	1										1.20E-05
4	2	97	1									7.40E-07
5	4	2	97	1								7.40E-08
98	5	4	2	97	1							2.90E-08
98	6	5	4	2	97	1						9.80E-09
98	3	6	5	4	2	97	1					3.40E-09
42	98	3	6	5	4	2	97	1				1.80E-09
42	77	98	3	6	5	4	2	97	1			9.20E-10
99	42	77	98	3	6	5	4	2	97	1		4.60E-10
99	42	77	13	98	3	6	5	4	2	97	1	2.60E-10

Source: own elaboration.

The table presents the minimum values of R ratio when a bank is deleted from the data cloud. The values associated to the ratio tend to zero, so the twelve banks shown in the table above are outliers.

I decided to keep in the analysis those banks detected as outliers by the Bogetoft and Otto methodology, since these banks are mainly shikin banks and other inter-regional financial institutions. It is interesting to see the results of super-efficiency analysis over the data sets and to check the super-efficiency measures for the banks detected as outliers.

Data envelopment analysis

In accordance with the stated methodology, I applied the linear programming problem that describes DEA on the data. DEA accounts for an input approach with variable returns to scale. The results show a large number of perfectly efficient banks – approximately 25% from the total number of banks. The low efficiency firms, with an efficiency score lower than 0,4, have a percentage of only 6%. The rest of the banks lie in a zone of higher efficiency that can still be improved. The average efficiency score is 0,754, meaning that overall, the banks could decrease input by 24,6% and still obtain the same output level. The obtained level of average efficiency brings us closer to the results of Drake et al. (2009) results rather than those of Fukuyama (1993).

Of the 24 banks that are perfectly efficient, the majority are represented by banks with inter regional relations and by big financial groups that have a monopoly in a specific area (example – Sapporo Hokuyo Holdings in the Hokkaido area).

The next question begins essentially after the DEA linear program calculates the perfectly efficient banks. Can these banks be ranked? Yes, these banks can be ranked using the super efficiency term.

During the super-efficiency analysis, the bank that is the subject of the analysis has its data eliminated from the analysis. The frontier is calculated using B-1 banks and then the distance from the B-th omitted bank, relative to the new calculated frontier, and represents a super-efficiency score that can be greater than 1. In some cases, the efficiency score tends to infinity. This is the case of hyper efficient firms.

The following table represents a descending review of super and hyper efficient banks.

Table 3. Super/hyper efficiency scores

Bank	Super efficiency scores
Mitsubishi UFJ Financial Group	Inf
Shizuoka Bank	Inf
Sumitomo Mitsui Financial Group	122,497
DBJ	30,5792
Fukushima Bank	5,5412
Daitou Bank	4,9221
Shinwa Bank	2,6364
Toyama Bank	2,413
Resona Bank	2,2348
Sumitomo Mitsui Trust Holdings	2,1668

Bank	Super efficiency scores
Sapporo Hokuyo Holdings	1,8972
Yokohama Bank	1,5993
Shoko Chukin Bank	1,4602
Gunma Bank	1,4211
Yamanashi Chuo Bank	1,3953
Daishi Bank	1,1454
Chugoku Bank	1,1317
Iyo Bank	1,1283
Kagoshima Bank	1,119
Kanagawa Bank	1,0925
Awa Bank	1,0863
Suruga Bank	1,0616
Shimizu Bank	1
Tochigi Bank	1

Source: own elaboration.

The big four shikin banks, which also act as a keiretsu bank for big corporations such as Mitsubishi Motors or Toyota MC, have the greatest super-efficiency scores, relative to all other banks, mainly inter-regional banks. Practically, Mitsubishi UFJ and Shizuoka Bank acts as hyper efficient banks on Japanese Banking market.

Aggregation of inputs and outputs

In their 2007 study, Daraio and Simar question the dimensionality effect over the convergence of the estimators resulting after applying DEA/FDH. As they have observed, the fewer inputs and outputs and the more observation that are considered for analysis, the more the probability of convergence increases.

Thus, Simar and Daraio (2007) propose a method of variables aggregation, using an aggregated vector that will retain the maximum information. They suggest data normalization, by dividing by mean or standard deviation, since it doesn't have an effect on the efficiency scores, due to DEA estimates of being scale-invariant.

They have also observed that the weights which form the vector which retains the maximum total variance are actually the eigenvector corresponding to the biggest eigenvalue of the matrix N`N (for inputs) and M`M (for outputs).

Using the elements of the eigenvector corresponding to the largest eigenvalue as weights, I aggregated the variables in two aggregated vectors (input/output);

thus, the data can be easily represented in a bi-dimensional space. The table below contains the Pearson correlation calculated between the initial variables and the aggregated ones; it can be observed that the aggregation was successful. Also, when calculating the principal components related to inputs/outputs, the largest eigenvalue retains the largest amount of information from the total variance (96%).

Table 5. Correlations between initial inputs and aggregated input

	Fees and commission expenses	Interest paid	Provisions expenses	Aggregated input
Fees and commission expenses	1			
Interest paid	0,91998	1		
Provisions expenses	0,70651	0,81913	1	
Aggregated input	0,75779	0,85607	0,98001	1

Source: own elaboration.

Table 6. Correlations between initial outputs and aggregated output

	Net income	Commissioning revenue	Interest revenue	Aggregated output
Net income	1			
Commissioning revenue	0,96551	1		
Interest revenue	0,97886	0,98813	1	
Aggregated output	0,98105	0,98190	0,99810	1

Source: own elaboration.

Once I aggregated the input and output matrices in two vectors, using input and output inertia as weights, I resumed the DEA model and I also represented in a bi-dimensional space the efficiency frontier that envelops the analyzed data.

**Table 7**. Aggregate vs. 3/3 (inputs/outputs) DEA

Bank	Dea scores	Super efficiency	Aggregate scores
Mitsubishi UFJ Financial Group	1	Inf	1
Sumitomo Mitsui Financial Group	1	122,497	1
Sumitomo Mitsui Trust Holdings	1	2,1668	0,99701
Resona Bank	1	2,2348	1
Daitou Bank	1	4,9221	0,15537
Gunma Bank	1	1,4211	0,54854
Sapporo Hokuyo Holdings	1	1,8972	1

Bank	Dea scores	Super efficiency	Aggregate scores
Yokohama Bank	1	1,5993	1
Kanagawa Bank	1	1,0925	0,5831
Daishi Bank	1	1,1454	1
Chugoku Bank	1	1,1317	0,12283
Shizuoka Bank	1	Inf	1

Source: own elaboration.

It is interesting to observe banks that seem perfectly efficient through the initial DEA model, but obtain low scores after aggregation e.g., Daitou Bank, Chugoku Bank. The simplest explanation of this phenomenon is that the element that helped the bank to reach a point on the frontier was lost after aggregation; the aggregation is done with minimal informational loss (similar to principal components analysis).

Figure 2. Aggregate dea plot – left (with shikin banks), right (without shikin banks)
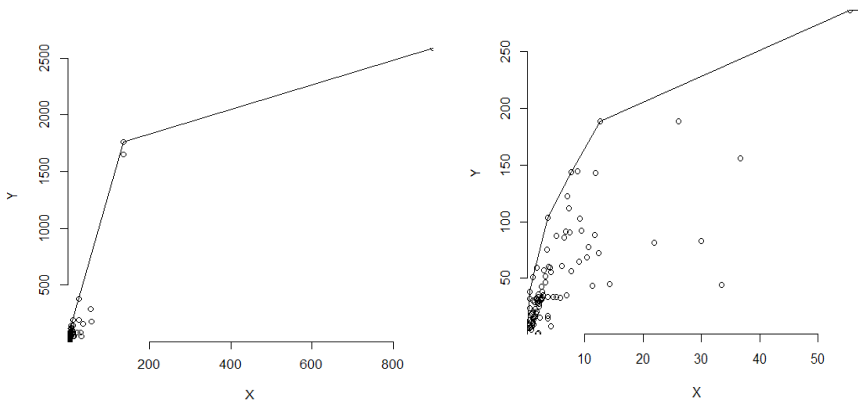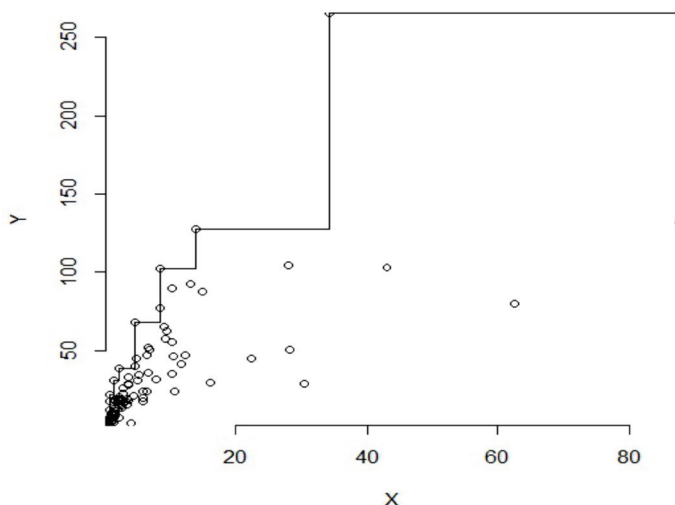

Source: own elaboration.

The hyper efficient banks can still be differentiated from the other analyzed banks, even when the data were normalized. For a better view of the Japanese banks' efficiency scores, I decided to remove the hyper efficient banks.

If the free disposability constraint is removed, banks that produce the same amount of output with less input than other banks are also considered efficient. This situation is represented graphically in the following figure, where, under the FDH assumption, I represented the data in a bi-dimensional space. For example, I took the highlighted points. The banks produce the same output with different input quantities.

The average FDH efficiency estimates is 0,9163, observing thus a higher value than the average of the efficiency estimates obtained by DEA.

Considering both methodologies (DEA and FDH), if I were to choose which one to apply during my future research papers, I would choose DEA. The main reason for my choice is the way FDH doesn't differentiate between banks with observable efficiency (same level of inputs, but different level of output).

Figure 3. FDH representation of aggregated data

Source: own elaboration.

Conclusion

This article intended to describe the current Japanese banking system from an efficiency point of view and to determine the difference between keiretsu banks and the other banks. Also, the effect of the financial crisis is another main point of this analysis. As can be seen from the obtained average score of efficiency, the Japanese banking system remained at a level of efficiency similar to the level where it was during the economic bubble at the beginning of the 1990s, according to the comparison between level obtained in 1993 by Fukuyama and the level obtained in this article. The FDH approach gives a smaller average, reaching 0,5.

The keiretsu banks are the most efficient banks considering the Japanese banking system (they rank at the top of the super-efficient banks). It would be interesting to see what makes them more efficient than the ordinary banks.

The present analysis can be used to detect banks that have an increased default probability. Also, this research can be considered for different microeconomic sectors, in order to predict, with a p probability, firms that can declare their insolvency in the following period of time.

Also, another main finding is that aggregation tends to have an effect on the efficiency measures, if the information that is lost during the aggregation leads to the increase in efficiency scores.

There are also other points that can be reached to completely analyze the Japanese banking system. A main point is the scale efficiency scores that are completely different from the total technical efficiency. This problem was also included in Fukuyama (1993). It would have been interesting to compare the obtained results.

For future work, a different DEA analysis on clusters would be useful in trying to separate the big financial institutions and small banks.

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Summary

Since the emergence of the efficiency frontier techniques, a series of comparisons between the methods that led to the resultant efficiency has been presented. In this paper, data from 99 Japanese banks are used in order to prove the applicability of efficiency frontier analysis on the East-Asian financial system and to reveal the differences between inter and intra-regional banks, showing the effect of the present financial crisis on the efficiency of the studied banks. DEA and FDH are used to determine the technical and scale efficiency of the analyzed banks and also it compares fully efficient banks by ranking them through the super-efficiency notion.