Estimating the Influences of Financial Crisis and Diversification on Efficiencies for Taiwan's Listed Securities Firms using the Two-Stage DEA Model

Ying-Hsiu Chen, Pao-Peng Hsu

***Abstract*—**This paper adopts two- stage Data Envelopment Analysis (DEA) taking account of operating risks, to examine the impact of global financial crisis on efficiencies and the existence of the efficiency improvements from revenue diversification. We use unbalanced panel data on 21 of Taiwan's listed securities firms during the period 2005-2010. Three main empirical results are obtained in this paper. First, the pure technical efficiency from inappropriate management constitutes the main source of the operating inefficiency. Second, the scale economies prevail in the majority of securities firms. Finally, the global financial crisis induces a decrease in scale efficiency and the increase of revenue diversification improves pure technical efficiency, but the raise of revenue diversification during global financial crisis reduces the damage of scale efficiency caused by global financial crisis.

***Keywords*—**Data Envelopment Analysis, Tobit Model, Financial Crisis, Diversification, Efficiency, Scale Economies

I. Introduction

THE concept of efficiency in financial institutions has been considered widely in the literature, utilizing both non-parametric and parametric techniques. According to Berger et al. (1993), the most common efficiency estimation techniques are data envelopment analysis (DEA), stochastic frontier approach (SFA), thick frontier approach (TFA), and distribution-free approach (DFA). The first of these are nonparametric techniques and the latter three are parametric methods. The two principal methods that have been used are DEA and SFA, which involve mathematical programming and econometric methods, respectively.

Several papers have further examined the determinants of efficiency for financial institutions as firm size, profitability, financial structure, liberalization, macroeconomic factor, regulatory and/or institutional factor, et cetera. Among others, the subject of diversification is gradually placed importance on account of financial conglomeration and the prevalence of mergers and acquisitions activity in recent years. A number of empirical studies provide little evidence of gains from diversified activity as [7], [10] and [13] and [13].

The typical advantages of diversification are economies of scope that boost performance and market valuations and risk reduction in joint production and marketing, but the diversified activity could incur extraneous expenses and agency problems for different managing organizations. This paper examines whether the observed shift toward diversification activities has improved the efficiencies of Taiwanese listed securities firms, e.g., technical efficiency and scale efficiency gains, by two-stage DEA. Focused on the sources of a firm's revenue, the degree of diversification is measured by gross sales and non-operating revenue.

It is worth noting that few studies research into efficiency estimate of financial institutions taking account of operating risk. [11] used SFA to investigate efficiency of banks operating in the Third Federal Reserve District using 1991-1992 data, accounting for the quality and riskiness of bank output. As [1], they investigated the impact of risk and quality factors on cost by using SFA to evaluate scale and X-inefficiencies for Japanese commercial banks during the period 1993-1996. Pastor (2002) proposed a new sequential DEA procedure to break down the main indicator of banking risk into internal and external components, in order subsequently to obtain measurements of efficiency adjusted for risk by application to the Spanish banking system.

Moreover,[15] used two-stage DEA to investigate the impact of operating risk on efficiency performance for integrated securities firms in Taiwan spanning 1991-1993, and they found that the operating risk had a significant negative impact on efficiency measures. Kao *et al.* (2011) also used two-stage DEA to examine the association of efficiency performances with the proxies of risk management for Taiwanese financial holding companies (FHCs) during the period of 2001-2009, and they found the evidence that risk management play a critical role in performance of FHCs, particularly in the credit risk after the financial crisis.

However, the above studies had taken operating risk into an explanatory variable of efficiency regression rather than a proxy of individual firm's input in production process. Chen *et al*. (2010) took operating risk into one of firm's inputs in DEA model, and they found that the efficiency estimates can be avoided to underestimate or overestimate. It is an important finding because it contrasts with the result of previous studies without considering operating risk. Therefore, this paper takes account of operating risk as an input following Chen *et al*. (2010), to obtain correct efficiency estimates and further analysis the determinants of efficiency performances.

The subprime crisis that began in the summer of 2007 was triggered by deteriorating quality of U.S. subprime mortgages and infected global economic and financial turbulence. In particular, after Lehman Brothers fail in September 2008, the global financial system confronted a huge credit risk and the dilemma is a principal cause of credit crunch to production sectors which induces global financial crisis. In the light of global financial crisis from 2008-2010, whether a decrease in

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efficiency performance of Taiwanese listed securities firms is caused by global financial crisis and whether the raise of diversification during global financial crisis brings efficiency increases, are concerned about the subjects in this paper.

The purpose of this paper is twofold. First, we estimate the efficiencies of Taiwanese listed securities firms by applying a version of DEA model taking account of operating risk as an input. Second, we apply the Tobit censored regression model controlling for firm-specific variables, to investigate the association of the efficiency estimates with global financial crisis and revenue diversification, and the impact of interaction of financial crisis and diversification on efficiency estimates.

The rest of this paper is structured as follows. Section II outlines the two-stage DEA model used for estimation, and defines a few efficiency concepts. Section III briefly describes the empirical data and variable definitions. Section IV analyses the empirical results including the efficiency estimates, scale economies and Tobit regression results, while Section V summarizes the main conclusions.

II. Model Specification

DEA has become popular in measuring efficiency and is based on the pioneering work of Farrell (1957), proposing the frontier function to measure efficiency. Subsequent studies use the concept to measure efficiency and productivity, which is a non-parametric linear programming technique used to compare input and output data of decision making units (DMUs), to measure and evaluate the relative performance of DMUs. The chief advantage of DEA is that it requires no specification of functional form, and account for technical inefficiency in using many inputs or producing many outputs. [1]

This paper employs the variable returns to scale (VRS) DEA model, which was developed by Banker *et al*. (1984) (henceforth BBC), which suggested an extension of the constant returns to scale (CRS) DEA model by Charnes *et al*. (1978), to account for VRS situations. The BBC model for VRS and input-oriented envelopment problem can be expressed as the linear programming problem:

$$\begin{aligned} &\underset{\theta,\lambda}{Min} \quad \theta \\ &subject\ to\ \theta x \geq X\lambda \\ &\qquad\quad Y\lambda \geq y \\ &\qquad\quad N1'\lambda = 1 \\ &\qquad\quad \lambda \geq 0 \end{aligned} \quad , \tag{1}$$

where θ is a scalar, λ is an N×1 vector of intensity variables, $x_i \geq 0$ is a K× 1 vector of inputs for the ith DMU, $y_i \geq 0$ is the ith DMU's M × 1 vector of outputs, X is an K × N matrix of input vectors in the comparison set, Y is an M × N matrix of output vectors in the comparison set, $N1$ is a N×1 vector of one, and note that $N1'\lambda = 1$ is convexity constraint in this VRS case. The problem is solved N times, once for each producer in the comparison set, and a value of θ is then obtained for each DMU with a value of 1 indicating a point on the frontier and hence a most technical efficiency DMU.

When all firms are not operating at optimal scale, the use of the CRS specification results in that measures of pure technical efficiency are confounded by scale efficiency. In other words, scale efficiency is due to the choice of production scale problem, which the DMU is not operating under CRS, measuring the ray average productivity at the observed input scale relative to what is attainable at the most productive scale size. The scale efficiency (*SE*) is calculated residually as

$$SE = \frac{TE_{CRS}}{TE_{VRS}}, \tag{2}$$

where TE_{CRS} and TE_{VRS} are technical efficiencies under the use of the CRS specification and pure technical efficiency, respectively, which are vary between 0 and 1.

In order to indicate whether the DMU is operating in an area of increasing returns to scale (IRS) or decreasing returns to scale (DRS), this can be determined by running an additional DEA problem with non- increasing returns to scale (NIRS) imposed, utilizing the following the problem:

$$\begin{aligned} &\underset{\theta,\lambda}{Min} \quad \theta \\ &subject\ to\ \theta x \geq X\lambda \\ &\qquad\quad Y\lambda \geq y \\ &\qquad\quad N1'\lambda \leq 1 \\ &\qquad\quad \lambda \geq 0 \end{aligned} \quad , \tag{3}$$

this is done by altering the DEA model in equation (1) by substituting the $N1'\lambda \leq 1$ restriction for $N1'\lambda = 1$.

Using the efficiency measures derived from the DEA estimations as the limited dependent variable, the determinants of efficiency scores are investigated by Tobit regression model. The efficiency score are regressed upon environmental variables as

$$\begin{aligned} ec_{it} = {} & \beta_0 + \beta_1 FC_{it} + \beta_2 DIV_{it} + \beta_3 (FC_{it} \times DIV) + \beta_4 AS_{it} \\ & + \beta_5 AS_{it}^2 + \beta_6 ROAA_{it} + \beta_7 DR_{it} + \beta_8 CAR + \beta_9 ET + \varepsilon_{it}, \end{aligned} \tag{4}$$

where i indexes the DMUs; t is the time index; *ec* is the efficiency score from first stage; *FC* represents the financial crisis period as a dummy variable valued at 1 for years of 2008 to 2010 and zero otherwise; *DIV* represents the degree of revenue diversification included gross sales and non-operating revenue, which is calculated as the measurement in Striroh and Rumble (2006).

AS is a proxy for assets scale computed as natural log of a DMU's assets; *ROAA* denotes the return on average assets representing the capacity for profitability; *DR* is the debt as share of total assets indicating the capacity for solvency; *CAR* indicates the capital adequacy ratio computed as a ratio of core capital to risk weighted assets; *ET* represents equity turnover which is calculated as a ratio of net sales to average equity and is a measure of how well a DMU uses its equity to generate revenue. Two extra variables, characterizing the sources of efficiency, are identified as (*FC*×*DIV*) representing the impact

1 For an introduction to DEA methodology, see Coelli *et al*. (1998) and Thanassoulis (2001) has explicit illustrations.

of interaction of financial crisis and diversification on the efficiency, and squared term of assets scale (AS^2) depicting the non-linear effect of assets scale.

III. DATA DESCRIPTION

The sample data are extracted from the data bank of Taiwan Economic Journal's financial database during the period 2005-2010. Since some banks wound up their businesses in 2008, this unbalanced panel data set contains 18 of Taiwan's listed securities firms with a total of 106 observations. Taking into account the diversification of total revenue in production process, we define the two sets of outputs as the gross sales (y_1) and non-operating revenue (y_2), while the inputs contain the physical capital (x_1), borrowed funds (x_2), labor (x_3) and equivalent amount of operating risk (x_4), respectively. All the nominal variables have been transformed into real term by the consumer price index of Taiwan with base year 2006.It is worth noting that the operating risk is classified as the fourth input to highlight the influence of the operating risks in production processes, which it includes the market risk, credit risk and operational risk. A market risk is the risk of losses in on and off-balance sheet positions arising from movements in market prices, including interest rates, exchange rates and equity values. A credit risk is most simply defined as the potential that a borrower or counterparty will fail to meet its obligations in accordance with agreed terms, such as the securities firms are facing credit risk in various financial instruments including trade financing, commitments and guarantees, derivative and the settlement of transactions et cetera. An operational risk indexes the risks arising from the people, systems and processes through which a company operates, and other aspects of it include major failure of information technology systems or events such as major fires or other disasters.

TABLE I
DESCRIPTIVE STATISTICS

Variables	Code	Mean	Standard Deviation
Panel A			
Gross sales	y_1	5,036,806	3,515,256
Non-operating revenue	y_2	346,792	401,569
Physical capital	x_1	1,847,655	1,089,697
Borrowed funds	x_2	17,025,972	14,398,210
Labor	x_3	1,289	711
Equivalent amount of operating risks	x_4	2,733,812,137	1,971,119,582
Panel B			
Revenue diversification (%)	*DIV*	12.27	6.23
Assets scale	*AS*	17.09	0.99
Return on average assets (%)	*ROAA*	2.50	3.46
Debt ratio (%)	*DR*	56.29	13.73
Capital adequacy ratio (%)	*CAR*	395.64	158.42
Equity turnover (%)	*ER*	0.34	0.12
Number of observations		106	

Notes:
1. The variables of y_1, y_2, x_1, x_2 and x_4 are reported in thousands of New Taiwan's dollar.
2. The variable of x_3 is number of employees which its measured unit is thousand of persons.

Sample statistics of output and input variables are summarized in Table I of panel A. After the global financial crisis from 2008 to 2010, all output and input variables have significantly reduced in substance. In Table I of panel B, the explanatory variables of Tobit regression model as equation (4) are have defined in the earlier section, which are the revenue diversification, assets scale, return on average assets, debt ratio, capital adequacy ratio, and equity turnover, respectively. It is worth noting that the degree of revenue diversification is measured as $DIV = 1 - (SALES^2 + NONSALES^2)$, where $SALES$ is the share of total revenue from gross sales sources and $NONSALES$ is the share of total revenue from non-operating revenue sources, according to Striroh and Rumble (2006).Correlation is used to measure the relativity between the two outputs and four inputs, and the results are shown in Table II. The correlations coefficients are all positive and above 0.5 significantly at 1%, the correlations between operating risks and gross sales and non-operating revenue have high level, particularly. The results exhibit that output and input variables selected in this paper should be able to capture the true production characteristics of Taiwan's listed securities firms.

IV. AN EMPIRICAL APPLICATION

A. Evaluations of Efficiency Scores and Scale Economies

Table III reports the estimated operating efficiency and measures of scale economies, which the former involve pure technical efficiency (TE_{VRS}) and scale efficiency (*SE*) scores, and the latter is examined by number of observations in the area of increasing returns to scale (IRS). If the number of observations in the area of IRS greater than in others areas of decreasing returns to scale (DRS) and constant returns to scale (CRS), it implies the securities firms exhibit the characteristic of scale economies, which is the opposite of the decreasing or constant returns to scale. For the purpose of comparison, Model A takes account of operating risks as an input, while Model B is a restricted model eliminating the input of operating risks.

TABLE II
CORRELATION BETWEEN OUTPUT AND INPUT VARIABLES

Variables	Code	y_1	y_2	x_1	x_2	x_3	x_4
Gross sales	y_1	1.0000					
Non-operating revenue	y_2	0.6239	1.0000				
Physical capital	x_1	0.7035	0.5652	1.0000			
Borrowed funds	x_2	0.7264	0.5483	0.7281	1.0000		
Labor	x_3	0.8077	0.5046	0.7429	0.6480	1.0000	
Equivalent amount of operating risks	x_4	0.8541	0.6173	0.7804	0.7828	0.8696	1.0000

TABLE III
DESCRIPTIVE STATISTICS OF EFFICIENCY SCORES AND SCALE ECONOMIES

	Pure Technical Efficiency (TE_{VRS})	Scale Efficiency (SE)	Measures of Scale Economies		
			CRS	DRS	IRS
Model A	0.7693	0.9371	20	18	68
	(0.2013)	(0.1120)			
Model B	0.7198	0.9247	14	14	78
	(0.2175)	(0.1315)			

Notes:
1. Number of total observations is 106.
2. Numbers in parentheses are standard deviation.

According to Model A, the average TE_{VRS} and SE scores of all securities firms are 0.769 and 0.937. The mean TE_{VRS} score exhibits that the sample securities firms can reduce around 23% of inputs given the same outputs, and the mean SE score reveals that the sample securities firms can increase up to around 6% average productivity if they operate at constant returns to scale. In addition, TE_{VRS} score is much less than SE score, which indicates that the technical inefficiency from inappropriate management constitutes the main source of the operating inefficiency. Comparing to Model A, TE_{VRS} and SE scores from Model B are underestimated without taking account of operating risks, and this result could not conducive to establishment of business strategy for the sample securities firms.

Returns to scale characteristics of the sample securities firms are also summarized in Table III. In the Model A, of the 106 observations, there are 68 observations to display IRS, accounting for 87% of whole sample securities firms, and the observations belonging to CRS and DRS only account for 19% and 17% of all samples, respectively. This result exhibits that the representative security firm exhibits increasing returns to scale, suggesting that the sample securities firms have sizes smaller than efficient scale. Expanding a security firm's production scale, e.g., through mergers and acquisitions, could lower its long-run average cost, promote profitability and increase market power.

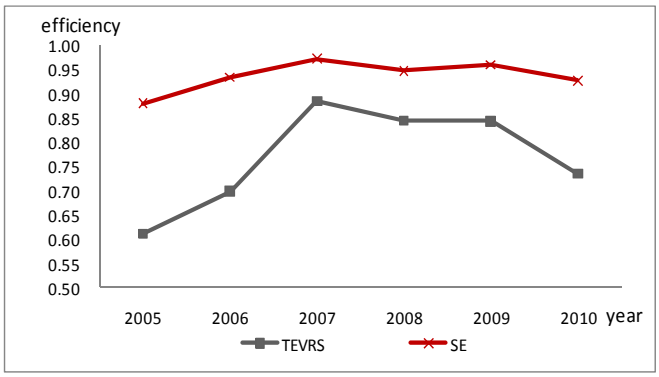

Fig. 1 The Volatility of Efficiency Scores From 2005 to 2010

In order to analyze the volatility of efficiencies over time, efficiency scores from Model A are drawn on a time series graph and these results are illustrated in Figure I. From 2005 to 2007, the average TE_{VRS} and SE scores have significantly improved in substance, especially in faster growth of TE_{VRS}. However, two efficiency scores exhibit significant declining after 2007, and although they are improved imperceptibly in 2009, but their speeds of declining are enormous in 2010.

Through above results, this paper is interested in three questions: one is that whether the decrease in efficiency is caused by global financial crisis, one is that whether revenue diversification is the determinant of efficiency improvements and last one is that whether the raise of revenue diversification during global financial crisis brings efficiency increases. Therefore, the purpose of next subsection is to take a step further in analyzing efficiency scores of the sample securities firms by looking at their potential determinants, and show the answers of above questions using the Tobit regression model.

B. Effects of Various Explanatory Variables on Efficiency

This subsection examines the association of the pure technical efficiency and scale efficiency scores with global financial crisis and revenue diversification by the Tobit regression described in equation (4) and controlling for firm-specific variables as assets scale, return on average assets, debt ratio, capital adequacy ratio and equity turnover. The regression results are summarized in Table IV.

First, in terms of the determinants of TE_{VRS} for the sample securities firms, it is found that global financial crisis insignificantly influences TE_{VRS}, but the effect of the revenue diversification is significant positive, representing that pure technical efficiency is likely improved by the increase of revenue diversification. However, the revenue diversification during global financial crisis could not bring pure technical efficiency gain, because the estimated coefficient of ($FC \times DIV$) is statistically insignificant. As for the other variables, the assets scale (AS) and its squared term (AS^2) exhibit negative and positive significantly effects, respectively, and it is likely to indicate the non-linear effect of assets scale on pure technical efficiency. The coefficients of return on average assets (ROAA), capital adequacy ratio (CAR) and equity turnover (ET) are positive significantly related to TE_{VRS} with anticipated signs, whereas the negative nexus between debt ratio (DR) and TE_{VRS}.

Next, in terms of the determinants of SE for the sample securities firms, although global financial crisis is likely to induce a decrease in scale efficiency significantly, and scale efficiency gain could not be obtained by the revenue diversification. It is worth noting that the impact of interaction of global financial crisis and revenue diversification on the scale efficiency is significant positive, which exhibits the revenue diversification raise during global financial crisis could improve scale efficiency significantly. As for the other

variables, the effect of assets scale on scale efficiency is also a non-linear relation as on pure technical efficiency. The securities firms with less debt ratio and capital adequacy ratio are likely more scale efficient, whereas scale efficiency gain could be obtained by increase of equity turnover, significantly.

TABLE IV
TOBIT REGRESSION RESULTS

	Dependent Variable			
	Pure Technical Efficiency (TE_{VRS})		Scale Efficiency (SE)	
Independent Variables	Coefficient	Standard Error	Coefficient	Standard Error
Intercept	9.0447 **	4.0543	-4.7274 **	2.3162
FC	0.0521	0.0533	-0.0657 **	0.0304
DIV	0.0089 ***	0.0029	-0.0020	0.0016
FC×DIV	-0.0032	0.0037	0.0057 ***	0.0021
AS	-1.0113 **	0.4858	0.6259 **	0.2775
AS^2	0.0289 **	0.0144	-0.0161 *	0.0082
ROAA	0.0058 *	0.0035	-0.0013	0.0020
DR	-0.0042 ***	0.0013	-0.0062 ***	0.0008
CAR	0.0007 ***	0.0001	-0.0002 ***	0.0000
ET	1.0963 ***	0.1153	0.4067 ***	0.0659
Log likelihood	80.7191		140.06285	

Note: ***, ** and * denote statistical significant at1, 5 percent and 10 percent levels respectively.

However, the return on average assets has an insignificantly impact on scale efficiency.

Based on the above results, we found that the global financial crisis and revenue diversification have different impacts on efficiency scores, further answer the three questions interested. Do the decreases in efficiencies of Taiwan's listed securities firms be caused by global financial crisis? The answer to this question is that global financial crisis induces a decrease in scale efficiency, but it insignificantly influences pure technical efficiency. Do efficiency improvements from revenue diversification occur in Taiwan's listed securities firms? The answer to this question is that the increase of revenue diversification could improve pure technical efficiency, but it could not extend scale efficiency. Does the raise of revenue diversification during global financial crisis bring efficiency increases in Taiwan's listed securities firms? The answer to this question is that the raise of revenue diversification during global financial crisis could reduce the damage of scale efficiency caused by global financial crisis, but it could not induce an increase in pure technical efficiency.

V. Conclusion

This paper adopts two-stage Data Envelopment Analysis (DEA) taking account of operating risks, to investigate the impacts of global financial crisis and revenue diversification on efficiencies of 21 Taiwan's listed securities firms during the period 2005-2010. In the first stage, the pure technical efficiency and scale efficiency scores are measured by the variable returns to scale DEA model. Using the efficiency measures derived from the first stage as the limited dependent variable, the determinants of efficiency scores are investigated by the Tobit regression model in the second stage.

Three main evidences are be found by this paper. First, taking account of operating risks, the pure technical efficiency and scale efficiency estimates can be avoided to underestimate, and the technical inefficiency from inappropriate management constitutes the main source of the operating inefficiency. It is an important finding because it contrasts with the result of previous studies without considering operating risks.

Second, the scale economies prevail in the majority of securities firms, indicating that a securities firm is competitively viable in the long-run by expanding its operating scale. Finally, according to the Tobit regression results by controlling for firm-specific variables, the global financial crisis induces a decrease in scale efficiency and the increase of revenue diversification could improve pure technical efficiency, but the raise of revenue diversification during global financial crisis could reduce the damage of scale efficiency caused by global financial crisis.

Acknowledgment

The authors are indebted to the National Science Council of the Republic of China, Taiwan, for their financial support of this research under Contract Nos. NSC 99-2410-H-264-004-. The authors are also most grateful for the anonymous referee's valuable comments and constructive suggestions. Remaining errors are the responsibility of the authors.

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