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The Effect of Risky Assets to Operating Efficiencies for Listed Securities Firms in Taiwan Using the Data Envelopment Analysis

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***Abstract*—**This paper employs a the variable returns to scale DEA model to take account of risky assets and estimate the operating efficiencies for the 21 domestic listed securities firms during the period 2005-2009. Evidence is found that on average the brokerage securities firms' operating efficiencies are better than integrated securities firms. Evidence is also found that the technical inefficiency from inappropriate management constitutes the main source of the operating inefficiency for both types of securities firms. Moreover, the scale economies prevail in brokerage and integrated securities firms, in other words, which exhibit the characteristic of increasing returns to scale.

***Keywords*—**Data Envelopment Analysis, Risky Assets, Pure Technical Efficiency, Scale Efficiency, Scale Economies.

I. Introduction

BASEL II which are recommendations on banking laws and regulations issue by the Basel Committee on Banking Supervision. It was initially published in June 2004, is to create an international standard that banking regulators can use when creating regulations about how much capital banks need to put aside to guard against the types of financial and operational risks banks face. According to the Basel rules, the capital adequacy ratio (CAR) of the bank is not lower than 8%, while is not lower than 150% of securities firm in Taiwan. The minimum capital requirement and operating risk are expected to have a negative impact on operating efficiency of financial institutions.

According to Berger *et al*. [3] 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.

These methodologies were used to the effect of risk in bank industry by many recent studies. Mester [10] 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. Altunbas *et al*. [1] 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. Bhattacharyya *et al*. [7] examined the productive efficiency of 70 Indian commercial banks during the early stages (1986-1991) of the ongoing period of liberalization by using DEA. They then used SFA regression model to investigate the effect of ownership form to efficiency.

In addition, Seiford and Zhu [12] employed DEA to examine the performance of the top 55 U.S. commercial banks via a two-stage production process that separates profitability and marketability. They find that large banks exhibit better performance on profitability, whereas smaller banks tend to perform better with respect to marketability. Pastor [11] 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.

Few studies address on efficiency estimate of securities firms, Goldberg *et al*. [9] estimated economies of scale and scope using DFA and the translog multiproduct cost function for the 74 U.S. securities industries during the period 1983-1988, and find that small specialized firms appeared to exhibit economies of scale, while large, diversified firms exhibited scale diseconomies. Fukuyama and Weber [8] adopted non-parametric linear programming methods to construct the production technology and measure overall cost efficiency and Malmquist input-based productivity index for the Big Four Japanese securities firms and other securities firms between 1988 and 1993.

Wang *et al.* [14] used DEA to measure the efficiency performance of integrated securities firms in Taiwan during 1991–1993, and applied the Tobit censored regression model to investigate the operating risk had a significant negative impact on cost and allocative efficiency measures. Liao *et al.* [15] used the DEA and Malmquist index to investigate the productivity change of securities firms in Taiwan during 1992 -2007, and find the key result that the effect of external monitoring mechanisms are more significant than the internal monitoring mechanisms.

The literature on the role of operating risks and efficiency is mostly aimed at banking in financial institutions, but the effect on securities firms shouldn't be ignored. Therefore, the principal objective in this paper is to measure and compare the

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operating efficiencies of securities firms taking account of operating risks. This paper regards risky assets as measurement of operating risks, particularly risky assets measure is used to be a proxy of individual firm's input in the DEA model.

This paper employs the variable returns to scale (VRS) DEA model, which was developed by Banker *et al*. [2] (henceforth BBC), is based on the pioneering work of Farrell [7], to construct the whole production frontier and relative efficiency levels of individual firm. The basic idea is to envelop the data in the smallest, or tightest fitting, convex cone, and the upper boundary of this set then represents the "best practice" production frontier. [1] 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.[2]

The rest of the paper is organized as follows: In Section II we introduce the BCC model, while section III briefly describes the data. Section IV discusses the main empirical results and the last section concludes the paper.

II. Model Specification

Banker *et al*. [2] suggested an extension of the constant returns to scale (CRS) DEA model by Charnes *et al*. [5] to account for VRS situations. When all firms are not operating at optimal scale, the use of the CRS specification results in that measures of technical efficiency (TE) are confounded by scale efficiencies (SE).

The BBC model for VRS and input-oriented envelopment problem can be expressed as the linear programming problem:

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

where θ is a scalar, λ is an N×1 vector of intensity variables, $x \geq 0$ is K× 1 a vector of inputs of a decision making unit (DMU), $y \geq 0$ is a 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 an 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.

Under the use of the VRS specification, the CRS technical efficiency score (TE_{CRS}) is decomposed into pure technical efficiency (TE_{VRS}) and scale efficiency (*SE*), which are vary between 0 and 1. In other words, if there is a difference in the CRS and VRS TE scores for a particular DMU, it indicates that this DMU has scale inefficiency. *SE* can be calculated as follows:

$$TE_{CRS} = TE_{VRS} \times SE \tag{2}$$

Scale inefficiency is due to the choice of production scale problem, which the DMU is not operating under CRS. 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:

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

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

III. Data Description

The data are extracted from the financial institution database of Taiwan Economic Journal Co., Ltd. The paper uses unconsolidated accounting statements for 21 domestic listed securities firms spanning 2005-2009. The unbalanced panel data contain 352 observations. We define the inputs and outputs following the intermediation approach, the inputs include physical capital (x_1), borrowed funds (x_2) and operating expenses (x_3), while the outputs contain the interest revenue (y_1), non-interest revenue (y_2) and non-operating revenue (y_3), respectively.

To highlight the influence of the operating risks in production processes, risky assets (x_4) is classified as the fourth input, which include 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 is arising from execution of a company's business functions which focuses on the risks arising from the people, systems and processes through which a company operates. It also includes other categories such as fraud risks, legal risks, physical or environmental risks. The most important types of operational risk involve breakdowns in internal controls which can lead to financial losses through error, fraud, or failure to perform. Other aspects of operational risk include major failure of information technology systems or

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

2 However, DEA does require an assumption about returns to scale of the technology, and the disadvantage of using this method is unable to take into account the effect of random noise.

events such as major fires or other disasters. The operational risk capital is as the proxy of the 25% of operating expenses last year. According to capital adequacy ratio (CAR), the risky assets (x_4) are the sum of the above three risk types of accrued capitals.

A security firm is classified by the current paper as a brokerage security firm if its ratio of brokerage revenue to total revenue is greater than the sample mean, which is the opposite of the integrated security firm. We identify 12 brokerage securities firms and 9 integrated securities firms and compute sample statistics of input and output quantities for all securities firms and the two groups in Table I to Table III. The consumer price index of Taiwan with base year 2007 is used to deflate nominal variables.

TABLE I
SAMPLE STATISTICS FOR ALL SECURITIES FIRMS

Variables	Mean	Standard Deviation
Interest revenue (y_1)	515,404	491,821
Non-interest revenue (y_2)	2,026,768	1,993,166
Non-operating revenue (y_3)	206,828	328,813
Physical capital (x_1)	2,357,384	1,579,741
Borrowed funds (x_2)	16,059,233	14,154,012
Operating expenses (x_3)	1,203,338	1,056,895
Risky assets (x_4)	2,446,670,564	1,956,652,980

Notes:
1. Number of observations are 352 and the measured unit is thousand NT dollars.
2. All values are measured in millions of 2007 NT dollars, deflated by the consumer price index.

TABLE II
SAMPLE STATISTICS FOR THE INTEGRATED SECURITIES FIRMS

Variables	Mean	Standard Deviation
Interest revenue (y_1)	580,240	517,307
Non-interest revenue (y_2)	2,527,716	2,259,232
Non-operating revenue (y_3)	256,456	451,964
Physical capital (x_1)	2,625,514	1,635,122
Borrowed funds (x_2)	22,074,417	16,083,997
Operating expenses (x_3)	1,298,439	1,116,554
Risky assets (x_4)	2,878,032,403	2,019,307,377

Notes:
1. Number of observations are 153 and the measured unit is thousand NT dollars.
2. All values are measured in millions of 2007 NT dollars, deflated by the consumer price index.

IV. AN EMPIRICAL APPLICATION

A. Evaluations of Pure Technical and Scale Efficiencies

Table IV reports the average estimated operating efficiencies involve pure technical efficiency (TE_{VRS}) and scale efficiency (*SE*) scores, labeled by Model A, take account of operating risks, i.e., the inputs include the risky assets. For the purpose of comparison, we also estimate a restricted model except for the risky assets, and the results are also shown in Table 4 and labeled by Model B.

TABLE III
SAMPLE STATISTICS FOR THE BROKERAGE SECURITIES FIRMS

Variables	Mean	Standard Deviation
Interest revenue (y_1)	465,556	465,185
Non-interest revenue (y_2)	1,641,617	1,661,790
Non-operating revenue (y_3)	168,665	175,612
Physical capital (x_1)	2,151,233	1,503,636
Borrowed funds (x_2)	11,434,493	10,308,262
Operating expenses (x_3)	1,130,219	1,002,514
Risky assets (x_4)	2,115,020,507	1,839,540,727

Notes:
1. Number of observations are 199 and the measured unit is thousand NT dollars.
2. All values are measured in millions of 2007 NT dollars, deflated by the consumer price index.

For Model A, the average TE_{VRS} and *SE* scores of all securities firms are 0.747 and 0.939, and the average TE_{VRS} and *SE* scores are 0.729 and 0.946 for Models B, respectively. The former mean TE_{VRS} score of Model A are higher than the corresponding average score of Model B, while the reverse is true for the latter mean *SE* score, arising possibly from whether the model considers risky assets or not. In addition, the mean TE_{VRS} score is much less than the mean *SE* score for Models A and B, which indicate that the technical inefficiency from inappropriate management constitutes the main source of the operating inefficiency. The above-mentioned results have appeared to underestimate and overestimate from Model B as take place in the groups of integrated and brokerage securities firms, respectively.

According to Model A of Table IV, the mean TE_{VRS} and *SE* scores of the integrated securities firms are 0.734 and 0.937, respectively. For the brokerage securities firms, the mean TE_{VRS} and *SE* scores are 0.757 and 0.940, respectively. These mean scores of the integrated securities firms are quite close to those of the brokerage securities firms. Furthermore, on average the operating efficiencies of brokerage securities firms are better than integrated securities firms, which reveal that the brokerage securities firms seem to use professional management to increase average profits.

B. Evaluations of Scale Economies

We next compute scale economies for all observations by running the equation (3). If the number of observations in the area of IRS greater than in others areas of DRS and CRS, it

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TABLE IV
DESCRIPTIVE STATISTICS OF PURE TECHNICAL EFFICIENCY AND SCALE EFFICIENCY SCORES

	Model A		Model B	
	TE_{VRS}	*SE*	TE_{VRS}	*SE*
All Securities Firms	0.747	0.939	0.729	0.946
	(0.180)	(0.101)	(0.182)	(0.096)
Integrated Securities Firms	0.734	0.937	0.721	0.943
	(0.177)	(0.100)	(0.179)	(0.095)
Brokerage Securities Firms	0.757	0.940	0.735	0.948
	(0.182)	(0.102)	(0.185)	(0.096)

Notes:
1. Numbers in parentheses are standard errors.
2. A security firm is classified as a brokerage security firms if its ratio of brokerage revenue to total revenue is greater than the sample mean.

implies the securities firms exhibit the characteristic of scale economies, which is the opposite of the decreasing or constant returns to scale.

Table V shows that the representative security firm exhibits increasing returns to scale for both models and both types of securities firms, 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.

TABLE V
MEASURES OF SCALE ECONOMIES

	Model A			Model B		
	CRS	DRS	IRS	CRS	DRS	IRS
All Securities Firms	68	59	225	70	73	209
Integrated Securities Firms	34	25	94	35	32	86
Brokerage Securities Firms	34	34	131	35	41	123

Notes:
1. Numbers in this table are number of observations.
2. CRS implied the characteristic of constant returns to scale, DRS means decreasing returns to scale, and IRS means increasing returns to scale.

V. CONCLUSION

This paper adopts a variable returns to scale DEA model, to investigate the influence of risky assets and the operating efficiencies for 21 domestic listed securities firms during the period 2005-2009. The literature on the role of operating risks and efficiency is mostly aimed at banking in financial institutions, but the effect on securities firms shouldn't be ignored.

Three main evidences are be found by this paper. First, taking account for risky assets, the pure technical efficiency estimates can be avoided to underestimate, while the reverse is true for the estimated scale efficiency. These are important finding because it contrast with the result of previous studies without considering risky assets.

Second, on average the operating efficiencies of brokerage securities firms are better than integrated securities firms, which reveal that the brokerage securities firms seem to use professional management to increase average profits. In particular, the technical inefficiency from inappropriate management constitutes the main source of the operating inefficiency for both types of securities firms.

Finally, the findings of scale economies suggest that a securities firm is competitively viable in the long-run by expanding its operating scale and jointly providing various financial products. This may be advantageous for securities firms and the society as a whole, through mergers and acquisitions, due to the potential cost savings.

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