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# *A study of production efficiencies of integrated securities firms in Taiwan*

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Based on the 1991–1993 data of integrated securities firms in Taiwan, this article first uses DEA to assess pure technical, scale, cost and allocative efficiencies of each firm, and then applies the Tobit censored regression model to investigate the determinants of each efficiency measure. The regression results show that firm size has a positive impact on pure technical, scale and cost efficiencies. The impacts of a firm's service concentration on pure technical and scale efficiencies are positive, but its impact on allocative efficiency is negative. Firms with a branch or branches are less efficient than those without any branch in terms of pure technical, scale and cost efficiencies. Firms with low operating risks are more efficient than those with high operating risk in terms of cost and allocative efficiencies. Competition pressure forces integrated securities firms to improve their pure technical and cost efficiencies, and shrinks the differences of pure technical efficiency among them in 1993.

## I. INTRODUCTION

To accelerate the internationalization and liberalization of the capital market in Taiwan, the Ministry of Finance eased the restrictions on the establishment of securities brokerage firms and introduced integrated securities firms to launch in May, 1988. In the meantime, accompanied with bull market, the number of securities brokerage and integrated securities firms increased rapidly from 28 in 1987 to 373 in 1990; the number of integrated securities firms increased from six in 1988 to 39 in 1990. And then, due to recession of the business cycle and outflow of the hot money, the Taiwan Stock Exchange Index (TAIEX) fell from 9624 at the end of 1989 to 4530 in 1990.[1] As a result of poor performance, some firms had gone out of business or had been merged, and the number of securities brokerage and integrated securities firms fell sharply from 373 in 1990 to 251 in 1993. However, the number of branches went up from 28 in 1989 to 155 in 1993, and the number of integrated securities firms increased from 39 in 1990 to 46 in 1993 (see Table 1). While the share of brokerage service revenue to the total revenues of the integrated securities firms fell down year by year, the other two major services (equity dealing and underwriting) revenue shares went up (see Table 2).

The above phenomena raise the following questions: Under the pressure of actual and/or potential competition as well as the high volatility characteristics of the stock market, can securities firms improve their production efficiencies and the competition power by expanding their operating scales? Can securities firms improve their production efficiencies by increasing the variety of services, and changing the operating form from securities brokerage firm to integrated securities firm? These questions motivate great interest in production efficiency evaluation and analyses of integrated securities firms in Taiwan. Furthermore, the ability to quantify efficiency will provide management with a control mechanism to monitor or to improve the performance of the securities firms. Therefore, the objectives of this article are first to evaluate the produc-

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[1] TAIEX is a weighted index of the stock market in Taiwan.

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Table 1. *Number of securities firms and trading value, 1991–1993*

| Year | Number of securities firms: Main | Branch | Number of integrated securities firms | Trading value |
|---|---|---|---|---|
| 1987 | 28 | 29 | | 2 663 630 |
| 1988 | 102 | 29 | 6 | 7 868 020 |
| 1989 | 247 | 28 | 30 | 25 407 960 |
| 1990 | 373 | 30 | 39 | 19 031 290 |
| 1991 | 338 | 75 | 45 | 9 682 740 |
| 1992 | 279 | 131 | 47 | 5 917 080 |
| 1993 | 251 | 155 | 46 | 9 056 720 |

*Note*: Trading value is measured in terms of million NT dollars.
Sources:
1. Securities and Futures Commission Annual Report, 1987, 1988 and 1989, Securities and Futures Commission, Ministry of Finance, Taiwan, R.O.C.
2. Taiwan Securities and Futures Markets, 1993, Institute of Securities Futures Markets Development.
3. Statistics of Securities Listed on Taiwan Stock Exchange, 1993, Taiwan Stock Exchange Corporation.

tion efficiencies of individual integrated securities firms, and then to study firms' specific characteristics related to variations in efficiencies among integrated securities firms.

Theoretically, production efficiency comprises two parts: the technical (physical) and allocative (price) parts. The former is measured by determining the maximum feasible reduction of inputs for the given levels of outputs (an input-conversing orientation), or by determining the maximum feasible expansion of outputs for the given levels of inputs (an output-augmenting orientation). In addition, taking the reference technology exhibiting different types of returns to scale into consideration, the technical efficiency can be decomposed into two components, pure technical efficiency and scale efficiency. The latter refers to the ability to combine inputs or outputs in optimal proportions at the prevailing prices.

Although most of the existing empirical studies have focused exclusively on assessing firms' technical efficiency in production, the measures of scale and allocative efficiency will be included in this article to provide a more complete analysis for cost efficiency in the provision of integrated securities services.

In addition to this section, the rest of this paper is organized as follows. Section II will first construct the empirical model of data envelopment analysis (DEA) to evaluate individual integrated securities firm's pure technical, scale, allocative and cost efficiencies. Then, regression

Table 2. *The ratio of major services revenues to total revenues of integrated securities firms, 1991–1993*

| Year | Brokerage to total revenues ratio | Equity dealing to total revenues ratio | Underwriting to total revenues ratio |
|---|---|---|---|
| 1991 | 0.4900 | 0.3606 | 0.1494 |
| 1992 | 0.4846 | 0.3503 | 0.1652 |
| 1993 | 0.4768 | 0.4242 | 0.0991 |

Sources: Securities Firms Income Statement, Taiwan Stock Exchange Corporation, 1991–1993.

models will be established to explore the relationship between integrated securities firm specific characteristics and each efficiency measure. Data description, interpretation of the efficiency evaluation results and the regression analysis will be presented in Section III. Section IV concludes this paper.

## II. EMPIRICAL MODELS

### *Efficiency evaluation models*

The DEA approach introduced by Charnes *et al.* (1978) uses a mathematical programming technique to determine a piecewise linear envelopment surface from the observed levels of inputs and outputs of decision making units (DMU).[2] The envelopment surface is referred to as the efficient frontier. DMUs which construct the frontier are termed efficient; DMUs which do not lie on the frontier are termed inefficient. The distance between the former and the latter provides a measure of efficiency or inefficiency.

As mentioned above, there are input-oriented and output-oriented models to evaluate the production efficiency in the DEA approach. Lovell (1993) suggested that if producers are required to meet the market demand, and if they can freely adjust the input usage, then an input-oriented model seems appropriate. Therefore, the input-oriented DEA model is used in this article.

According to Färe *et al.* (1985), suppose that there are $n$ DMUs in a market, each using $m$ inputs and producing $s$ outputs. Let $x_{ij}$ and $y_{rj}$ denote the $i$th ($i = 1, 2, \ldots, m$) input usage and the $r$th ($r = 1, 2, \ldots, s$) output production of the $j$th ($j = 1, 2, \ldots, n$) DMU. Under the assumptions of the reference technology exhibiting constant returns to scale (CRS) and free disposability of inputs, the $k$th DMU's technical efficiency measure ($F_k$) can be gauged by solving the following problem (Model I):[3]

[2] DEA has been widely applied to the efficiency measurement of various organizations in public and private sectors, such as financial institutions, hospitals and nursing homes, courts, school districts, airforce maintenance units, municipalities, etc. See Seiford (1996) for detailed review of DEA literatures.

[3] Free disposability, or called strong disposability, refers to the ability to dispose of unwanted commodity with no private cost. Free disposability of inputs models the situation in which inputs can be increased without reducing output. That is, this condition excludes 'upward sloping' isoquants (Färe *et al.*, 1994: 38).

$$F_k = \min_{\theta_k,\lambda,\ldots,\lambda_n} \theta_k$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_k x_{ik}, \quad i = 1,2,\ldots,m$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rk}, \quad r = 1,2,\ldots,s$$

$$\lambda_j \geq 0, \quad j = 1,2,\ldots,n \tag{1}$$

where $\lambda_j$ is the weight of the $j$th DMU's production action used. Just as the Model I describes, the technical efficiency is evaluated in terms of the feasibility of its inputs usage radial reduction, if the inputs usage radial reduction is feasible, then optimal $F_k < 1$; otherwise, $F_k = 1$.

The technical efficiency measure ($F_k$) evaluated above is not only influenced by the pure technical inefficiency, but also by the inappropriate production scale chosen. To decompose these two inefficient factors, the reference technology assumption of the Model I is relaxed to those of nonincreasing returns to scale (NIRS) and variable returns to scale (VRS) by imposing the constraints $\sum_{j=1}^{n} \lambda_j \leq 1$ and $\sum_{j=1}^{n} \lambda_j = 1$, respectively. Thereafter, two more technical efficiency measures, $F_k(NIRS)$ and $F_k(VRS)$, are produced. Since $F_k(VRS)$ excludes the production scale impacts, it is regarded as the $k$th DMU's pure technical efficiency measure, and the scale efficiency measure ($SE_k$) corresponding to the $k$th DMU is defined as the ratio of $F_k$ to $F_k(VRS)$, that is:[4]

$$SE_k \equiv F_k/F_k(VRS) \tag{2}$$

Obviously, $F_k \leq F_k(NIRS) \leq F_k(VRS) \leq 1$.[5] It implies $SE_k \leq 1$. If $SE_k = 1$, then the $k$th DMU is scale–efficient; if $SE_k < 1$, then the $k$th DMU is scale-inefficient due to either increasing returns to scale (IRS) as $F_k(NIRS) < F_k(VRS)$, or decreasing returns to scale (DRS) as $F_k(NIRS) = F_k(VRS)$.

The pure technical and scale efficiency measures are all physical measures, and price-independent efficiency measures. If input prices are also available, then input price-dependent measures, cost and allocative efficiencies, can be formed. The cost efficiency measure ($CE_k$) of the $k$th DMU is defined as the ratio of minimum cost ($C_k$) to actual observed cost, that is:

$$CE_k \equiv C_k/\sum_{i=1}^{m} p_{ik} x_{ik} \tag{3}$$

where $p_{ik}$ denotes the $i$th input price of the $k$th DMU, and $C_k$ is computed by the following cost-minimizing linear programming problem (Model II):

$$C_k = \min_{x_1,\ldots,x_m,\lambda_1,\ldots,\lambda_n} \sum_{i=1}^{m} p_{ik} x_i$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_i, \quad i = 1,2,\ldots,m$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rk}, \quad r = 1,2,\ldots,s$$

$$\lambda_j \geq 0, \quad j = 1,2,\ldots,n$$

$$x_i \geq 0, \quad i = 1,2,\ldots,m \tag{4}$$

Suppose $CE_k < 1$. The $k$th DMU is spending more on inputs than what is required to produce given levels of outputs at given input prices. This excess must logically be due to either or both of two factors (i) using proportionately too much of all inputs, and (ii) using inputs in the wrong mix. The first factor, technical efficiency measure, has already been obtained, the second factor is obtained residually from $CE_k$ and $F_k$ (Färe *et al.*, 1994). Hence, the allocative efficiency measure ($AE_k$) of the $k$th DMU is defined as the ratio of $CE_k$ to $F_k$, that is:[6]

$$AE_k \equiv CE_k/F_k \tag{5}$$

According to Equation 2, Equation 5 can be rewritten as follows:

$$AE_k = CE_k/SE_k \times F_k(VRS) \tag{6}$$

### *Regression models*

In the previous studies, efficiency in production has been linked with a number of firm-specific attributes. These attributes include firm size, services diversification, location and operating risk, etc. (Rangan *et al.*, 1988; Goldberg and Rai, 1996). The factor that captures the firm's long-term strategic consideration in the industry, for example, whether an integrated securities firm set up a branch or branches to meet clients' needs geographically, is also considered. Consequently, the regression models for examining the relationship between each efficiency measure and firm-specific attributes in this paper can be built as follows:

[4] See Färe *et al.* (1985).
[5] The ordering of technical efficiency measures according to scale property of the technology is due to Afriat (1972) and Grosskopf (1986).
[6] The decomposition of cost efficiency into its technical and allocative components was first obtained from Farrell (1957).

$$F(VRS) = f_1(\underset{(?)}{FS}, \underset{(+)}{H}, \underset{(?)}{NBD}, \underset{(-)}{OR}) \quad (7)$$

$$SE = f_2(\underset{(?)}{FS}, \underset{(+)}{H}, \underset{(?)}{BD}, \underset{(-)}{OR}) \quad (8)$$

$$CE = f_3(\underset{(?)}{FS}, \underset{(?)}{H}, \underset{(?)}{BD}, \underset{(-)}{OR}) \quad (9)$$

$$AE = f_4(\underset{(?)}{FS}, \underset{(-)}{H}, \underset{(?)}{BD}, \underset{(-)}{OR} \quad (10)$$

where $FS$ is the firm size; $H$ is the service concentration, which is the sum of the squared ratios of revenues from each revenues to total operating revenues;[7] $BD$ represents the dummy variable that indicates whether the firm has a branch or branches or not; $OR$ represents the operating risk; the notation under each independent variable indicates its expected sign. Since the values of dependent variable $F(VRS)$, $SE$, $CE$ and $AE$ all lie between 0 and 1, Equations 7–10 are censored regression models (see Appendix).

Theoretical foundation for the relationship between efficiency measures and firm-specific attributes can be illustrated as follows.

*Firm size (FS).* In general, firms can enjoy economies of scale as their sizes expand from the very beginning, and suffer diseconomies of scale while they grow beyond some level of size. Similarly, scale efficiency increases as firm size expands from IRS to CRS, but it decreases as firm size expands from CRS to DRS (refer to Fig. 1). The advantage from sharing or joint utilization of inputs and the disadvantage from allocative complexity will exist simultaneously as firm size expands (Baumol *et al.*, 1982: 75–9). However, the former dominates the latter at the very beginning, and then the latter outweighs the former after some point. Therefore, the relationships between firm size and four efficiency measures are ambiguous without further estimation.

*Service concentration (H).* By specializing in a single product (service), integrated securities firms can increase their efficiencies due to employees' familiarity with their simple and routine work (Baumol *et al.*, 1982: 75; Eaton and Eaton, 1995: 197–9; Cheng *et al.*, 2000). Therefore, service concentration is expected to have a positive impact on pure technical efficiency because of gains from specialization. As the degree of service concentration goes up, gains from specialization will come up, but the economies of scope may disappear gradually. The former effect will raise a firm's scale and cost efficiencies; the latter effect will reduce the firm's cost efficiency. As a result, the relationship between service concentration and scale efficiency is expected to be positive; that between service concentration and cost efficiency is indeterminate. A firm may not be able to allocate its inputs flexibly while its service concentration rises. Hence, service concentration is expected to have a negative effect on allocative efficiency.

*Branches (BD).* The purpose for setting up a branch or branches by a firm may be for efficient utilization of excess capacities or just for enlargement of the geographical coverage of the market (Cheng *et al.*, 2000). In case of the former, setting up a branch or branches will be helpful to efficiency improvement; otherwise, it is not expected to have a favourable influence on the firm's efficiencies. Hence, the direction of the impact of setting up a branch or branches on four efficiency measures is hard to determine without further empirical investigation.

*Operating risk (OR).* Generally, it is more difficult for integrated securities firms to perform well while their operating risk is rising (Wang *et al.*, 1998). Therefore, operating risk is expected to have a negative impact on all efficiency measures.

## III. DATA DESCRIPTION AND EMPIRICAL RESULTS

### Data description

The data used in this article are based on Taiwan's 40 integrated securities firms operated in 1991, 1992 and

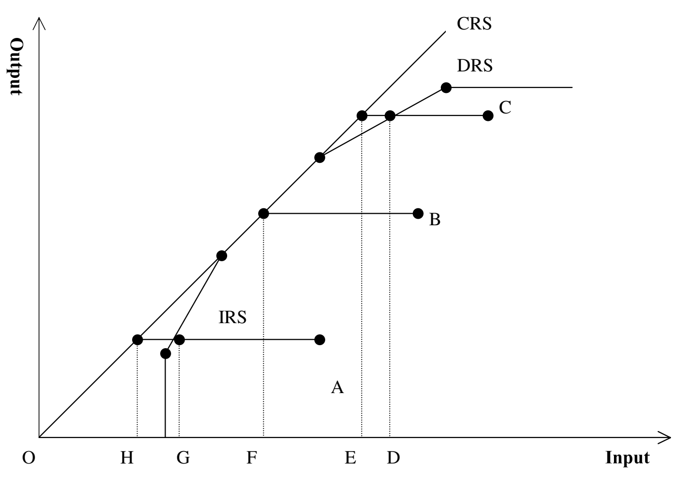


Fig. 1. *Measurement of scale efficiency*
*Notes*:
(1) $SE_A = OH/OG < 1$. (2) $SE_B = 1$. (3) $SE_C = OE/OD < 1$.

[7] The concept of Hirfindahl–Hirschman index is used here to measure the service concentration since it takes into account both the number of services and the inequality of services' revenue shares.

1993. For the convenience of comparability, only the integrated securities firms that provide at least two categories of services are included in the sample. After deleting unqualified and incomplete observations, the effective sample size is 95.

Three outputs and two inputs are specified in the efficiency analyses. On the output side, by referring to Wang and Yu (1995) and Wang *et al.* (1998), the outputs of integrated securities are divided into three categories: brokerage, equity dealing and underwriting measured in terms of NT dollars. On the input side, two types of inputs are distinguished: labour and capital. Referring to Goldberg *et al.* (1991) and Wang *et al.* (1998), the quantity of labour is measured by the number of employees; and the capital is measured by the floor area of office. The price of labour input is approximately measured by dividing annual labour expenditures (including salaries and fringe benefits) by the number of total employees. The price of capital input is approximately measured by dividing rent expenditure by the floor area of office.

In the regression analyses, FS is measured by an integrated securities firm's total operating revenues (including brokerage, equity dealing and underwriting revenues). A firm's H is the sum of the squared ratios of revenues from each service to total operating revenues. Theoretically, the value of H lies between 0 and 1. Since integrated securities firms in the sample provide at least two categories of services, H is actually in a range of 1/3 to 1, with the value 1/3 representing balanced development of services and a higher value representing a higher service concentration. The dummy variable $BD = 1$ indicates that an integrated securities firm has a branch or branches; otherwise, $BD = 0$. OR is measured by the ratio of the sum of default and error account losses to total operating revenues. The descriptive statistics of the relevant variables for both efficiency and regression analyses are presented in Table 3.

### *Empirical results*

*DEA evaluation results.* The DEA evaluation results for each efficiency measure are summarized in Tables 4–8. The mean pure technical efficiency measure of integrated securities firms is 0.743. It implies that integrated securities firms could have reduced inputs by 25.7%, on average, and still have produced the same level of services. The percentage of firms operating on the frontier is 36.8. The mean efficiency measure for non-frontier firms is 0.594, implying that the inefficient firms use on average roughly 40.6% more inputs per units of output than the efficient firms. The standard deviation of pure technical efficiency measure, declines year by year. It implies that competition pressure forces integrated securities firms to improve their pure technical efficiencies, and, thereafter, the differences of pure technical efficiency among them shrinks year by year.

The mean scale efficiency measure of integrated securities firms is 0.827, implying that they could have reduced inputs by 17.3%, on average, and still have produced the same level of services under the optimal scale (CRS). Of integrated securities firms 22.1% operate in the region of CRS, and are gauged scale-efficient. Of integrated securities firms 61.1% operate in the region of IRS and are gauged scale-inefficient. It implies that most of the scale inefficiency is owing to operating at a relatively small firm size. The mean efficiency measure of non-frontier firms is 0.778,

Table 3. *The descriptive statistics of the relevant variables*

| Variable | Average | Std. Dev. | Max | Min |
|---|---|---|---|---|
| Brokerage revenue | 219 929 794 | 221 676 510 | 1 580 800 701 | 0 |
| Equity dealing revenue | 194 470 526 | 222 200 752 | 119 099 691 | 458 905 |
| Underwriting revenue | 60 552 344 | 62 793 822 | 305 368 285 | 0 |
| Total revenues | 474 952 664 | 393 717 359 | 1 993 021 126 | 6 026 932 |
| Labour | 141.5894 | 86.3327 | 537 | 21 |
| Salaries | 102 348 234 | 75 161 809 | 519 463 710 | 12 625 898 |
| Fringe benefits | 1 368 014 | 2 443 637 | 15 622 596 | 0 |
| Office floor area | 1502.03 | 1476.30 | 7930 | 150 |
| Rent expenditure | 22 640 751 | 20 878 398 | 111 327 930 | 0 |
| Labour price | 76 283 | 384 507 | 2 566 235 | 299 519 |
| Capital price | 18 526 | 15 138 | 71 191 | 0 |
| Service concentration | 0.5054 | 0.1434 | 0.9918 | 0.3340 |
| Branch dummy (BD) | 0.4421 | 0.4992 | 1 | 0 |
| Operating risk (OR) | 0.0146 | 0.0167 | 0.1462 | 0 |
| Number of observation: 95 | | | | |

*Notes*:
1. All items of revenues, Expenditures, and Input prices are measured in terms of NT dollars.
2. Office floor area is measured in 'ping' ($= 3.30579\,m^2$).
3. The number of integrated securities firms with a branch or branches is 42.

Table 4. *Summary of integrated securities firms' pure technical efficiency measures*

| | Number of observations | Mean | Standard deviation | Max | Min |
|---|---|---|---|---|---|
| Total | 95 | 0.743 | 0.243 | 1.000 | 0.192 |
| 1991 | 34 | 0.696 | 0.264 | 1.000 | 0.192 |
| 1992 | 28 | 0.662 | 0.248 | 1.000 | 0.296 |
| 1993 | 33 | 0.861 | 0.163 | 1.000 | 0.538 |
| Not on the frontier | 60 | 0.594 | 0.179 | 0.961 | 0.192 |
| On the frontier | 35 | 1.000 | 0.000 | 1.000 | 1.000 |
| BD = 0 | 53 | 0.808 | 0.227 | 1.000 | 0.296 |
| BD = 1 | 42 | 0.662 | 0.240 | 1.000 | 0.192 |

Table 5. *Summary of integrated securities firms' scale efficiency measures*

| | Number of observations | Mean | Std. Dev. | Max | Min |
|---|---|---|---|---|---|
| Total | 95 | 0.827 | 0.191 | 1.000 | 0.258 |
| 1991 | 34 | 0.823 | 0.173 | 1.000 | 0.412 |
| 1992 | 28 | 0.783 | 0.201 | 1.000 | 0.258 |
| 1993 | 33 | 0.870 | 0.198 | 1.000 | 0.309 |
| Not on the frontier | 74 | 0.778 | 0.190 | 0.999 | 0.258 |
| On the frontier | 21 | 1.000 | 0.000 | 1.000 | 1.000 |
| BD = 0 | 53 | 0.794 | 0.221 | 1.000 | 0.258 |
| BD = 1 | 42 | 0.870 | 0.138 | 1.000 | 0.317 |

Table 6. *Summary of integrated securities firms' production properties*

| Production properties | Number of observations |
|---|---|
| IRS | 58 (61.1%) |
| CRS | 21 (22.1%) |
| DRS | 16 (16.8%) |

Table 7. *Summary of integrated securities firms' cost efficiency measures*

| | Number of observations | Mean | Std. Dev. | Max | Min |
|---|---|---|---|---|---|
| Total | 95 | 0.522 | 0.264 | 1.000 | 0.109 |
| 1991 | 34 | 0.462 | 0.249 | 1.000 | 0.152 |
| 1992 | 28 | 0.44 | 0.246 | 1.000 | 0.109 |
| 1993 | 33 | 0.654 | 0.250 | 1.000 | 0.284 |
| Not on the frontier | 82 | 0.446 | 0.196 | 0.991 | 0.109 |
| On the frontier | 13 | 1.000 | 0.000 | 1.000 | 1.000 |
| BD = 0 | 53 | 0.512 | 0.277 | 1.000 | 0.109 |
| BD = 1 | 42 | 0.535 | 0.249 | 1.000 | 0.187 |

Table 8. *Summary of integrated securities firms' allocative efficiency measures*

| | Number of observations | Mean | Std. Dev. | Max | Min |
|---|---|---|---|---|---|
| Total | 95 | 0.858 | 0.204 | 1.000 | 0.181 |
| 1991 | 34 | 0.824 | 0.205 | 1.000 | 0.332 |
| 1992 | 28 | 0.868 | 0.221 | 1.000 | 0.181 |
| 1993 | 33 | 0.884 | 0.188 | 1.000 | 0.335 |
| Not on the frontier | 80 | 0.831 | 0.212 | 0.999 | 0.181 |
| On the frontier | 15 | 1.000 | 0.000 | 1.000 | 1.000 |
| BD = 0 | 53 | 0.809 | 0.244 | 1.000 | 0.181 |
| BD = 1 | 42 | 0.920 | 0.112 | 1.000 | 0.584 |

implying that the inefficient firms use on average roughly 22.2% more inputs per units of output than the efficient firms.

The mean cost efficiency measure of integrated securities firms is 0.522, implying that they on average would have needed to lower operating costs by 47.8%. The percentage of firms operating on the frontier is 13.7. The mean efficiency measure for non-frontier firms is 0.446, implying that the inefficient firms use on average roughly 55.4% more costs per units of output than the efficient firms.

The mean allocative efficiency measure of integrated securities firms is 0.858, implying that, given input prices, they on average operate at 14.2% higher costs than the cost-minimizing level due to the inappropriate input mix. The percentage of firms operating on the frontier is 15.8. The mean efficiency measure for non-frontier firms is 0.831, implying that the inefficient firms use on average roughly 16.9% more costs per units of output than the efficient firms.

The Kruskal–Wallis test classified by year is further performed on each efficiency measure (see Table 9).[8] It is found that, except allocative efficiency measures, pure technical and cost efficiency measures in 1991 as well as 1992 are lower than those in 1993 at the 0.01 level of significance; scale efficiency measures in 1991 as well as 1992 are lower than those in 1993 at the 0.1 level of significance. However, there is no significant difference between the efficiency measures in 1991 and 1992. The result indicates that integrated securities firms need time to adjust their inputs usage to meet the market demand.

*Regression results*. Since Equations 7–10 are censored regression models, applying the OLS approach to these regression models will lead the estimated coefficients to be asymptotically biased towards zero (Greene, 1981). Therefore, by referring to McCarty and Yaisawarng (1993), Aokei *et al.* (1994), Kooreman (1994), Cheng *et al.*

[8] As to Kruskal–Wallis test, please refer to Black (1997: 851–6).

Table 9. *Results of Kruskal–Wallis test – classified by year*

| | Pure technical efficiency | Scale efficiency | Cost efficiency | Allocative efficiency |
|---|---|---|---|---|
| $\chi^2$-statistic | 11.748 | 4.9761 | 13.876 | 3.3859 |
| *p*-value | (0.0028) | (0.0831) | (0.0010) | (0.1840) |

(2000) and Wang *et al.* (2001), the tobit censored regression model will be used to estimate Equations 7–10. The regression results of four efficiency measures on firm-specific attributes are presented in Table 10.[9] Since the Kruskal–Wallis test results above imply that the efficiencies of an integrated firm in different years may be significantly different, two more dummy variables, *Year*92 and *Year*93, are added to the regression Equations 7–10. That is, if the observation is in 1992, then $Year92 = 1$; otherwise, $Year92 = 0$. Similarly, if the observation is in 1993, then $Year93 = 1$; otherwise, $Year93 = 0$.

The regression result of pure technical efficiency shows that firm size has a positive impact on pure technical efficiency at the 0.01 significant level. That is, firms exploit economies of scale as their sizes expand. There exist a positive relationship between the firms' service concentration and pure technical efficiency at the 0.01 significant level. That is, integrated securities firms with higher service concentrations do enjoy higher pure technical efficiency due to the existence of gains from specialization. The coefficient of the branch dummy variable is negative at the 0.01 significant level, implying that the firms with a branch or branches are less efficient than those without any branch. Two possible explanations for the result are that the stock market was declining, and most of the branches were established by merging the poorly performed securities firms during the period of 1991–1993. The coefficient of the *Year*93 dummy variable is positive at the 0.01 siginificant level, implying that the firms in 1993 are more efficient that those in 1991 and 1992. This result indicates that competition pressure forces integrated securities firms to improve their pure technical efficiencies. As expected, the coefficient of operating risk is negative as expected; however, it is insignificant.

The regression result of scale efficiency shows that the logarithm of firm size has a positive coefficient at the 0.01 significant level, implying that a firm's size has a positive impact on scale efficiency while the firm grows beyond some level of size; but the positive impact is decreasing. There exist a positive relationship between the firms' service concentration and scale efficiency at the 0.01 significant level. That is, integrated securities firms with higher service concentrations do enjoy higher scale efficiency due to the existence of gains from specialization. The coefficient of the branch dummy variable is negative at the 0.1 significant level, implying that the firms with a branch or

Table 10. *Regression results of pure technical, scale, cost and allocative efficiencies*

| | Pure technical efficiency | Scale efficiency | Cost efficiency | Allocative efficiency |
|---|---|---|---|---|
| Intercept | −0.7372*** | −4.0079*** | −0.8503*** | −1.024 |
| | (0.208) | (0.814) | (0.224) | (0.695) |
| FS | 5.11E-10*** | | 6.44E-10*** | |
| | (1.61E-10) | | (1.95E-10) | |
| ln(FS) | | 0.1874*** | | 0.0583 |
| | | (0.041) | | (0.036) |
| H | 1.1473*** | 0.5407*** | 0.2285 | −0.3385** |
| | (0.384) | (0.187) | (0.387) | (0.170) |
| BD | −0.5547*** | −0.0979* | −0.3257*** | −0.0120 |
| | (0.102) | (0.0523) | (0.116) | (0.047) |
| OR | −0.3679 | −0.3027 | −3.4291* | −3.2277*** |
| | (1.972) | (0.951) | (2.075) | (1.197) |
| Year92 | | | | 0.0639 |
| | | | | (0.051) |
| Year93 | 0.2827*** | 0.0304 | 0.3115*** | 0.0618 |
| | (0.106) | (0.051) | (0.040) | (0.052) |
| Log likelihood | −58.8418 | −19.5708 | −82.1896 | −17.3065 |

*Notes*:
1. ***, ** and * represent that the coefficients are significantly different from 0 at the 0.01, 0.05 and 0.1 levels, respectively.
2. The figures given in parentheses are standard errors.

[9] In fact, four different models are estimated for each efficiency measure in order to achieve the best result. Only the preferred result for each efficiency measure is listed in Table 10. However, the regression results of other three models will be available upon request. Additionally, the variance inflationary factor is also used to test the degree of multicollinearity among independent variables. The result shows that there is no multicollinearity among these variables.

branches are less efficient than those without any branch. The implication for the result might be that the purpose of integrated securities firms to set up branches was just to enlarge the geographical coverage of the market while the stock market was declining, and the increased complexities on operations make it difficult for managers' decisions to be put into effect. The coefficient of the operating risk is negative, and that of the *Year*93 dummy variable is positive; however, they are insignificant.

The regression result of cost efficiency shows that firm size has a positive impact on cost efficiency at the 0.01 significant level. That is, firms exploit economies of scale as their sizes expand. The coefficient of the branch dummy variable is negative at the 0.01 significant level, implying that the firms with a branch or branches are less efficient than those without any branch. The explanation for the result might be the same reasons for pure technical and scale efficiencies. The coefficient of the operating risk is negative at the 0.1 significant level. The coefficient of the *Year*93 dummy variable is positive at the 0.01 siginificant level, implying that competition pressure forces integrated securities firms to improve their cost efficiencies. The relationship between service concentration and cost efficiency is insignificantly positive.

The regression result of allocative efficiency shows that there exist a negative relationship between service concentration and allocative efficiency at the 0.05 significant level. It implies that integrated securities firms with higher service concentrations might not be able to allocate their inputs flexibly. The coefficient of operating risk is significantly negative. Firm size has an insignificantly positive impact on allocative efficiency. The coefficient of the branch dummy variable is insignificantly different from 0. The coefficients of the *Year*92 and *Year*93 dummy variables are positive, but they are statistically insignifiant.

## IV. CONCLUSIONS

Based on the 1991–1993 pooling data of integrated securities firms in Taiwan, this article first uses DEA to assess pure technical, scale, cost as well as allocative efficiencies, and then applies the tobit censored model to investigate the relationship between each efficiency measure and firm-specific attributes. The DEA evaluation results shows that, the mean pure technical efficiency measure is 0.743, indicating that integrated securities firms could have reduced inputs on average by 25.7%; the inefficient integrated securities firms overuse 40.6% inputs on average than the efficient ones do. Of integrated securities firms 22.1% operate in the region of constant returns to scale, and are gauged scale-efficient. Of integrated securities firms 61.1% operate in the region of increasing returns to scale, and are gauged scale-inefficient. That is, most of the scale inefficiency is due to operating at a relatively small firm size. Average cost efficiency measure is 0.522, implying that integrated securities firms on average would have needed to lower operating costs by 47.8%. Given prices of inputs, integrated securities firms on average operate at 14.2% higher costs than the cost-minimizing level due to the inappropriate input mix.

The regression results show that firm size has a positive impact on pure technical, scale as well as cost efficiencies because of the existence of scale economies and/or the advantage from joint use of inputs. The impacts of a firm's service concentration on pure technical and scale efficiencies are positive due to gains from specialization, but it has a negative effect on allocative efficiency since integrated securities firms with higher service concentration might not be able to allocate their inputs flexibly. Firms with a branch or branches are less efficient than those without any branch in terms of pure technical, scale and cost efficiencies because the stock market was declining, and most of the branches were established by merging the poorly performed securities firms. Firms with low operating risks are more efficient than those with high operating risk in terms of cost and allocative efficiencies. Competition pressure forces integrated securities firms to improve their pure technical and cost efficiencies, and shrinks the differences of pure technical efficiency among them in 1993.

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## APPENDIX

### *Micro-econometrics foundation of the empirical models*

In evaluating pure technical efficiency, there exists a feasible solution $\theta_k = 1,\ \lambda_k = 1,\ \lambda_j = 0 (j \neq k)$ in Model I. Hence, the optimal $\theta_k$, denoted by $\theta_k^*$, is not greater than 1. On the other hand, due to the nonzero assumption for the data, the constraint in Model I, $\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rk}$, $r = 1, 2, \ldots, s$, forces $\gamma_j (j = 1, 2, \ldots, n)$ to be non-zero because $y_{rk} \geq 0$, and $y_{rk} \neq 0$. Hence, from the constraint in Model I, $\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_k x_{ik}$, $i = 1, 2, \ldots, m$, $\theta_k$ must be greater than zero. Putting this all together, we have $0 < \theta_k^* \leq 1$. Similarly, the same reasoning can be applied to scale, cost and allocative efficiency measures.

Since the ranges of all dependent variables in Equations 7–10 are limited, the censored regression technique is applied to all the four regression models. Theoretically, the standard censored regression model or the tobit model censored at the point zero can be defined as:

$$y_i^* = \boldsymbol{\beta}'\mathbf{x}_i + \varepsilon_i$$

$$y_i = 0 \quad \text{if } y_i^* \leq 0$$

$$y_i = y_i^* \quad \text{if } y_i^* > 0$$

where $\varepsilon_i \sim \text{i.i.d.N}(0, \sigma^2)$. The dependent variable of the model is observed when $y_i^* > 0$ while exogenous variables are observed for $i = 1,\ 2, \ldots, N$. Therefore, the log-likelihood function for the censored regression model is:

$$\ln \mathrm{L} = \sum_{y_i > 0} \ln\left[\frac{\phi(y_i - \beta' x_i)}{\sigma}\right] + \sum_{y_i = 0} \ln\left[1 - \Phi\left(\frac{\beta' x_i}{\sigma}\right)\right]$$

where $\phi(.)$ is the standard normal probability density function, and $\Phi(.)$ is the standard normal cumulative density function. Then, the Tobit model can be generalized to handle observation-by-observation censoring. As a result, the log-likelihood function for the censored model on the upper limit in this article can be analogously derived as follows:

$$\ln \mathrm{L} = \sum_{y_i < R_i} \ln \phi\left(\frac{y_i - \beta' x_i}{\sigma}\right)/\sigma + \sum_{y_i = R_i} \ln\left[1 - \Phi\left(\frac{R_i - \beta' x_i}{\sigma}\right)\right]$$

where $R_i$ is the upper-limit censoring point. The two parts in the above function correspond to the classical regression for the non-limit observations and the relevant probabilities for the limit observations. Though it is a mixture of discrete and continuous distributions, Amemiya (1973) showed that maximizing in $L$ in the usual fashion would produce an estimator with all of the usual desirable properties assumed for maximum likelihood estimator. Hence, the maximum likelihood estimates are obtained by applying the Tobit model to the regression equations in the article.