# 國立交通大學

## 經營管理研究所

## 博 士 論 文

No.125

# 零和限制下探討證券商經營效率之研究

# An Efficiency Study of the Securities Firms under the Zero-Sum Gains Constraint

研 究 生：方進義

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中 華 民 國 九十八 年 一 月

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國 立 交 通 大 學

經 營 管 理 研 究 所

博 士 論 文

A Dissertation
Submitted to Institute of Business and Management
College of Management
National Chiao Tung University
in Partial Fulfillment of the Requirements
for the Degree of
Doctor of Philosophy
in
Business and Management

January 2009

Taipei, Taiwan, Republic of China

中華民國九十八年一月

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## 摘　　要

台灣證券市場因政府鼓勵金融控股公司成立而競爭更趨激烈，金控公司提供了全方位之金融服務：包括銀行、證券與保險等業務。目前文獻中，研究金控母公司對於其證券子公司效率之影響的相關實證研究甚少，缺乏個別證券公司的資料造成了實證研究的困難，更遑論研究金控對於其證券子公司之管理效率的影響。目前傳統之資料包絡分析模式從事的研究，並未考慮在總和產出有限制情況下（如證券商之短期目標為爭奪市占率，但市占率之總和為 100%）作經營效率之評估，其所衡量的經營效率值有低估的現象。因此，本研究以 2001 年至 2005 年台灣綜合券商為觀察對象，所有變數經由 GDP 平減指數轉成以 2001 年為基期的實質變數，以去除物價變動的影響，以探討在零和限制下券商經營效率之研究，實證研究顯示：外資券商的所有權對經營效率呈現顯著正向影響，二階段最小平方法（The two-stage least squares procedure）確認了市占率與經營效率之聯立關係。

接著再利用 Fried 等人於 1999 年發展的四階段資料包絡分析模式（Four-stage data envelopment analysis）評估台灣綜合券商之管理效率。實證研究顯示：在主管機關主導下所成立之金控公司對於其證券子公司之管理效率是有顯著之不良影響;顯示台灣在法令誘導成立下的金控公司，並非是有效率之綜合券商與銀行合組金控;成立年限愈久的券商相對其效率亦愈高；整體而言，成立金控後的確對券商市場造成威脅與改善整體的證券商經營效率。

關鍵詞：四階段資料包絡分析法、縱橫面資料、證券商成立年限、證券子公司、零和限制之資料包絡分析法、二階段最小平方法、股權結構

# An Efficiency Study of the Securities Firms under the Zero-Sum Gains Constraint

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**ABSTRACT**

Taiwan's government has been actively promoting financial holding companies (FHCs), which offer various services including banking, securities and insurances. The issue of whether or not the FHC system can effectively improve a securities firms' managerial efficiency is still not empirically studied. The lack of firm-level data has made research on securities firms (SFs) very difficult and rare to see, not to mention the effects of FHC on their managerial efficiency.

Current studies that use traditional data envelopment analysis (DEA) neglect the 100% market share restriction. This study adopts zero-sum gains data envelopment analysis (ZSG-DEA) to measure the efficiency scores of SFs and indicates that the traditional DEA model underestimates the efficiency scores of inefficient SFs. This research analyses 266 integrated securities firms (ISFs) in Taiwan from 2001 to 2005 and employs three inputs (fixed assets, financial capital, and general expenses) and a single output (market share). All nominal variables are transformed by GDP deflator with 2001 as the base year. The foreign-affiliated ownership of SFs positively affects the efficiency scores. The two-stage least squares procedure (2SLS) confirms that the market share and efficiency score simultaneously reinforce each other.

The four-stage DEA proposed by Fried *et al*. (1999) is then further applied. The securities subsidiaries under the law-induced FHCs are not the efficient ISFs in Taiwan. An FHC has a significantly negative effect on the managerial efficiency of an ISF. A higher duration of an ISF also significantly improves its efficiency score. Meanwhile, forming FHCs imposes a threat and creates the incentives for efficiency increasing in the securities industry.

**Keywords:** Four-stage data envelopment analysis (DEA); Panel data; Duration; Securities subsidiaries; Zero-sum gains data envelopment analysis (ZSG-DEA); Two-stage least square procedure (2SLS); Ownership

## ACKNOWLEDGEMENT

This dissertation has benefited greatly from the comments and suggestions of the research committee including Professor Jin-Li Hu, Professor Cherng G. Ding and Professor Edwin Tang. This research also thanks President Chin-Tsai Lin, Professor Yung-Ho Chiu, Professor Wun-Hwa Chen, and Professor Homin Chen. They provided many great comments and suggestions in my oral examination to strengthen this research. Furthermore, my great advisor, Professor Hu has been encouraging me to write and submit many papers to the highly esteemed journals. He let me know what a great professor should be. I am eternally grateful to him.

I would express my sincere gratitude to Professor Pao Long Chang, Professor Chyan Yang, Professor Chih-Cheng Li, and Professor Chi-Kuo Mao for providing me detailed instructions and valuable suggestions during my Ph. D. program. I am also grateful to Ms. Hsiao at NCTU for her great help and detail handling throughout my Ph. D. program.

This dissertation is dedicated to my father and mother. They always encourage and fully support me to pursue my goals. I also thank my sister and brother and all of my classmates at National Chiao Tung University (NCTU). My special appreciation should be given to my wife who always accompanies me and supports me to accomplish this research.

Meanwhile, special thanks for Professor Jer-Jeong Chen at China University of Technology (CUTE). He helps me find out one of the best academic environments and let me devote myself to this dissertation. I also express my great gratitude to all of my colleagues at CUTE.

Furthermore, I would like to thank Professor Otto H. Chang, Professor Chi Soo Kim, and seminar participants for their helpful comments at the 2006 International Conference on Knowledge-Based Economy & Global Management, and seminar participants at the 2006 International Conference on Globalization and the Regional Economic Development.

No matter where I work, I will always remember what I have learned in this Ph. D. program and keep on achieving my goal.

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# 1. INTRODUCTION

This chapter demonstrates the research motivation and background, and research purpose of the dissertation.

## 1.1 Motivation and Purpose

Many studies consider the strategic incentives of a product's market power when examining the effects of market share, and market share is a frequently identified goal of corporate management (Mueller, 1983). Firms focus on market share in order to increase shareholder value through improved efficiency score, thereby benefiting consumers. Goldberg and Rai (1996), Smirlock (1985), Peltzman (1977) and Demsetz (1973) note the correlation between market share and profitability. Hannan (1991) considers the greater efficiency score of firms with larger market shares to be a source of the positive relationship between profits and concentration. Goldberg and Rai (1996) develop the efficient-structure (EFS) hypothesis which suggests that efficient firms increase in terms of their size and market share due to their ability to generate higher profits, thus leading to a higher degree of market concentration. Smirlock (1985) includes market share as an independent variable that is positively and significantly related to profitability even after controlling for concentration. However, Goldberg and Rai (1996) and Shepherd (1986) indicate that the conclusion depends on whether market share can be regarded as a proxy for the efficiency score of larger firms rather than as a measure of their market power. Martin (1988) shows how larger firms have lower costs due to the economies of scale in their industries or because of their inherent superiority within their respective industries. The larger firms have price-cost margin advantages over their smaller rivals. Based on the above literature, this study considers the restriction imposed by constant output in investigating the relationship between the market share and the efficiency score.

Blundell *et al.* (1999) point out that total industry profits decrease when more firms share the market. The dominant firms tend to innovate more and industry evolution is characterised by their persistent dominance. In the securities industry, investors at large discount brokerages using personal computer-based trading tend to trade more actively. Barber and Odean (2001) have strongly suggested that there is a link between the Internet and increased trading. Guerrero *et al.* (2007) examine how banks use Internet banking to lower costs and increase their income by attracting new customers and increasing sales to current customers.

The securities industry in Taiwan has become increasingly competitive, especially following the establishment of financial holding companies (FHCs) in 2003. The regulatory authority in Taiwan has repeatedly encouraged domestic financial institutions to form into FHCs. The main purpose of forming an FHC is to create bigger and stronger financial conglomerates that are capable of competing with international financial groups and gain a foothold on the worldwide financial market. Accordingly, the Taiwan government enacted the *Financial Holding Company Act* in 2001 and permitted only integrated securities firms (ISFs) to join as FHC's subsidiaries. As a consequence, law-induced FHCs in Taiwan provide the opportunity to assess the impacts on the managerial efficiency of their securities subsidiaries. Table 1-1 lists fourteen FHCs in Taiwan.

**TABLE 1-1. 14 FHCs Establishment in Taiwan**

| FHC | Registered Date | ISF as its Subsidiary | Joined Date |
|---|---|---|---|
| First | 2003/1/2 | First Taisec | 2003/7/31 |
| Chinatrust | 2002/5/17 | Chinatrust | 2002/5/17 |
| SinoPac | 2002/5/9 | SinoPac | 2002/5/9 |
| Waterland | 2002/3/26 | Waterland | 2002/3/26 |
| Shin Kong | 2002/2/19 | Shin Kong | 2002/2/19 |
| Taishin | 2002/2/18 | Taiwan | 2003/1/1 |
| Jih Sun | 2002/2/5 | Jih Sun | 2002/2/5 |
| Fuhwa | 2002/2/4 | Fuhwa | 2002/2/4 |
| Mega | 2002/2/4 | Mega | 2002/2/4 |
| E. Sun | 2002/1/28 | E. Sun | 2002/1/28 |
| Cathay | 2001/12/31 | Cathay | 2004/5/12 |
| China Development | 2001/12/28 | Grand Cathay | 2002/11/8 |
| Fubon | 2001/12/19 | Fubon | 2001/12/19 |
| Huanan | 2001/12/19 | Huanan Entrust | 2002/11/14 |

In other words, the environment in Taiwan is close to one with zero-sum gains (Lins *et al.*, 2003) in which securities firms (SFs) expand their market share within a 100% constraint. Tracy and Chen (2005) significantly improve existing data envelopment analysis (DEA) models by providing a methodology for weight restrictions. In addition, Lins *et al.* (2003) introduce a zero-sum gains data envelopment analysis (ZSG-DEA) model, in which the sum of the outputs is constrained, in order to assess the ranking of participating countries in the Sydney 2000 Olympic Games based on single aggregated medals. With these developments in mind, this research proposes a framework to apply this ZSG-DEA model to the study of the securities industry that is based upon the maximisation of market share.

Since efficiency is an important topic in banking and finance, there have been numerous related studies (Camanho and Dyson, 2005; Chong *et al.*, 2006; Drake and Hall, 2003; Drake *et al.*, 2006). However, very few studies have paid attention to the securities industry's efficiency. There are still several important securities issues that need to be further explored.

First, while market share is a frequently identified goal among market players, the literature seldom considers the pursuit of market share, and also neglects the zero-sum gains restriction. The development of the performance evaluation under zero-sum gains deserves further careful study. This research therefore applies this model of maximising the market share to analyse the competition among SFs in Taiwan.

Second, many studies use the DEA model to compute technical efficiency. However, empirical studies rarely investigate the relationship between the market share and the efficiency score. The research thus studies the simultaneity between the market share and the efficiency score using the two-stage least squares procedure (2SLS) proposed by Heckman (1978). Martin (1979) indicates that advertising intensity, seller concentration, and profitability are simultaneously determined. Brockett *et al.* (2004) recommend the use of simultaneous-equation estimation methods to examine the endogeneity of joint advertising and other variables in future studies. O'Brien (2002) employs 2SLS simultaneous equations systems to test whether expenditures and votes are simultaneously determined. Daneshvary and Clauretie (2007) examine the effect of employer-provided health insurance on the annual earnings of married men and married women and account for the endogeneity of the health insurance decision using 2SLS.

Moreover, a comparison of the operating efficiency between foreign-affiliated and domestic SFs has seldom been empirically investigated. In order to accelerate the internationalisation and liberalisation of the domestic capital market, the Ministry of Finance in Taiwan launched ISFs in May 1988. Foreign securities firms were subsequently permitted to set up branches in Taiwan in 1989. At the end of 2005, a total of 11 foreign securities firms had set up branches in Taiwan. Advanced technology accompanies foreign direct investment entering the host country, thereby making foreign firms more efficient than their domestic competitors (Dimelis and Louri 2002). Feinberg (2001) indicates that 94.1% of households use domestic financial institutions as their primary provider of financial services in the U.S. Deyoung and Nolle (1996) find that foreign banks are less profit-efficient than U.S. banks. This research also investigates the impact of a foreign ownership structure on the efficiency score of SFs in a small open economy, namely, Taiwan. We define the foreign-affiliated SFs as those branches of multinational SFs in Taiwan since 1989, in contrast to the domestic SFs.

Meanwhile, the issue of whether or not FHCs parent companies can effectively improve an ISF's managerial efficiency is still not empirically studied. The lack of firm-level data has made research on securities firms very difficult and rare to see (Goldberg *et al*., 1991), not to mention the effects of FHC on their managerial efficiency. Drake *et al*. (2006) mention that little paper has been made in banking sectors of the Fried *et al*. (1999) approach to adjusting inputs of DEA for incorporating with the impact of environmental factors. This research also investigates the influence of the law-induced FHC on its securities subsidiaries in terms of managerial efficiency.

### 1.2 Organisation of the Dissertation

The content and organisation of this dissertation summarize as follows:

1. Introduction: this section demonstrates the research motive and background, research purpose of the dissertation.
2. Literature Review: this section outlines the literature review of financial holding companies, securities industry in Taiwan, efficiency studies in securities firms, the two-stage data envelopment analysis method, the relationship between market share and efficiency score, and the 2SLS method.
3. Research Design: this section performs efficiency models and panel data descriptive.
4. Empirical Findings: this section demonstrates the research results of ZSG-DEA and BCC-DEA models, confirms the simultaneity between market share and efficiency score via the 2SLS, and presents the findings of the four-stage DEA model.
5. Conclusion, research limitation, and future research: this section presents the research limitation and plans future researches.

The research flow chart lists in Figure 1-1.

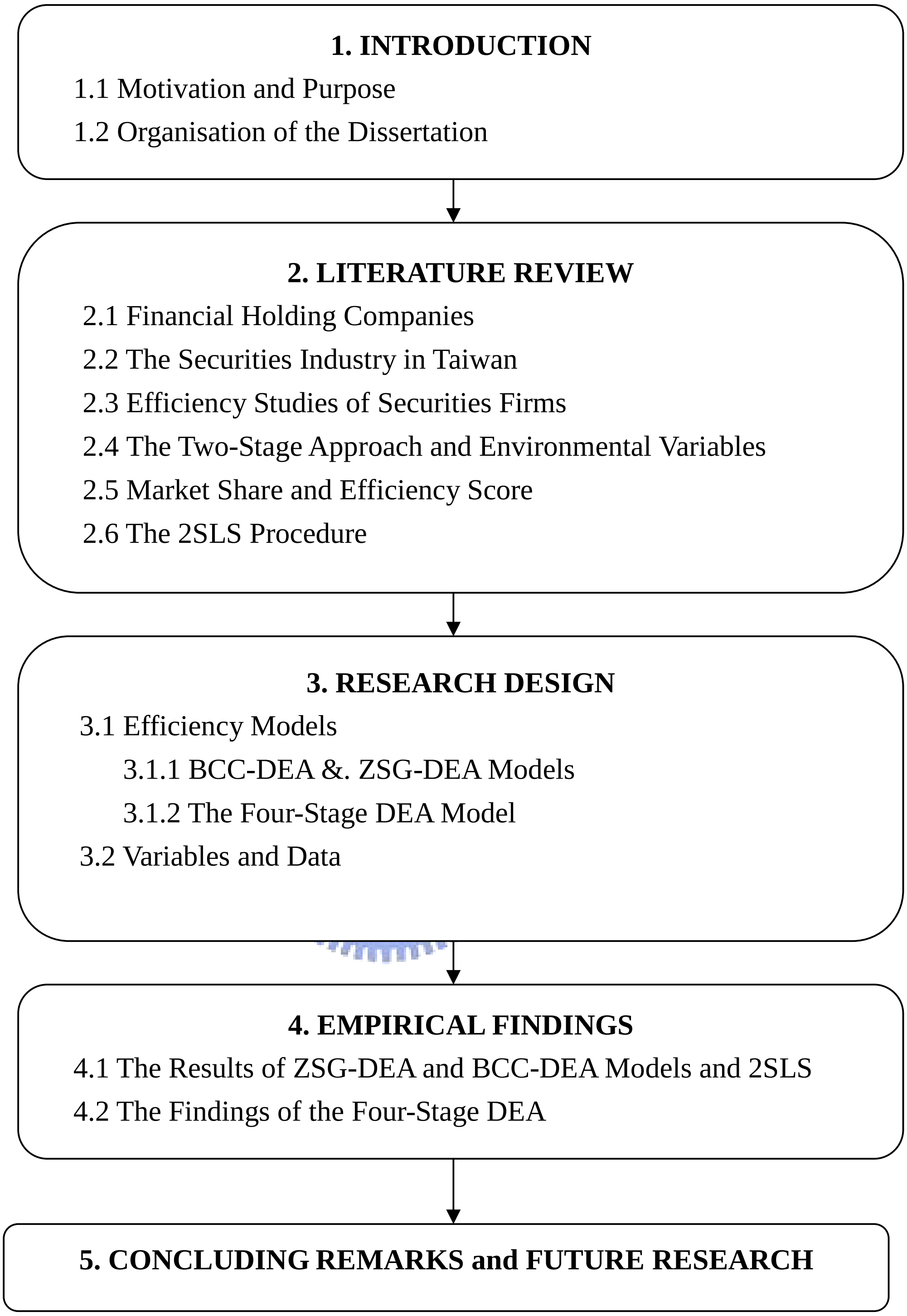


**FIGURE 1-1. Research Flow Chart**

# 2. LITERATURE REVIEW

This chapter demonstrates the literature review of financial holding companies, securities industry in Taiwan, efficiency studies in securities firms, the two-stage data envelopment analysis method, the relationship between market share and efficiency score, and the 2SLS method.

## 2.1. Financial Holding Companies

Many economies encourage financial conglomeration and universal banking, including all European Union (EU) member countries and the United States. In the United States, the *Gramm-Leach-Bliley Act* on 12 November 1999 permitted single holding companies to offer banking, securities, and insurance (Barth *et al*., 2000). This new regulation is expected to accelerate the consolidation of the financial services industry. In the EU, financial conglomerates and universal banking are backdated to the 1989 *Second Banking Directive*, which was implemented earlier by all member economies. Banks, investment firms, and insurance companies may hold reciprocal equity participation, implying that there are no limits on the formation of financial conglomerates. Following the progress of the European Union and the United States, FHC is a newly arising organisational form in developing economies.

Some researchers have addressed the efficiency comparisons between financial conglomerates and specialised banks. Vander Vennet (2002) analyses the cost and profit efficiency of European financial conglomerate, universal banks, and specialised banks. He further defines three main areas of financial services in the EU: traditional banking, insurance, and securities-related activities. Financial conglomerates are defined as financial services institutions that offer at least two of three main areas of financial services. Universal banks are defined as diversified banking firms that hold equity stakes in non-financial companies. Operationally, universal banks are those firms whose equity stakes in non-financial companies account for more than 1 % of total assets. Furthermore, universal banks are required to adhere to the criteria that the ratio of non-interest income to total revenues be higher than 5 %. It is reported that financial conglomerates are more revenue efficient than specialised banks, and the universal banks are both more cost and profit efficient than the non-universal banks. Research on the effect of forced mergers and acquisitions on the acquirer and the acquiring target is very limited. Chong *et al*. (2006) used an event study methodology to examine the impact of the forced merger scheme on the market-adjusted abnormal returns of Malaysian banks. That research shows that the forced merger mechanism destroys shareholders' value. Contrary to the findings on voluntary mergers in the United States and Europe, Malaysian banks have a significantly negative cumulated abnormal return under the forced merger scheme. The result further affirms that politics are often intertwined with economic activities in less developed countries.

Steinherr and Huveneers (1994) also define that the key feature of universal banking is to hold equity shares of 5-20 % in other companies so as to monitor corporations as equity owner or to maintain a universal banking relationship. Allen and Gale (1995) define the relationship banks, such as the German, Dutch, and Swiss main banks, as providing both debt and equity financing to companies as well as establishing the long-lasting relationship with these companies. This is another term for universal banks. Benston (1994) also mentions that government regulators have to regulate universal banks very tightly, hence hindering their economic efficiency when considering the risk of financial instability. From this viewpoint, the smaller specialised banks have a number of advantages. Because their functions are limited, government agents can monitor them more efficiently. Allen and Rai (1996) divide countries into two groups, universal banking countries and separated banking countries, which prohibit the functional integration of commercial and investment banking. That study shows that large banks in separated banking countries have the largest measure of input inefficiency.

## 2.2. The Securities Industry in Taiwan

Ashton (2001) mentions that many research studies in the USA and Europe have investigated the efficiency characteristics of banking. Few studies address on the efficiency score of securities firms. The securities industry is the centre of a capital market. In Taiwan and in the UK, the stock market value to GDP is approximately 140. In addition, there is a higher turnover ratio in terms of trading value for the Taiwan stock market compared to other major stock markets. The total trading amount in Taiwan's securities market in 2006 achieved NT$24,205 billion including 98.7% in stocks (in dealing and brokerage), 0.12% in TDRs, 0.72% in warrants, 0.31% in ETFs, and 0.10% in others, respectively. ISFs in Taiwan perform various major services including brokerage activity, underwriting services, and proprietary trading. The regulatory authority in Taiwan released the restriction on the establishment of foreign-owned SFs in the mid of 1990s and introduced FHCs in 2003, but only allowing the ISFs to be a member of FHC. The number of ISFs increased from 39 in 1990 to 48 in 2006; the number of foreign-owned securities firms increased to 18 in 2006; the number of FHC-affiliated ISFs was 14 in 2006.

This shows that the Taiwan stock market is an important market to be addressed as a research topic. ISFs, which perform various major services including investment banking, brokerage activity, underwriting services, and proprietary trading, are undergoing significant changes in Taiwan. Except for voluntary mergers in the market, financial groups have acquired many of the largest SFs including FHCs which have acquired them as one of their subsidiaries. Consequently, the top-14 market players account for 60 % of the total market share in the brokerage sector.

### 2.3. Efficiency Studies of Securities Firms

Very limited knowledge is known about the efficiency score of the securities sector. Goldberg *et al*. (1991) adopt survey data in a translog multi-product cost function to examine the economies of scale and suggest that if the *Glass-Steagall* restrictions are relaxed, then banks can enter the securities industry with a brokerage division with about US$30 million in revenue. The author reveals that cross-selling activities between banks and securities are able to increase brokerage revenue.

Wang *et al*. (2003) use DEA and Tobit censored regression to assess the technical efficiencies of ISFs in Taiwan based on 1991-1993 data. They conclude that the impact of a firm's service concentration on its technical efficiency is positive, which means that the diversity of services decreases its technical efficiency. Firms with branches have lower technical efficiencies than those without any branches, revealing that the purpose of setting up a new branch for an ISF is to enlarge the geographical coverage of the brokerage market. When the stock market is declining, having more branches instead becomes a burden for management and the increased complexities on operations make it difficult for managers to make decisions.

There are some research studies focusing on the relationship between specialisation and efficiency score. Fung (2006) investigates the relationship between scale efficiencies and X-efficiency for bank holding companies (BHCs) and indicated that a higher level of X-efficiency caused by more specialised banking activities might increase the efficiency scale. Eaton (1995) and Wang *et al*. (1998) indicate that if firms dedicate themselves to one or two specialised businesses, then this helps create high efficiency score, because of the learning-curve effect. Wang and Yu (1995) investigate the economies of scope and economies of scale for ISFs in Taiwan. Their study points out that the performances of ISFs are better than that of specialised brokerage securities in terms of sales margin. Wang and Yu also select the ISF as their sample and concluded that when the number of branch offices increases, the ISF is in a diseconomy of scope.

Unlike the research concerning the impact of the parent holding company on its subsidiary being limited in amount, most studies have addressed the merger impact on the financial institutions. Drake and Hall (2003) look at the technical efficiency in Japanese banking incorporating problem loans under the large-scale merger wave. Their result suggests that larger banks operate well above the minimum efficiency scale and mergers have a limited opportunity to gain from eliminating X-inefficiencies. If the efficiencies have more to do with specialisation, then the trend towards enlargement and financial conglomeration in Japan may lead to decreasing levels of scale efficiency and X-efficiency. On the contrary, Worthington (2001) uses discrete choice regression models to investigate the influence of financial, managerial, and regulatory factors on the probability of a credit union merging during the period 1993-1995 and examines whether efficiency score has increased in these same institutions in the post-merger period 1996-1997.

The author adopts a Tobit censored regression model with a panel framework to analyse post-merger efficiency. Mergers appear to have improved both on pure technical efficiency and scale efficiency for the credit union industry. Grabowski *et al*. (1995) also conclude that the threat of takeovers serves as an efficiency enforcement mechanism in banks. Fukuyama and Weber (1999) construct the production technology and measure the cost efficiency score for Japanese SFs during 1988-1993 using a DEA model. Wang *et al*. (2003) use the two-stage DEA procedures to assess the technical efficiencies of integrated securities firms (ISFs) and conclude that the diversity of services decreases technical efficiency. Zhang *et al.* (2006) adopt a DEA approach to investigate the technological progress, efficiency score and productivity of the U.S. securities industry during 1980-2000 and report that smaller regional firms experience large decreases in both efficiency score and productivity. Hence, this research examines the technical efficiency of top-14 ISFs and then investigates the threat from FHC imposed upon ISF's managerial efficiency.

## 2.4. The Two-stage Approach and Environmental Variables

The two-stage approach (McCarty and Yaisawarng, 1993; Wang *et al*., 2003) involves solving a DEA problem in the first stage and then the efficiency score obtained in the first stage being regressed upon the environmental variables in the second stage. Some factors, which are environmental variables, may affect the efficiency score of DMUs. The sign of the coefficients of the environmental variables indicates the direction of the influence, and the standard hypothesis tests can be used to measure the strength of the relationship Researchers adopt the Tobit regression model instead of the OLS model to measure the significance of the relationship. Esho (2001) adopts the second-stage regression to investigate the relationship between the capital to asset ratio, size, age, and efficiency score.

Mukherjee *et al*. (2001) investigate the relationships between the asset value, the square of asset value, and productivity growth and find out that the bigger-sized American banks have significantly positive influences on productivity growth, but insignificant coefficients on the square of asset value. Dimelis and Louri (2002) analyse the efficiency gains caused by the diverse degree of foreign ownership in Greece in 1997 which indicate a positive effect on labour productivity of foreign ownership. Deyoung and Nolle (1996) find out that foreign-owned banks are less profit-efficient than U.S.–owned banks. Elyasiani and Mehdian (1997) report that foreign-owned banks are less cost efficient than U.S. bank and even statistically insignificant. Wheelock and Wilson (2000) include a dummy variable to test whether membership in a multi-bank holding company affects the probability of failure. These authors indicate that if a parent company injects cash into a weak subsidiary, than a holding company membership might lessen the chance of failure. On the other hand, the failure of a primary bank in a holding company has sometimes led regulators to close all holding company members. It is an interesting issue of this research to investigate whether the efficiency score of foreign-owned securities firms or members of FHCs is better than that of the domestic specialised securities firms or not.

## 2.5. Market Share and Efficiency Score

Firms focus on market share in order to increase shareholder value through improved efficiency score, thereby benefiting consumers. Goldberg and Rai (1996), Smirlock (1985), Peltzman (1977) and Demsetz (1973) note the correlation between market share and profitability. Hannan (1991) considers the greater efficiency score of firms with larger market shares to be a source of the positive relationship between profits and concentration. Goldberg and Rai (1996) develop the efficient-structure (EFS) hypothesis which suggests that efficient firms increase in terms of their size and market share due to their ability to generate higher profits, thus leading to a higher degree of market concentration. Smirlock (1985) includes market share as an independent variable that is positively and significantly related to profitability even after controlling for concentration. However, Goldberg and Rai (1996) and Shepherd (1986) indicate that the conclusion depends on whether market share can be regarded as a proxy for the efficiency score of larger firms rather than as a measure of their market power. Martin (1988) shows how larger firms have lower costs due to the economies of scale in their industries or because of their inherent superiority within their respective industries. The larger firms have price-cost margin advantages over their smaller rivals. Based on the above literature, this study considers the restriction imposed by constant output in investigating the relationship between the market share and the efficiency score.

Blundell *et al.* (1999) point out that total industry profits decrease when more firms share the market. The dominant firms tend to innovate more and industry evolution is characterised by their persistent dominance.

### 2.6. The Two-Stage Least Squares Procedure (2SLS)

The two-stage least squares procedure (2SLS) was proposed by Heckman (1978). Martin (1979) indicates that advertising intensity, seller concentration, and profitability are simultaneously determined. Brockett *et al.* (2004) recommend the use of simultaneous-equation estimation methods to examine the endogeneity of joint advertising and other variables in future studies. O'Brien (2002) employs the 2SLS approach to test whether expenditures and votes are simultaneously determined. Daneshvary and Clauretie (2007) examine the effect of employer-provided health insurance on the annual earnings of married men and married women and account for the endogeneity of the health insurance decision using 2SLS.

# 3. RESEARCH DESIGN

Avkiran (1999) employs two DEA models to measure the efficiency score and indicates that DEA analysis is sensitive to the choice of variables. However, this is also a kind of strength in providing management-specific information as the method for improving firm-level efficiency score. Efficiency measurement using DEA models from different perspectives can depend on the decision-making requirements.

## 3.1. Efficiency Models

### 3.1.1. Traditional BCC-DEA and Zero-Sum Gains DEA Methodology

DEA is a linear programming model that identifies an efficient frontier, which consists of efficient decision-making units (DMUs). Efficient DMUs are those units for which no other DMUs are able to generate at least the same amount of each output under given inputs (Charnes *et al.*, 1978). The efficiency score reflects the ability of firms to generate the maximum outputs under a given level of inputs.

#### *3.1.1.1 Traditional BCC-DEA Model*

$DMU_i$ represents the object unit that is attempting to maximise its output. All DMUs in the same year constitute the reference set used to construct the efficiency frontier for each $DMU_i$. The aim of the traditional DEA model is to make the less efficient object unit at least as efficient as the others by increasing its output. For each $DMU_i$ the efficiency score ($\theta_i$) is obtained from a measure of the ratio of all outputs over all inputs. Charnes *et al.* (1978) develop the constant-returns-to-scale (CRS) DEA model as below:

$$\theta_i = Max \frac{\sum_{m=1}^{M} u_m y_i^m}{\sum_{k=1}^{K} v_k x_i^k}$$

$$s.t. \quad \frac{\sum_{m=1}^{M} u_m y_j^m}{\sum_{k=1}^{K} v_k x_j^k} \leq 1, \ j = 1, \ldots, N \tag{1}$$

$$u_m, v_k \geq 0, m = 1, \ldots, M, k = 1, \ldots, K$$

where $\theta_i$ is the efficiency score of $DMU_i$; $x_j^k$, $y_j^m > 0$ represent input and output data for the $j$-th DMU with the ranges for $j$, $k$, and $m$ indicated in (1); $N$ is the number of DMUs; $x_j^k$ is the amount of the $k$-th input consumed by the $j$-th DMU; $y_j^m$ is the amount of the $m$-th output produced by the $j$-th DMU; and $u_m$ and $v_k$ are output and input weights assigned to the $m$-th output and the $k$-th input, respectively.

One problem with this above ratio form is that the number of solutions is infinite - e.g., if $(u_m^*, v_k^*)$ is a solution, then $(cu_m^*, cv_k^*)$ is another solution, where $c$ is a constant. In order to avoid this problem, an output-oriented DEA model, which is to achieve the efficient DMU by a radial expansion in outputs, can impose the constraint $\sum_{m=1}^{M} u_m y_j^m = 1$, which provides:

$$Min \sum_{k=1}^{K} v_k x_j^k$$

$$s.t. \ \sum_{m=1}^{M} u_m y_j^m = 1 \tag{2}$$

$$\sum_{k=1}^{K} v_k x_j^k - \sum_{m=1}^{M} u_m y_j^m \geq 0, \ j = 1, \ldots, N$$

$$u_m, v_k \geq 0, m = 1, \ldots, M, k = 1, \ldots, K$$

Banker *et al.* (1984) extend the constant returns to scale (CRS) DEA model to a variable returns to scale (VRS) situation. The dual solution of the traditional output-oriented BCC-DEA model using duality expressed by Coelli *et al.* (2005) to measure the efficiency score $\theta_i$ for DMU$_i$ is shown as:

$$\begin{aligned}
& {}^{1}\!/_{\theta_i} = Max\ \phi_i \\
& \phi_i, \lambda_1, ..., \lambda_N \\
& s.t. \qquad \phi_i y_i^m \le \sum_{j=1}^{N} \lambda_j y_j^m,\ m = 1, ..., M, \\
& \qquad\qquad x_i^k \ge \sum_{j=1}^{N} \lambda_j x_j^k, k = 1, ..., K, \\
& \qquad\qquad \sum_{j=1}^{N} \lambda_j = 1, \\
& \qquad\qquad \lambda_1, ..., \lambda_N \ge 0
\end{aligned} \tag{3}$$

where $\phi_i$ depicts the inverse of the efficiency score of DMU$_i$; the efficiency score $\theta_i$ of DMU$_i$ is $1/\phi_i$; $N$ is the number of DMUs; $K$ and $M$ are, respectively, the numbers of inputs and outputs; $x_j^k$ is the amount of the $k$-th input consumed by the $j$-th DMU; $y_j^m$ is the amount of the $m$-th output produced by the $j$-th DMU; and $\lambda_j$ is each efficient DMU's individual share in the definition of the target for DMU$_i$.

The BCC-DEA model here measures the firm-level efficiency score ($\theta_i$) in the securities industry. An SF (as a DMU in the DEA model) that is pursuing more market share naturally means that other SFs lose some market share, because the total market share is 100%. Accordingly, this constant sum of output is unable to use the traditional BCC-DEA model, in which the output of any given DMU is not influenced by the output of the others, to assess the efficiency score. This is our motivation for adopting the ZSG-DEA model to measure the efficiency scores of SFs.

### *3.1.1.2 Zero-Sum Gains DEA Model*

The ZSG-DEA model assesses the efficiency score provided that the sum of outputs is constant. Lins *et al.* (2003) indicate that this is similar to a zero-sum game whereby how much is won by a player is lost by one or more of the other players. The equal output reduction strategy is generated to measure the efficiency score

($\theta_{iR} = 1/\phi_{iR}$) for DMU$_i$ in equation (4) using duality expressed shown below and is graphically represented using a simple case involving one input, $x$, and one output, $y$, in Figure 3-1:

$$
\begin{aligned}
&1/\theta_{iR} = Max\ \phi_{iR} \\
&\phi_{iR}, \lambda_1, \ldots, \lambda_N \\
&s.t. \qquad \phi_{iR} y_i^m \le \sum_{j=1}^{N} \lambda_j y_j^m [1 - \frac{y_i^m(\phi_{iR} - 1)}{N - 1}],\ m = 1, \ldots, M, \\
&\qquad\qquad x_i^k \ge \sum_{j=1}^{N} \lambda_j x_j^k, k = 1, \ldots, K, \\
&\qquad\qquad \sum_{j=1}^{N} \lambda_j = 1, \\
&\qquad\qquad \lambda_1, \ldots, \lambda_N \ge 0
\end{aligned} \tag{4}
$$

where the term $\phi_{iR}$ is the inverse of the efficiency score of the ZSG-DEA model with $\phi_{iR} \ge 1$; and the efficiency score $\theta_{iR}$ of DMU$_i$ is the inverse of $\phi_{iR}$ ($\theta_{iR} = 1/\phi_{iR}$) in the ZSG-DEA model. The term $y_i^m(\phi_{iR} - 1)$, representing losses of the other DMU$_j$ ($j \ne i$), must have one DMU$_i$ to gain $y_i^m(\phi_{iR} - 1)$ output units.

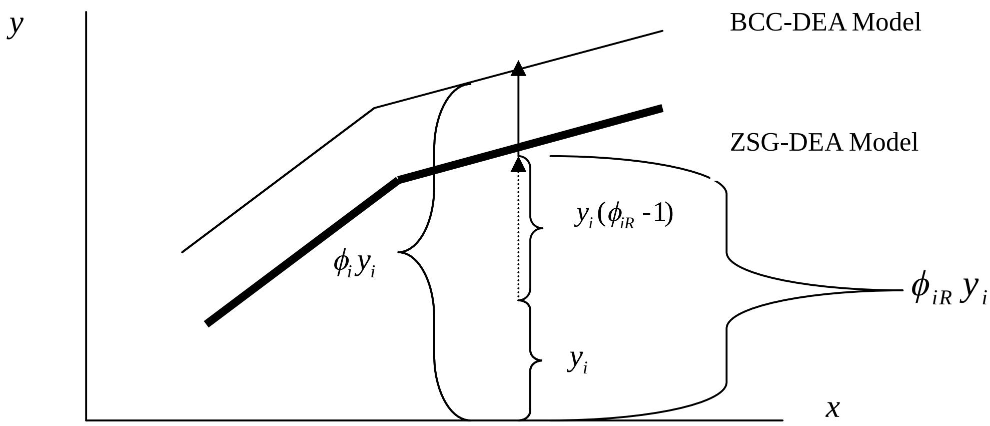


**FIGURE 3-1. Graphical Representation of the Equal Output Reduction Method**

This model here causes some DMUs to have a negative output after replacing the output as the reduction coefficient. A simple example in Appendix A illustrates an unreasonable case in which an equal output reduction under a zero-sum game generates a negative output. Hence, provided that $y_i^m(\phi_{iR}-1) \leq \min\ (y_j^m),\ m=1,...,M$, this equal output reduction strategy can apply. To avoid this major weakness, Lins *et al.* (2003) further develop the proportional output reduction strategy for any given DMU$_i$ using the ratio $\frac{y_i^m(\phi_{iR}-1)}{Y^m - y_i^m}$, where $Y^m$ is the constant sum of the *m*-th output. Thus, DMU$_i$ needs to win $y_i^m(\phi_{iR}-1)$ output units, and the losses of the other DMUs are proportional to their levels of output. The condition that the sum of the losses is equal to the gains of DMU$_i$ still holds.

Figure 3-2 represents the ZSG-DEA frontier created by this proportional reduction strategy and the BCC-DEA frontier using a simple case involving one input and one output. DMU$_i$ gains $y_i^m(\phi_{iR}-1)$ output units, and the losses of other DMUs are proportional to their respective levels of output, which is $y_j^m(\frac{y_i^m(\phi_{iR}-1)}{Y^m - y_i^m})$. If the output $y_j$ of DMU$_j$ is larger than those of other DMUs, then the output reduction $y_j^m(\frac{y_i^m(\phi_{iR}-1)}{Y^m - y_i^m})$ is also larger than those of the others, and vice versa. Model (5) substitutes model (4) for the proportional output reduction strategy in measuring the efficiency score ($\theta_{iR} = 1/\phi_{iR}$) of DMU$_i$ as:

$$
\begin{aligned}
&{1}/{\theta_{iR}} = Max\ \phi_{iR} \\
&\phi_{iR}, \lambda_1, \ldots, \lambda_N \\
&s.t. \qquad \phi_{iR} y_i^m \le \sum_{j=1}^{N} \lambda_j y_j^m [1 - \frac{y_i^m(\phi_{iR} - 1)}{Y^m - y_i^m}], m = 1, \ldots, M, \\
&\qquad\qquad x_i^k \ge \sum_{j=1}^{N} \lambda_j x_j^k, k = 1, \ldots, K, \\
&\qquad\qquad \sum_{j=1}^{N} \lambda_j = 1, \\
&\qquad\qquad \lambda_1, \ldots, \lambda_N \ge 0
\end{aligned} \tag{5}
$$

However, Lins *et al.* (2003) report that obtaining results based on this non-linear programming problem is very labour-consuming in particular because of the large number of variables. The model is thus simplified by having only a single output ($m$ =1). Appendix A provides an example to explain the computational steps of the proportional output reduction strategy.

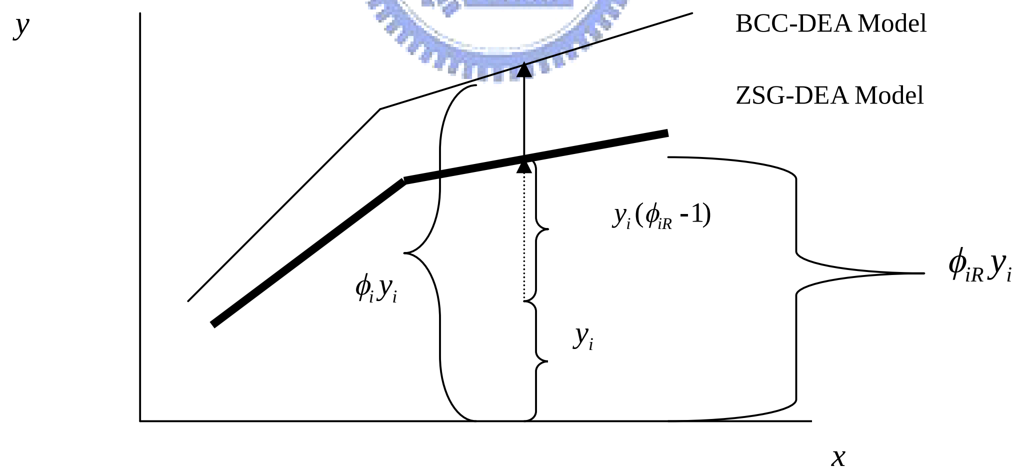


**FIGURE 3-2. Graphical Representation of the Proportional Output Reduction Method**

The following theorem holds under a single output ZSG-DEA proportional reduction strategy:

**LGSS Theorem** (Lins *et al.*, 2003). The target for a DMU to reach the efficiency frontier in a ZSG-DEA proportional output reduction strategy model equals the same target in the traditional BCC-DEA model multiplied by the reduction coefficient (1-$\frac{y_i(\phi_{iR}-1)}{Y-y_i}$).

Owing to this theorem, equation (6) below holds.

$$\begin{aligned}\phi_{iR}y_i &= \sum_{j=1}^{N}\lambda_j y_j[1-\frac{y_i(\phi_{iR}-1)}{Y-y_i}] \\ &= \phi_i y_i[1-\frac{y_i(\phi_{iR}-1)}{Y-y_i}]\end{aligned} \tag{6}$$

The efficiency score of the ZSG-DEA model is obtained from equation (7):

$$\theta_{iR} = \frac{\theta_i y_i(Y-y_i)+y_i^2}{y_i(Y-y_i+1)} \tag{7}$$

In this research, due to the fact that the sum of the total market share in percentage terms is 100, $Y$ is always 100 and equation (7) above can be expressed as equation (8):

$$\theta_{iR} = \frac{\theta_i y_i(100-y_i)+y_i^2}{y_i(100-y_i+1)} \tag{8}$$

Lins *et al.* (2003) also infer that the value of the weight of DMU$_i$'s peers ($\lambda_i$) equals its value in the traditional BCC-DEA model. This ZSG-DEA model is then applied to measure the efficiency score of SFs when the market share in percentage terms always sums up to 100.

### 3.1.2. The Four-Stage DEA

Technical efficiency reflects the ability of firms to use as little input as possible to obtain a given level of output. Fried *et al.* (1999) introduce a four-stage DEA. The management component of inefficiency is separated from the influences of the external environment as the management level is not able to control these influences. The result is a radial measurement of managerial efficiency. The managerial efficiency is the efficiency score purged of the influences of the external environments, as the management level are not able to control these influences, indeed the assessment of managerial competence on running a business.

The first stage calculates a DEA frontier using the observable inputs and outputs according to the variable returns to scale (VRS) model. Charnes *et al.* (1978) propose an input-oriented model and assume constant returns to scale (CRS) as follows:

$$\begin{aligned} &\underset{\theta_i, \lambda_1, \dots, \lambda_N}{Min} \quad \theta_i \\ &s.t. \quad -y_i^m + \sum_{j=1}^{N} \lambda_j y_j^m \geq 0,\ m = 1, \dots, M, \\ &\qquad \theta_i x_i^k - \sum_{j=1}^{N} \lambda_j x_j^k \geq 0, k = 1, \dots, K, \\ &\qquad \lambda_1, \dots, \lambda_N \geq 0 \end{aligned} \tag{9}$$

where $\theta_i$ is the technical efficiency (*TE*) of $DMU_i$ ; $N$ is the number of ISF; $K$ and $M$ are respectively the number of inputs and outputs; $x_i^k$ is the amount of the $k$-th input consumed by the $i$-th ISF; $y_i^m$ is the amount of the $m$-th output produced by the $i$-th ISF; and $\lambda_j$ is a scalar value representing a proportional contraction of all inputs, holding input ratios and output level constant.

Banker *et al.* (1984) extend the CRS DEA model to account for a VRS situation. The CRS linear programming problem can be easily added onto the equation and modified to be the VRS model as below:

$$\min_{\theta_i, \lambda_1, \ldots, \lambda_N} \quad \theta_i$$

$$\begin{aligned} s.t. \quad & -y_i^m + \sum_{j=1}^{N} \lambda_j y_j^m \geq 0, \ m = 1, \ldots, M, \\ & \theta_i x_i^k - \sum_{j=1}^{N} \lambda_j x_j^k \geq 0, k = 1, \ldots, K, \\ & \sum_{j=1}^{N} \lambda_j = 1, \\ & \lambda_1, \ldots, \lambda_N \geq 0 \end{aligned} \tag{10}$$

where $\theta_i$ is the pure technical efficiency (*PTE*) of $DMU_i$. *TE* is the ability of management to implement a technically efficient production plan (Berger *et al*., 1993):

$$TE_i = PTE_i \times SE_i \tag{11}$$

where $SE_i$ is the scale efficiency index for $DMU_i$ in a period. That is, technical efficiency is decomposed into pure technical efficiency and scale efficiency (Banker *et al*., 1984; Fung, 2006). If there is a difference in the *TE* and *PTE* scores for the *i*-th DMU, then this indicates that the firms have scale inefficiency. The radial technical efficiency scores, input slacks, and output surplus are computed for each observation (Farrell, 1957).

The DEA has been applied in activities of a very diverse nature such as: public health (hospitals, clinics), education (schools, universities), banks, factories, fast food restaurants, etc. Few papers use DEA to study the efficiency score of securities firms. Here we adopt the VRS-DEA to compute the securities firms' input slacks.

The second stage estimates the *K* input equations using a Tobit censored regression. The dependant variables are radial plus slack input movement; the independent variables are measures of environmental variables applicable to the particular input. The objective is to quantify the effect of external conditions on the excessive use of inputs. The $K$ equations are specified as:

$$xs_i^k = f_k(E_i^k,\ \beta_k,\ u_i^k);\ \ i = 1,\ldots,\ N;\ k = 1,\ldots,\ K \tag{12}$$

where $xs_i^k$ is the total radial plus slack movement for input $k$ of ISF $I$ based on the DEA results from stage 1; $E_i^k$ is a vector of variables characterizing the operating environment for ISF $i$ that may affect the utilization of input; $\beta_k$ is a vector of coefficient and $u_i^k$ is a disturbance term. Here, we adopt both continuous and categorical variables as regressors.

The third stage uses the estimated coefficients from the above-mentioned equations to predict total input slack for each ISF based on its environmental variables:

$$xs_i^k = f_k(E_i^k,\ \beta_k);\ \ i = 1,\ldots,\ N;\ k = 1,\ldots,\ K \tag{13}$$

These predictions are used to adjust the primary input data for each ISF based on the difference between maximum predicted total input slack and predicted total input slack:

$$x_i^{k\,adj} = x_i^k + [Max^k\{xs_i^k\} - \hat{E}(xs_i^k \mid E_i^k)];\ \ i = 1,\ldots,\ N;\ k = 1,\ldots,\ K \tag{14}$$

This generates a new projected dataset where the inputs are adjusted for the influence of external conditions.

The final stage uses the adjusted dataset to re-compute the DEA model under the initial output data and adjusted input data. The result generates new radial and slack measures of inefficiency. These radial and slack scores measure the inefficiency that is attributable to management that is wholly managerial inefficiency.

## 3.2. Variables and Data

### *3.2.1 Variables*

This research follows the model developed by Lins *et al.* (2003) in that it chooses a single output and multiple inputs to measure the efficiency score. Drake *et al.* (2006) introduce a profit-oriented model with revenue components as outputs and cost components as inputs in a banking efficiency study. Banks pursue their profit maximisation goal by increasing revenue and reducing cost. In the securities industry, an individual SF pursues the goal of market share maximisation by innovating itself as an e-broker or e-trader. Thus, this output-oriented ZSG-DEA model chooses market share as the single output. Drake and Hall (2003) adopt general and administrative expenses and fixed assets as the two inputs of the DEA model. Berger and Mester (1997) indicate that another important aspect of efficiency measurement is the treatment of financial capital. A bank's financial capital that is available to absorb possible losses helps reduce its insolvency risk. Accordingly, the study adopts fixed assets, in which the SFs increase their fixed assets by investing in computer hardware, financial capital as well as general and administrative expenses as the three inputs of the ZSG-DEA model.

### *3.2.2 Data*

A panel dataset covering the period 2001-2005 includes 266 ISFs in Taiwan. During 2002, eight SFs were merged and one foreign-affiliated SF established branches in Taiwan. In 2003, four SFs were merged and one foreign-affiliated institution joined the securities market in Taiwan. Appendix B lists the number of observations from 2001-2005. Since the data cover five years, several variables, including three inputs, which are exogenous variables in the 2SLS, are deflated with the gross domestic product (GDP) deflator (2001=100) to avoid the distortion caused by inflation (Bierlen and Featherstone, 1998; Li *et al.*, 2004). Market share is the trading amount in brokerage and proprietary trading of an individual firm divided by the total trading amount of all securities' brokers and dealers. The firm-level data for the exogenous variables in the 2SLS are the trading amounts, fixed assets, general expenses, financial capital, total assets, and profits. All variable data are obtained from the reports of the *Taiwan Stock Exchange Corporation* during the 2001-2005 period (http://www.tse.com.tw/ch/statistics/statistics_list.php?tm=03&stm=004, accessed April 4, 2007). The descriptive statistics for all the variables are shown in Table 3-1.

**TABLE 3-1. Descriptive Statistics for the BCC-DEA, ZSG-DEA and 2SLS**

| *Variables* | *Yr.* | *Obs.* | *Average* | *Min* | *Max* | *σ* |
|---|---|---|---|---|---|---|
| *Inputs* | | | | | | |
| $x^1$: Fixed assets (NT$Mn) | 2001 | 61 | 932.13 | 5.74 | 4455.02 | 1074.12 |
| | 2002 | 54 | 1006.18 | 1.84 | 4306.02 | 1132.26 |
| | 2003 | 51 | 1067.66 | 0.00 | 4413.71 | 1259.69 |
| | 2004 | 50 | 1135.49 | 0.00 | 6203.25 | 1439.44 |
| | 2005 | 50 | 1141.64 | 0.00 | 6692.11 | 1482.82 |
| $x^2$: Financial capital (NT$Mn) | 2001 | 61 | 1637.57 | 48.70 | 7815.06 | 1733.19 |
| | 2002 | 54 | 5112.88 | 151.29 | 24689.52 | 5439.46 |
| | 2003 | 51 | 5594.04 | 154.58 | 25382.95 | 5958.09 |
| | 2004 | 50 | 6163.88 | 156.84 | 31988.93 | 6822.10 |
| | 2005 | 50 | 6284.13 | 157.81 | 33559.95 | 7069.14 |
| $x^3$: Expenses (NT$Mn) | 2001 | 61 | 4413.48 | 150.00 | 22315.20 | 4730.23 |
| | 2002 | 54 | 1935.13 | 10.64 | 10560.52 | 2323.28 |
| | 2003 | 51 | 2126.09 | 11.12 | 8587.78 | 2555.90 |
| | 2004 | 50 | 3010.77 | 21.18 | 14008.10 | 3757.83 |
| | 2005 | 50 | 3213.83 | 26.80 | 12772.28 | 3682.73 |
| *Output* | | | | | | |
| *y*: Market share (%) | 2001 | 61 | 1.64 | 0.05 | 8.66 | 1.89 |
| | 2002 | 54 | 1.85 | 0.02 | 10.48 | 2.42 |
| | 2003 | 51 | 2.02 | 0.01 | 11.01 | 2.53 |
| | 2004 | 50 | 2.00 | 0.02 | 9.39 | 2.51 |
| | 2005 | 50 | 2.00 | 0.02 | 7.63 | 2.31 |
| *Exogenous Variables* | | | | | | |
| *Asset* : Total Assets (NT$Bn) | 2001 | 61 | 13.69 | 0.24 | 91.03 | 17.59 |
| | 2002 | 54 | 16.34 | 0.25 | 103.37 | 20.66 |
| | 2003 | 51 | 19.31 | 0.22 | 120.35 | 24.55 |
| | 2004 | 50 | 21.96 | 0.35 | 127.17 | 28.72 |
| | 2005 | 50 | 23.93 | 0.58 | 149.49 | 31.55 |
| *Profit*: Profits (NT$Bn) | 2001 | 61 | 0.36 | -0.80 | 2.96 | 0.65 |
| | 2002 | 54 | 0.25 | -0.57 | 3.87 | 0.69 |
| | 2003 | 51 | 0.57 | -0.58 | 6.11 | 1.05 |
| | 2004 | 50 | 0.43 | -0.60 | 2.29 | 0.70 |
| | 2005 | 50 | 0.19 | -1.18 | 1.44 | 0.50 |

Note: 1. Variables are deflated with the gross domestic product (GDP) deflator (2001=100) to avoid the distortion caused by inflation.
2. ***Data Sources***: Taiwan Stock Exchange Corporation
(Website: http://www.tse.com.tw/ch/statistics/statistics_list.php?tm=03&stm=004).

We furthermore construct a panel dataset during 2002-2005 of the top twelve to fourteen securities firms in Taiwan. The firm-specific financial data are collected from peers' data exchange among the securities firms and the reports of the *Taiwan Stock Exchange Corporation* (Website: http://www.tse.com.tw/ch/statistics/statistics_list.php?tm=03&stm=004). For the fiscal year of 2002, some of these ISFs were committed themselves as an FHC's subsidiary in 2003. This period offers to measure the technical efficiency and managerial efficiency before imposing the impact of FHC. Each of these ISFs is treated as a DMU under the DEA model. Two guidelines are commonly applied on the number of DMUs. One is that the total number of inputs and outputs should be less than one third that the number of DMUs in the DEA model. (Friedman and Sinuany-Stern, 1998) Another is that the number of DMUs should be at least two times the number of inputs multiplied by the number of outputs (Dyson *et al*., 2001). In our model there are two inputs and two outputs. The number of DMUs in a year is hence more than triple the total number of input and output items.

In order to increase the homogeneity of DMUs, the ISFs with the top twelve to fourteen asset values are selected. As Table 3-2 shows, these selected ISFs account for more than 70 percent of the total assets of the entire ISF sectors in Taiwan.

**TABLE 3-2. The Asset Value (NT$Bn) of Top-14 ISFs in Taiwan**

| Securities Firms | 2002 | Ranking | 2005[#] | Ranking |
|---|---|---|---|---|
| 1. Fubon [f] | 65.012 | 2 | 62.639 | 7 |
| 2. Taiwan [f] | 48.895 | 5 | 52.259 | 12 |
| 3. KGI | 38.264 | 11 | 90.776 | 2 |
| 4. Yuanta Core Pacific | 102.490 | 1 | 148.224 | 1 |
| 5. Capital | 45.910 | 6 | 72.677 | 4 |
| 6. President | 41.741 | 8 | 53.487 | 10 |
| 7. Polaris | 42.397 | 7 | 70.531 | 5 |
| 8. MasterLink | 40.012 | 9 | 70.391 | 6 |
| 9. SinoPac [f] | 49.346 | 4 | 53.826 | 9 |
| 10. Grand Cathay [f] | 51.415 | 3 | 77.436 | 3 |
| 11. Jih Sun [f] | 38.718 | 10 | 57.848 | 8 |
| 12. Taiwan International | 22.582 | 13 | 41.379 | 13 |
| 13. Fuhwa [f] | 23.143 | 12 | 30.825 | 14 |
| 14. Mega [f] | 18.792 | 14 | 51.903 | 11 |
| Subtotal for top-14 firms | 628.720 | 71.86%[a] | 895.520 | 78.74%[a] |
| Total Assets for ISFs | 874.859 | | 934.202 | |

Note:
1. [f] represents this ISF is the subsidiary of an FHC;
2. [a] Total asset value of the observation ISFs accounts for 71.9% and 78.7% of the total ISF's population in 2002 and 2006, respectively;
3. [#] Asset value has been divided by GDP deflator (2002 = 100);
4. Data Sources: *Taiwan Stock Exchange Corporation* (website: http://www.tse.com.tw/ch/statistics/statistics_list.php?tm=03&stm=004).

The top twelve ISFs have exchanged data such as market share and brokerage revenue for peer comparison since 2001. Fuhwa Securities and Mega Securities did not exchange financial data with peers due to the smaller assets of Mega and unavailable data of Fuhwa in 2002. Mega Securities merged with another ISF to increase its asset by almost triple compared with its assets in 2002. Two more ISFs joined the exchange pool in 2003, making fourteen securities firms available for DEA.

The top twelve ISFs have exchanged data such as market share and brokerage revenue for peer comparison since 2001. Fuhwa ISF and Mega ISF did not exchange financial data with peers due to the smaller assets of Mega and unavailable data of Fuhwa in 2002. Mega ISF merged with another ISF to increase its asset by almost triple compared with its assets in 2002. Two more ISFs joined the exchange pool in 2003, making fourteen securities firms available for DEA.

This study further employs a profit-oriented, non-parametric model, which uses revenue components as outputs, and cost components as inputs. Drake *et al*. (2006) use this profit-oriented DEA model to investigate the bank efficiency in Hong Kong.

The first stage input-oriented DEA model includes physical inputs and outputs in the strict production theory sense. There are two outputs: market share of brokerage business (*MS*) and revenue (*BR*), which includes the fee income and service charge in the brokerage business. The market share of the brokerage business is an important factor to evaluate performance for senior managers. This research is the first one to introduce market share as an output to evaluate an ISF's efficiency score. Revenue from the brokerage business accounts for roughly 70 % of total revenue of the top-10 Taiwanese Securities firms. Revenue from the brokerage business as an output is shown on the existing literature.

Two inputs are used to produce brokerage services: branches (*BO*) and the discounted expense amount of the brokerage business (*DE*). *BR* and *DE* have been divided by GDP deflator (2002 = 100). Table 3-3 presents the definition and explanation of variables.

**TABLE 3-3. Definition and Explanation of Variables for the Four-Stage DEA**

| Variable | Definition |
|---|---|
| $MS = y^1$ | Market share for brokerage business (%) |
| $BR = y^2$ | Brokerage revenue (NT$100Mn) |
| $BO = x^1$ | Branch offices |
| $DE = x^2$ | Discounted expenses (NT$100Mn) |

Goldberg *et al*. (1991) also adopted branch office as one of the inputs in the literature. In practice, high discounted expenses provide benefits to customers. When the discounted amount is more, then it motivates customers to trade equities with this ISF. It also benefits the broker's market share. This research is the first one to adopt the discounted expense amount as one input for research. Market share of the brokerage business is measured in percentage terms. Brokerage revenue and the discounted expenses are measured in NT$100 million. Table 3-4 displays descriptive statistics of the raw data.

**TABLE 3-4. Descriptive Statistics of ISFs for the Four-Stage DEA**

| *Variables* | 2002 | | | | 2003 | | | | 2004 | | | | 2005 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avg | SD | Max | Min | Avg | SD | Max | Min | Avg | SD | Max | Min | Avg | SD | Max | Min |
| ***Outputs*** | | | | | | | | | | | | | | | | |
| *MS*(%) | 4.3 | 2.0 | 9.2 | 1.7 | 4.2 | 1.6 | 8.1 | 1.6 | 4.2 | 1.6 | 8.1 | 1.9 | 4.2 | 1.6 | 8.3 | 1.9 |
| *MS*-FHC | 4.3 | 1.8 | 7.1 | 2.1 | 4.2 | 1.3 | 6.3 | 2.4 | 4.2 | 1.3 | 6.1 | 2.4 | 4.1 | 1.4 | 6.1 | 2.2 |
| *MS*-Non-FHC | 4.3 | 2.4 | 9.2 | 1.7 | 4.2 | 2.0 | 8.1 | 1.6 | 4.3 | 1.9 | 8.1 | 1.9 | 4.2 | 2.0 | 8.3 | 1.9 |
| BR | 22.7 | 10.5 | 48.4 | 9.7 | 18.9 | 10.5 | 45.1 | 1.4 | 24.9 | 12.4 | 55.4 | 1.5 | 27.1 | 11.3 | 59.3 | 12.6 |
| *BR*-FHC | 22.6 | 8.9 | 35.1 | 10.5 | 17.0 | 9.8 | 30.6 | 1.4 | 23.1 | 11.7 | 37.2 | 1.5 | 25.0 | 7.7 | 33.3 | 14.0 |
| *BR*-Non-FHC | 22.7 | 12.3 | 48.4 | 9.7 | 20.8 | 11.6 | 45.1 | 8.3 | 26.7 | 13.8 | 55.4 | 11.3 | 29.2 | 14.4 | 59.3 | 12.6 |
| ***Inputs*** | | | | | | | | | | | | | | | | |
| *BO* | 42.5 | 18.6 | 88.0 | 20.0 | 46.7 | 17.3 | 93.0 | 20.0 | 51.0 | 19.4 | 107.0 | 26.0 | 49.5 | 18.2 | 99.0 | 26.0 |
| *BO*-FHC | 43.8 | 14.5 | 61.0 | 21.0 | 47.1 | 11.3 | 64.0 | 31.0 | 52.3 | 10.8 | 64.0 | 34.0 | 50.6 | 12.6 | 65.0 | 27.0 |
| *BO*-Non-FHC | 41.6 | 22.2 | 88.0 | 20.0 | 46.3 | 22.8 | 93.0 | 20.0 | 49.7 | 26.4 | 107.0 | 26.0 | 48.4 | 23.6 | 99.0 | 26.0 |
| *DE* | 6.9 | 2.5 | 10.4 | 2.4 | 6.7 | 2.8 | 11.6 | 2.5 | 10.0 | 3.4 | 15.1 | 4.3 | 8.9 | 3.3 | 14.8 | 4.0 |
| *DE*-FHC | 7.3 | 2.9 | 10.3 | 3.9 | 6.8 | 3.0 | 10.4 | 3.7 | 10.2 | 3.8 | 14.9 | 6.0 | 9.1 | 3.7 | 14.8 | 5.2 |
| *DE*-Non-FHC | 6.5 | 2.4 | 10.4 | 2.4 | 6.6 | 2.8 | 11.6 | 2.5 | 9.8 | 3.3 | 15.1 | 4.3 | 8.6 | 3.2 | 14.7 | 4.0 |

Note: 1. The sample size is 54;
2. *BR* and *DE* (NT$100Mn) have been divided by GDP deflator (2002 = 100);
3. Data Sources: *Taiwan Stock Exchange Corporation*
(website: http://www.tse.com.tw/ch/statistics/statistics_list.php?tm=03&stm=004).

Four environmental variables are introduced to measure the effect of input utilization. Annual sales volume is the exchanged data among the top-14 ISFs. Durations are calculated by each firm's registration date in the Taiwan Market Post Information System and asset values are the annual report data listed in the Taiwan Securities and Futures Bureau.

# 4. EMPIRICAL RESULTS

This chapter demonstrates the research results of ZSG-DEA and BCC-DEA models, confirms the simultaneity between market share and efficiency score via the 2SLS, and the findings of the four-stage DEA model.

## 4.1. The Result of ZSG-DEA, BCC-DEA Models and 2SLS Procedure

Section 4.1.1 analyses the result of ZSG-DEA and traditional DEA models. Section 4.1.2 confirms the simultaneous relationship between market share and efficiency score via 2SLS.

### 4.1.1. Examining the Results of the ZSG-DEA and BCC-DEA Models

This research adopts the output-oriented variable-returns-to-scale BCC-DEA model (Banker *et al.*, 1984) and the ZSG-DEA model (Lins *et al.*, 2003) to compute the efficiency scores of the SFs. Output orientation is a better choice here because the obvious aim of an individual SF is to obtain the maximum market share in order to dominate the market. The securities industry in Taiwan provides an opportunity to apply the ZSG-DEA model, because of its characteristics of high competition and low concentration (the top-three banks' concentration ratios, *CR3*, were all less than 0.3 during 2001-2005). Market share is the most important performance indicator among the securities firms.

Equations (3) and (8) calculate the efficiency scores $\theta_i$ and $\theta_{iR}$ from the BCC-DEA and ZSG-DEA models using the annual cross-sectional data, respectively, which are presented in Appendix B. It is obvious that when faced with the reality of a constant sum of outputs, the traditional BCC-DEA model underestimates the average efficiency score compared with the ZSG-DEA model. This study calculates a paired-difference *t* test to determine whether the efficiency scores of these two models are significantly different. Table 4-1 presents the results of the paired *t* test. The efficiency scores ($\theta_{iR}$) in the ZSG-DEA model are statistically significantly higher than those ($\theta_i$) in the BCC-DEA model during 2001-2005. The gap in efficiency scores between the efficient and inefficient SFs under a zero-sum gains framework is significantly less than that under the traditional models. Hence, with the objective of maximising their market share, the efficient SFs need to develop more marketing strategies and introduce more techniques to maintain their leading role in the market. We are also able to derive this trend in the descriptive statistics. The average fixed assets of ($x^1$) and financial capital ($x^2$) in 2005 respectively increased by 23% and by more than three times the value in 2001, showing that the SFs continuously enhance their capital and fixed assets to develop electronic trading hardware to maximise their market shares. The average expenses in 2005 were also nearly 30% lower than the corresponding values in 2001. However, the average market share of SFs in 2005 reflected an increase of only 22% compared with the value in 2001. Owing to the fact that the market share competition is like a zero-sum constraint, the severe competition resulted in each SF obtaining a higher efficiency score under the ZSG-DEA model than under the BCC-DEA model.

**TABLE 4-1. Tests of the Efficiency Differences between the BCC-DEA and ZSG-DEA**

| Year | *N* | BCC-DEA | ZSG-DEA | BCC-ZSG | *t*-Test (BCC-ZSG) |
|---|---|---|---|---|---|
| | | Mean | Mean | Difference | *t* value |
| 2001 | 61 | 80.10 | 80.68 | -0.58 | -3.54** |
| 2002 | 54 | 74.89 | 75.64 | -0.75 | -3.50** |
| 2003 | 51 | 74.82 | 75.81 | -1.01 | -3.83** |
| 2004 | 50 | 80.87 | 81.44 | -0.57 | -2.73** |
| 2005 | 50 | 76.73 | 77.21 | -0.48 | -2.71** |

Notes: 1. Eight SFs were merged and one Hong Kong-based SF established its Taiwan branch in 2002;
2. Four securities firms were merged and one American-based SF was established in 2003;
3. ** indicates significance at the 1% level;
4. Shapiro-Wilk *W* test is verified for examining the normality of the data.

### 4.1.2. Simultaneous Relationship between Market Share and Efficiency Score

The EFS hypothesis states that efficient firms increase in size and market share due to their ability to generate higher profits (Goldberg and Rai, 1996). Martin (1988) indicates that larger firms have lower costs, either because of the economies of scale in their industries or due to the inherent superiority of the larger firms in their industries. Lo and Lu (2006) report that large-sized financial institutions are more likely to generate profits with their large scales of assets. Three research hypotheses are thus constructed:

Hypothesis A: More efficient SFs have larger market shares.

Hypothesis B: The larger market share SFs have higher efficiency scores.

Hypothesis C: The efficiency scores and market shares of SFs have positive impacts on each other.

Consequently, this study examines the simultaneous relationship between the efficiency scores, market shares and firm-specific attributes using the 2SLS procedure in equations (15) and (16):

$$ms_i = b_0 + b_1\theta_{iR} + b_2 asset_i + b_3 profit_i + \varepsilon_{i1} \tag{15}$$

$$\theta_{iR} = a_0 + a_1 ms_i + a_2 Foreign_i + \varepsilon_{i2} \tag{16}$$

where $\theta_{iR}$ is the efficiency score of $SF_i$ in the ZSG-DEA model; $ms_i$ is the firm-level market share of $SF_i$; equation (15) includes firm-level asset values (*asset*) and profit (*profit*) as exogenous variables, while equation (16) includes one exogenous variable: a dummy variable (*Foreign*) with 1 for a foreign-affiliated SF and 0 for a domestic SF in Taiwan; and $\varepsilon_{i1}$ and $\varepsilon_{i2}$ are stochastic error terms with mean $E(\varepsilon_{i1}) = 0, E(\varepsilon_{i2}) = 0$ and variance $\sigma^2(\varepsilon_{i1}) = \sigma_1^2, \sigma^2(\varepsilon_{i2}) = \sigma_2^2$. It is verified that these equations satisfy all of the assumptions of the classical linear regression model.

The 2SLS procedure involves obtaining unique estimates that are consistent and asymptotically efficient, and the equations may be exactly identified or over-identified (Ramanathan, 2002). This research estimates these two simultaneous equations using the following procedure:

First, by estimating the reduced form for the endogenous variable ($ms_i$), we obtain the following reduced form equations through equations (15) and (16):

$$ms_i = b_0 + b_1\theta_{iR} + b_2 asset_i + b_3 profit_i + \varepsilon_{i1}$$

$$ms_i = b_0 + b_1(a_0 + a_1 ms_i + a_2 Foreign_i + \varepsilon_{i2}) + b_2 asset_i + b_3 profit_i + \varepsilon_{i1}$$
$$= b_0 + b_1 a_0 + b_1 a_1 ms_i + b_1 a_2 Foreign_i + b_1\varepsilon_{i2} + b_2 asset_i + b_3 profit_i + \varepsilon_{i1}$$

$$ms_i = \left(\frac{b_0 + a_0 b_1}{1 - a_1 b_1}\right) + \left(\frac{a_2 b_1}{1 - a_1 b_1}\right) Foreign_i + \left(\frac{b_2}{1 - a_1 b_1}\right) asset_i + \left(\frac{b_3}{1 - a_1 b_1}\right) profit_i + \frac{b_1\varepsilon_{i2} + \varepsilon_{i1}}{1 - a_1 b_1}$$

$$ms_i = \pi_0 + \pi_1 Foreign_i + \pi_2 asset_i + \pi_3 profit_i + v_1 \tag{17}$$

where $v_1$ is a new error term that depends on $\varepsilon_{i1}$ and $\varepsilon_{i2}$.

Consequently, tackling the endogeneity problem involves the following stages:

Stage 1 Regress $ms_i$ on *Foreign*, *asset*, *profit*, and the constant based on equation (17).

Then save $\hat{ms}_i$ , the predicted value of $ms_i$ as obtained from the reduced form estimates, where $\hat{ms}_i = \hat{\pi}_0 + \hat{\pi}_1 \, Foreign_i + \hat{\pi}_2 \, asset_i + \hat{\pi}_3 \, profit_i$ .

Stage 2 Estimate the structured equation and use as instruments the predicted endogenous variables obtained in the first stage. We regress $\theta_{iR}$ on the constant, $\hat{ms}$, *Foreign*, for equation (16).

**Test for Randomness and Multicollinearity**

The Durbin-Watson statistic (Durbin and Watson, 1950, 1951) is 1.717 when derived from equation (17) and 1.923 when derived from equation (16), indicating that the error terms are not auto-correlated with $p$ =0.01. Variance inflation factors (*VIF*) are used to detect the presence of multicollinearity (Belsley *et al.*, 1980). $VIF_{foreign}$, $VIF_{asset}$ and $VIF_{profit}$ are 1.137, 2.235 and 2.045 in equation (17), respectively. $VIF_{Foreign}$ and $VIF_{ms}$ are 1.127 in equation (16). A *VIF* value in excess of 10 is taken as an indication of multicollinearity. Hence, multicollinearity among these explanatory variables is not a problem in our 2SLS equations. This dissertation employs the pooled data to estimate parameters obtained using 2SLS as follows (standard errors are in the parentheses):

$$\hat{ms}_i = \underset{(0.104)}{0.326} - \underset{(0.110)}{0.144}\, Foreign_i + \underset{(0.009)}{0.071}\, asset_i + \underset{(0.230)}{0.706}\, profit_i \tag{18}$$

$$R^2 = 0.902, F = 244.8$$

$$\hat{\theta}_{iR} = \underset{(0.019)}{0.617} + \underset{(0.007)}{0.058}\, \hat{ms}_i + \underset{(0.027)}{0.279}\, Foreign_i \tag{19}$$

$$R^2 = 0.426, F = 63.1$$

The coefficients of market share and foreign-affiliated organisations are significantly positive, and the adjusted $R^2$ of equation (19) is 0.426. These two factors, namely, the market share and the foreign-affiliated ownership structure, have a significantly beneficial impact on the efficiency scores, suggesting that foreign-affiliated SFs are more efficient than domestic ones in Taiwan. The foreign-affiliated SFs take advantage of their fine, international reputation as well as the investment knowledge of global research teams to attract more customers and maximise market share using less expenditure. This result further confirms the trend that there was a continuous stream of prestigious foreign-affiliated SFs that established branches in Taiwan during 2001-2005, including Deutsche Securities (Asia) Limited, Lehman Brothers Incorporated, HSBC Securities (Asia) Limited and Macquarie Securities (this was originally ING Securities in Taiwan and was bought by Macquarie Securities).

Market share also has a significantly positive impact on the efficiency score. This result also supports the view that larger firms have lower costs, because of the economies of scale in their industries or due to the inherent superiority of the larger firms in these industries (Martin, 1988). The larger market share SFs are also able to more easily attract the attention of customers and account for higher efficiency scores. The empirical results support the conjectures of policy-makers in Taiwan that merging large-sized financial institutions can simultaneously increase their market shares and efficiency scores.

In equation (18), the other two exogenous variables, namely, total assets and profits, have significantly beneficial effects on market share. This conclusion also proves that large-sized SFs do achieve benefits from their market share and is consistent with the finding that large-sized financial institutions are more likely to generate profits with their large-scale assets (Lo and Lu, 2006). During 2001-2005, at least 80% of the top ten SFs in terms of assets also gained leading roles in terms of market share. This fact further confirms that the large-sized SFs are able to capture larger market shares.

## 4.2. The Findings of the Four-Stage DEA

### 4.2.1. Stage One: Initial DEA (The CCR and BCC Input-Oriented Models)

This DEA model includes two outputs and two inputs. Efficiency scores for twelve integrated securities firms in 2002 and fourteen integrated securities firms in 2005 are computed using an input orientation and variable returns to scale technology.

Table 4-2 shows the initial result from the stage 1. The average technical efficiency (*TE*) of ISFs is 0.915 in 2002. The mean *TE* (0.876) of ISFs under FHC is obviously less than the mean *TE* (0.943) of ISFs without joining an FHC. Research shows that it is not only the efficient Integrated Securities Firms (ISFs) that are allied with banks to form a financial holding company. Based on the result of technical efficiency in the first stage, only one of the efficient ISF became an FHC's subsidiary in 2003. In addition, the average technical efficiency among ISFs has been increasing from 0.888 in 2003 to 0.928 in 2005 from the first-stage DEA results. It shows that forming an FHC imposes a threat and creates incentives for efficiency score. One year before most FHCs were established in 2002, 67 percent of the ISFs in the sample have increasing returns to scale; 25 percent of the ISFs have constant returns to scale. There is only one ISF with the decreasing returns to scale that is the subsidiary of an FHC, because this FHC was approaching to merge with another bank and did not dedicate its efforts on the securities business. During 2003-2004, Fubon Securities, Taiwan Securities, KGI Securities, and Sinopac Securities have decreasing returns to scale owing to expanding their business via acquiring other specialised securities. Three-fourths ISFs are under an FHC. Non-FHC ISFs were trying to close inefficient branches owing to the threat from FHCs. For example, Yuanta Core Pacific Securities cut their branch offices from 107 in 2004 to 99 in 2005, but still maintained 8.26 percent market share in 2005 (8.1 percent in 2004) and increased its brokerage revenue from NT$5.54 billion to NT$5.93 billion.

**TABLE 4-2. Comparison of Stage 1 and Stage 4 Results in 2002-2005**

| DMU | The 1st Stage in 2002 | | | | The 4th Stage in 2002 | | | |
|---|---|---|---|---|---|---|---|---|
| | *TE* | *PTE* | *SE* | RTS | *TE* | *PTE* | *SE* | RTS |
| 1. Fubon [f] | 1.000 | 1.000 | 1.000 | crs | 1.000 | 1.000 | 1.000 | crs |
| 2. Taiwan [f] | 0.789 | 0.832 | 0.949 | irs | 0.862 | 0.902 | 0.956 | irs |
| 3. KGI | 0.923 | 0.959 | 0.963 | irs | 0.921 | 0.946 | 0.974 | irs |
| 4. Yuanta Core Pacific | 1.000 | 1.000 | 1.000 | crs | 1.000 | 1.000 | 1.000 | crs |
| 5. Capital | 0.969 | 0.986 | 0.983 | irs | 1.000 | 1.000 | 1.000 | crs |
| 6. President | 1.000 | 1.000 | 1.000 | crs | 1.000 | 1.000 | 1.000 | crs |
| 7. Polaris | 0.961 | 0.991 | 0.970 | irs | 0.982 | 1.000 | 0.982 | irs |
| 8. MasterLink | 0.873 | 0.890 | 0.980 | irs | 0.891 | 0.912 | 0.976 | irs |
| 9. SinoPac [f] | 0.760 | 0.773 | 0.984 | drs | 0.812 | 0.813 | 0.999 | irs |
| 10. Grand Cathay [f] | 0.841 | 1.000 | 0.841 | irs | 0.878 | 1.000 | 0.878 | irs |
| 11. Jih Sun [f] | 0.992 | 1.000 | 0.992 | irs | 0.877 | 0.880 | 0.975 | drs |
| 12. Taiwan International | 0.875 | 1.000 | 0.875 | irs | 0.882 | 1.000 | 0.909 | irs |
| Mean | 0.915 | 0.953 | 0.961 | | 0.925 | 0.954 | 0.971 | |
| FHC-Mean | 0.876 | 0.921 | 0.953 | | 0.886 | 0.919 | 0.962 | |
| Non-FHC Mean | 0.943 | 0.975 | 0.967 | | 0.954 | 0.980 | 0.977 | |
| DMU | The 1st Stage in 2003 | | | | The 4th Stage in 2003 | | | |
| | *TE* | *PTE* | *SE* | RTS | *TE* | *PTE* | *SE* | RTS |
| 1. Fubon [f] | 0.926 | 1.000 | 0.926 | drs | 1.000 | 1.000 | 1.000 | crs |
| 2. Taiwan [f] | 0.859 | 0.894 | 0.961 | drs | 0.946 | 0.969 | 0.977 | irs |
| 3. KGI | 0.906 | 0.937 | 0.967 | drs | 0.949 | 0.966 | 0.982 | irs |
| 4. Yuanta Core Pacific | 0.912 | 1.000 | 0.912 | drs | 0.994 | 1.000 | 0.994 | drs |
| 5. Capital | 0.838 | 0.864 | 0.970 | irs | 0.964 | 0.981 | 0.983 | irs |
| 6. President | 1.000 | 1.000 | 1.000 | crs | 1.000 | 1.000 | 1.000 | crs |
| 7. Polaris | 0.893 | 0.896 | 0.997 | irs | 1.000 | 1.000 | 1.000 | crs |
| 8. MasterLink | 0.774 | 0.801 | 0.966 | irs | 0.867 | 0.905 | 0.958 | irs |
| 9. SinoPac [f] | 0.935 | 0.996 | 0.939 | drs | 1.000 | 1.000 | 1.000 | crs |
| 10. Grand Cathay [f] | 0.808 | 0.891 | 0.907 | irs | 0.922 | 1.000 | 0.922 | irs |
| 11. Jih Sun [f] | 1.000 | 1.000 | 1.000 | crs | 0.969 | 0.972 | 0.997 | drs |
| 12. Taiwan International | 0.820 | 1.000 | 0.820 | irs | 0.774 | 1.000 | 0.774 | irs |
| 13. Fuhwa [f] | 1.000 | 1.000 | 1.000 | crs | 1.000 | 1.000 | 1.000 | crs |
| 14. Mega [f] | 0.767 | 0.825 | 0.929 | irs | 0.909 | 0.962 | 0.942 | irs |
| Mean | 0.888 | 0.936 | 0.950 | | 0.950 | 0.983 | 0.966 | |
| FHC-Mean | 0.899 | 0.944 | 0.952 | | 0.964 | 0.986 | 0.977 | |
| Non-FHC Mean | 0.878 | 0.928 | 0.947 | | 0.935 | 0.979 | 0.956 | |

Note: 1. *TE* represents technical efficiency; *PTE* represents pure technical efficiency; *SE* represents scale efficiency; RTS represents the returns to scale; crs, irs, and drs represent constant returns to scale, increasing returns to scale, and decreasing returns to scale, respectively;
2. [f] means ISF under an FHC.

**(Table continued)**

| DMU | The 1st Stage in 2004 | | | | The 4th Stage in 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| | *TE* | *PTE* | *SE* | RTS | *TE* | *PTE* | *SE* | RTS |
| 1. Fubon [f] | 0.976 | 1.000 | 0.976 | drs | 1.000 | 1.000 | 1.000 | crs |
| 2. Taiwan [f] | 0.836 | 0.865 | 0.966 | drs | 0.898 | 0.899 | 0.999 | irs |
| 3. KGI | 0.970 | 1.000 | 0.970 | drs | 1.000 | 1.000 | 1.000 | crs |
| 4. Yuanta Core Pacific | 1.000 | 1.000 | 1.000 | crs | 0.955 | 1.000 | 0.955 | drs |
| 5. Capital | 0.945 | 0.945 | 1.000 | crs | 0.926 | 0.958 | 0.967 | irs |
| 6. President | 1.000 | 1.000 | 1.000 | crs | 1.000 | 1.000 | 1.000 | crs |
| 7. Polaris | 1.000 | 1.000 | 1.000 | crs | 1.000 | 1.000 | 1.000 | crs |
| 8. MasterLink | 0.877 | 0.904 | 0.970 | irs | 0.869 | 0.925 | 0.939 | irs |
| 9. SinoPac [f] | 0.933 | 0.989 | 0.943 | drs | 1.000 | 1.000 | 1.000 | crs |
| 10. Grand Cathay [f] | 0.808 | 0.890 | 0.908 | irs | 0.823 | 0.984 | 0.836 | irs |
| 11. Jih Sun [f] | 0.990 | 1.000 | 0.990 | irs | 0.858 | 0.860 | 0.998 | irs |
| 12. Taiwan International | 0.867 | 1.000 | 0.867 | irs | 0.757 | 1.000 | 0.757 | irs |
| 13. Fuhwa [f] | 1.000 | 1.000 | 1.000 | crs | 1.000 | 1.000 | 1.000 | crs |
| 14. Mega [f] | 0.757 | 0.810 | 0.934 | irs | 0.777 | 0.879 | 0.884 | irs |
| Mean | 0.926 | 0.957 | 0.966 | | 0.919 | 0.965 | 0.953 | |
| FHC-Mean | 0.900 | 0.936 | 0.960 | | 0.908 | 0.946 | 0.960 | |
| Non-FHC Mean | 0.951 | 0.978 | 0.972 | | 0.930 | 0.983 | 0.945 | |
| DMU | The 1st Stage in 2005 | | | | The 4th Stage in 2005 | | | |
| | *TE* | *PTE* | *SE* | RTS | *TE* | *PTE* | *SE* | RTS |
| 1. Fubon [f] | 0.927 | 1.000 | 0.927 | drs | 1.000 | 1.000 | 1.000 | crs |
| 2. Taiwan [f] | 0.870 | 0.909 | 0.957 | drs | 0.958 | 0.961 | 0.997 | drs |
| 3. KGI | 1.000 | 1.000 | 1.000 | crs | 0.889 | 0.891 | 0.998 | drs |
| 4. Yuanta Core Pacific | 1.000 | 1.000 | 1.000 | crs | 1.000 | 1.000 | 1.000 | crs |
| 5. Capital | 0.974 | 0.980 | 0.994 | drs | 0.990 | 0.992 | 0.998 | irs |
| 6. President | 1.000 | 1.000 | 1.000 | crs | 1.000 | 1.000 | 1.000 | crs |
| 7. Polaris | 1.000 | 1.000 | 1.000 | crs | 1.000 | 1.000 | 1.000 | crs |
| 8. MasterLink | 0.876 | 0.905 | 0.968 | irs | 0.811 | 0.883 | 0.919 | irs |
| 9. SinoPac [f] | 0.909 | 0.912 | 0.997 | drs | 0.988 | 0.990 | 0.998 | irs |
| 10. Grand Cathay [f] | 0.857 | 1.000 | 0.857 | irs | 0.646 | 0.803 | 0.804 | irs |
| 11. Jih Sun [f] | 1.000 | 1.000 | 1.000 | crs | 1.000 | 1.000 | 1.000 | crs |
| 12. Taiwan International | 0.848 | 1.000 | 0.848 | irs | 0.768 | 1.000 | 0.768 | irs |
| 13. Fuhwa [f] | 1.000 | 1.000 | 1.000 | crs | 0.978 | 1.000 | 0.978 | irs |
| 14. Mega [f] | 0.733 | 0.798 | 0.919 | irs | 0.839 | 1.000 | 0.839 | irs |
| Mean | 0.928 | 0.965 | 0.962 | | 0.919 | 0.966 | 0.950 | |
| FHC-Mean | 0.900 | 0.946 | 0.951 | | 0.916 | 0.965 | 0.945 | |
| Non-FHC Mean | 0.957 | 0.984 | 0.973 | | 0.923 | 0.967 | 0.955 | |

Note: 1.*TE* represents technical efficiency; *PTE* represents pure technical efficiency; *SE* represents scale efficiency; crs, irs, and drs represent constant returns to scale, increasing returns to scale, and decreasing returns to scale, respectively;

2. [f] means ISF under an FHC.

### 4.2.2. Stage Two: Quantifying the Effect of the Operating Environment

There are two regression equations from equation (12), one for each input as below.

$$xs_i^1 = f_1(E_i^1, \ \beta_1, \ u_i^1) \tag{20}$$

$$xs_i^2 = f_2(E_i^2, \ \beta_2, \ u_i^2) \quad . \tag{21}$$

The dependent variables ($xs_i^1$ and $xs_i^2$) are total radial movement plus slack movement based on the first stage DEA results. Here, $E_i^1$ and $E_i^2$ are the vectors of environmental variables for ISF *i* that may affect the utilization of input.

The four independent variables are *VOL* for annual brokerage volume in an ISF, which is deeply influenced by Taiwan's trading volume, *DUR* for the duration or the years of service in the securities market, *ASV* for the ISF's asset value and one dummy variable *FHC* to show if this ISF is a subsidiary of an FHC. The purpose of the *FHC* dummy is to investigate whether the FHC would benefit from its ISF subsidiary or not.

A (positive) negative coefficient on these environmental variables suggests that the environment is (un)favorable for a DMU, since it is associated with (greater) less excess use of inputs.

This regression result indicates that the duration of establishment (*DUR*) has a significantly negative coefficient in two equations, suggesting that it is a favorable environmental variable. It shows that the ISFs with a longer duration are able to draw the customers' attention, build up customer loyalty, and create a lot of wealth from the brokerage revenue. Experienced ISFs are able to make less discounted expenditures and utilize branch resources.

The FHC subsidiary variable (*FHC*) has a significantly positive coefficient in two equations. This suggests that an ISF under FHC is in an unfavorable operating environment. The empirical result in the first stage has shown that it is most of the non-efficient ISFs that are able to join FHCs. Fourteen law-induced FHCs were established through persuasion from Taiwan's regulatory authority. This might reveal that politics are possibly intertwined with economic activities in Taiwan. Consequently, the purpose of forming an FHC is not to leverage the synergy among subsidiaries and to improve their efficiency score, but instead an FHC is turned into a negative factor from its securities subsidiary. This result is consistent with the empirical finding for Malaysian banks in 2006. Chong *et al*. (2006) indicated that the forced merger mechanism destroys shareholders' value. Contrary to the findings on voluntary mergers in the United States and Europe, Malaysian acquiring banks that had merged the other target banks have a significantly negative cumulated abnormal return under the forced merger scheme. Moreover, FHC's securities subsidiaries diversify their dedication on the brokerage business in Taiwan due to on-going mergers from FHCs and the cross-selling of banking products. Plus, Taiwanese regulatory authority limited banking branches to not sell securities products to customers directly due to the firewall issue and protecting small-scale securities firms from banks competition. It is another major reason corrupting the one-stop shopping synergy. It also prompts the ISFs under FHCs not to be able to leverage the banking resources and furthermore decrease branches.

The annual sales amount has an insignificant coefficient on two equations in model I of Table 4-3. It shows that ISFs could increase their share of the brokerage market even though Taiwan's trading turnover is uncontrollable. In addition, the asset value of each firm has also an insignificant coefficient on two equations in model I of Table 4-3. More assets is not proven to be favorable or unfavorable to the securities firms.

The coefficients of annual sales volume variable (*VOL*) and asset value (*ASV*) are insignificant and are hence omitted from the equation of slack prediction. Those environmental variables with significant coefficients such as *DUR* and *FHC* are included for slack prediction.

**TABLE 4-3. Tobit Regression Results**

| | Model I<br>Dependent Variable | | Model II<br>Dependent Variable | |
|---|---|---|---|---|
| Independent Variable | $xs^1$ | $xs^2$ | $xs^1$ | $xs^2$ |
| Constant | 5.92144† (3.07348) | 1.007757 (0.771678) | 5.35987** (1.67524) | 1.18623† (0.606758) |
| Annual Sales Volume (VOL) | -0.16747 (0.138793) | -0.009493 (0.036362) | - | - |
| Duration (DUR) | -0.399029* (0.159752) | -0.092441* (0.038561) | -0.31405** (0.103068) | -0.090371* (0.036396) |
| FHC Subsidiary (FHC) | 2.62616† (1.52742) | 0.688963† (0.403324) | 1.8928* (0.891556) | 0.643657† (0.387277) |
| Asset Value (ASV) | 0.0532 (0.049616) | 0.00572278 (0.013104) | - | - |
| $\sigma$ | 4.60222** (0.719161) | 1.2154** (0.190384) | 4.73582** (0 .740611) | 1.21709** (0.190592) |
| Log likelihood function | -89.3665 | -56.1899 | -90.2002 | -56.2851 |

Note: 1. Numbers in the parentheses are standard errors;
2. **, *, and † indicate significance at the 1%, 5%, and 10% levels, respectively;
3. The sample size is 54.

The parameter estimates present in model II of Table 4-3 and the following Tobit regression models (22) and (23) shown below are used to adjust the original input data according to equation (13).

$$\hat{xs}^1 = 5.35987 - 0.31405\ DUR + 1.8928\ FHC \qquad (22)$$

$$x\hat{s}^2 = 1.18623 - 0.090371\ DUR + 0.0643657\ FHC \qquad (23)$$

Table 4-4 summarizes the predicted slacks and maximum predicated slacks for all inputs based on equation (14). The adjusted data control influences the external operating environment. In 2002, one year before most FHCs' establishment, the result that Taiwan, Sinopac and Grand Cathay securities firms under FHCs contributed to the maximum predicted slack reveals an unfavourable external environment under FHCs. In 2003 and 2004, the maximum predicted slacks are from Fuhwa and Mega securities firms, which own the least favourable external environment including the shortest duration in the securities industry and a subsidiary of an FHC. The maximum predicted slacks are contributed by Fuhwa securities firms in 2004 and Mega securities firms in 2005, respectively which are all securities subsidiaries in FHC. This predicted slack result is also consistent with the result of the parameter estimates above.

## TABLE 4-4. Predicted Slacks and Maximum Predicted Slacks

| Year | ISF | DUR | FHC | Predicted Slack $\hat{E}(xs_i^k \vert E_i^k)$ for | |
|---|---|---|---|---|---|
| | | | | $xs^1$ | $xs^2$ |
| 2002 | 1. Fubon [f] | 19 | 1 | 1.286 | 0.113 |
| | 2. Taiwan [f] | 14 | 1 | 2.856 | 0.565 |
| | 3. KGI | 14 | 0 | 0.963 | -0.079 |
| | 4. Yuanta Core Pacific | 41 | 0 | -7.516 | -2.519 |
| | 5. Capital | 14 | 0 | 0.963 | -0.079 |
| | 6. President | 14 | 0 | 0.963 | -0.079 |
| | 7. Polaris | 14 | 0 | 0.963 | -0.079 |
| | 8. MasterLink | 13 | 0 | 1.277 | 0.011 |
| | 9. SinoPac[f] | 14 | 1 | 2.856 | 0.565 |
| | 10. Grand Cathay [f] | 14 | 1 | 2.856 | 0.565 |
| | 11. Jih Sun [f] | 41 | 1 | -5.623 | -1.875 |
| | 12. Taiwan International | 14 | 0 | 0.963 | -0.079 |
| **Maximum predicted slack [Max$^k$ {$\hat{xs}_i^k$}]** | | | | **2.856** | **0.565** |
| 2003 | 1. Fubon [f] | 20 | 1 | 0.972 | 0.022 |
| | 2. Taiwan [f] | 15 | 1 | 2.542 | 0.474 |
| | 3. KGI | 15 | 0 | 0.649 | -0.169 |
| | 4. Yuanta Core Pacific | 42 | 0 | -7.830 | -2.609 |
| | 5. Capital | 15 | 0 | 0.649 | -0.169 |
| | 6. President | 15 | 0 | 0.649 | -0.169 |
| | 7. Polaris | 15 | 0 | 0.649 | -0.169 |
| | 8. MasterLink | 14 | 0 | 0.963 | -0.079 |
| | 9. SinoPac[f] | 15 | 1 | 2.542 | 0.474 |
| | 10. Grand Cathay [f] | 15 | 1 | 2.542 | 0.474 |
| | 11. Jih Sun [f] | 42 | 1 | -5.937 | -1.966 |
| | 12. Taiwan International | 15 | 0 | 0.649 | -0.169 |
| | 13. Fuhwa [f] | 7 | 1 | 5.054 | 1.197 |
| | 14. Mega [f] | 14 | 1 | 2.856 | 0.565 |
| **Maximum predicted slack [Max$^k$ {$\hat{xs}_i^k$}]** | | | | **5.504** | **1.197** |
| 2004 | 1. Fubon [f] | 21 | 1 | 0.658 | -0.068 |
| | 2. Taiwan [f] | 16 | 1 | 2.228 | 0.384 |
| | 3. KGI | 16 | 0 | 0.335 | -0.260 |
| | 4. Yuanta Core Pacific | 43 | 0 | -8.144 | -2.700 |
| | 5. Capital | 16 | 0 | 0.335 | -0.260 |
| | 6. President | 16 | 0 | 0.335 | -0.260 |
| | 7. Polaris | 16 | 0 | 0.335 | -0.260 |
| | 8. MasterLink | 15 | 0 | 0.649 | -0.169 |
| | 9. SinoPac[f] | 16 | 1 | 2.228 | 0.384 |
| | 10. Grand Cathay [f] | 16 | 1 | 2.228 | 0.384 |
| | 11. Jih Sun [f] | 43 | 1 | -6.251 | -2.056 |
| | 12. Taiwan International | 16 | 0 | 0.335 | -0.260 |
| | 13. Fuhwa [f] | 8 | 1 | 4.740 | 1.107 |
| | 14. Mega [f] | 15 | 1 | 2.542 | 0.474 |
| **Maximum predicted slack [Max$^k$ {$\hat{xs}_i^k$}]** | | | | **4.740** | **1.107** |
| 2005 | 1. Fubon [f] | 22 | 1 | 1.914 | 0.294 |
| | 2. Taiwan [f] | 17 | 1 | 1.914 | 0.294 |
| | 3. KGI | 17 | 0 | -8.458 | -2.790 |
| | 4. Yuanta Core Pacific | 44 | 0 | 0.021 | -0.350 |
| | 5. Capital | 17 | 0 | 0.021 | -0.350 |
| | 6. President | 17 | 0 | 0.021 | -0.350 |
| | 7. Polaris | 17 | 0 | 0.335 | -0.260 |
| | 8. MasterLink | 16 | 0 | 0.021 | -0.350 |
| | 9. SinoPac[f] | 17 | 1 | 1.914 | 0.294 |
| | 10. Grand Cathay [f] | 17 | 1 | -6.566 | -2.146 |
| | 11. Jih Sun [f] | 44 | 1 | 1.914 | 0.294 |
| | 12. Taiwan International | 17 | 0 | 2.533 | 0.373 |
| | 13. Fuhwa [f] | 9 | 1 | 2.228 | 0.384 |
| | 14. Mega [f] | 16 | 1 | 6.939 | 1.740 |
| **Maximum predicted slack [Max$^k$ {$\hat{xs}_i^k$}]** | | | | **6.939** | **1.740** |

### 4.2.3. Stage Four: Re-Computing the Managerial Efficiency

Table 4-2 shows the initial result from stage 1 and stage 4. In 2002, incorporating with the environmental effect, the average *TE* for the ISFs under an FHC increased from 0.915 to 0.925. It is shown that the ISFs are able to dedicate their effort to improve efficiency score if these securities could address their specialised brokerage business. This result is also consistent with the existing literature whereby if the firms would dedicate themselves to one or two specialised business, then they are able to reach the high efficiency score, because of learning-curve effect. As a consequence of controlling for the environmental variables at the fourth stage, the average *TE* is increasing during 2002 and 2003. This result indicates that the FHC's impact to ISFs under the unfavorable environment is greater than the benefit to ISFs with a longer duration under a favorable environment. On the other hand, the average *TE* is decreasing and the average *PTE* is increasing in the fourth stage during 2004 and 2005. This result indicates that the FHC's negative impact to ISFs is less than the duration's positive impact to ISFs in terms of *TE*. From the perspective of *PTE*, the penalty to ISFs under an FHC's negative impact is greater than the duration impact.

# 5. CONCLUDING REMARKS & FUTURE RESEARCH

Current studies that apply the traditional BCC-DEA model (Banker *et al*., 1984) assume that an increase in the output of any given DMU does not affect the output of the other units. However, given the fact that a SF's gain in market share is another's market share loss, the traditional DEA models are unable to take into account the zero-sum game competition reality. Since SFs in Taiwan have developed Internet trading techniques to expand their market shares, this provides a plausible reason to apply the ZSG-DEA model developed by Lins *et al.* (2003).

This study analyses 266 integrated SFs in Taiwan covering the period from 2001 to 2005 and employs three inputs (including fixed assets, financial capital, and general expenses) and a single output (market share). In view of the fact that a SF's market share gain is another's market share loss, the traditional BCC-DEA model has a shortcoming in that it ignores the zero-sum game competition and underestimates the average efficiency score as compared with the ZSG-DEA model. Meanwhile, the gap in efficiency scores between the efficient and inefficient SFs under a zero-sum gains framework is significantly less than that under the traditional model.

Meanwhile, in evaluating the performance, it is useful to compute measures of managerial inefficiency for firms operating under different environments. This research demonstrates the four-stage DEA model on the panel data of ISFs during 2002 to 2005 and investigates the impact of environmental variables.

A foreign-affiliated ownership structure is found to have a significantly positive effect on the efficiency scores of SFs. This empirical result also explains the tendency for Deutsche Securities (Asia) Ltd., Lehman Brothers Incorporated and HSBC Securities (Asia) Ltd. to set up new branches in Taiwan during the sample period.

The 2SLS estimation of the simultaneous equations model confirms the simultaneity between the efficiency score and the market share. The empirical results indicate that SFs with larger market shares achieve higher efficiency scores, because large-market-share SFs are able to more easily attract the attention of customers. The more efficient SFs are also able to generate larger market shares, because of the advantages associated with larger profits and more substantial assets. The empirical results support the current suggestions from policy-makers in Taiwan that mergers among large-sized financial institutions should be encouraged in order to increase market shares and efficiency scores.

Regarding to using the four-stage DEA, the first stage computes the technical efficiency through the traditional CCR and BCC DEA models based on inputs and outputs and after excluding the external variables. The second stage specifies a system of equations with total input radial plus slack movement as the dependent variables obtained from the BCC DEA model and environmental variables as the independent variables. The third stage applies the results of Tobit regression to calculate the maximum predicted data and adjust the original input data. The fourth stage re-computes the DEA based on the adjusted input value and generate the adjusted radial efficiency scores that remove the influence of the external variables on inefficiency.

Based on this four-stage DEA result, the FHC has a significantly negative effect on the managerial efficiency of an ISF. The mean *TE* of ISFs under an FHC is obviously less than the mean *TE* of ISFs that have not joined an FHC. Research has shown that it is not only the efficient integrated securities firms (ISFs) that are allied with banks to form a financial holding company. However, the empirical result shows that forming an FHC imposes a threat and creates the incentives for efficiency.

For example, in 2002, one year before FHCs' establishment, the majority of ISFs have increasing returns to scale. On the contrary, an ISF would have decreasing returns to scale if its parent FHC addressed quicker merger activities instead of efficiency improvement. Furthermore, if the firms are dedicated to one or two specialized businesses, then it helps create the high efficiency, because of the learning-curve effect, which is also consistent with the existing literature. It is obvious that the way an individual ISF is run is much more important than its form of organisation. We are also able to observe that non-FHC ISFs were trying to close inefficient branches owing to the threat from FHCs.

Law-induced FHCs in Taiwan provide an opportunity to assess the impacts on the managerial efficiency of their subsidiaries. It might reveal that politics are possibly intertwined with economic activities in Taiwan. Consequently, the purpose of forming an FHC is not to leverage the synergy among subsidiaries and to improve their efficiency, but instead an FHC turns into a negative factor from its securities subsidiary. This result is consistent with the empirical finding in Malaysian banks in 2006. Moreover, FHC's securities subsidiaries have diversified their dedication on their brokerage business in Taiwan due to on-going mergers from FHCs and cross-selling of banking products. In addition, Taiwanese regulatory authority limited banking branches to not sell securities products to customers directly due to the firewall issue and protecting small-scale securities firms from banks competition. It's another major reason to corrupt the one-stop shopping synergy. It also means the ISFs under FHCs are not allowed to leverage banking resources and furthermore decrease brokerage branches. Relatively, most FHCs try hard to expand their asset value through M&A instead of improving their internal efficiency score.

The annual sales amount and asset value have an insignificant impact on managerial efficiency, showing that ISFs can increase their share of the brokerage market even though the trading turnover is uncontrollable. A higher duration of an ISF also significantly improves its technical efficiency. It shows that ISFs with a longer duration have established a good reputation with customers.

Limitations of this research can be relaxed and overcome by future studies: First, this research estimates the simultaneity between market share and efficiency score using 2SLS with pooled data. Future research may consider the time-series effects using panel data to estimate the simultaneous relationship between market share and efficiency. Second, this research takes the market share as the single output of the ISFs, while future research may assess the efficiency score with both constrained and unconstrained outputs in one DEA model.

This research provides a general framework to test the simultaneity between the market share and ZSG-DEA efficiency score, which can be applied to studying other financial or non-financial markets in the future.

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# APPENDICES

## Appendix A

### A Simple Numerical Example

To illustrate the equal reduction strategy and proportional strategy pointed out by Lins *et al.* (2003), we derive our new measure of output reduction by providing a simple example involving observations for ten DMUs with their market share $y_i$ in Table A1.

Step 1: Assume that $DMU_1$ tries to achieve an efficiency score of 100 via market share maximisation from 25% to 43%. $DMU_1$ gains an 18% market share, indicating that the other $DMU_j$ ($j \neq 1$) loses a market share of $y_i(\phi_{iR} - 1) = 18\%$.

Step 2: Replace the output ($y_j$) of each $DMU_j$ ($j \neq 1$) based on the original output minus the equal output reduction following the equation: $y_j - \frac{y_i(\phi_{iR} - 1)}{N - 1}$. $\frac{y_i(\phi_{iR} - 1)}{N - 1} = \frac{18\%}{10 - 1} = 2\%$. Then calculate $y_{je} = y_j - \frac{y_i(\phi_{iR} - 1)}{N - 1}$ for each $j$ in Table A1.

Step 3: The fourth column of Table A1 shows that the equal output reduction strategy is inappropriate because of the negative market share value ($y_{10e} = -0.5\%$) in $DMU_{10}$ after applying this measurement.

Step 4: The proportional output reduction calculations are shown in the last column of Table A1 via $y_{jp} = y_j - \frac{y_j y_i(\phi_{iR} - 1)}{Y - y_i} = y_j - \frac{y_j \times 18}{(100 - 25)}$ for $DMU_j$ ($j \neq 1$).

When $j$=2, $y_{2p}$= $y_j - \frac{y_j y_i(\phi_{iR} - 1)}{Y - y_i} = 20 - \frac{20 \times 18}{(100 - 25)} = 20 - 4.8 = 15.2(\%)$.

When $j$=3, $y_{3p}$= $y_j - \frac{y_j y_i(\phi_{iR} - 1)}{Y - y_i} = 15 - \frac{15 \times 18}{(100 - 25)} = 15 - 3.6 = 11.4(\%)$, etc.

The proportional output reduction strategy avoids the drawback of the equal output reduction, and becomes the model that we apply.

**Table A1** An Illustrative Example

| $DMU_j$ | $y_i$(%) | Equal Output Reduction ($e_j$) ($j \neq 1$) | $y_{ie}$(%) $= y_i - e_j$ ($j \neq 1$) | Proportional Output Reduction ($p_j$) ($j \neq 1$) | $y_{ip}$(%) $= y_i - p_j$ ($j \neq 1$) |
|---|---|---|---|---|---|
| $DMU_1$ | 25.0 | 18 | 43.0 | 18.0 | 43.0 |
| $DMU_2$ | 20.0 | -2 | 18.0 | -4.8 | 15.2 |
| $DMU_3$ | 15.0 | -2 | 13.0 | -3.6 | 11.4 |
| $DMU_4$ | 10.0 | -2 | 8.0 | -2.4 | 7.6 |
| $DMU_5$ | 8.0 | -2 | 6.0 | -1.9 | 6.1 |
| $DMU_6$ | 6.0 | -2 | 4.0 | -1.4 | 4.6 |
| $DMU_7$ | 5.5 | -2 | 3.5 | -1.3 | 4.2 |
| $DMU_8$ | 5.0 | -2 | 3.0 | -1.2 | 3.8 |
| $DMU_9$ | 4.0 | -2 | 2.0 | -1.0 | 3.0 |
| $DMU_{10}$ | 1.5 | -2 | -0.5 | -0.4 | 1.1 |
| Total Market Share | 100.0 | 0 | 100.0 | 0.0 | 100.0 |

Note: Assume that $DMU_1$ tries to achieve an efficiency score of 100 via market share maximisation from 25% to 43%. The equal output reduction strategy prompts $DMU_{10}$ to become a negative output ($y_{10e}$ = -0.5%), using equation $\frac{y_i^m(\phi_{iR} - 1)}{N - 1}$; however, the proportional output reduction strategy avoids this drawback.

## Appendix B

Table B1 shows the efficiency scores using the BCC-DEA and ZSG-DEA models for the SFs in Taiwan during the period 2001-2005.

**Table B1** Efficiency Scores ($\theta_i$) of BCC-DEA and ZSG-DEA Models for the SFs in Taiwan during 2001-2005

| | 2001 | | 2002 | | 2003 | | 2004 | | 2005 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Securities Firms | BCC | ZSG | BCC | ZSG | BCC | ZSG | BCC | ZSG | BCC | ZSG |
| JIH SUN | 95.10 | 98.93 | 100.00 | 100.00 | 76.30 | 81.05 | 88.40 | 93.07 | 100.00 | 100.00 |
| JEN HSIN | 59.70 | 59.58 | | | | | | | | |
| FIRST | 59.60 | 59.54 | 85.40 | 85.12 | 62.60 | 62.47 | 64.20 | 63.87 | 43.00 | 42.75 |
| ASIA | 74.80 | 75.24 | 58.40 | 58.72 | 56.40 | 56.64 | | | | |
| TINGKONG | 65.30 | 65.55 | | | | | | | | |
| ENTRUST | 55.20 | 55.06 | | | | | | | | |
| HORIZON | 45.20 | 46.01 | 37.60 | 37.89 | 47.80 | 48.18 | 38.50 | 38.65 | 46.70 | 46.66 |
| MACQURIE* | 50.10 | 49.86 | 62.30 | 61.98 | 100.00 | 100.00 | 100.00 | 100.00 | 89.80 | 89.36 |
| ABN AMRO* | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| MERRILL LYNCH* | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| NOMURA (HK)* | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 67.10 | 66.57 |
| SOCIETE GENERALE(HK)* | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 67.20 | 66.57 | 87.50 | 87.40 |
| GOLDMAN SACHS (ASIA)* | 100.00 | 100.00 | 100.00 | 100.00 | 49.90 | 49.44 | 100.00 | 100.00 | 100.00 | 100.00 |
| ORIENTAL | 98.00 | 98.65 | 49.00 | 49.24 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| FIRST TAIWAN | 48.00 | 47.87 | 44.20 | 44.02 | | | | | | |
| TACHAN | 73.50 | 73.37 | 78.10 | 77.81 | 53.40 | 53.33 | 99.30 | 98.81 | 76.50 | 76.37 |
| HUA NAN | 80.90 | 82.72 | 95.70 | 97.97 | 78.60 | 80.49 | 95.00 | 96.54 | 86.00 | 87.96 |
| FULL LONG | 62.50 | 62.35 | 64.80 | 64.63 | 31.40 | 31.30 | 54.70 | 54.33 | 18.60 | 18.55 |
| PACIFIC | 82.70 | 83.10 | 61.40 | 61.66 | 51.60 | 51.77 | 46.00 | 46.02 | 46.50 | 46.48 |
| TA CHING | 84.40 | 84.39 | 79.40 | 79.36 | 69.10 | 69.12 | 77.70 | 77.43 | 68.60 | 68.36 |
| CAPITAL | 88.70 | 92.73 | 81.20 | 85.88 | 72.80 | 77.07 | 100.00 | 100.00 | 92.00 | 96.66 |
| CHUNG HSING | 62.30 | 62.24 | 55.80 | 55.71 | | | | | | |
| FIRST TAISEC | 90.80 | 90.88 | 79.80 | 79.94 | 81.30 | 81.76 | 75.10 | 75.89 | 92.50 | 94.28 |
| FORWIN | 44.60 | 44.51 | 35.30 | 35.18 | 38.40 | 38.26 | 49.20 | 48.84 | 17.30 | 17.16 |
| SINOPAC | 89.90 | 93.29 | 85.40 | 90.73 | 87.60 | 93.87 | 87.60 | 92.25 | 96.50 | 100.00 |
| TAIWAN | 100.00 | 100.00 | 89.90 | 94.53 | 84.60 | 90.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| TAIYU | 65.90 | 66.17 | 66.90 | 67.39 | | | | | | |
| KGI | 100.00 | 100.00 | 83.30 | 87.40 | 75.90 | 80.44 | 99.50 | 100.00 | 100.00 | 100.00 |

**Table continued**

| | 2001 | | 2002 | | 2003 | | 2004 | | 2005 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Securities Firms | BCC | ZSG | BCC | ZSG | BCC | ZSG | BCC | ZSG | BCC | ZSG |
| IBT | 97.70 | 97.65 | 67.20 | 67.30 | 100.00 | 100.00 | 100.00 | 100.00 | 92.10 | 93.18 |
| GRAND CATHAY | 83.10 | 86.91 | 69.70 | 73.32 | 78.00 | 81.83 | 94.80 | 100.00 | 100.00 | 100.00 |
| TAIWAN INTL. | 88.10 | 90.40 | 85.00 | 87.77 | 68.70 | 71.13 | 71.40 | 73.60 | 78.50 | 81.17 |
| PRESIDENT | 92.80 | 96.67 | 95.80 | 100.00 | 89.20 | 93.58 | 94.50 | 98.14 | 94.60 | 98.11 |
| MASTERLINK | 85.80 | 89.02 | 75.60 | 79.10 | 80.90 | 85.20 | 91.30 | 95.06 | 89.80 | 92.96 |
| PRIMASIA | 48.20 | 48.16 | 65.10 | 64.82 | 60.70 | 60.50 | 79.90 | 79.70 | 48.70 | 48.45 |
| CHINATRUST | 100.00 | 100.00 | 51.10 | 51.59 | 77.70 | 78.59 | 90.90 | 91.88 | 100.00 | 100.00 |
| BARITS | 100.00 | 100.00 | 71.20 | 71.82 | | | | | | |
| GRAND FORTUNE | 58.30 | 58.24 | 53.00 | 52.82 | 60.10 | 59.89 | 41.20 | 40.87 | 56.30 | 55.79 |
| TA CHONG | 93.70 | 93.53 | 63.20 | 63.12 | 53.20 | 53.14 | 77.60 | 77.29 | 64.60 | 64.45 |
| RELIANCE | 77.20 | 76.99 | 100.00 | 100.00 | 40.60 | 40.87 | 58.90 | 58.56 | 58.10 | 57.70 |
| MEGA | 62.10 | 62.77 | 56.90 | 57.43 | 86.30 | 90.44 | 75.70 | 78.64 | 88.40 | 91.21 |
| CONCORD INTL. | 65.30 | 65.32 | 90.50 | 90.24 | 57.80 | 57.67 | 100.00 | 100.00 | 47.70 | 47.60 |
| JINHWA | 60.50 | 60.13 | | | | | | | | |
| WATERLAND | 62.30 | 62.77 | 60.70 | 61.60 | 52.90 | 53.87 | 69.60 | 70.26 | 55.60 | 56.20 |
| HSINBAO | 99.50 | 99.91 | | | | | | | | |
| J.P. MORGAN* | 65.70 | 65.75 | 68.80 | 68.71 | 61.90 | 61.78 | 60.10 | 59.97 | 79.60 | 79.40 |
| CONCORD | 83.20 | 84.03 | 64.80 | 65.58 | 62.80 | 63.61 | 79.70 | 80.21 | 72.40 | 73.28 |
| CONCOURSE | 67.80 | 67.81 | | | | | | | | |
| SINOPAC(OLD) | 78.70 | 79.28 | | | | | | | | |
| GRAND ORIENT | 61.10 | 61.05 | | | | | | | | |
| SHINKONG | 61.40 | 61.44 | 25.90 | 25.98 | 76.80 | 76.56 | 67.80 | 67.45 | 72.80 | 72.75 |
| CITIBANK* | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| FU HWA | 83.10 | 84.98 | 87.90 | 90.52 | 82.80 | 85.40 | 88.00 | 90.34 | 70.30 | 72.59 |
| SUN-FUND | 100.00 | 100.00 | 49.80 | 49.55 | 37.40 | 37.21 | 40.90 | 40.57 | 32.10 | 31.82 |
| HO TUNG | 100.00 | 100.00 | 50.30 | 49.90 | 82.30 | 81.65 | 63.30 | 62.79 | | |
| E. SUN | 80.70 | 80.13 | 70.50 | 70.04 | 44.20 | 44.14 | 61.80 | 61.60 | 65.50 | 65.39 |
| DAIWA | 100.00 | 100.00 | 94.30 | 93.63 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| FUBON | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| POLARIS | 95.30 | 99.44 | 97.50 | 100.00 | 99.50 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| YUANTA | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| FAR EASTERN | 66.00 | 65.59 | 60.90 | 60.42 | 44.30 | 43.98 | 55.40 | 54.93 | 25.20 | 25.03 |
| YUAN LI | 91.60 | 91.33 | 74.30 | 74.01 | 100.00 | 100.00 | | | | |

**Table continued**

| | 2001 | | 2002 | | 2003 | | 2004 | | 2005 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Securities Firms | BCC | ZSG | BCC | ZSG | BCC | ZSG | BCC | ZSG | BCC | ZSG |
| DEUTSCHE (ASIA)* | | | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| LEHMAN BROTHERS* | | | | | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| HSBC (HK)* | | | | | | | | | 46.70 | 46.30 |
| CATHAY | | | | | | | 38.40 | 38.07 | 69.10 | 68.66 |
| Average | 80.10 | 80.68 | 74.89 | 75.64 | 74.82 | 75.81 | 80.87 | 81.44 | 76.73 | 77.21 |

Notes: 1. The reason for the unbalanced panel data was mainly due to the mergers that took place in the securities industry during 2002-2003 and the new Taiwan branches that were set up by foreign-owned SFs in 2003, respectively. To establish the financial holding companies (FHCs), eight SFs were merged in 2002. Deutsche Securities (Asia) Limited, Lehman Brothers Incorporated, HSBC Securities (Asia) Limited and Macquarie Securities. (ING) Securities in Taiwan was acquired by Macquarie Securities) established new branches in Taiwan during 2002-2005;

2. * indicates the foreign-owned SFs.

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Working Experiences

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Apr. 1997-May 2001 Manager, Citibank, N.A.

Assistant Vice President, Citibank, N. A.

Vice President, Citibank, N. A.

Jun. 2001-Mar. 2006 Senior Vice President, Jih-Sun Securities Firms.

Senior Vice President, Jin-Sun Financial Holdings.

Aug. 2007- Assistant Professor, Dept. of Finance, China University of Tech.

Publications

1. Hu, Jin-Li and Chin-Yi Fang, Forthcoming, "Do Market Share and Efficiency Matter for Each Other? An Application of the Zero-Sum Gains Data Envelopment Analysis," Journal of the Operational Research Society (SSCI, SCI).
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## Award

「合作金庫商業銀行 95 年度研究獎學金」博士論文組