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Integration and application of rough sets and data envelopment analysis for assessments of the investment trusts industry

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Abstract

Approximately 40% of pension funds for military officials, civil servants, and educators in Taiwan are entrusted to international and domestic management funds. However, the average return rate for domestically outsourced funds is not greater than the earnings of self-managed funds. This study establishes a selection mechanism for pension fund outsourcing that conforms to current outsourcing management policies and accounts for both safety and profitability. This study conducts a network data envelopment analysis with considerations of dynamism to gauge the internal management efficiency and investment performance of 37 investment trust companies in Taiwan, thereby accurately measuring the links between internal economic activities and improving overlooked internal productivity activities. The results of this study indicate the internal and external corporate learning benchmarks, which are sequenced to assist the optimal outsourcing measures by applying rough set theory concepts. This study also provides suggestions for the Public Service Pension Fund Management Board in Taiwan in terms of future operations in domestic investment trust companies.

Keywords Rough sets · Data envelopment analysis · Performance evaluation · Investment trust companies

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1 Introduction

The present study aims to develop an evaluation and selection mechanism for fund commissioners and propose methods to increase return on investment and reduce investment risk. The Public Service Pension Fund Management Board (PSPFMB) in Taiwan aims to utilize the asset management experience, rigorous investment decision-making, and risk control systems of investment trust companies (ITCs) to reduce risks, enhance management, increase efficiency, and boost the investment performance for the public service pension fund. To date, more than NT$177.7 billion of the funds (34.24%) is commissioned by domestic and international ITCs. According to annual reports released by the PSPFMB, over the past 10 years, domestic fund management commissions reported only five annual percentage yields exceeding the target annual yield and four annual percentage yields that exceeded that achieved through PSPFMB management.

Fund managers face gradually increasing risks during assets management in the current increasingly liberalized financial markets wherein public administration systems hire professional and licensed ITCs as public fund managers, and they play prominent roles to ensure returns and maintain efficiency. Therefore, the use of ITCs to manage funds maintains long-term returns and offers flexibility in the selection of investment opportunities. Moreover, the use of different ITCs to manage funds can diversify the risks.

The literature has indicated substantial examination of the basic questions about the individual- and institutional-level performance of ITCs, particularly pertaining to the performance of mutual funds (Shu et al. 2002; Brandouy et al. 2015; Zhou et al. 2017), and the factors determining the performance (Ferreira et al. 2013). Despite being a booming market, institutional-level research regarding the ITC performance in Taiwan is lacking because of data unavailability. Moreover, Khorana et al. (2005) noted that a country's securities trading environment is imperative for providing investors with a positive impression of the optimum investment vehicle. Therefore, an individual examination of the performance of ITCs can offer an insight into the performance of financial institutions in the country.

To measure the operating performance of an organization, multiple indicators are required to prevent inappropriate managerial decisions. Data envelopment analysis (DEA) estimates production frontiers that measure productive efficiency by constructing a multifactor financial performance model for multiple inputs and outputs through linear programming (Cooper et al. 2006). However, scholars have adopted the traditional one-stage DEA while evaluating an organization's operating performance. This method does not indicate the effects of intermediate indicators and connecting movement, and therefore, cannot provide the entire management information by using the productive efficiency. Recent studies have increasingly utilized two-stage DEA to measure organizations' operating performance in various industries (Liu et al. 2013b). In the present study, a two-stage DEA procedure is constructed to estimate the operating performance of ITCs commissioned to manage the public service pension fund in Taiwan. The evaluation results can help the PSPFMB to select adequate ITCs.

The ITCs' efficiency can only be ranked using the derived DEA scores while disregarding the effects of the condition attribute on the sensitivity of inclusion/exclusion or different combinations of inputs, intermediates, and outputs. However, rankings derived using the overall efficiency of the DEA approach may be subject to the multicollinearity problem, thus resulting in biased rankings. Rough set theory, which uses imprecise information, balances other mathematical techniques using the same rough information (Walczak and Massart

1999; Greco et al. 2001; Pawlak 2002). Therefore, rough set theory complements the DEA approach, particularly in terms of rankings.

The aims of the present study are as follows: (1) To construct a two-stage dynamic operating performance evaluation procedure to gauge the internal management efficiency and investment performance of 37 ITCs commissioned to manage the public service pension fund in Taiwan from 2007 to 2011, the present study applies the dynamic two-stage slacks-based measure (SBM) of DEA (Tone and Tsutsui 2014). (2) To combine rough set theory and DEA for ranking the efficiency of the ITCs, the present study develops a selection mechanism to determine companies that are appropriate for the commission, and provide a practical reference for the PSPFMB and domestic ITC managers; the 5-year data is averaged, and the network DEA is used for further analysis, whereas the rough set method is used to explore the relative importance of different inputs to the overall efficiency analysis while ranking the ITCs.

This study contributes the following findings to the literature. The study illustrates how combining DEA and rough set theory provides improved measurement and ranking for ITC performance. The DEA approach uses a dynamic two-stage DEA model that not only simultaneously incorporates various performance indicators while evaluating the ITC performance but also reveals the black box of the ITC performance across various times. Rough set theory ranks the ITC performance after considering the effects of the condition attribute on the sensitivity of inclusion/exclusion or different combinations of inputs, intermediates, and outputs. In other words, this study provides improvements for the DEA approach and incorporates a complementary theory. These improvements eliminate the potential for biased rankings because the relative significance of different inputs to the overall efficiency analysis is explored in this study. Therefore, the study findings can provide an increasingly detailed guideline to help the Taiwanese PSPFMB identify an ITC for the management of pension funds. This study also highlights the integration and adoption of rough set theory and the DEA approach, and hopes to provide a solution for practitioners, such as mutual fund managers, to identify the best ITC for managing the public service pension funds in Taiwan.

The following section presents a literature review, followed by a description of this study's research design. The study findings are presented in the proceeding section and the final section details the conclusion of the study.

2 Literature review

2.1 Overview of the pension fund in Taiwan

In 1995, to reduce the considerable financial burden caused by pension payments to retired public servants (i.e., military, government, and teaching personnel), Taiwan's central government altered the public servant pension system from a superannuation pension plan (i.e., a noncontributory plan that entitles public servants to a pension without deductions from their wage or salary) into a contributory pension plan and established a public service pension fund. The PSPFMB is legally responsible for the budgeting, management, and allocation of the pension fund. The public service pension fund is appropriated to recipients on a regular basis and is a medium-to-long-term fund that fulfills future payment obligations. Therefore, the allocation of this fund should provide both protection and guarantee to recipients. In 2011, the PSPFMB published the ratio of expenditure to income per capita for the public service pension fund for government (61%), teaching (75%), and military (107%) personnel;

these figures indicated signs of deterioration in the management of this fund. Figures from the end of 2012 indicated that the ratio for government (73%), teaching (85%), and military (118%) personnel further deteriorated; the figures had increased by 10–12% from those of the preceding year. Therefore, improving the management of Taiwan's public service pension fund has become an urgent and critical task.

Before 2001, the PSPFMB managed the public service pension fund itself. However, insufficient manpower, immature brokerage skills, and considerable pressure because of the minimum yield threshold guarantee led to excessively conservative investment decisions, low long-term return on investment, and poor fund management performance. To increase market capital flows, the government opened this business up to private investment companies. In response to this change in government fiscal policy and to internationalize the development of the public service pension fund, the PSPFMB began commissioning private ITCs in December 2003.

ITCs are currently categorized as foreign, financial holding, and domestic ITCs. Foreign ITCs with abundant capital and investing experience usually enter Taiwan's investment trust market through mergers and acquisitions or joint ventures with enterprises in Taiwan. They receive assistance from their parent companies, which is helpful for global resource integration. Financial holding ITCs feature diversified business, large-scale organization, and centralized equity ownership; their unified resource planning and sales and distribution channels facilitate local development. By contrast, domestic ITCs have existed in the local market for a longer time, have fewer cultural barriers for business development, and have enough experience in issuing and underwriting business. In addition, they have a deeper understanding of the characteristics of the securities market in Taiwan, have developed a market reputation and flexible distribution strategies, and have advantages, such as knowledge of Taiwan's status quo, development of retail investors, and ownership of comprehensive product lines.

Since the establishment of the public service pension fund, Taiwan has experienced the 1997 Asian financial crisis, the collapse of the Internet bubble in 2000, the 2003 SARS outbreak, the 2007 subprime mortgage crisis, and the 2008 financial crisis. These crises have resulted in constant changes in the public service pension fund asset allocation. Studies on the management of this fund have indicated that the fund expenditure is constantly exceeding its income and is on the brink of bankruptcy. Therefore, the present study formulates a commission selection method to identify adequate ITCs with professional brokers that can appropriately manage the public service pension fund, thereby reducing external investment risks, increasing fund management effectiveness using the fund's economy of scale, and accumulating stable fund assets.

2.2 ITC performance

Because this study focuses on estimating ITC performance, this section reviews studies that focus on the adoption of the DEA approach. Murthi et al. (1997) examined the mutual fund industry in the United States; they noted that funds with higher efficiency are those that feature "growth," "asset allocation," "equity income," and "income type" and that larger funds demonstrate higher efficiency because of their lower conversion costs. Galagedera and Silvapulle (2002) examined the Australian mutual fund market and revealed that the efficiency of mutual funds is positively affected by time and, in particular, that the efficiency of mutual funds is higher when the issuance period is longer. Basso and Funari (2003) adopted the DEA approach and a traditional performance indicator to investigate 47 Italian mutual funds; their findings indicated that the DEA approach delivers superior results and provides more useful information for investors than do traditional mutual fund performance evaluation techniques. Furthermore, Haslem and Scheraga (2003) noted increased efficiency in Morningstar's 500 large-cap mutual funds in the United States; likewise, Haslem and Scheraga (2006) found that large-cap mutual funds have increased efficiency and that only 11 out of 58 of Morningstar's 500 small-cap mutual funds in the United States are efficient. Gregoriou (2006) evaluated the largest stocks, bonds, and balanced funds in the United States for the period 1990–2005 and argued that the DEA approach can effectively evaluate mutual fund performance.

The efficiency of financial institutions has been extensively discussed, and DEA has become one of the most frequently applied techniques (Liu et al. 2013a, b). Sherman and Gold (1985) adopted the CCR model (CCR, 1978) to conduct an efficiency evaluation of the 14 branches of a savings bank. Favero and Papi (1995) used the two-stage contextual method to gauge the efficiency of 174 banking institutions in Italy and their findings indicated that productive specialization, size, and location can be used to explain efficiency. Elyasiani and Mehdian (1990) analyzed changes in efficiency in 191 large banks in the United States and compared the banks' production frontier for the period 1980–1985. In a similar vein, studies (Berg et al. 1992, 1993) employed the Malmquist productivity index to examine bank productivity in Nordic countries. Furthermore, Kantor and Maital (1999) combined DEA with activity-based accounting to measure the performance and costs of a large Middle East bank and its 250 branches. Du et al. (2018) examined the performance of banks using DEA. In their attempt to evaluate financial corporations' performance, several studies examined banking efficiency in a two-stage DEA process (Seiford and Zhu 1999; Luo 2003; Paradi and Schaffnit 2004; Liu and Lu 2010; Wang et al. 2014). In this regard, Liu (2011) focused on the performance of financial holding companies in Taiwan, whereas Premachandra et al. (2012) examined the US mutual fund families' efficiency. Similarly, Galagedera et al. (2016) inserted a new dimension to the two-stage model proposed by Premachandra et al. (2012) by adding total cash flow or reward to investors as the output of the first-stage efficiency, thereby decreasing the discriminatory power of the model. Recently, Galagedera et al. (2018) developed a general multiplier-based three-stage DEA model for mutual fund performance evaluation, which further improved the discriminatory power regarding mutual fund performance.

Overall, the aforementioned studies have highlighted the development of the DEA approach; however, despite the numerous studies that have examined two-stage efficiencies in the financial services industry, evidence regarding ITC performance in Taiwan is limited. The exception is the study conducted by Lu et al. (2016), in which the additive efficiency decomposition approach in DEA was applied. The present study evaluates the management and investment efficiencies of ITCs in Taiwan for the period 2007–2011.

3 Research methodology and data

3.1 ITC production process

Evaluating the operating performance of a company is a complex process. Multiple indicators are required to measure internal linking activities within the organization and prevent inappropriate management decisions. The financial statements of ITCs indicate that they first invest in resources (e.g., employees, operating expenses, and fixed assets), among which fixed assets are carried over from one financial year to the next, to generate intermediates (e.g.,

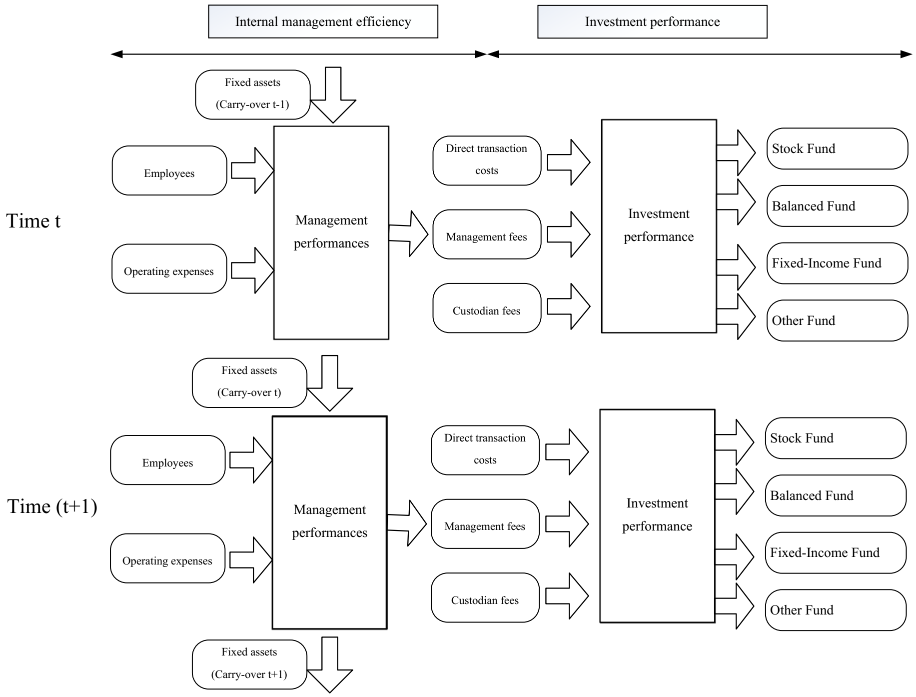

Fig. 1 Two-stage dynamic production process for ITCs

management fees, custodian fees, and direct transaction costs), and then utilize intermediate resources to manage the mutual fund investments (e.g., equity, balanced, fixed-income, and other funds). Under most conditions, the fundamental process between the input and output includes two stages of network structure (Chen et al. 2010a). The outputs from the first stage are regarded as the inputs to the second stage. The two-stage network DEA model was proposed by Seiford and Zhu (1999) to analyze how profitable and marketable the 55 largest US commercial banks are. Therefore, the present study evaluates the performance of ITCs by applying the production process concept to develop a continuous network framework (Fig. 1). During the first stage, the management performances of ITCs are measured, and their fund investment performance is evaluated in the second stage. To accomplish this evaluation, this study treats fixed assets as a carry-over input.[1] A dynamic network DEA model is applied to examine how efficient ITCs manage their inputs, such as employees, operating expenses, and fixed assets and generate intermediates such as direct transaction costs, management fees, and custodian fees, which are used to produce investment outputs such as stock funds, balanced funds, fixed-income funds, and other funds. The first stage is known as "internal management efficiency," whereas the second stage is called "investment performance." The present study derives an overall efficiency of each ITC and summarizes the two aforementioned efficiencies. Table 1 presents descriptions of the input and output indicators and their reference sources.

[1] This is an item known as "permanent account" in the accounting field; it is accumulated and continuously carried over from one financial year to the following one.

Table 1 Definitions of the input and output indicators

Indicators	Definitions	Units	References
Inputs			
Employees	Year-end total number of employees	Person	Xu et al. (2009); Ray and Das (2010)
Operating expenses	Year-end operating expenses for deducting payroll costs, as well as rental expenses, utilities, depreciation etc	NTD10,000	Hu and Fang (2010); Ray and Das (2010)
Carry-over			
Fixed assets	Opening properties, plants and equipment	NTD10,000	Ho and Wu (2009)
Intermediates			
Management fees	Fund asset management service fees	NTD10,000	Gregoriou (2006)
Custodian fees	Fund asset management custodian fees	NTD10,000	
Direct transaction costs	Fund transactions fees and taxes	NTD10,000	Ho and Wu (2009); Sueyoshi et al. (2009); Chen et al. (2010b)
Output			
Investments	The difference between the year-end and opening amounts of equity, balanced, fixed-income, and other types of funds, respectively	NTD1 million	Gregoriou (2006)

3.2 Research subjects, study period, and data sources

The research subjects are ITCs in Taiwan and the (secondary) data sources are the current conditions of the domestic fund industry reported by the Securities Investment Trust and Consulting Association and the financial statements of ITCs published by the Taiwan Stock Exchange Market Observation Post System. Based on the availability of the data sources and data, 2007–2011 is established as the study period; ITCs with insufficient annual data and those that did not operate within the specified period are excluded. A total of 37 ITCs (decision-making units [DMUs]) are selected and evaluated.

The weighted average of the inputs and outputs of each company during 2007–2011 is calculated to effectively evaluate their performance. Their descriptive statistics are summarized in Table 2. The values over the last 5 years (see Panel A, Table 2) are compared with those of 2011 (see Panel B, Table 2). The comparison results indicate that several countries have reduced their interest rates on national debt to mitigate economic problems caused by various global financial crises (i.e., the 2007 subprime mortgage crisis caused by the collapse of Freddie Mac and Fannie Mae, the 2008 financial crisis caused by the Lehman Brothers' bankruptcy, and the 2010 European debt crisis that began in Greece) and the declining raw material and energy prices resulting from a weak global economy. Therefore, investors who favor high-risk and high-yield equity funds or secure

Table 2 Descriptive statistics of DEA indicators

Indicators	Mean	S.D.	Median	Maximum
Panel A: 2007–2011				
Employee	107	66	98	322
Operating expenses	24,768	24,145	15,265	141,666
Fixed assets	8262	11,970	1566	53,392
Management fees	18,699	18,762	11,839	84,747
Custodian fees	43,359	43,362	28,421	191,737
Direct transaction costs	6270	6065	4574	26,962
Equity funds	17,689	21,042	8443	101,952
Balanced funds	1601	3226	285	18,209
Fixed-income funds	15,875	21,058	6611	82,688
Other funds	13,994	24,347	3700	175,770
Panel B: 2011				
Employee	113	74	93	322
Operating expenses	26,893	23,218	21,718	90,347
Fixed assets	7705	12,129	1518	51,187
Management fees	15,755	15,898	11,275	59,145
Custodian fees	44,164	42,679	34,172	155,936
Direct transaction costs	6255	5835	4892	22,585
Equity funds	15,213	17,153	7602	65,484
Balanced funds	869	1732	140	8114
Fixed-income funds	2899	4713	563	19,478
Other funds	27,804	34,256	15,268	175,770

and robust fixed funds have been encouraged to shift their investment strategy toward other defensive asset funds, including money market, real estate investment trust, and index funds.

Golany and Roll (1989) proposed a DEA isotonicity hypothesis, which states that the output should not decrease when the input increases and a correlation analysis is required to verify whether the input and output indicators have an isotonic relationship. Table 3 presents the results of the Pearson correlation coefficient matrix analysis for the input and output indicators used in the two evaluation stages (on management and investment performance). These results reveal a significant positive relationship between the input and output indicators in both stages, thus supporting the requirement to select DEA indicators.

Golany and Roll (1989) recommended that the minimum number of DMUs should be two times the sum of the inputs and outputs. Therefore, in the present study, the total number of DMUs is $37 > 2 \times (3 + 3 + 4) = 20$. Cooper et al. (2006) determined that the minimum number of DMUs should be three times the sum of the inputs and outputs; the present study also satisfies this requirement: $37 > 3 \times (3 + 3 + 4) = 30$.

The number of DMUs employed in the present study exceeds the minimum thresholds proposed in the literature. The correlation coefficient analysis of the input and output indicators also satisfies the isotonicity and homogeneity requirements for a DEA model. Therefore, the sample and data fulfill the requirements of the construct validity for DEA.

Table 3 Correlation coefficient matrix of DEA indicators

Stage	Indicators	Direct transaction costs	Management fees		Custodian fees
1	Employees	0.734 ($p = 0.000$)	0.821 ($p = 0.000$)		0.826 ($p = 0.000$)
	Operating expenses	0.564 ($p = 0.000$)	0.845 ($p = 0.000$)		0.858 ($p = 0.000$)
	Fixed assets (carry-over)	0.407 ($p = 0.000$)	0.406 ($p = 0.000$)		0.418 ($p = 0.000$)
	Indicators	Equity funds	Balanced funds	Fixed-income funds	Other funds
2	Direct transaction costs	0.776 ($p = 0.000$)	0.617 ($p = 0.000$)	0.549 ($p = 0.000$)	0.265 ($p = 0.000$)
	Management fees	0.913 ($p = 0.000$)	0.678 ($p = 0.000$)	0.426 ($p = 0.000$)	0.308 ($p = 0.000$)
	Custodian fees	0.887 ($p = 0.000$)	0.665 ($p = 0.000$)	0.457 ($p = 0.000$)	0.326 ($p = 0.000$)

3.3 Measure performance

DEA models can gauge efficiency in a relative manner (Liu et al. 2016; Charnes and Cooper 1984; Ali and Lerme 1997; Seiford 1997). Traditional DEA models neglected the connectivity of inner economic activities and could not indicate the management messages of those activities. These inner economic activities are considered a "black box." Lu et al. (2012) classified the staged DEA models into four main groups: separate DEA model, separate two-stage DEA model, network DEA model, and integrated two-stage DEA model. The integrated two-stage DEA model has been proven to be an effective approach for evaluating two stages of performance in a single implementation (Liu 2011; Vaz et al. 2010). Cook et al. (2010) listed extensive details regarding these models. SBM network DEA, which was proposed by Tone and Tsutsui (2009), evaluates individual and overall performances of a staged performance evaluation framework. The SBM approach uses slacks in ITCs and recognizes the nonproportional characteristic of worsening ITC performance. Other advantageous characteristics of the SBM model are (i) its unit invariance (i.e., the measure is invariantly related to the unit of measurement for DEA inputs and outputs) and (ii) its monotone behavior (i.e., the measure monotonically decreases with each increase of slacks in inputs and outputs) (Wen 2015; An et al. 2015).

Therefore, this study uses SBM network DEA (Tone and Tsutsui 2009) to evaluate management performance and changes in ITC performance in the consecutive network activities. The DEA approach can precisely evaluate the inner structures of companies and mitigate the neglect of production capability in the inner activities while evaluating companies' performances. Furthermore, ITC resources can be divided into internal management efficiency and investment performance, thereby analyzing the main resource of performance contribution, and building the evaluation mechanism of an ITC's inner network production structure.

In addition, studies have applied methods, such as window analysis (Klopp 1985) and the Malmquist index (Färe et al. 1994), for gauging dynamic efficiency. However, these studies considered the effect of time variation, but not the connecting carry-over movement.

Moreover, these methods aim to attain local optimization in an independent periodic analysis. The present study integrates both two-stage SBM DEA and dynamic SBM or two-stage DEA with considerations of dynamism (Tone and Tsutsui 2014) to gauge the internal management efficiency and investment performance over a period. This approach involves the use of a two-stage DEA model with considerations of dynamism, which not only simultaneously incorporates various performance indicators while evaluating the ITC performance but also reveals the black box of the ITC performance across various times.

Referring to the dynamic two-stage production processes in Fig. 1, assume there are n ITCs ($j = 1,\ldots,n$) with two stages ($k = 1, 2$) over T periods ($t = 1, \ldots, T$). At each period, ITCs employ m inputs ($i = 1, \ldots, m$) to generate D outputs ($d = 1, \ldots, D$) for the first stage. These D outputs, which are referred to as intermediate measures, become the inputs for the second stage. ITCs use D intermediate measures to produce s outputs ($r = 1,\ldots, s$) for the second stage. Additionally, H variables ($h = 1, \ldots, H$) at stage 1 are carried over from time t to time $t + 1$.

$x_{ij}^{t}(i = 1, \ldots, m;\ j = 1, \ldots, n;\ t = 1, \ldots, T)$ is input i to DMU_j for stage 1 at time t, and $y_{rj}^{t}(r = 1, \ldots, s;\ j = 1, \ldots, n;\ t = 1, \ldots, T)$ is output r to DMU_j for stage 2 at time t. $z_{dj}^{t}(d = 1, \ldots, D;\ j = 1, \ldots, n;\ t = 1, \ldots, T)$ links intermediate products of DMU_j from stage 1 to stage 2 at time t. $c_{hj}^{(t,t+1)}(h = 1, \ldots, H;\ j = 1, \ldots, n;\ t = 1, \ldots, T)$ is the carry-over of DMU_j at stage 1 from time t to time $t + 1$. Let x_{ij}^{t}, y_{rj}^{t}, and z_{dj}^{t} indicate the input, output, and connector from stage 1 to stage 2 values of ITC j, which consists of two stages at period t. The $c_{hj}^{(t,t+1)}$ signifies carry-overs from t to $t + 1$ for stage 1.

The present study derives the efficiency by solving the nonoriented function as follows:

$$\phi_o = Min\frac{1}{2T}\sum\nolimits_{t=1}^{T}\left[1-\frac{1}{m}\left(\sum\nolimits_{i=1}^{m}\frac{s_{io}^{t^-}}{x_{io}^{t}}\right)\right]+\left[1\Big/\left[1+\frac{1}{s}\left(\sum\nolimits_{r=1}^{s}\frac{s_{ro}^{t^+}}{y_{ro}^{t}}\right)\right]\right] \quad (1)$$

$s.t.$

$$x_{io}^{t} = \sum\nolimits_{j=1}^{n} x_{ij}^{t}\lambda_{j1}^{t} + s_{io}^{t^-},\ (i = 1, \ldots, m;\ t = 1, \ldots, T), \quad (2)$$

$$y_{ro}^{t} = \sum\nolimits_{j=1}^{n} y_{rj}^{t}\lambda_{j2}^{t} - s_{ro}^{t^+},\ (r = 1, \ldots, s;\ t = 1, \ldots, T), \quad (3)$$

$$\sum\nolimits_{j=1}^{n} z_{dj}^{t}\lambda_{j2}^{t} = \sum\nolimits_{j=1}^{n} z_{dj}^{t}\lambda_{j1}^{t},\ (d = 1, \ldots, D; t = 1, \ldots, T), \quad (4)$$

$$z_{do}^{t} = \sum\nolimits_{j=1}^{n} z_{dj}^{t}\lambda_{j1}^{t} + s_{do}^{t},\ (d = 1, \ldots, D; t = 1, \ldots, T), \quad (5)$$

$$\sum\nolimits_{j=1}^{n} c_{hj}^{(t,t+1)}\lambda_{jk}^{t} = \sum\nolimits_{j=1}^{n} c_{hj}^{(t,t+1)}\lambda_{jk}^{t+1},\ (h = 1, \ldots, H; t = 1, \ldots, T-1; k = 1, 2), \quad (6)$$

$$c_{ho}^{(t,t+1)} = \sum\nolimits_{j=1}^{n} c_{hj}^{(t,t+1)}\lambda_{jk}^{t} + s_{ho}^{(t,t+1)},\ (h = 1, \ldots, H; t = 1, \ldots, T-1; k = 1, 2), \quad (7)$$

$$\sum\nolimits_{j=1}^{n} \lambda_{jk}^{t} = 1,\ (k = 1, 2; t = 1, \ldots, T),$$

$$\lambda_{jk}^{t} \geq 0,\ s_{io}^{t^-} \geq 0,\ s_{ro}^{t^+} \geq 0,\ s_{do}^{t} \text{ and } s_{ho}^{(t,t+1)} \in free. \quad (8)$$

where $s_{io}^{t^-}$ and $s_{ro}^{t^+}$ are, respectively, input and output slacks, s_{do}^{t} is the slack of the free link value, and $s_{ho}^{(t,t+1)}$ is the carry-over deviation, λ_{jk}^{t} is the intensity corresponding to stage k at at time t. The inequality and equality symbols in links and carry-overs correspond to their characteristics as explained in the following. Equations (2) and (3) are the input at stage 1 and output constraints at stage 2. Equations (4) and (5) suggest that the linking activities are freely determined when continuity between inputs and outputs is maintained. Therefore, this case can verify whether the current link flow is appropriate in the light of other DMUs. The link flow may increase or decrease in the optimal solution of the linear programs. Equations (6) and (7) indicate that this corresponds to the carry-over that DMUs can use freely; its value can be increased or decreased from that of the observed one. The deviation from the current value is not directly reflected in the efficiency evaluation, but the continuity condition between two periods detailed below exerts an indirect effect on the efficiency score. Equation (8) represents the assumption of variable returns to scale at stages.

Equations (2), (3), (4), (5), (6), (7), and (8) designate the production possibility set for the objective $DMU_o((o = 1, \ldots, n))$. An optimum solution of Eq. (1), accounting for Eqs. (2), (3), (4), (5), (6), (7), and (8), are written as follows:$\left\{\lambda_{jk}^{t*}, j = 1, \ldots, n;\ s_{io}^{t-*}, i = 1, \ldots, m;\ s_{ro}^{t+*}, r = 1, \ldots, s;\ s_{do}^{t*}, d = 1, \ldots, D;\ s_{ho}^{(t,t+1)*}; h = 1, \ldots, H;\ k = 1, 2;\ t = 1, \ldots, T\right\}$. The present study derives the overall dynamic efficiency, which ranges from zero to unity, by solving the nonoriented function in terms of T for the objective DMU_o as follows:

$$\phi_o^* = Min \frac{1}{2T} \sum\nolimits_{t=1}^{T} \left[1 - \frac{1}{m}\left(\sum\nolimits_{i=1}^{m} \frac{s_{io}^{t-*}}{x_{io}^t}\right)\right] + \left[1 \middle/ \left[1 + \frac{1}{s}\left(\sum\nolimits_{r=1}^{s} \frac{s_{ro}^{t+*}}{y_{ro}^t}\right)\right]\right], \tag{9}$$

Equation (9) is an extended SBM model (Tone 2001) under a nonoriented function, which accounts for superfluous inputs and carry-overs. The dividend of the fraction is the average input-related efficiency, and the divisor is the average inverted output-related efficiency.

The present study derives the periodic efficiency for the objective DMU_o as follows:

$$\pi_o^{t*} = \frac{1}{2}\left(\left[1 - \frac{1}{m}\left(\sum\nolimits_{i=1}^{m} \frac{s_{io}^{t-*}}{x_{io}^t}\right)\right] + \left[1 \middle/ \left[1 + \frac{1}{s}\left(\sum\nolimits_{r=1}^{s} \frac{s_{ro}^{t+*}}{y_{ro}^t}\right)\right]\right]\right), (\forall t) \tag{10}$$

The present study derives the staged efficiency for the objective DMU_o as follows:

$$\eta_o^{k=1*} = \frac{1}{T} \sum\nolimits_{t=1}^{T} \left[1 - \frac{1}{m}\left(\sum\nolimits_{i=1}^{m} \frac{s_{io}^{t-*}}{x_{io}^t}\right)\right], \tag{11}$$

$$\eta_o^{k=2*} = \frac{1}{T} \sum\nolimits_{t=1}^{T} \left[1 \middle/ \left[1 + \frac{1}{s}\left(\sum\nolimits_{r=1}^{s} \frac{s_{ro}^{t+*}}{y_{ro}^t}\right)\right]\right], \tag{12}$$

The present study derives the periodic-staged efficiency for the objective DMU_o as follows:

$$\varphi_{ot}^{k=1*} = \left[1 - \frac{1}{m}\left(\sum\nolimits_{i=1}^{m} \frac{s_{io}^{t-*}}{x_{io}^t}\right)\right], (\forall t) \tag{13}$$

$$\varphi_{ot}^{k=2*} = \left[1 \middle/ \left[1 + \frac{1}{s}\left(\sum\nolimits_{r=1}^{s} \frac{s_{ro}^{t+*}}{y_{ro}^t}\right)\right]\right], (\forall t) \tag{14}$$

The notation for data and variables is summarized in Table 4.

3.4 Rankings based on rough set theory

Based on the concept of boundary region, Pawlak (1982, 2012) proposed rough set theory for dealing with uncertainties and ambiguities. This differs from the general use of statistical inference analysis techniques (Pawlak et al. 1995). Rough set theory has been commonly used in numerous classification issues in recent years because it can effectively deal with data

Table 4 Data and variables

Data			Variables		
Input	x_{ij}^{t}	Input i to DMU_j for stage 1 at time t	Input slack	s_{io}^{t-}	Slack of input i of DMU_o for stage 1 at time t
Output	y_{rj}^{t}	Output r to DMU_j for stage 2 at time t	Output slack	s_{ro}^{t+}	Slack of output r of DMU_o for stage 2 at time t
Link	z_{dj}^{t}	Link d to DMU_j from stage 1 to stage 2 at time t	Link Slack	s_{do}^{t}	Slack of link d of DMU_o from stage 1 to stage 2 at time t
Carry-over	$c_{hj}^{(t,t+1)}$	Carry-over h to DMU_j from time t to time $t+1$	Carry-over	$s_{ho}^{(t,t+1)}$	Slack of carry-over h of DMU_o form time t to time $t+1$
			Intensity	λ_{jk}^{t}	Intensity of DMU_j corresponding to stage k at time t

reduction, develop inductive reasoning, and convey the relevance and classification of data. The main advantages of this theory include the analysis of information without pre-processing information, its ability to deal with qualitative and quantitative data, and the processing of uncertainties. The main advantages of this theory include the analysis of information without pre-processing information, its ability to deal with qualitative and quantitative data, and the processing of uncertainties (Bai et al. 2017; Greco et al. 2010, 2011; Huang et al. 2014; Li et al. 2009). Most importantly, rough set theory enables the present study to rank ITCs based on different combinations of inputs and outputs, wherein the individual effects of inputs, intermediaries, and outputs on the efficiency values of the ITCs can be observed to distinguish efficient DMUs.

Data analysis using rough set theory begins with an information table wherein the data are discretized to determine the irreplaceable relationship between the objects' attributes. Therefore, the decision rules of this tool can be summarized in five steps: (i) constructing an information table that is made up of events or objects (rows) and attributes (columns) (Pawlak 2002); (ii) determining the indiscernibility relation; (iii) approximating the lower and upper approximation of the rough sets; (iv) determining the core and reduct attributes; and (v) setting decision rules using coverage or strength.

In the present study, the DEA approach is combined with rough set theory. The steps implemented using MATLAB are as follows:

Step 1 A two-stage production process for ITCs is established as indicated in Fig. 2. This study utilizes a two-stage SBM DEA model (Tone and Tsutsui 2009), with internal linking activities in a single implementation, to evaluate the internal management efficiency and investment performance of the ITCs. This study employs n ITCs ($j = 1, \ldots, n$) and two stages ($k = 1, 2$). The numbers of inputs, intermediate measures, and outputs are m, D, and r, respectively. The nonoriented two-stage SBM model under the free link activities program problem is as follows:

$$\eta_o = Min \frac{1}{2}\left[\left[1 - \frac{1}{m}\left(\sum_{i=1}^{m} \frac{s_i^-}{x_{io}}\right)\right] + \left[1 \Big/ \left[1 + \frac{1}{s}\left(\sum_{r=1}^{s} \frac{s_r^+}{y_{ro}}\right)\right]\right]\right]$$

$$S.T.$$

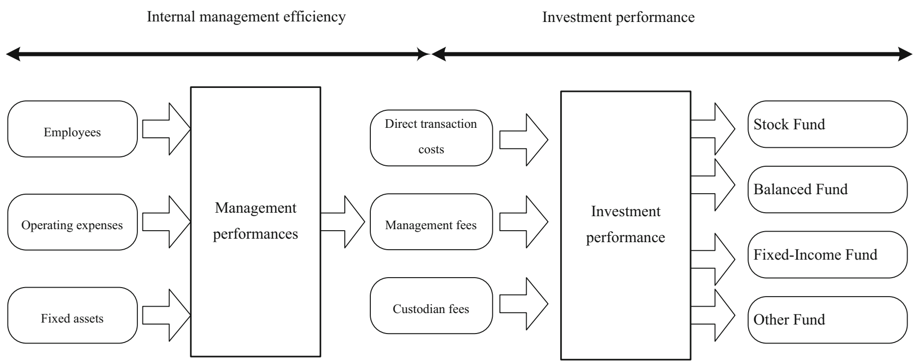

Fig. 2 Two-stage production process for ITCs

$$
\begin{aligned}
&x_{io} = \sum\nolimits_{j=1}^{n} x_{ij}\lambda_{j1} + s_i^-,\ i = 1, \ldots, m \\
&y_{ro} = \sum\nolimits_{j=1}^{n} y_{rj}\lambda_{j2} - s_r^+,\ r = 1, \ldots, s \\
&\sum\nolimits_{j=1}^{n} z_{dj}\lambda_{j2} = \sum\nolimits_{j=1}^{n} z_{dj}\lambda_{j1},\ d = 1, \ldots, D, \\
&z_{do} = \sum\nolimits_{j=1}^{n} z_{dj}\lambda_{j1} + s_{do},\ d = 1, \ldots, D, \\
&\quad \sum\nolimits_{j=1}^{n} \lambda_{jk} = 1,\ k = 1, 2, \\
&\quad \lambda_j^k \geq 0,\ s_i^- \geq 0,\ s_r^+ \geq 0, ,
\end{aligned}
\tag{15}
$$

where x_{ij} is the input i to ITC j at stage 1; z_{dj} is the linking of intermediate product d from stage 1 to stage 2 to the ITC j; y_{rj} is the output r to ITC j at stage two; $\sum_{j=1}^{n} \lambda_{jk} = 1$ suggests that the constructed best practice frontier exhibits variable returns to scale at stage k (Banker et al. 1984). This program problem can be solved through transformation into a linear program using the Charnes and Cooper transformation (Tone 2001).

If $\eta_o^* = 1$ in Eq. (1), the observed ITC is called the overall efficiency. The stage k efficiency score is defined as

$$
\eta_o^{k=1*} = \left[1 - \frac{1}{m}\left(\sum\nolimits_{i=1}^{m} \frac{s_i^{-*}}{x_{io}}\right)\right] \tag{16}
$$

$$
\eta_o^{k=2*} = \left[1 \Big/ \left[1 + \frac{1}{s}\left(\sum\nolimits_{r=1}^{s} \frac{s_r^{+*}}{y_{ro}}\right)\right]\right] \tag{17}
$$

where s_i^{-*} and s_r^{+*} are the optimal input slacks and output slacks in Eq. (1). If $\eta_o^{k=1*} = 1$, then the target ITC is technically efficient at stage 1. If $\eta_o^{k=1*}$ is lower than one, then the target ITC is technically inefficient.

Step 2 This study examines 10 possible different combinations of inputs and outputs for each DMU while calculating their respective efficiency. In the present study, the two-stage production process for ITCs is completed using three inputs, three intermediaries, and four outputs. In the case of fixed intermediaries and outputs, the present study examines the individual effect of input indicators on the efficiency values of the ITCs. Therefore, a total of $10 = (3 + 3 + 4)$ groups of data are obtained. These 10 DEA analyses with different combinations of inputs, intermediaries, and outputs are also used to distinguish efficient units (see Appendices A and B for the derived efficiency scores).[2]

Step 3 Using the efficiency values obtained in Step 2, the present study selects the combinations of performance indicators in the case of fixed inputs, intermediates, and outputs, respectively. This enables the present study to observe the effects of DEA indicators on the sensitivity of inclusion/exclusion of inputs, intermediates, and outputs, which is defined as the condition attribute of the present study. The efficiency analysis model is used to analyze the inputs and outputs of the two stages, and the efficiency values of all possible combinations of inputs and outputs in both stages are obtained. This step enables the present study to extract the most information and determine the advantages and disadvantages of the potential sets of combination from the analyses.

Step 4 The continuous value is transformed into a discrete state, the efficiency values generated by the different combinations are defined as the discrete numerical ranges, and are replaced by equivalents; for example, the efficiency values are divided into (i) 1–0.9, (ii) 0.9–0.6, (iii) 0.6–0.3, (iv) 0.3–0, and (v) 0, and are replaced by the values 4, 3, 2, 1, and 0, respectively.

Step 5 The overall dynamic efficiency of the two-stage production process for ITCs is regarded as the decision attribute of the present study. The overall dynamic efficiency scores are classified into five ranges, viz. (i) 1.00–0.90, (ii) 0.90–0.60, (iii) 0.60–0.30, (iv) 0.30–0.00, and (v) 0, which are substituted by the values of 4, 3, 2, 1, and 0, respectively to construct an information table based on rough set theory.

Step 6 The significance of each condition attribute is calculated based on the decision attribute's degree of dependence on the condition attribute.

Definition 1 *Information systems* In rough set theory, information systems are used to present knowledge. An information system $S = (U, A, V, f)$ consists of: U, a nonempty, finite set named universe, which is a set of objects, $U = \{dm_1, dm_2, \ldots, dm_n\}$; A, a nonempty, finite set of attributes, $A = C \cup D$, in which C is the set of condition attributes and D is the set of decision attributes; $V = \bigcup_{a \in A} V_a$, the domain of a; and $f : U \times A \to V$, an information function. For each $a \in A$ and $dm \in U$, an information function $f(dm, a) \in V_a$ is defined; thus, for each object dm in U, f specifies its attribute value.

Definition 2 *Lower and upper approximation* Let $A = (U, R)$ be an approximation space and let DM be any subset of U. The R-lower approximation of DM, denoted $\underline{R}(DM)$, and R - upper approximation of DM, $\bar{R}(DM)$ are defined by

$$\underline{R}(DM) = \cup\left\{[dm]_R \in U\big/R : [dm] \subseteq DM\right\} \tag{18}$$

and

$$\bar{R}(DM) = \cup\left\{[dm]_R \in U\big/R : [dm] \cap DM \neq \phi\right\}. \tag{19}$$

Definition 3 *Dependability* Suppose $S = (U, A, V, f)$ is a decision table. The dependability between condition attribute C and decision attribute D is defined as:

$$k = \gamma_C(D) = \frac{card(POS_C(D))}{card(U)}, \tag{20}$$

where card(U) represents the cardinal number of sets.

[2] Data will be made available upon request.

Definition 4 *Significance of single attribute and attribute sets* In the aforementioned decision table, the significance of condition attribute subset $C'\left(C' \subseteq C\right)$ related to D is defined as:

$$\sigma_{CD}\left(C'\right) = \gamma_C(D) - \gamma_{C-C'}(D). \tag{21}$$

In particular, $C' = \{a\}$, the significance of a single attribute $a \in C$ related to D is defined as follows:

$$\sigma_{CD}\left(C'\right) = \gamma_C(D) - \gamma_{C-\{a\}}(D). \tag{22}$$

Step 7 Based on the results of Step 6, the condition attribute with a value of 0 is deleted to reduce excess attributes and simplify the calculation process.

Step 8 The significance of the rough set is converted into a value through the weighted average method, whereby the average weight between the input and output combinations is calculated.

Step 9 Rank the ITCs based on the weight values in descending order to provide a reference for selecting ideal ITCs to manage the public service pension fund.

4 Empirical analysis

4.1 ITC performance analysis

To evaluate the overall dynamic operating performance and internal linking activities of the 37 ITCs during 2007–2011, the NDSBM (Tone and Tsutsui 2014) is employed to analyze the efficiency of the ITCs' production process (i.e., the performance evaluation of the internal management efficiency and investment performance). Performance within the preceding year is regarded as short-term performance, within 3 years as medium-term performance, and over 3 years as long-term performance. An observation period of 3–5 years is required to ensure the objectivity and dynamism of the observed fund management performance. The short- ($\leq$ 1 year), medium- ($\leq$ 3 years), and long-term ($\leq$ 5 years) performances of the participating ITCs are analyzed based on the overall efficiency, internal management, and investment, and align with the findings of Kao (2016).

As discussed in Sect. 3.1, the performance of ITCs in the present study is evaluated through internal management efficiency and investment performance, both of which can be summarized into overall efficiency. Table 5 presents an analysis of the ITCs' overall efficiency, particularly the average efficiency scores of 0.792, 0.793, and 0.800 for their short-, medium-, and long-term performances, respectively. The average standard deviation for the last 5 years with a score of 0.091 indicates stable and low-volatility growth in the ITCs. Domestic ITCs reported the strongest performance for all durations. Financial holding ITCs exhibited stronger short- and medium-term performances than foreign investment ITCs did, and the long-term performance of foreign investment ITCs exceeded those of financial holding ITCs. An examination of the long-term overall efficiencies of the companies indicates that JP Morgan, Capital Investment Trust Corporation, and Union Securities Investment Trust Corporation are the most efficient companies. Therefore, these companies should be prioritized if the overall operating performance of ITCs is emphasized among the criteria for selecting commissions for the public service pension fund.

Table 6 presents an analysis of the ITCs' internal management efficiency. The companies exhibited average efficiency scores of 0.769, 0.771, and 0.775 for their short-, medium-, and long-term management performance, respectively. The average standard deviation for the

Table 5 Overall dynamic efficiency of ITCs

Name		Overall dynamic efficiency							
		2007	2008	2009	2010	2011	S.D.	3-year mean	5-year mean
Financial Holding ITCs	Mega International	0.667	0.685	0.931	0.747	0.967	0.126	0.882	0.799
	First Securities	1.000	0.964	0.921	0.735	0.849	0.094	0.835	0.894
	Yuanta	1.000	0.704	1.000	0.871	0.912	0.109	0.928	0.897
	Fubon	0.752	0.628	0.750	0.800	0.725	0.057	0.758	0.731
	Hua Nan	0.673	0.778	0.729	0.543	0.705	0.079	0.659	0.686
	Shin Kong	0.876	0.776	0.658	0.677	0.768	0.078	0.701	0.751
	SinoPac	0.996	0.631	0.592	0.634	0.653	0.149	0.626	0.701
	Truswell	0.782	0.890	1.000	1.000	1.000	0.087	1.000	0.934
	Cathay	1.000	1.000	1.000	1.000	0.866	0.054	0.955	0.973
	Paradigm	0.354	0.376	0.442	0.370	0.413	0.032	0.409	0.391
	Taishin	0.855	0.819	0.991	0.506	0.849	0.160	0.782	0.804
Sub mean		0.814	0.750	0.819	0.717	0.792	0.093	0.776	0.778
Foreign ITCs	HSBC	0.864	0.821	0.715	0.681	0.825	0.071	0.740	0.781
	Invesco	0.520	0.611	0.648	0.624	0.611	0.044	0.628	0.603
	Eastspring	0.915	0.900	0.851	0.876	0.911	0.024	0.879	0.891
	Prudential	0.820	0.837	0.832	0.804	0.853	0.016	0.829	0.829
	JP Morgan	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	UBS	0.999	0.932	1.000	1.000	0.871	0.052	0.957	0.960
	Alliance Bernstein	0.517	0.590	0.712	0.823	0.895	0.140	0.810	0.707
	Pine Bridge	0.852	0.769	0.887	0.827	1.000	0.077	0.905	0.867

Table 5 continued

Name		Overall dynamic efficiency							
		2007	2008	2009	2010	2011	S.D.	3-year mean	5-year mean
	Manulife	1.000	0.599	0.564	0.494	0.501	0.188	0.519	0.632
	BlackRock	0.658	0.611	1.000	0.351	0.260	0.260	0.537	0.576
	ING	0.872	0.942	0.826	0.745	0.711	0.084	0.761	0.819
	Mirae Asset	0.620	0.642	0.655	0.611	0.669	0.021	0.645	0.639
	Allianz	0.880	0.981	0.985	0.947	0.897	0.043	0.943	0.938
	Fidelity	0.805	0.873	1.000	1.000	1.000	0.082	1.000	0.936
	Deutsche Far Eastern	0.895	0.672	0.827	0.750	0.776	0.075	0.784	0.784
	Schroder	1.000	1.000	0.479	0.420	0.357	0.287	0.418	0.651
	Franklin Templeton Sino Am	1.000	0.777	0.851	0.579	0.663	0.147	0.698	0.774
	Sub mean	0.836	0.797	0.814	0.737	0.753	0.095	0.768	0.787
Group ITCs	Uni-President	0.787	0.797	0.726	0.670	0.780	0.048	0.725	0.752
	Polaris	0.950	0.824	0.783	1.000	1.000	0.091	0.928	0.911
	Capital	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	Reliance	0.762	0.808	0.999	0.673	0.705	0.115	0.792	0.790
	Jih Sun	0.938	1.000	0.940	0.938	0.869	0.042	0.916	0.937
	Fuh Hwa	0.682	0.656	0.763	1.000	0.649	0.131	0.804	0.750
	Antorio	0.848	0.476	0.620	1.000	1.000	0.209	0.873	0.789
	Union	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	Value Partners Concord	0.871	0.729	0.647	0.642	0.803	0.089	0.697	0.738
	Sub mean	0.871	0.810	0.831	0.880	0.867	0.081	0.860	0.852
	Overall mean	0.838	0.786	0.820	0.766	0.792	0.091	0.793	0.800

last 5 years with a score of 0.119 suggests that management performance in the operation of these companies are not receiving enough attention, which exhibits substantial differences in volatility. Among the three types of ITCs, domestic ITCs reported the highest scores in management performance, and their short-, medium-, and long-term efficiency scores exceeded the average scores. Foreign investment ITCs exhibited stronger performance in medium- and long-term management and volatility control than financial holding ITCs did, but no significant differences were detected between their short-term management performances. An examination of the long-term management performances of the companies reveal that JP Morgan, Capital Investment Trust Corporation, and Union Securities Investment Trust Corporation are the most competent companies. Therefore, these companies should be prioritized if the overall management performance of ITCs is emphasized among the criteria for selecting commissions for the public service pension fund.

Table 7 presents an analysis of the ITCs' investment performance. The companies received average efficiency scores of 0.897, 0.874, and 0.875 for their short-, medium-, and long-term investment performances, respectively. The average standard deviation for the last 5 years with a score of 0.102 suggests that all the subject companies employ high-yield strategies to attract investors and generate additional income. Among the three types of ITCs, domestic ITCs exhibited the highest scores for management performance for all durations, with a volatility score of 0.057. Financial holding ITCs presented stronger performance in medium- and long-term investment performance and volatility control than foreign investment ITCs did, with little differences between their short-term investment performances. An examination of the long-term investment performances of the companies revealed that seven of the ITCs (i.e., Yuanta Securities Investment Trust Corporation, Cathay Securities Investment Trust Corporation, JP Morgan, Capital Investment Trust Corporation, Fuh Hwa Securities Investment Trust Corporation, Ontario Securities Investment Trust Corporation, and Union Securities Investment Trust Corporation) are the most competent companies. Therefore, these companies should be prioritized if high-yield investment performance is emphasized among the criteria for selecting commissions for the public service pension fund.

4.2 Rough set-based rankings

Before discussing the results of the rough set-based rankings, this study performs Spearman rank-order correlation analyses, which is a nonparametric measure of the degree and sign of association between two ordinal-scale variables. First, as shown in Table 8, this study finds that the rough set-based rankings are highly and significantly correlated with the ordinary rankings of derived DEA scores in both stages (Stage 1: coefficient = 0.918, p value $<$ 0.05; Stage 2: coefficient = 0.982, p-value $<$ 0.05). These results indicate proximity between the two ranking methods. The rough set-based rankings can thus be used to substitute the ordinary rankings by virtue of the feature of rough set theory in considering the effects of the condition attribute on the sensitivity of inclusion/exclusion inputs, intermediates, and outputs. Second, the Spearman rank-order results in Table 8 show that the correlation between Stage-1 rough set-based rankings and Stage-1 network-based rankings is significant (coefficient = 0.642, p-value $<$ 0.05), but that between Stage-2 rough set-based rankings and Stage-2 network-based rankings is not significant (coefficient = 0.290, p-value $>$ 0.05). The inconsistent significance of correlations between the two models suggests that both sets of estimates are dissimilar. Although network-based ranking method[3] has been shown by Liu et al. (2014) to be effective

[3] Readers are encouraged to refer Liu et al. (2009), Liu and Lu (2010), and Liu and Lu (2012) for more information about the network-based ranking method.

Table 6 Internal management efficiency of ITCs

Name		Internal management efficiency							
		2007	2008	2009	2010	2011	S.D.	3-year mean	5-year mean
Financial Holding ITCs	Mega International	0.519	0.655	0.867	0.864	1.000	0.171	0.910	0.781
	First Securities	1.000	0.932	0.851	0.731	0.730	0.108	0.770	0.849
	Yuanta	1.000	1.000	1.000	0.564	0.839	0.170	0.801	0.881
	Fubon	0.753	0.485	0.626	0.606	0.799	0.112	0.677	0.654
	Hua Nan	0.673	0.662	0.817	0.552	0.691	0.084	0.687	0.679
	Shin Kong	0.823	0.808	0.496	0.624	0.608	0.126	0.576	0.672
	SinoPac	1.000	0.497	0.501	0.506	0.515	0.198	0.507	0.604
	Truswell	0.719	1.000	1.000	1.000	1.000	0.112	1.000	0.944
	Cathay	1.000	1.000	1.000	1.000	0.647	0.141	0.882	0.929
	Paradigm	0.252	0.326	0.399	0.342	0.385	0.052	0.375	0.341
	Taishin	0.832	0.864	0.993	0.391	0.710	0.205	0.698	0.758
Sub mean		0.779	0.748	0.777	0.653	0.720	0.134	0.717	0.736
Foreign ITCs	HSBC	0.491	0.940	0.649	0.656	0.698	0.145	0.668	0.687
	Invesco	0.470	0.505	0.548	0.584	0.507	0.039	0.546	0.523
	Eastspring	0.908	0.823	0.796	0.786	0.815	0.043	0.799	0.826
	Prudential	0.811	0.730	0.839	0.736	0.725	0.047	0.767	0.768
	JP Morgan	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	UBS	1.000	1.000	1.000	1.000	0.875	0.050	0.958	0.975
	Alliance Bernstein	0.532	0.565	0.667	0.827	0.914	0.148	0.802	0.701
	Pine Bridge	0.893	0.985	1.000	1.000	1.000	0.042	1.000	0.976

Table 6 continued

Name		Internal management efficiency							
		2007	2008	2009	2010	2011	S.D.	3-year mean	5-year mean
	Manulife	1.000	0.537	0.561	0.467	0.409	0.210	0.479	0.595
	BlackRock	0.568	0.569	1.000	0.350	0.263	0.255	0.538	0.550
	ING	1.000	1.000	1.000	0.912	0.711	0.112	0.874	0.925
	Mirae Asset	0.590	0.611	0.659	0.614	0.663	0.029	0.645	0.627
	Allianz	0.781	1.000	1.000	1.000	0.860	0.091	0.953	0.928
	Fidelity	0.794	0.849	1.000	1.000	1.000	0.089	1.000	0.929
	Deutsche Far Eastern	0.877	0.596	0.792	0.688	0.762	0.096	0.747	0.743
	Schroder	1.000	1.000	0.434	0.396	0.318	0.305	0.383	0.630
	Franklin Templeton Sino Am	1.000	0.834	0.788	0.707	0.692	0.111	0.729	0.804
	Sub mean	0.807	0.797	0.808	0.748	0.718	0.107	0.758	0.776
Group ITCs	Uni-President	0.654	0.755	0.617	0.538	0.645	0.070	0.600	0.642
	Polaris	0.745	0.667	0.824	1.000	1.000	0.134	0.941	0.847
	Capital	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	Reliance	0.724	0.846	1.000	0.676	0.672	0.125	0.783	0.783
	Jih Sun	0.892	1.000	0.882	1.000	1.000	0.055	0.961	0.955
	Fuh Hwa	0.251	0.076	0.232	1.000	1.000	0.403	0.744	0.512
	Antorio	0.852	0.427	0.625	1.000	1.000	0.224	0.875	0.781
	Union	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	Value Partners Concord	0.975	0.884	0.741	0.806	1.000	0.098	0.849	0.881
	Sub mean	0.788	0.739	0.769	0.891	0.924	0.123	0.861	0.822
	Overall mean	0.794	0.768	0.789	0.755	0.769	0.119	0.771	0.775

Table 7 Investment performance of ITCs

Name		Investment Performance							
		2007	2008	2009	2010	2011	S.D.	3-year mean	5-year mean
Financial Holding ITCs	Mega International	1.000	0.734	1.000	0.623	0.941	0.153	0.855	0.860
	First Securities	1.000	1.000	1.000	0.740	1.000	0.104	0.913	0.948
	Yuanta	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	Fubon	0.750	1.000	0.940	0.988	0.638	0.144	0.855	0.863
	Hua Nan	0.673	0.969	0.625	0.519	0.723	0.150	0.622	0.702
	Shin Kong	0.951	0.732	1.000	0.751	1.000	0.120	0.917	0.887
	SinoPac	0.986	0.950	0.843	0.870	0.904	0.052	0.872	0.910
	Truswell	0.992	0.628	1.000	1.000	1.000	0.148	1.000	0.924
	Cathay	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	Paradigm	0.868	0.653	0.735	0.585	0.593	0.105	0.638	0.687
	Taishin	0.912	0.665	0.998	1.000	1.000	0.130	0.999	0.915
Sub mean		0.921	0.848	0.922	0.825	0.890	0.101	0.879	0.881
Foreign ITCs	HSBC	1.000	0.761	0.818	0.718	0.979	0.114	0.838	0.855
	Invesco	0.684	1.000	1.000	0.751	0.927	0.131	0.893	0.873
	Eastspring	0.923	1.000	0.926	0.993	1.000	0.036	0.973	0.968
	Prudential	0.831	0.995	0.823	0.897	1.000	0.076	0.907	0.909
	JP Morgan	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	UBS	0.924	0.475	1.000	1.000	1.000	0.205	1.000	0.880
	Alliance Bernstein	0.487	0.678	0.885	0.565	0.691	0.135	0.714	0.661
	Pine Bridge	0.795	0.485	0.717	0.596	1.000	0.176	0.771	0.719

Table 7 continued

Name		Investment Performance							
		2007	2008	2009	2010	2011	S.D.	3-year mean	5-year mean
	Manulife	1.000	0.849	1.000	0.717	1.000	0.114	0.906	0.913
	BlackRock	0.989	0.954	1.000	0.360	1.000	0.251	0.787	0.860
	ING	0.743	0.881	0.657	0.625	0.711	0.089	0.664	0.723
	Mirae Asset	0.757	0.046	1.000	0.808	0.789	0.328	0.866	0.680
	Allianz	1.000	0.979	0.984	0.929	0.907	0.035	0.940	0.960
	Fidelity	1.000	1.000	1.000	1.000	0.984	0.007	0.995	0.997
	Deutsche Far Eastern	1.000	0.981	0.937	1.000	0.815	0.070	0.917	0.947
	Schroder	1.000	0.956	1.000	0.705	0.735	0.131	0.813	0.879
	Franklin Templeton Sino Am	1.000	0.681	1.000	0.308	0.607	0.261	0.638	0.719
	Sub mean	0.890	0.807	0.926	0.763	0.891	0.127	0.860	0.855
Group ITCs	Uni-President	1.000	0.857	0.923	0.938	1.000	0.053	0.953	0.943
	Polaris	1.000	0.824	1.000	1.000	1.000	0.070	1.000	0.965
	Capital	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	Reliance	0.844	0.722	0.936	0.530	0.868	0.143	0.778	0.780
	Jih Sun	1.000	1.000	0.994	0.881	0.761	0.095	0.879	0.927
	Fuh Hwa	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	Antorio	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	Union	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000
	Value Partners Concord	0.678	0.643	0.363	0.318	0.618	0.152	0.433	0.524
	Sub mean	0.947	0.894	0.913	0.852	0.916	0.057	0.894	0.904
	Overall mean	0.913	0.840	0.922	0.803	0.897	0.102	0.874	0.875

Table 8 Spearman rank-order correlation analyses

	Rough set-based	Network-based	Ordinary
Stage 1—Internal management efficiency			
Rough set-based	1.000		
Network-based	0.642*	1.000	
Ordinary	0.918*	0.668*	1.000
Stage 2—Investment performance			
Rough set-based	1.000		
Network-based	0.290	1.000	
Ordinary	0.982*	0.317	1.000

*Denotes the five per cent significance level

in discriminating efficient DMUs, the method ranks only efficient DMUs, suggesting incomplete rankings. In contrast, the rough set-based ranking method takes into consideration all DMUs under investigation, as well as different combinations of inputs, intermediates, and outputs.

Specifically, rough set theory emphasizes the capacity for data classification and data pattern identification, which is helpful for obtaining specific information from uncertain or unclear data and for examining the classification quality and accuracy of the analysis results. Therefore, rough set theory is widely used in areas such as decision analysis, knowledge discovery from databases, expert systems, and pattern recognition in decision support systems (Pawlak 2002). In the present study, a network dynamic DEA model is first constructed to measure the performance of the companies; these companies are then ranked based on their efficiency after incorporating rough set theory to eliminate the drawbacks of traditional DEA models. Tables 9 and 10 present the empirical results.

The ranking of the management efficiency scores (Table 9) indicate that three companies (i.e., Capital Investment Trust Corporation, Union Securities Investment Trust Corporation, and JP Morgan) are the most competent companies in terms of internal management and utilization of organizational resources. Their ability to obtain the maximum returns on the invested resources is a quality that the other companies should develop. Resources are a crucial element for the organization of a company and serve as a critical catalyst for corporate development and the establishment of a competitive edge. In addition to superior quality resources, companies require the ability to maximize the utility of these resources to gain profits. The synergistic results obtained by combining the feasible resources are more valuable, rare, and inimitable than the effects generated by individual resources. The aforementioned three companies should be prioritized if the deployment of investment strategies for ensuring stable fund growth is emphasized among the criteria for selecting commissions for the public service pension fund. The findings of the first stage can also serve as a reference for ITCs intending to improve their management or resource allocation approaches to enhance operating and management performance.

The ranking investment performance scores (Table 10) also identify the three strongest companies as Capital Investment Trust Corporation, Union Securities Investment Trust Corporation, and JP Morgan. These companies have a positive reputation, their investor market comprises domestic legal persons, they feature a wide range of marketing channels and product lines, they provide comprehensive financial assets and various investment platforms, and they have developed an understanding of industrial trends and investment opportunities in Taiwan and can satisfy investors' market hedging requirements. Therefore, their investment performance is significantly stronger than that of their peers, and these three companies

Table 9 Rankings analysis based on Stage 1—Internal management efficiency

Name	Weight	Rankings	Name	Weight	Rankings
Capital	1.000	1	Mega International	0.792	17
Union	1.000	1	Deutsche Far Eastern	0.791	18
JPMorgan	1.000	1	Yuanta	0.776	19
UBS	0.997	2	Allianz	0.750	20
Value Partners Concord	0.997	2	PineBridge	0.714	21
Truswell	0.992	3	Fuh Hwa	0.679	22
Cathay	0.991	4	Hua Nan	0.662	23
Jih Sun	0.988	5	Ontario	0.654	24
FIL	0.981	6	Alliance Bernstein	0.652	25
Polaris	0.979	7	Uni-President	0.641	26
Schroder	0.967	8	Invesco	0.619	27
Fubon	0.933	9	Reliance	0.614	28
Taishin	0.875	10	ING	0.605	29
Shin Kong	0.873	11	Blackrock	0.561	30
Mirae Asset	0.869	12	Prudential	0.552	31
SinoPac	0.867	13	Franklin Templeton SinoAm	0.515	32
Paradigm	0.852	14	Eastspring	0.504	33
First Securities	0.824	15	HSBC	0.441	34
Manulife	0.806	16			

Table 10 Rankings analysis based on Stage 2—Investment performance

Name	Weight	Rankings	Name	Weight	Rankings
Capital	1.000	1	SinoPac	0.301	18
Union	1.000	1	Prudential	0.283	19
JPMorgan	1.000	1	Reliance	0.239	20
FIL	0.982	2	Alliance Bernstein	0.224	21
UBS	0.954	3	Hua Nan	0.189	22
Fuh Hwa	0.936	4	Fubon	0.166	23
Cathay	0.910	5	Manulife	0.108	24
Polaris	0.884	6	Invesco	0.098	25
Truswell	0.847	7	Paradigm	0.097	26
Eastspring	0.829	8	Schroder	0.096	27
First Securities	0.766	9	Mirae Asset	0.096	27
Jih Sun	0.717	10	PineBridge	0.071	28
Mega International	0.556	11	Uni-President	0.055	29
Yuanta	0.508	12	Blackrock	0.038	30
Allianz	0.478	13	Deutsche Far Eastern	0.037	31
HSBC	0.477	14	Value Partners Concord	0.020	32
Shin Kong	0.473	15	Ontario	0.010	33
ING	0.454	16	Franklin Templeton SinoAm	0.001	34
Taishin	0.390	17			

should be prioritized if the deployment of investment strategies for obtaining high returns is emphasized among the criteria for selecting commissions for the public service pension fund.

5 Conclusion

Based on a dynamic network DEA model, this study constructs a performance evaluation mechanism to assess the production processes of ITCs in Taiwan by analyzing the internal linking activities of these ITCs over a period and incorporating rough set theory into the procedure to rank their efficiency. The present study's results not only serve as a reference for the PSPFMB to select ideal ITCs to manage the public service pension fund but also assist investment trust managers and board directors in improving corporate operating efficiency and developing new management approaches and investment strategies. In addition, the results can be analyzed and used to further assist ITCs to adjust their internal resource allocation and increase the objectivity and rationality of their management decisions on a long-term basis.

Domestic ITCs exhibited the highest management scores over all durations. Foreign investment ITCs presented stronger performance in medium- and long-term management and volatility control than financial holding ITCs did. Domestic ITCs exhibited higher investment performance scores and less volatility than the other two types of ITCs over all durations. Financial holding ITCs performed significantly better in medium- and long-term investment and volatility control than foreign investment ITCs did.

This study incorporates rough set theory into a dynamic two-stage evaluation procedure to rank ITCs based on their performance. The empirical analysis results indicate that, to promote fund safety and profitability, the PSPFM should commission Capital Investment Trust Corporation and JP Morgan. The ITC selection mechanism devised in this study ranks these companies as the highest in terms of management and investment performance, thus making them the ideal companies for managing the public service pension fund. This selection mechanism can objectively judge the adequacy of ITCs based on their professional performance, reduce external investment risks, increase fund management effectiveness, ensure steady accumulation of fund assets, and achieve sustainable fund development. Future studies may also adopt the innovative application of both DEA and rough set theory or other types of fuzzy sets to analyze the investment performance of companies in the financial industry. For example, researchers can rank insurance companies based on different combinations of inputs, intermediates, and outputs that are important for determining their investment efficiencies.

Appendix

See Tables 11, 12.

Table 11 Internal management efficiency scores of 10 different combinations of inputs/intermediates/outputs

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	Ranking
Capital	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Union	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
JPMorgan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
UBS	0.924	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.997
Value Partners Concord	1.000	0.997	1.000	0.999	0.999	0.954	0.999	1.000	0.999	0.999	0.997
Truswell	1.000	0.956	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.992
Cathay	1.000	1.000	0.953	1.000	1.000	1.000	0.861	1.000	1.000	1.000	0.991
Jih Sun	1.000	1.000	0.924	1.000	1.000	1.000	0.890	1.000	1.000	1.000	0.988
FIL	0.484	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.981
Polaris	1.000	1.000	1.000	1.000	0.999	0.612	1.000	1.000	1.000	0.744	0.979
Schroder	0.959	0.997	0.977	0.970	0.970	0.970	0.970	0.906	0.970	0.970	0.967
Fubon	1.000	1.000	0.923	0.894	0.968	0.972	0.966	0.751	0.985	0.985	0.933
Taishin	0.876	1.000	0.880	0.843	0.861	0.861	0.790	0.821	0.826	0.861	0.875
Shin Kong	0.940	0.987	0.891	0.848	0.776	0.900	0.808	0.884	0.817	0.808	0.873
Mirae Asset	0.821	1.000	0.938	0.793	0.793	0.817	0.816	0.793	0.901	0.901	0.869
SinoPac	1.000	0.731	1.000	0.953	0.914	0.859	0.733	0.884	0.782	0.926	0.867
Paradigm	0.956	0.927	1.000	0.838	0.855	0.874	0.865	0.585	0.865	0.865	0.852
First Securities	1.000	0.466	1.000	1.000	1.000	0.576	1.000	1.000	0.608	1.000	0.824
Manulife	0.740	0.758	1.000	0.812	0.801	0.780	0.765	0.737	0.812	0.812	0.806
Mega International	1.000	0.630	0.951	0.949	0.650	0.650	0.995	0.995	0.649	0.650	0.792
Deutsche Far Eastern	0.758	0.779	0.871	0.840	0.805	0.912	0.706	0.733	0.733	0.763	0.791
Yuanta	0.986	0.720	0.998	0.676	0.693	0.693	0.631	0.989	0.669	0.682	0.776
Allianz	0.749	0.914	0.693	0.795	0.648	0.731	0.467	0.666	0.775	0.775	0.750
PineBridge	0.800	0.831	0.744	0.807	0.653	0.595	0.702	0.716	0.533	0.602	0.714

Table 11 continued

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	Ranking
Fuh Hwa	1.000	0.459	0.759	0.639	0.612	0.545	1.000	0.572	1.000	0.711	0.679
Hua Nan	0.539	0.562	0.936	0.650	0.650	0.650	0.650	0.650	0.650	0.650	0.662
Ontario	0.509	0.542	0.957	0.643	0.645	0.645	0.644	0.644	0.644	0.610	0.654
Alliance Bernstein	0.526	0.596	0.920	0.626	0.633	0.637	0.630	0.626	0.630	0.626	0.652
Uni-President	0.534	0.569	0.875	0.606	0.606	0.606	0.606	0.710	0.606	0.606	0.641
Invesco	0.567	0.534	0.813	0.686	0.658	0.628	0.551	0.557	0.557	0.621	0.619
Reliance	0.509	0.545	0.881	0.590	0.593	0.597	0.594	0.593	0.593	0.603	0.614
ING	0.455	0.677	0.639	0.590	0.588	0.575	0.632	0.568	0.595	0.583	0.605
Blackrock	0.648	0.564	0.622	0.702	0.628	0.552	0.429	0.426	0.426	0.651	0.561
Prudential	0.375	0.485	0.762	0.539	0.540	0.538	0.628	0.545	0.540	0.537	0.552
Franklin Templeton SinoAm	0.596	0.561	0.551	0.487	0.485	0.485	0.373	0.506	0.506	0.530	0.515
Eastspring	0.253	0.552	0.651	0.478	0.470	0.458	0.477	0.466	0.505	0.484	0.504
HSBC	0.259	0.395	0.596	0.420	0.413	0.403	0.444	0.424	0.502	0.420	0.441

Column #1 represents the efficiency scores derived after excluding employees. Column #2 represents the efficiency scores derived after excluding operating expenses. Column #3 represents the efficiency scores derived after excluding fixed assets. Column #4 represents the efficiency scores derived after excluding management fees. Column #5 represents the efficiency scores derived after excluding custodian fees. Column #6 represents the efficiency scores derived after excluding direct transaction costs. Column #7 represents the efficiency scores derived after excluding equity funds. Column #8 represents the efficiency scores derived after excluding balanced funds. Column #9 represents the efficiency scores derived after excluding fixed-income funds. Column #10 represents the efficiency scores derived after excluding other funds

Table 12 Investment performance efficiency scores of 10 different combinations of inputs/intermediates/outputs

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	Ranking
Capital	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Union	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
JPMorgan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
FIL	0.003	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.982
UBS	0.003	1.000	1.000	0.007	1.000	1.000	1.000	1.000	1.000	1.000	0.954
Fuh Hwa	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.789	1.000	0.695	0.936
Cathay	1.000	1.000	0.376	1.000	1.000	1.000	0.343	1.000	1.000	1.000	0.910
Polaris	1.000	1.000	0.999	1.000	1.000	0.999	1.000	1.000	1.000	0.184	0.884
Truswell	1.000	0.110	1.000	0.516	1.000	1.000	1.000	1.000	1.000	1.000	0.847
Eastspring	0.848	0.844	0.862	0.848	0.848	0.848	0.705	0.892	0.890	0.715	0.829
First Securities	1.000	0.370	1.000	1.000	1.000	0.568	1.000	1.000	0.451	1.000	0.766
Jih Sun	1.000	1.000	0.107	1.000	0.999	0.571	0.133	1.000	1.000	0.310	0.717
Mega International	0.966	0.304	0.590	0.647	0.545	0.489	0.960	0.994	0.473	0.404	0.556
Yuanta	0.976	0.286	0.976	0.540	0.498	0.428	0.245	1.000	0.505	0.356	0.508
Allianz	0.475	0.475	0.400	0.458	0.505	0.459	0.218	0.405	0.685	0.497	0.478
HSBC	0.482	0.481	0.482	0.482	0.483	0.483	0.376	0.509	0.563	0.407	0.477
Shin Kong	0.503	0.413	0.384	0.487	0.510	0.433	0.410	0.370	0.484	0.666	0.473
ING	0.456	0.456	0.456	0.456	0.456	0.456	0.337	0.672	0.413	0.395	0.454
Taishin	0.472	0.294	0.413	0.425	0.399	0.370	0.469	0.582	0.429	0.275	0.390
SinoPac	0.298	0.322	0.280	0.300	0.283	0.249	0.303	0.299	0.388	0.275	0.301
Prudential	0.270	0.266	0.269	0.269	0.269	0.269	0.192	0.603	0.234	0.221	0.283
Reliance	0.215	0.108	0.215	0.206	0.215	0.207	0.170	0.165	0.174	0.608	0.239
Alliance Bernstein	0.249	0.140	0.249	0.234	0.238	0.227	0.212	0.220	0.219	0.295	0.224
Hua Nan	0.174	0.111	0.174	0.172	0.170	0.151	0.145	0.608	0.137	0.132	0.189

Table 12 continued

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	Ranking
Fubon	0.104	0.101	0.082	0.107	0.100	0.091	0.080	0.887	0.080	0.081	0.166
Manulife	0.113	0.097	0.114	0.114	0.104	0.094	0.099	0.104	0.093	0.151	0.108
Invesco	0.065	0.097	0.102	0.073	0.083	0.073	0.076	0.078	0.084	0.183	0.098
Paradigm	0.051	0.085	0.103	0.101	0.103	0.096	0.092	0.152	0.082	0.087	0.097
Schroder	0.101	0.101	0.058	0.100	0.087	0.101	0.077	0.158	0.086	0.089	0.096
Mirae Asset	0.110	0.065	0.105	0.106	0.097	0.107	0.099	0.147	0.084	0.084	0.096
PineBridge	0.008	0.007	0.007	0.010	0.007	0.008	0.002	0.686	0.007	0.005	0.071
Uni-President	0.034	0.021	0.034	0.033	0.033	0.031	0.025	0.309	0.026	0.026	0.055
Blackrock	0.018	0.038	0.044	0.025	0.031	0.031	0.034	0.034	0.037	0.058	0.038
Deutsche Far Eastern	0.010	0.014	0.014	0.011	0.011	0.011	0.011	0.275	0.010	0.012	0.037
Value Partners Concord	0.020	0.019	0.020	0.020	0.020	0.019	0.015	0.035	0.016	0.017	0.020
Ontario	0.009	0.007	0.009	0.009	0.009	0.009	0.007	0.014	0.007	0.015	0.010
Franklin Templeton SinoAm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.001

Column #1 represents the efficiency scores derived after excluding employees. Column #2 represents the efficiency scores derived after excluding operating expenses. Column #3 represents the efficiency scores derived after excluding fixed assets. Column #4 represents the efficiency scores derived after excluding management fees. Column #5 represents the efficiency scores derived after excluding custodian fees. Column #6 represents the efficiency scores derived after excluding direct transaction costs. Column #7 represents the efficiency scores derived after excluding equity funds. Column #8 represents the efficiency scores derived after excluding balanced funds. Column #9 represents the efficiency scores derived after excluding fixed-income funds. Column #10 represents the efficiency scores derived after excluding other funds

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