Pacific Economic Review

Pacific Economic Review, 22: 4 (2017) pp. 620–648
doi: 10.1111/1468-0106.12235

EFFICIENCY OF TAX COLLECTION AND TAX MANAGEMENT IN TAIWAN'S LOCAL TAX OFFICES

Shwu-Huei Huang *National Taichung University of Science and Technology*
Ming-Miin Yu* *National Taiwan Ocean University*
Ming-Shenq Hwang *National Chengchi University*
Yu-Shan Wei *National Yunlin University of Science and Technology*
Ming-Huei Chen *Taichung City Government*

Abstract. This study investigated the performance of individual departments and the efficiency of resource utilization in tax offices. The results can be used to improve the performance of tax offices and to increase tax revenues. In this study, the operational flow of local tax offices was divided into two stages: tax collection and tax management. Network data envelopment analysis (NDEA) and a Russell directional distance function were used to evaluate operating efficiency in departments of 20 Taiwanese local tax offices for 2013. The results indicated that, first, efficiency was significantly different for tax collection and tax management. Second, the input inefficiency of tax collection was mainly due to total floor area, which was 15% larger than required, and the input inefficiency of tax management was mainly due to total floor area (23% larger than required), followed by direct labour input (19% larger than required). Finally, on average, the amount of collected property transfer taxes was 23% smaller than required. The model used in the present study included undesirable outputs. The findings indicated that the highest levels of overall inefficiency were due to inability to collect taxes (intermediate outputs) in Hsinchu County (9.27%), Chiayi County (3.25%) and Pingtung County (20.44%), which required reduction in the number of instances of inability to collect property taxes by 5619, 1258 and 12 350 cases, respectively. In total, 19 227 fewer cases of uncollectable property taxes in Taiwan would indicate improved arrears settlement and tax prevention measures.

1. INTRODUCTION

Finance is the cornerstone of state operations. The various regions of Taiwan have suffered due to the issue of unequal distribution of financial resources for many years. According to an analysis of certified financial statements for 2013, expenditures were higher than revenues in all the counties and cities of Taiwan, excluding Taoyuan, Yilan, Hsinchu, Nantou, Hualien, Kinmen, Keelung, Hsinchu and Chiayi. Moreover, the percentage of own-source revenues was exceedingly low. Areas with comparatively higher percentages of own-resource revenues included Taipei City (79.18%), New Taipei City (75.51%), Taoyuan City (81.08%), Kinmen County (93.54%), Hsinchu City (75.08%), Taichung City (73.17%) and Kaohsiung City (70.39%). In other areas, own-source revenues accounted for only approximately half of the utilized resources, meaning that these areas depended heavily on government subsidies.

According to statistics, a higher percentage of tax revenues in the total revenues of local governments indicates high fiscal capacity. Thus, tax revenues are given high consideration in local government financial systems, and the efficiency of tax offices is of great importance.

**Address for Correspondence*: Department of Transportation Science, National Taiwan Ocean University, Keelung, Taiwan, ROC. E-mail: yumm@mail.ntou.edu.tw.

Efficiency assessments of the public sector are more complicated than such assessments of the private sector, as the products and services in question cannot be based on market values. These evaluation issues can be overcome by using data envelopment analysis (DEA), which requires input–output information for performance assessments. DEA can process multiple inputs and outputs of different measurement units without the need to assume a production function relationship. This helps to avoid problems associated with parameter estimation. Rigorous analysis is particularly necessary in analysing the public sector, where the input–output relationship is unclear. Thus, DEA was used in the present study to evaluate the performance of the tax offices.

The performance of a local tax office is determined by the careful implementation of full and accurate operation plans. Although they are linked to the overall efficiency of operating flow, the performance of individual departments should be examined separately. In this study, the tax offices' operating flow was divided into the tax collection stage and the tax management stage. The tax offices in different counties and cities were compared with regard to their execution efficiency over both stages, and this information was provided to managers as a reference for making adjustments to input and output allocations.

Traditionally, DEA uses a decision-making unit (DMU) viewed as a 'black box' (Färe and Grosskopf, 2000), and no consideration is given to internal production operations or the network structure of the DMU. DEA assumes that the departments within an organization have similar production technologies and does not consider their actual differences. In other words, the connections between operations of different departments within an organization are ignored in DEA; thus, it cannot provide adequate information on operations management.

Much attention has been recently given to network data envelopment analysis (NDEA), which can be used to evaluate the efficiency of individual departments within a DMU. Previous studies on the efficiency of tax offices have used DEA and have focused on comparing tax offices based on their overall efficiency. By not examining the performance of different departments, however, these studies failed to identify those departments with the lowest levels of operating efficiency that could affect the overall results, which is necessary considering that it is unlikely that all departments have equally low efficiency. Consequently, the managerial implications that could be inferred based on the efficiency results were limited. In this respect, NDEA is a more effective approach than DEA.

In recent years, to support local finance sectors and meet public expectations, Taiwanese local tax offices have been taking measures to improve their administrative performance, with special attention being paid to their performance concerning taxation. The evaluation of tax collection and tax management efficiency can provide a better understanding of the inefficiencies of local offices, which can benefit the state finance sector and promote local development. This study is the first attempt to evaluate the efficiency levels of tax offices using NDEA. The model was expected to provide a more comprehensive and objective analysis, the results of which would help to increase tax revenues. If efficiency scores are determined by radial measures, then inefficiencies where non-radial slack values were not considered may result in deviations in those efficiency scores. To address this issue, this study incorporated the Russell directional distance function proposed by Fukuyama and Weber (2009) in its efficiency evaluations.

The sample used in this study consisted of data collected from 20 Taiwanese local tax offices in 2013. The operating flow was divided into two stages, tax collection and tax management. Once the operations of both stages were completed in the business and management departments, the inputs and outputs observed in the two stages were linked to measure operation and department performance to understand the reasons for different efficiencies and inefficiencies, and to provide a better understanding of the tax offices' strengths and weaknesses. The results can help in the estimation of more efficient resource allocations and serve as a reference for future operations strategies. This study makes the following contributions: (i) it is the first attempt to evaluate tax office performance using NDEA; (ii) inability to collect taxes in both current and prior years was considered; (iii) common inputs were analysed for which the input use cannot be clearly distinguished; and (iv) reasons were determined for the input–output inefficiencies of internal taxation processes and departments.

This paper proceeds as follows. Section 2 provides a review of relevant literature. Section 3 outlines the research methodology and the empirical model. Section 4 presents the empirical results. Section 5 concludes and provides suggestions for tax offices.

2. LITERATURE REVIEW

First proposed by Charnes *et al.* (1978), DEA has been widely used in different fields for performance evaluation, including by both for-profit and nonprofit organizations. Much literature is, therefore, available on the use of DEA. The present study focused on the efficiency levels of tax offices belonging to the government sector and excluded nonprofit organizations. In addition, literature regarding the multi-department NDEA approach was also reviewed.

2.1. Government sector efficiency

Studies on efficiency in the government sector can be divided into those focusing on local governments and those focusing on state governments.

Efficiency in the local government sector was studied by Worthington and Dollery (2002), who used DEA to analyse the cost performance of 173 local governments in New South Wales in Australia in 1993. Stevens (2005) discussed the efficiency of local government departments and public organizations in Britain. According to the findings of Afonso and Fernandes (2005) regarding 51 local governments in Portugal, reducing the utilized resources by 41% would not affect outcomes, meaning that local office performance could be improved without any extra expense. Wang and Tseng (2006) examined the changes in Taiwanese local governments' relative efficiencies in making public expenditures in 2002 and 2003. Their findings showed that reduced scale efficiency resulted in reduced average technical efficiency. Raising financial resources was found to improve efficiency, and it was concluded that the most important strategy to improve efficiency was to plan expenditures based on available resources. Afonse and Fernandes (2007) used a two-stage approach to analyse the relative efficiencies in making public expenditures for 278 local governments of Portugal in 2001. According to their results, to increase efficiency in the public sector, public expenditures must be reduced to a minimum. A two-stage approach was also applied by Teresa *et al.* (2007) in evaluating the efficiencies of local governments in Spain; the results suggested that larger municipalities could better allocate resources.

Efficiency in the state government sector was discussed by Afonso *et al.* (2010), who analysed the government efficiencies of 24 new member states of the European Union and emerging markets. According to their findings, small states were able to reach the efficiency frontier and the same outputs with just one-third of inputs, while other states needed 45% of inputs. Adam *et al.* (2011) evaluated the relative public sector efficiencies of 19 OECD countries; higher efficiency levels were found in right-wing states and in states with more powerful governments, higher voter turnouts and decentralized financial systems. Efficiency across different state governments was examined by Wang and Alvi (2011), who found that (i) based on DEA estimations, Japan and Singapore had the highest levels of allocative efficiency, and (ii) corruption was the key factor affecting government performance. In summary, all of the above studies investigated the efficiencies of the government sector.

2.2. *Tax office efficiency*

The following studies evaluated the efficiencies of tax offices using DEA. Fuentes and Lillo-Bañuls (2015) used a smoothed bootstrap Malmquist index based on the DEA model to analyse the productivity levels of tax offices in Spain. Ruy and Lee (2013) used an input-oriented CCR DEA model to evaluate the efficiencies of tax offices in six regions of Korea and found that they had decreased since the 1997 financial crisis, and that the average efficiency score was 0.62. Alm and Duncan (2014) applied a three-step strategy incorporating DEA and stochastic frontier analysis (SFA) models to evaluate the efficiencies of tax offices in 28 OECD states; overall, it was suggested that the current levels of those countries' revenues could be collected with approximately 10–16% less inputs. Moesen and Persoon (2002) used the non-parametric free disposal method and DEA to evaluate the productive efficiencies of 289 local tax offices in Belgium and found that tax office efficiency was directly related to tax office size. Tsakas and Katharaki (2014) used DEA with bootstrap methods to examine the performance of 35 tax offices in Greece. The DEA model was also used in Barros's (2007) study to evaluate the efficiencies of applied mechanisms and asset allocation in tax offices in Lisbon, Portugal. Barrilao and Villar (2013) used DEA under variable returns to scale to evaluate the overall technical, pure technical and scale efficiency of tax offices in Spain in 2008. Thirtle *et al.* (2000) applied DEA and Malmquist productivity indices to evaluate the tax efficiency in 15 Indian states from 1980 to 1992; the results indicated the small size of tax jurisdictions as a more probable reason for inefficiency than low technical efficiency. Førsund *et al*. (2006) used DEA and Malmquist productivity indices to evaluate the efficiencies of tax offices in Norway and bootstrapping to correct DEA estimations.

To summarize, when the DEA was used in the evaluation of efficiencies in the government sector and tax offices, as demonstrated by the past studies mentioned above, only the overall efficiencies were analysed and which departments contributed most to overall inefficiency was not determined. NDEA can be used to evaluate each efficiency component of a tax office; that is, the efficiencies in each process and department belonging to a so-called 'black box'. As there is a lack of research in this field, this study used NDEA to evaluate the production efficiencies in each taxation phase (department) for 20 Taiwanese local tax offices and compared the efficiencies of internal departments.

2.3. Multi-department network data envelopment analysis

As mentioned above, DEA is mainly used to measure the relative efficiencies of sample DMU based on their input–output ratios. However, it does not consider the internal production structure of DMU and does not provide information on the efficiencies of related activities. Therefore, the managerial implications of DEA-based efficiency results are limited. To address this issue, a growing number of studies have extended the DEA model to include an internal analysis of company production to provide decision-makers with more comprehensive information on efficiency assessments. Castelli *et al*. (2010) classified the DEA models of DMU into shared-flow, multi-level and network models based on the internal structure of the DMU.

Multi-activity data envelopment analysis (MDEA) was first introduced by Beasley (1995) and further revised by Mar Molinero (1996), Cook *et al*. (2000) and Tsai and Mar Molinero (2002). In this model, the operational activity of DMU can be split into different components and production activities which may have shared inputs.

The multi-level DEA model proposed by Cook *et al*. (1998) is based on the analysis of DMU subunits (or sub-DMU), which all have their own production activities. This means that the inputs (or outputs) of DMU are at the same time inputs (or outputs) for subunits. This model can be used to measure the efficiencies of DMU and their subunits.

Network data envelopment analysis was first proposed by Färe and Grosskopf (1996), who examined two-level subunits that form a DMU; network connections were formed through subunit outputs and their transformation into the inputs for subunits of another level, thus introducing the issue of DMU intermediate outputs. This model is sometimes referred to as a two-stage network model. Färe and Grosskopf (2000) later extended the number of DMU subunits, and Tone and Tsutsui (2009) developed a network slack-based model (SBM) that included non-radial slacks.

As shown by the literature review, many studies have been conducted on the application of DEA in the evaluation of operational efficiency. NDEA has been mainly used to evaluate efficiency in insurance companies, restaurants, transportation systems, farmers' associations, pig farms, property management and banks. However, there has been no research on the application of NDEA in the evaluation of tax offices. The operating process of tax offices can be divided into two closely related stages: tax collection and tax management. Together with operations, inputs may be also shared by these two stages. According to the literature review, the main difference between DEA and NDEA is the fact that the internal production components of a DMU are considered by the latter. NDEA evaluates all black box structures; thus, equal effects of processes and departments on overall efficiency are no longer assumed. Using NDEA to evaluate the efficiencies of tax offices can contribute to an understanding of the reasons for their inefficiencies. Consequently, competent authorities can focus on certain departments when giving recommendations on improving an organization's efficiency.

3. METHODS

3.1. Model development

Previous studies on the efficiency of tax offices have mainly focused on the evaluation of relative efficiencies based on the ratio of final outputs to inputs without considering intermediate production activities, such as investigations, tax invoice authorizations, services, the imposition of taxes, the collection of overdue taxes, and administrative remedies. In the traditional one-stage DEA approach, these production processes are seen as a 'black box', and, thus, they were not given much consideration in the present study (Fig. 1).

In this study, the entire taxation process was divided into two stages: tax collection and tax management. The tax collection stage consists of investigation, tax invoice authorization and delivery. The tax management stage includes imposition of taxes, collection of overdue taxes, tax preservative and administrative remedy. These two production stages occur in sequential order. However, the activities within the two stages can occur simultaneously. For instance, tax collection may be conducted together with collection of overdue taxes, administrative remedy or compulsory enforcement measures for delinquent taxes. The collection process can be illustrated by Figure 2.

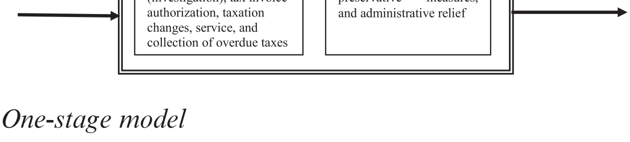

Figure 1. One-stage model

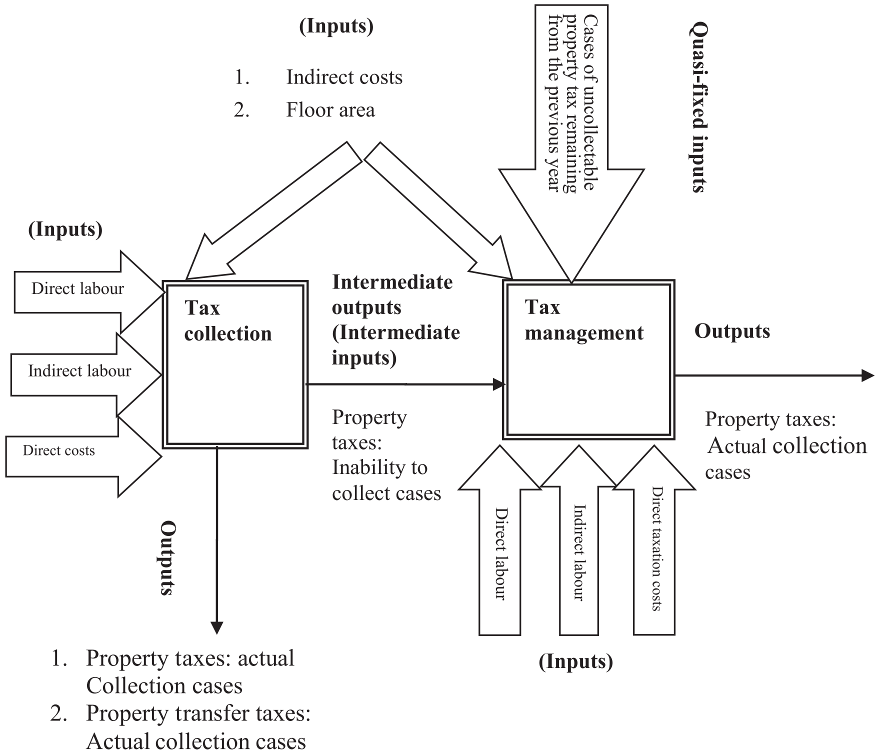

Figure 2. Two-stage tax collection process

Tax collection and tax management are conducted separately by the business and management departments of tax offices. Existing local tax offices have different organizational structures and divisions of labour; departments' names and duties also vary from office to office. However, their actual attributes fall under the classifications described above. For this reason, the process structure (Fig. 2) was developed in this study based on the administrative operations flow chart promulgated by the Ministry of Finance, Taiwan. The results of this study are explained using this classification rather than differences between divisions of labour.

As part of the public sector, local tax offices can also be considered as belonging to the production sector. From an economic point of view, factors of production include labour, capital, land and entrepreneurship. Thus, labour was determined in this study as an important input factor in taxation operations. Based on the review of studies evaluating the efficiencies in local tax offices, direct/indirect labour, direct/indirect costs and floor area were chosen as input factors in this study. Indirect costs included facilities and capital investments. Therefore, the selected inputs corresponded to factors of production as defined in economics.

Costs refer to the expenses associated with collection of taxes and are shared by employees. Definitions of direct and indirect costs are provided in Table 1. Business departments are those that employ direct labour for tax collection. Based on statistics, their direct labour includes first-layer employees; that is, those falling under the direct jurisdiction of property tax, consumption tax and information department units (including employees who directly perform operations related to collection of land value, land value increment, house, vehicle license, and deed taxes). Management departments employ direct labour for tax management. Based on statistics, their direct labour includes second-layer employees; that is, employees of audit, legal affairs, planning and tax management department units, excluding first-layer employees.

Indirect labour involved in the taxation process normally consists of supporting staff, such as directors-general, deputy directors-general, chief secretaries, senior executive officers, secretaries, and the secretariat, personnel office, civil service ethics office and accounting office. Indirect labour used in the business and management departments is calculated as the ratio of direct labour to the two departments. The methods of tax labour calculation are different for Taipei and Kaohsiung, as they were the first special municipalities in Taiwan. Direct labour in these cases is divided into three layers; the third-layer employees fall under the jurisdiction of the second-layer employees (i.e. direct labour of management departments).

Currently, local tax offices in Taiwan are responsible for collecting land value, land value increment, house, vehicle license, deed, stamp, amusement and

Table 1. Definitions of inputs and outputs

Variable	Definition
Input	
Specific inputs	
Direct labour	Number of first-layer and second-layer employees among the total number of tax office employees by the end of 2013.
Indirect labour	Number of senior officers and administrative employees among the total number of tax office employees by the end of 2013.
Direct costs	Include operation costs (relating to operational planning of tax collection), subsidies, and losses.
Common inputs	
Indirect costs	Include operation costs (relating to general administration planning), equipment, investment costs etc.
Floor area	Total floor area of the office (in square metres).
Quasi-fixed inputs	Cases of uncollectable property tax remaining from the previous year.
Output	
Tax collection (Stage 1):	
Intermediate output: Cases of uncollectable tax	The number of cases obtained by subtracting the taxes collected in 2013 from the total number of taxes levied for taxation in 2013.
Final output: Cases of actual collection tax	The number of collected taxes in 2013 was as reported by the Ministry of Finance.
Tax management (Stage 2)	
Final output: cases of actual collection tax	The total number of taxes collected in 2012 and 2013 according to statistics of local taxation, excluding the taxes not collected by the end of 2013.

exceptional taxes in corresponding areas. Exceptional taxes (i.e. local self-government taxes) were not investigated in this study. According to statistics of public finance, among the seven remaining tax categories, higher tax revenues were observed in land value increment, land value, house, vehicle license and deed taxes. For this reason, these five tax categories were selected for analysis in this study. As stamp and amusement taxes historically have low tax revenues, they were not included for discussion. Depending on characteristics of property use, taxes can be divided into property taxes and property transfer taxes. Property taxes include land value, house and vehicle license taxes, while property transfer taxes include land value increment and deed taxes.

Thus, the inputs involved in tax collection performed by business departments include direct and indirect labour, direct and indirect costs, and total floor area. Local tax offices must balance revenues and strengthen tax sources. Local governments calculate their revenues by comparing annual expenditures and incomes to determine whether local tax offices are fulfilling their duties. Tax revenues are mostly affected by the inability to collect taxes. Because property transfers cannot be conducted until land value increment and deed taxes have been paid, arrears are rare in these cases. With regard to the final outputs for tax collection, the present study distinguished between property tax payments and property transfer tax payments. However, intermediate outputs included only uncollectable property tax cases (unfinished outputs), and the focus was placed on the number of taxes collected during the first stage of tax collection.

The inputs for tax management by management departments include direct and indirect labour, direct and indirect costs, and floor area. Because not all taxes can be collected during the tax collection stage, any cases of inability to collect were transformed from intermediate outputs of tax collection into intermediate inputs of tax management. Prior year cases of uncollectable property tax are an important indicator that needs to be considered during efficiency evaluation. Final outcomes are represented by the amount of actual collection of property taxes.

Indirect costs refer to expenditures of supporting staff, and are a common factor shared by both tax collection and tax management stages.

3.2. Network data envelopment analysis model

Black box-based DEA only evaluates the inputs and outputs of an organization and does not examine the production and operation processes. To overcome these limitations, Färe and Grosskopf (2000) developed the NDEA model.

As the taxation process was split into different stages in this study, an issue arose regarding the intermediate outcomes and common factors shared between different production activities (Fig. 2). Russell's (1987) directional distance function was applied to establish a two-stage network DEA model for this study. By incorporating the treatment of shared inputs in the MDEA model proposed by Tsai and Mar Molinero (2002) and the network model proposed by Färe and Grosskopf (1996, 2000), the model used in this study solved the issue of shared factors and intermediate outputs/inputs occurring in the operational process.

The Russell directional distance function also addresses the issue of non-radial slacks not considered in the DEA's radial measurement of efficiency (Cooper *et al.,* 2007; Fukuyama and Weber, 2009; Tone and Tsutsui, 2009). The following sections introduce the production possibility set and two NDEA models constructed using the traditional and Russell directional distance functions.

(1) Production possibility set

First, assume that there are K local tax offices, i.e. $DMU_k(k = 1, 2, \cdots, K)$, and each tax office conducts both tax collection and tax management. During tax collection, $x_{vk}^L(v = 1, 2, \cdots, V)$ specific factors and x_{ck}^{LM} $(c = 1, 2, \cdots, C)$ common factors are used to produce the final outputs $y_{nk}^L(n = 1, 2, \cdots, N)$ in this stage and intermediate outputs $z_{rk}(r = 1, 2, \cdots, R)$, which become inputs for the subsequent stage. For a common factor x_c^{LM}, assume μ_{ck} is the proportion of its use in tax collection. This means that the remainding $(1 - \mu_{ck})x_c^{LM}$ common factor is used in tax management. In addition, this stage involves specific inputs x_{hk}^M $(h = 1, 2, \cdots, H)$, x_{fk}^M $(f = 1, 2, \cdots, F)$ service that was not finished in the previous stage, and z_{rk} intermediate inputs formed during tax collection. $y_{jk}^M(j = 1, 2, \cdots, J)$ final outputs are produced.

Therefore, under variable returns to scale (VRS), two production possibility sets, T^L and T^M, are developed for the two production stages.

First, the production possibility set for tax collection (T^L) is:

$$
\begin{aligned}
T^L = \{ \left(x_{vk}^L, x_{ck}^{LM}, z_{rk}, y_{nk}^L\right) : & \sum_{k=1}^{K} \lambda_k^L x_{vk}^L \le x_v^L, v = 1, \cdots, V \\
& \sum_{k=1}^{K} \lambda_k^L \mu_{ck} x_{ck}^{LM} \le \mu_{ck} x_c^{LM}, c = 1, \cdots, C \\
& \sum_{k=1}^{K} \lambda_k^L z_{rk} \ge z_r, r = 1, \cdots, R \\
& \sum_{k=1}^{K} \lambda_k^L y_{nk}^L \ge y_n^L, n = 1, \cdots, N \\
& \sum_{k=1}^{K} \lambda_k^L = 1 \\
& 0 \le \mu_{ck} \le 1, c = 1, \cdots, C \\
& \lambda_k^L \ge 0, k = 1, \cdots, K\}.
\end{aligned} \tag{1}
$$

Second, the production possibility set for tax management (T^M) is:

$$
\begin{aligned}
T^M = \{ \left(x_{hk}^M, x_{fk}^M, z_{rk}, y_{jk}^M \right) : & \sum_{k=1}^{K} \lambda_k^M x_{hk}^M \le x_h^M, h = 1, \cdots, H \\
& \sum_{k=1}^{K} \lambda_k^M z_{rk} \le z_r, r = 1, \cdots, R \\
& \sum_{k=1}^{K} \lambda_k^M (1 - \mu_{ck}) x_{ck}^{LM} \le (1 - \mu_{ck}) x_c^{LM}, c = 1, \cdots, C \\
& \sum_{k=1}^{K} \lambda_k^M x_{fk}^M \le x_f^M, f = 1, \cdots, F \\
& \sum_{k=1}^{K} \lambda_k^M y_{jk}^M \ge y_j^M, j = 1, \cdots, J \\
& \sum_{k=1}^{K} \lambda_k^M = 1 \\
& 0 \le \mu_{ck} \le 1, c = 1, \cdots, C \\
& \lambda_k^M \ge 0, k = 1, \cdots, K \}.
\end{aligned} \tag{2}
$$

Here, λ_k^L and λ_k^M stand for intensity variables for tax collection and tax management, respectively, which refer to input and output weights of all DMU for the DMU under evaluation reaching the efficiency frontier.

Considering that tax collection and tax management are two internal production processes of a tax office, the production possibility set ($T^{network}$) can be computed as follows:

$$
\begin{aligned}
T^{network} = \{ \left(x_{vk}^L, x_{ck}^{LM}, x_{hk}^M, x_{fk}^M, z_{rk}, y_{nk}^L, y_{jk}^M \right) : & \sum_{k=1}^{K} \lambda_k^L x_{vk}^L \le x_v^L, v = 1, \cdots, V \\
& \sum_{k=1}^{K} \lambda_k^L \mu_{ck} x_{ck}^{LM} \le \mu_{ck} x_c^{LM}, c = 1, \cdots, C \\
& \sum_{k=1}^{K} \lambda_k^L y_{nk}^L \ge y_n^L, n = 1, \cdots, N \\
& \sum_{k=1}^{K} \lambda_k^L z_{rk} \ge \sum_{k=1}^{K} \lambda_k^M z_{rk}, r = 1, \cdots, R \\
& \sum_{k=1}^{K} \lambda_k^M x_{hk}^M \le x_h^M, h = 1, \cdots, H \\
& \sum_{k=1}^{K} \lambda_k^M (1 - \mu_{ck}) x_{ck}^{LM} \le (1 - \mu_{ck}) x_c^{LM}, c = 1, \cdots, C \\
& \sum_{k=1}^{K} \lambda_k^M x_{fk}^M \le x_f^M, f = 1, \cdots, F \\
& \sum_{k=1}^{K} \lambda_k^M y_{jk}^M \ge y_j^M, j = 1, \cdots, J \\
& 0 \le \mu_{ck} \le 1, c = 1, \cdots, C \\
& \sum_{k=1}^{K} \lambda_k^L = 1 \\
& \sum_{k=1}^{K} \lambda_k^M = 1 \qquad . \\
& \lambda_k^L, \lambda_k^M \ge 0, k = 1, \cdots, K \}
\end{aligned} \tag{3}
$$

(2) Two-stage network data envelopment analysis model with Russell directional distance function

According to Färe and Grosskopf (2000), the directional distance function is the most generalized distance function. Therefore, it was used in this study to compute tax offices' productive efficiencies by comparing the distances of their products to the efficiency frontier derived from the production possibility set presented in Equation 3. The orientation for efficiency comparison was based on the principle of economics proposed by Adam Smith, the founder of the Classical school of economics, which stated that expenses associated with tax collection and administrative costs should be minimized to improve taxation efficiency. Similarly, Wagner's principles of sufficiency and cost efficiency maintain that tax revenues should meet the needs of national funds, and tax collection costs should be minimal. Thus, this study used a graph-oriented model to measure efficiency.[1] In tax collection, DMU efficiency was determined by measuring the minimum inputs required to produce maximum outputs. Tax management employs intermediate inputs, and the number of final outputs is determined by the intermediate inputs as well as the inputs used in the first stage. Therefore, a semi-graph-oriented model was used to measure efficiency for the second stage.

The overall relative efficiency of a tax office can be computed based on the two-stage NDEA model equation, which can also identify inefficient units at each stage. The overall relative efficiency of a tax office can be computed based on the two-stage NDEA model equation, which can also identify inefficient units at each stage. To address this issue, the present study applied a two-stage NDEA model and Fukuyama and Weber's (2009) Russell directional distance function. The revised model is presented below:

$$\beta_{k'}^{RLM} = \text{Max} \begin{array}{l} w^L \times \left(\frac{1}{3V} \sum_{v=1}^{V} \beta_{vk'}^{Lx} + \frac{1}{3C} \sum_{c=1}^{C} \beta_{ck'}^{Ls} + \frac{1}{3N} \sum_{n=1}^{N} \beta_{nk'}^{Ly} \right) + \\ w^M \times \left(\frac{1}{3H} \sum_{h=1}^{H} \beta_{hk'}^{Mx} + \frac{1}{3C} \sum_{c=1}^{C} \beta_{ck'}^{Ms} + \frac{1}{3N} \sum_{j=1}^{J} \beta_{jk'}^{My} \right) \end{array} \tag{4}$$

subject to

Tax Collection

$$\sum_{k=1}^{K} \lambda_k^L x_{vk}^L \le \left(1 - \beta_{vk'}^{Lx}\right) x_{vk'}^L, v = 1, \cdots, V \tag{4-1}$$

$$\sum_{k=1}^{K} \lambda_k^L \mu_{ck} x_{ck}^{LM} \le \left(1 - \beta_{ck'}^{Ls}\right) \mu_{ck'} x_{ck'}^{LM}, c = 1, \cdots, C \tag{4-2}$$

[1] Tone and Tsutsui (2009) refer to the graph-oriented model in the study by Färe *et al.* (1985) as a non-oriented model which considers minimum inputs and maximum outputs.

$$\sum_{k=1}^{K} \lambda_k^L z_{rk} \geq z_{rk'}, r = 1, \cdots, R \tag{4-3}$$

$$\sum_{k=1}^{K} \lambda_k^L y_{nk}^L \geq \left(1 + \beta_{nk'}^{Ly}\right) y_{nk'}^L, n = 1, \cdots, N \tag{4-4}$$

$$\sum_{k=1}^{K} \lambda_k^L = 1 \tag{4-5}$$

$$\lambda_k^L \geq 0, k = 1, \cdots, K \tag{4-6}$$

Tax Management

$$\sum_{k=1}^{K} \lambda_k^M x_{hk}^M \leq \left(1 - \beta_{hk'}^{Mx}\right) x_{hk'}^M, h = 1, \cdots, H \tag{4-7}$$

$$\sum_{k=1}^{K} \lambda_k^M x_{fk}^M \leq x_{fk'}^M, \ f = 1, \cdots, F \tag{4-8}$$

$$\sum_{k=1}^{K} \lambda_k^M z_{rk} \leq z_{rk'}, r = 1, \cdots, R \tag{4-9}$$

$$\sum_{k=1}^{K} \lambda_k^M (1 - \mu_{ck}) x_{ck}^{LM} \leq \left(1 - \beta_{ck'}^{Ms}\right) (1 - \mu_{ck'}) x_{ck'}^{LM}, c = 1, \cdots, C \tag{4-10}$$

$$\sum_{k=1}^{K} \lambda_k^M y_{jk}^M \geq \left(1 + \beta_{jk'}^{My}\right) y_{jk'}^M, \ j = 1, \cdots, J \tag{4-11}$$

$$\sum_{k=1}^{K} \lambda_k^M = 1 \tag{4-12}$$

$$\lambda_k^M \geq 0, \ \ k = 1, \cdots, K. \tag{4-13}$$

Property taxes not paid in the previous year must be managed during the current year. Therefore, these cases, which are quasi-fixed inputs in tax management, are indicated by the quasi-fixed input constraint (4-8).

Because minimizing intermediate outputs is preferred, Equations 4-3 and 4-9 can be rewritten as Equations 4–3′ and 4–9′:

$$\sum_{k=1}^{K} \lambda_k^L z_{rk} = z_{rk'} \text{-} s_{rk'}, \ \ r = 1, \cdots, R \tag{4-3'}$$

$$\sum_{k=1}^{K} \lambda_k^M z_{rk} = z_{rk'} \text{-} s_{rk'}, \ \ r = 1, \cdots, R, \tag{4-9'}$$

where $s_{rk'}, \ \ r = 1, \cdots, R$ is a slack variable for intermediate outputs. The only intermediate output in this study was the number of cases with inability to collect property taxes remaining from the previous year (i.e. unfinished work in the tax collection stage); the smallest number of this output is preferred. For tax management, the smallest number of corresponding intermediate inputs is also preferred. Thus, Equations 4-3 and 4-9 in this study were replaced by Equations 4-3′ and 4-9′.

In this study, input efficiency in tax collection was defined as $1 - \left(\frac{1}{2V}\sum_{v=1}^{V}\beta_{vk'}^{Lx} + \frac{1}{2C}\sum_{c=1}^{C}\beta_{ck'}^{Ls}\right)$, output efficiency was defined as $\left(1 + \frac{1}{N}\sum_{n=1}^{N}\beta_{nk'}^{Ly}\right)$ and overall tax-collection efficiency was defined as $\left[1 - \left(\frac{1}{2V}\sum_{v=1}^{V}\beta_{vk'}^{Lx} + \frac{1}{2C}\sum_{c=1}^{C}\beta_{ck'}^{Ls}\right)\right] / \left(1 + \frac{1}{N}\sum_{n=1}^{N}\beta_{nk'}^{Ly}\right)$. If input (output) efficiency of tax collection is equivelent to unity then no input can be contracted (expanded) without leaving the feasible set, and the tax collection process is technically efficient. Conversely, if input (output) efficiency of tax collection is less (larger) than unity, then at least one input (output) can be feasibly contracted (expanded), showing that the tax collection process is technically inefficient. For tax management, input efficiency was defined as $1 - \left(\frac{1}{2H}\sum_{h=1}^{H}\beta_{hk'}^{Mx} + \frac{1}{2C}\sum_{c=1}^{C}\beta_{ck'}^{Ms}\right)$, output efficiency was defined as $\left(1 + \frac{1}{N}\sum_{j=1}^{J}\beta_{jk'}^{My}\right)$ and overall tax management efficiency was defined as $\left[1 - \left(\frac{1}{2H}\sum_{h=1}^{H}\beta_{hk'}^{Mx} + \frac{1}{2C}\sum_{c=1}^{C}\beta_{ck'}^{Ms}\right)\right] / \left(1 + \frac{1}{N}\sum_{j=1}^{J}\beta_{jk'}^{My}\right)$. The explanation of input and output efficiencies of the tax management process are analogous to those of the tax collection process. The overall efficiency of a tax office was defined as the sum of w^L multiplied by the overall tax-collection efficiency and w^M multiplied by the overall tax-management efficiency, where $w^L + w^M = 1$ and w^L, w^M are relative importance weights for taxation units in tax collection and tax management, respectively. In practice, appropriate weights can be determined by decision-makers. Equal importance weights in tax collection and tax management, $w^L = 0.5$ and $w^M = 0.5$, were assumed in this study.

4. EMPIRICAL RESULTS

4.1. *Study sample*

There are 20 local tax offices in charge of levying local taxes in Taiwan. Therefore, the 2013 data for 20 local tax offices used as the samples in this paper cover all the tax offices. Due to the time lag in open government data, the 2013 data were the latest and most complete data available to this study.

The sample included data provided by the Directorate General of Budget, Accounting and Statistics (DGBAS), Executive Yuan, data collected from taxation statistics, final account audit reports, and statistical yearbooks for 20 counties and cities in Taiwan, statistical data from the Ministry of Finance, and departmental databases from Taiwanese local tax bureaus.

4.2. *Inputs and outputs*

The inputs and outputs selected for this study are defined below.

4.3. *Descriptive statistics*

Analysis results for the inputs and outputs of the Taiwanese local tax offices are presented in Table 2. With regard to tax collection inputs, on average, 160.64 person-times were allocated as the direct labour, with a maximum of 479.7 person-times in New Taipei City and a minimum of 23 person-times in Penghu County. On average, 41.79 person-times were allocated as the indirect labour force, with a maximum of 84.31 person-times in New Taipei City and a minimum of 17.81 person-times in Penghu County. In general, counties and cities were found to differ greatly in human resource allocation. The average direct costs were 51.50 million NT dollars, ranging from a minimum of 8 million NT dollars in Penghu County to a maximum of 164 million NT dollars in New Taipei City. The average indirect costs were 23.14 million NT dollars, ranging from a minimum of 4.76 million NT dollars in Penghu County to a maximum of 52.91 million NT dollars in Taipei City. With regard to outputs, on average, 59 700 cases of property transfer taxes and 1 030 550 cases of property taxes were collected, with maximums of 231 000 cases and 3.651 million cases, respectively, in New Taipei City and minimums of 6000 cases and 51 000 cases in Penghu County. On average, 79 250 cases of uncollectable property taxes remained from the prior year, with a maximum of 246 000 cases in New Taipei City and a minimum of 4000 cases in Penghu County.

With regard to tax management inputs, on average, 65.48 person-times were allocated as the direct labour, with a maximum of 246.68 person-times in Taipei City and a minimum of 8 person-times in Penghu County. On average, 18.52 person-times were allocated as the indirect labour force, with a maximum of 57.12 person-times in Kaohsiung City and a minimum of 5.82 person-times in Taitung County. The average direct costs were 21.95 million NT dollars, ranging from a minimum of 3 million NT dollars in Penghu County to a maximum of 66 million NT dollars in Taichung City. The average indirect costs were 10.80 million NT dollars, ranging from a minimum of 2 million NT dollars in Miaoli County to a maximum of 28 million NT dollars in New Taipei City. On average, 75 000 cases of uncollectable property taxes remained from the prior year, with a maximum of 232 000 cases in New Taipei City and a minimum of 6000 cases in Penghu County. On average, 147 700 cases of property taxes were collected, with a maximum of 472 000 Cases in New Taipei City and a minimum of 6000 cases in Penghu County.[2]

[2] Wilson's (1995) method for identifying outliers in production data with multiple inputs and outputs is used in this model.

Table 2. Descriptive statistics of inputs and outputs in tax collection and tax management

	Tax collection (Stage 1)					Tax management (Stage 2)				
	Number	Minimum	Maximum	Mean	Standard deviation	Number	Minimum	Maximum	Mean	Standard deviation
Specific inputs										
Direct labour (person-times)	20	23.00	479.70	160.64	134.71	20	8.00	246.68	65.48	62.73
Indirect labour (person-times)	20	17.81	84.31	41.79	20.18	20	5.82	57.12	18.52	12.59
Direct costs (million)	20	8	164	51.50	46.89	20	3	66	21.95	19.86
Common inputs										
Indirect costs (million)	20	4.76	52.91	23.14	16.81	20	2	28	10.80	8.34
Floor area	20	.14	4.35	1.13	1.14	20	.06	2.77	.56	.63
Quasi-fixed inputs										
Cases of uncollectable property tax remaining from the previous year (thousand)							6	232	75.00	63.93
Intermediate outputs (inputs)										
Cases of uncollectable tax (thousand)	20	4	246	79.25	69.83	20	4	246	79.25	69.83
Final outputs										
Cases of actual collection property transfer tax (thousand)	20	6	231	59.70	66.43	20				
Cases of actual collection property tax (thousand)	20	51	3651	1030.55	1050.91	20	6	472	147.70	135.40

4.4. *Wilcoxon signed-rank test*

Prior to evaluation of the efficiency in Taiwanese local tax offices, first, this study used a Wilcoxon signed-rank test to determine whether there is a statistically significant difference between the black box model and the network Russell directional distance function. Second, the present study applied the Wilcoxon signed-rank test under variable returns to scale to compare tax collection and tax management in terms of their inputs, outputs and overall efficiencies to determine whether the efficiency of black box operations should be analysed separately for these two stages. The Wilcoxon signed-rank test is a non-parametric statistical test used to analyse the differences between paired samples when a normal distribution of the population and equal variances are not assumed. As shown in the first column of Table 3, a Wilcoxon signed-rank test shows that there is a significant difference between the black box model and the network Russell directional distance function. The asymptotic significance is 0.022; therefore, we reject the null hypothesis at the 5% significance level. In addition, the test results indicated a significant difference between tax collection and tax management with regard to their input and output efficiencies at the 5% level of significance (Table 3), which justified the rationality and necessity of splitting the operating flow into two stages.

4.5. *Efficiency evaluation*

As shown by the Wilcoxon signed-rank test results, the tax collection and tax management stages differed significantly in their efficiencies. Thus, results provided by the black box model, which include only overall efficiency analysis, are not sufficient to be used by decision-makers. Evaluation analysis was performed based on the NDEA model presented earlier. Figure 3 and Table 4 show the empirical results for the difference between the black box and the NDEA, the network Russell directional distance function. Therefore, Figure 3 clearly indicates that the discrimination of the NDEA model is superior to that of the black box model, and the ranks of the scores of the two models are not corresponding. The results are given below.

Table 3. Wilcoxon's test results

	Black box – NDEA efficiency	Input efficiency 2 - Input efficiency 1	Output efficiency 2 - Output efficiency 1	Overall efficiency 2 - Overall efficiency 1
Asymptotic significance (two-tailed)	0.022	.028	.012	.594

NDEA, network data envelopment analysis.

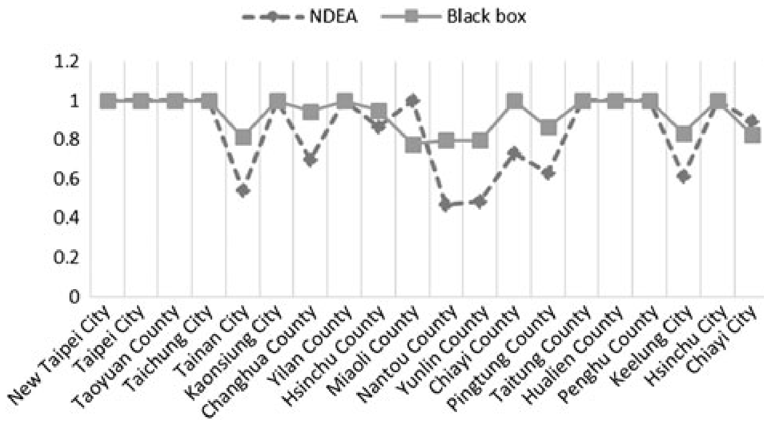

Figure 3. Comparisons of scores between black box and separation models

(1) Efficiency under variable returns to scale

The results regarding pure technical efficiency of the 20 Taiwanese local tax offices are given in Table 4. With regard to tax collection, a total of 12 tax offices had overall efficiencies equal to 1, including the tax offices in New Taipei City, Taipei City, Taoyuan City, Hsinchu City, Miaoli County, Changhua County, Taichung City, Kaohsiung City, Yilan County, Taitung County, Hualien County and Penghu County. The lowest pure technical efficiencies were found in Nantou and Yunlin Counties.

With regard to tax management, 12 tax offices had overall efficiencies equal to 1, including the tax offices in New Taipei City, Taipei City, Taoyuan City, Hsinchu City, Miaoli County, Taichung City, Kaohsiung City, Chiayi City, Yilan County, Taitung County, Hualien County and Penghu County. The lowest pure technical efficiencies were found in Changhua County, Tainan City and Keelung City.

With regard to regional differences, the highest pure technical efficiencies for both tax collection and tax management were observed in Eastern Taiwan and its outlying islands, followed by Northern Taiwan. The lowest pure technical efficiency was observed in Central Taiwan.

Changhua County should be given special attention, as its efficiencies were markedly different between tax collection and tax management, which indicated a significant difference in the efficiencies of local tax offices in the two stages. This provides an additional argument in favour of dividing the operating flow into two stages to identify possible reasons for inefficiencies in local tax offices and to test whether the allocation of their responsibilities is appropriate.

(2) Slack analysis

Slack analysis was used to determine insufficient units and to identify the number of inputs and outputs that need to be reduced and increased,

Table 4. Pure technical efficiencies of local tax offices in Taiwan

Region	County/City	Network							
		Tax collection			Tax management				Black box
		Input efficiency	Output efficiency	Overall efficiency	Input efficiency	Output efficiency	Overall efficiency	Total	
Northern Taiwan	New Taipei City	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Taipei City	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Taoyuan County	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Hsinchu City	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Hsinchu County	0.969	1.002	0.968	0.767	1.000	0.767	0.867	0.952
	Miaoli County	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.777
	Keelung City	0.748	1.027	0.728	0.492	1.000	0.492	0.610	0.832
	Mean	0.960	1.004	0.957	0.894	1.000	0.894	0.925	0.937
Central Taiwan	Nantou County	0.604	1.646	0.367	0.571	1.000	0.571	0.469	0.798
	Changhua County	1.000	1.000	1.000	0.397	1.000	0.397	0.698	0.946
	Yunlin County	0.690	1.775	0.389	0.584	1.000	0.584	0.486	0.796
	Taichung City	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	0.824	1.355	0.689	0.638	1.000	0.638	0.663	0.885
Southern Taiwan	Tainan City	0.752	1.181	0.637	0.444	1.000	0.444	0.540	0.814
	Kaohsiung City	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Chiayi County	0.906	1.362	0.665	0.793	1.000	0.793	0.729	1.000
	Chiayi City	0.838	1.062	0.790	1.000	1.000	1.000	0.895	0.827
	Pingtung County	0.890	1.259	0.707	0.557	1.000	0.557	0.632	0.864
	Mean	0.877	1.173	0.760	0.759	1.000	0.759	0.759	0.901
Eastern Taiwan & Outlaying Islands	Yilan County	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Taitung County	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Hualien County	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Penghu County	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

respectively, to reach the required level of efficiency. The analysis results can be used as a reference to improve efficiency.

Tables 5 and 6 show values for input and output efficiencies with variable returns to scale and slack analysis results in the form of proportions by which input (output) should be reduced (increased) to reach pure technical efficiency.

The tax collection inputs that required the most reduction at all Taiwanese local tax offices included floor area and indirect costs, which could be reduced by 14.69 and 10.94%, respectively. Direct labour, indirect labour and direct costs required 4.66, 6.83 and 2.91% reduction, respectively. With regard to outputs, the number of collected property transfer taxes and property taxes were 23.03and 0.11% lower than required, respectively. In Nantou County, 33.1% less direct labour, 15.4% less indirect labour, 3.7% less direct costs, 76.3% less indirect costs and 69.4% less floor area would be sufficient to produce the same outputs; 127.4% more property transfer taxes and 1.9% more property taxes could be collected with the same inputs. In other words, to improve the efficiency of tax collection in Nantou County, common inputs and the collection of property transfer taxes should be given the highest priority. In Yunlin County, 28.9% less direct labour, 34.8% less indirect labour, 5.7% less direct costs, 5.2% less indirect costs and 80.1% less floor area would be sufficient to produce the same outputs; 155.1% more property transfer taxes could be collected with the same inputs. In other words, to improve the efficiency of tax collection in

Table 5. Input and output efficiencies of tax collection

	Specific inputs			Common inputs		Outputs	
	Direct labour	Indirect labour	Direct costs	Indirect costs	Floor area	Property transfer taxes	Property taxes
New Taipei City	1	1	1	1	1	1	1
Taipei City	1	1	1	1	1	1	1
Taoyuan City	1	1	1	1	1	1	1
Taichung City	1	1	1	1	1	1	1
Tainan City	0.941	0.673	0.742	0.819	0.585	1.362	1
Kaohsiung City	1	1	1	1	1	1	1
Changhua County	1	1	1	1	1	1	1
Yilan County	1	1	1	1	1	1	1
Hsinchu County	0.998	0.97	1	1	0.878	1	1.003
Miaoli County	1	1	1	1	1	1	1
Nantou County	0.669	0.846	0.963	0.237	0.306	2.274	1.019
Yunlin County	0.711	0.652	0.943	0.948	0.199	2.551	1
Chiayi County	1	0.934	1	1	0.596	1.724	1
Pingtung County	0.962	1	1	0.506	0.985	1.517	1
Taitung County	1	1	1	1	1	1	1
Hualien County	1	1	1	1	1	1	1
Penghu County	1	1	1	1	1	1	1
Keelung City	0.902	0.616	0.913	0.557	0.751	1.055	1
Hsinchu City	1	1	1	1	1	1	1
Chiayi City	0.885	0.943	0.858	0.744	0.762	1.123	1
Mean	**0.9534**	**0.9317**	**0.9710**	**0.8906**	**0.8531**	**1.2303**	**1.0011**
Required reduction/ increase	**−0.0466**	**−0.0683**	**−0.02905**	**−0.10945**	**−0.1469**	**0.2303**	**0.0011**

Table 6. Input and output efficiencies of tax management

	Specific inputs			Common inputs		Outputs
	Direct labour	Indirect labour	Direct costs	Indirect costs	Floor area	Property taxes
New Taipei City	1	1	1	1	1	1
Taipei City	1	1	1	1	1	1
Taoyuan City	1	1	1	1	1	1
Taichung City	1	1	1	1	1	1
Tainan City	0.377	0.424	0.57	0.568	0.282	1
Kaohsiung City	1	1	1	1	1	1
Changhua County	0.348	0.49	0.567	0.287	0.292	1
Yilan County	1	1	1	1	1	1
Hsinchu County	0.715	0.759	0.793	0.991	0.577	1
Miaoli County	1	1	1	1	1	1
Nantou County	0.622	0.98	0.772	0.205	0.278	1
Yunlin County	0.549	0.597	0.722	0.872	0.18	1
Chiayi County	0.813	0.853	1	0.768	0.531	1
Pingtung County	0.381	0.535	0.689	0.446	0.732	1
Taitung County	1	1	1	1	1	1
Hualien County	1	1	1	1	1	1
Penghu County	1	1	1	1	1	1
Keelung City	0.423	0.411	0.622	0.469	0.532	1
Hsinchu City	1	1	1	1	1	1
Chiayi City	1	1	1	1	1	1
Mean	0.8114	0.8525	0.8868	0.8303	0.7702	1
Required reduction/ increase	−0.1886	−0.14755	−0.11325	−0.1697	−0.2298	0

Yunlin County, the reduction of floor area and collection of property transfer taxes should be given the highest priority.

On average, 18.86% less direct labour, 14.76% less indirect labour, 11.33% less direct costs, 16.97% less indirect costs and 22.98% less floor area would be sufficient to produce the same outputs during the stage of tax management in 20 Taiwanese local tax offices. In Changhua County, 65.2% less direct labour, 51% less indirect labour, 43.3% less direct costs, 71.3% less indirect costs and 70.8% less floor area would be sufficient to produce the same outputs. In Tainan City, 62.3% less direct labour, 57.6% less indirect labour, 43% less direct costs, 43.2% less indirect costs and 71.8% less floor area would be sufficient to produce the same outputs. In Keelung City, 57.7% less direct labour, 58.9% less indirect labour, 37.8% less direct costs, 53.1% less indirect costs and 46.8% less floor area would be sufficient to produce the same outputs.

In addition, this paper investigates whether the efficiency scores are affected by the regional characteristics of agricultural counties and non-agricultural counties, respectively. As listed in Table 7, the result of performing the Mann–

Table 7. Mann–Whitney U-test

	Agriculture versus non-agriculture
Asymptotic significance	0.000

Whitney *U*-test for agricultural counties, including Changhua County, Nantou County, Yunlin County, Tainan City, Chiayi County and Pingtung County, and the 14 non-agricultural counties, including Taipei City and New Taipei City, demonstrates that the regional differences significantly affect the efficiency scores.

Based on the above, the proportions by which inputs should be reduced and outputs should be increased are different depending on the region and the stage of operations in the tax office. Therefore, each case requires individual improvement. Figures 4–8 show the inefficient units of Taiwanese local tax agencies. Overall, input inefficiencies of tax collection mainly stemmed from the total floor area, while output inefficiencies arose from the number of collected property transfer taxes. As a fixed asset, floor area cannot be changed over the short term, but it can be set as a goal to be improved in the future. The small number of collected property transfer taxes in Nantou and Yunlin may be related to the relatively calm real estate markets in these agricultural counties, resulting from many young people relocating to other counties. Local governments can assist residents by expanding tourism, developing countryside areas, and attracting investments to create employment opportunities for young people, increase local prosperity and revive the property market. Input inefficiency of tax management was mainly due to total floor area, which, as mentioned before, can be considered in the future as an improvement objective. The highest levels of inefficiency of tax management were observed in Changhua County, Tainan City and Keelung City, and were mainly determined by input inefficiency. With regard to fixed inputs, both direct and indirect labour in these areas required over 50% reduction. Floor area as a common input needed to be reduced by over 70% in Changhua County and Tainan City.

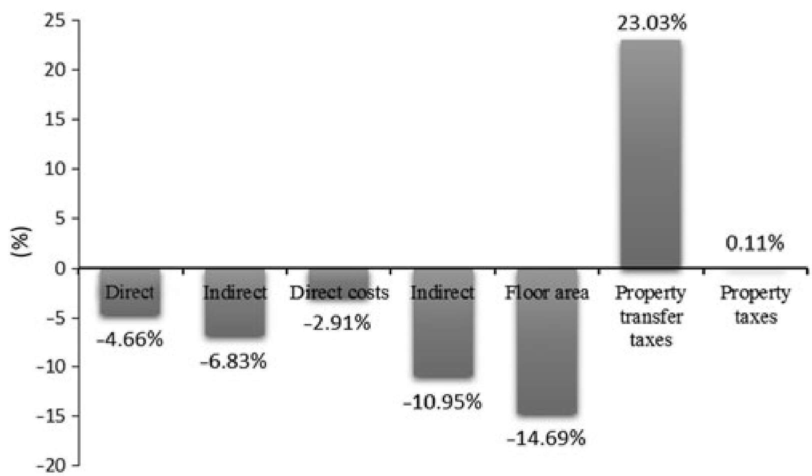

Figure 4. Proportions by which inputs/outputs of tax collection should be reduced/increased

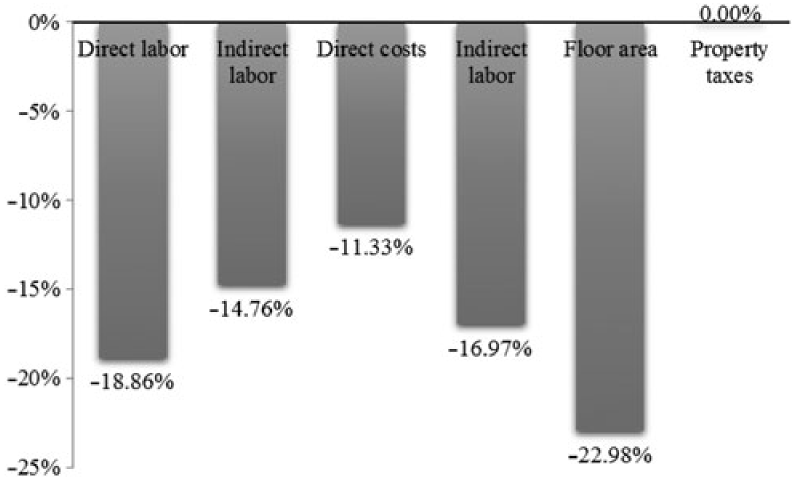

Figure 5. Proportions by which inputs/outputs of tax management should be reduced/increased

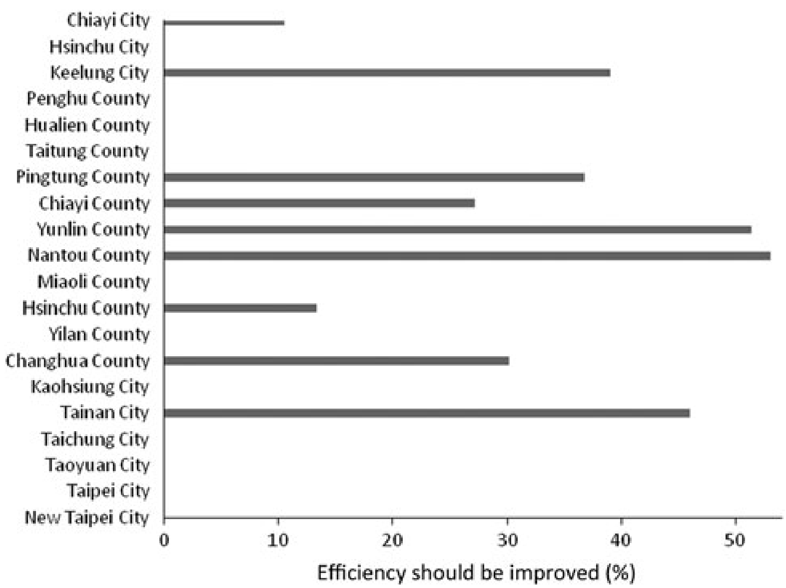

Figure 6. Proportions by which overall efficiency should be improved in Taiwan's local tax offices

(3) Slack analysis for intermediate outputs

As intermediate outputs, property taxes not collected during the stage of tax collection were to be collected during the stage of tax management (Fig. 2).

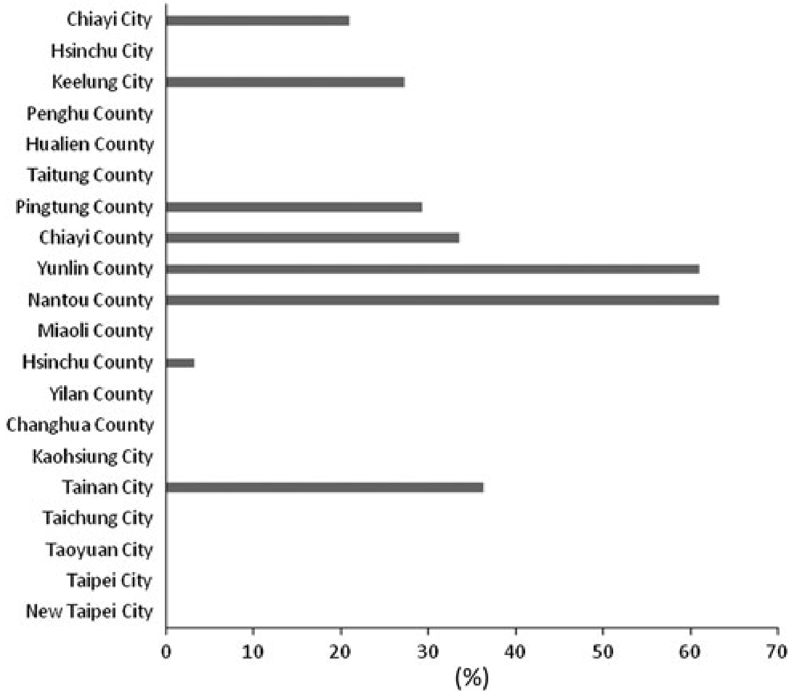

Figure 7. Proportions by which efficiency of tax collection should be improved in Taiwan's local tax offices

Because the minimum possible amount of such taxes is preferred by any tax office, they were considered in the efficiency evaluation. As shown in Table 8, the highest levels of intermediate output (input) inefficiency were observed in Hsinchu, Chiayi and Pingtung Counties, where the amount of uncollectable property taxes needed to be decreased by 9.27% (5619 cases), 3.25% (1258 cases) and 20.44% (12350 cases), respectively. Overall, the amount of uncollectable property taxes in Taiwan needed to be decreased by 19227 cases. Possible reasons for the high intermediate output inefficiency in the three counties mentioned above could include high employee turnover in the tax offices of these non-metropolitan areas as well as their insufficient experience. These issues can be addressed by tax promotion among local residents and by the training of tax officers.

5. MANAGERIAL IMPLICATIONS

Finance is the cornerstone of state operations. Strong financial systems can be built by improving finances on the local level. In recent years, many of the counties and cities of Taiwan have suffered critical financial situations, while also bearing the responsibility to increase treasury revenues. In this respect, the improvement of tax efficiency is of great importance. The objective of tax

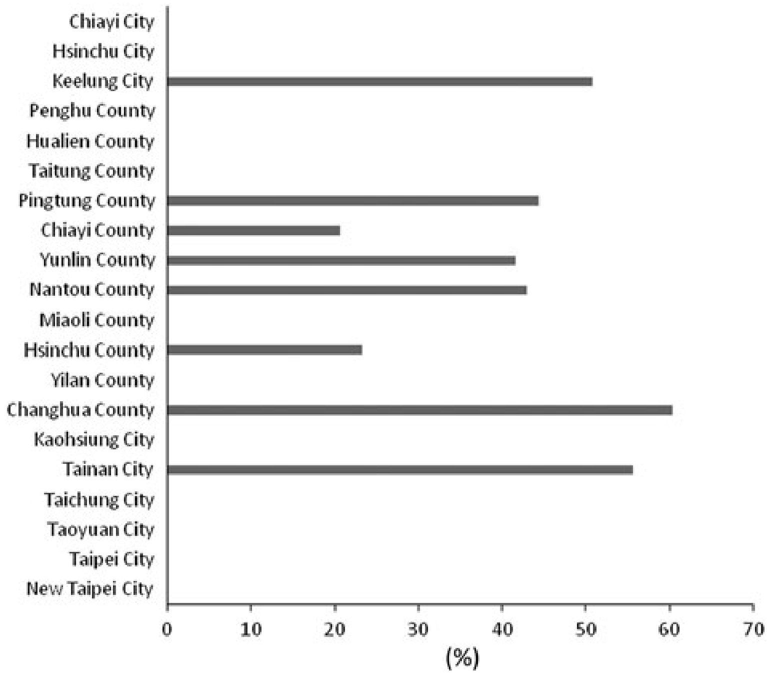

Figure 8. Proportions by which efficiency of tax management should be improved in Taiwan's local tax offices

Table 8. Intermediate output slacks in local tax offices of Taiwan

	Overall efficiency	Intermediate output slacks		Overall efficiency	Intermediate output slacks
New Taipei City	1.000	0.000	Nantou County	0.469	0.000
Taipei City	1.000	0.000	Yunlin County	0.486	0.000
Taoyuan City	1.000	0.000	Chiayi County	0.729	1257.987
Taichung City	1.000	0.000	Pingtung County	0.632	12349.677
Tainan City	0.540	0.000	Taitung County	1.000	0.000
Kaohsiung City	1.000	0.000	Hualien County	1.000	0.000
Changhua County	0.698	0.000	Penghu County	1.000	0.000
Yilan County	1.000	0.000	Keelung City	0.610	0.000
Hsinchu County	0.867	5619.299	Hsinchu City	1.000	0.000
Miaoli County	1.000	0.000	Chiayi City	0.895	0.000

offices is to maximize tax collection, while minimizing expenses. However, performance evaluations previously conducted in tax offices have only considered overall performance levels, thus creating blind spots. In this study, tax offices' operating flow was split into two stages, tax collection and tax management. Each of these stages was analysed for input and output efficiency. Proportions by which inputs and outputs could be reduced or increased were provided as references for the local tax offices. The results can give tax offices a better understanding of tax collection issues and their appropriate solutions, in addition to helping them increase tax revenues by improving tax efficiency. Implications based on the empirical results of this study are given below.

Inefficiency in tax collection was mainly due to output inefficiency, which was, in turn, determined by the number of collected property transfer taxes. Property transfer taxes include land value increment taxes collected at the time of a land transfer, and deed taxes collected at the time of a house transfer. High inefficiency related to the collection of these taxes was observed in Nantou, Yunlin and Chiayi counties. As agricultural counties, these regions face the issue of young people leaving for more urban areas, meaning that a high percentage of local residents are older, and resulting in an inactive real estate market. Hence, governments need to improve resource allocation, support local development, expand tourism, develop countryside areas, and attract investments to create employment opportunities for young people, increase local prosperity and revive the property market. Input inefficiency was found to be mainly due to floor area. In contrast to metropolitan regions, this issue was especially serious and hard to avoid in Yunlin and Nantou Counties, which are vast but sparsely populated areas. However, as a fixed asset, floor area cannot be changed over a short period of time and should be targeted for improvement in the future. Inefficiency in tax management was mainly due to input inefficiency, while its output efficiency was found to be good. Input inefficiency was mainly determined by total floor area, followed by direct labour. Input inefficiency due to total floor area was especially high in Yunlin and Nantou counties and, as mentioned before, total floor areas can be considered as targets for improvement in the future. The highest input inefficiencies for direct labour were observed in Changhua County, Tainan City and Pingtung County, meaning that considerably more unnecessary direct labour was used in these local tax offices than in other regions of Taiwan. It is suggested that local governments reconsider the distribution of labour in tax offices.

The highest levels of intermediate input inefficiency determined by the number of non-collected taxes were observed in Hsinchu, Chiayi and Pingtung Counties. A possible reason for this could be high employee turnover in the tax offices of these non-metropolitan areas. Aside from increased tax promotion among local residents and increased training of tax officers, tax offices should closely cooperate with local administrative enforcement agencies to improve the amount of tax collected during a given period.

There are six special municipalities in Taiwan: New Taipei City, Taipei City, Taoyuan City, Taichung City, Tainan City and Kaohsiung City. The tax offices of all of the six studied Taiwanese special municipalities except for Tainan City demonstrated good performance in both tax collection and tax management. It is suggested that the tax offices in other areas interact with these cities and learn from their experiences. The government should aim at reducing such differences between the various regions of Taiwan, improving their investment environments, expanding public works, enhancing tax promotion efforts, providing further training to regular and temporary workers, and inspecting the distribution of labour in local tax offices.

6. CONCLUSIONS

Local tax offices are responsible for allocating the financial resources of local governments. The results of this study regarding the efficiency of tax offices provide a better understanding of their operational performance. Moreover, the results help to clarify the current situation of internal operations in tax offices as well as the input and output efficiencies of operations and resource allocation efforts conducted by their departments. As such, the results can be used by decision-makers to revise management strategies and by readers to further inspect the operating efficiencies of local tax offices.

In the traditional DEA model, the entire process of tax operations is seen as a 'black box', making it difficult to identify specific inefficient units. More detailed information on the efficiency levels of tax offices cannot be provided due to the interactions between the different internal processes of tax collection. Tax offices' operating flow can be divided into two independent and different stages: tax collection and tax management.

In this study, the operating flow of the tax offices was divided into two stages, and NDEA analysis under variable returns to scale was performed. The results indicated that input inefficiency in tax collection was mainly due to inputs of floor area, which were on average 15% larger than required. Input inefficiency in tax management was also mainly due to floor area inputs (which were 23% larger than required), followed by direct labour inputs (which were 19% larger than required). On average, the number of collected property transfer taxes was 23% lower than required. The highest levels of intermediate input inefficiency were observed in Hsinchu, Chiayi and Pingtung Counties, where the amount of uncollectable property taxes needed to be decreased by 9.27% (5619 cases), 3.25% (1258 cases) and 20.44% (12 350 cases), respectively. Overall, the amount of uncollectable property taxes in Taiwan needed to be decreased by 19 227 cases.

This study differed from previous studies involving efficiency evaluations in that the tax offices' operating flow was seen as consisting of two stages. Moreover, information was provided regarding the proportions by which inputs/outputs needed to be reduced/increased for better efficiency among the tax offices. The results can be referred to by tax offices to improve their performance.

Furthermore, because tax offices seek to minimize levels of non-collected taxes due to their potential damage to local finances, these taxes were included in the NDEA model used in this study as intermediate outputs to provide a more objective evaluation of the tax offices' performance.

Due to the nonlinear nature of the proposed model, this study only guarantees a locally optimal solution. Further research is needed to discuss a sufficient condition showing that a locally optimal solution is also a globally optimal solution, or to modify this model to a linear one for a globally optimal solution.

REFERENCES

Adam A., M. Delis and P. Kammas (2011) 'Public sector efficiency: Leveling the playing field between OECD countries', *Public Choice* 146, 163–683.

Afonse A. and S. Fernandes (2007) 'Assessing and explaining the relative efficiency of local government', *Journal of Socio-Economics* 621, 1–34.

Afonso A. and S. Fernandes (2005) 'Assessing and explaining the relative efficiency of local government: Evidence for Portuguese Municipalities', *Journal of Socio-Economics* 37, 1946–79.

Afonso A., L. Schuknecht and V. Tanzi (2010) 'Public sector efficiency: Evidence for new EU member states and emerging markets', *Applied Economics* 42, 2147–64.

Alm J. and D. Duncan (2014) 'Estimating tax agency efficiency', *Public Budgeting and Finance* 34, 92–110.

Barrilao P. E. and E. Villar (2013) 'The efficiency of the regional management centres of the tax administration in Spain', *Journal of US–China Public Administration* 10, 49–56.

Barros C. P. (2007) 'Technical and allocative efficiency of tax offices: A case study', *International Journal of Public Sector Performance Management* 1, 41–61.

Beasley J. E. (1995) 'Determining teaching and research efficiencies', *The Journal of the Operational Research Society* 40, 441–52.

Castelli L., R. Pesenti and W. Ukovich (2010) 'A classification of DEA models when the internal structure of the decision making units is considered', *Annals of Operations Research* 173, 207–35.

Charnes A., W. W. Cooper and E. Rhodes (1978) 'Measuring the efficiency of decision making units', *European Journal of Operational Research* 2, 429–44.

Cook W. D., M. Hababou and H. J. H. Tuenter (2000) 'Multicomponent efficiency measurement and shared inputs in data envelopment analysis: An application to sales and service performance in bank branches', *Journal of Productivity Analysis* 14, 209–24.

Cook W., D. Chai, J. Doyle and R. Green (1998) 'Hierarchies and groups in DEA', *Journal of Productivity Analysis* 10, 177–98.

Cooper W. W., Huang, Z. Li, S. X. , B. R. Parker and J. T. Pastor (2007) 'Efficiency aggregation with enhanced russell measures in data envelopment analysis', *Socio-Economic Planning Sciences* 41, 1–21.

Färe R. and S. Grosskopf (1996) *Intertemporal production frontiers: With dynamic DEA*. Boston: Kluwer Academic Publishers.

Färe R. and S. Grosskopf (2000) 'Network DEA', *Socio-Economic Planning Sciences* 34, 35–49.

Färe R., S. Grosskopf and C. A. K. Lovell (1985) *The measurement of efficiency of production*. Boston: Kluwer Academic.

Førsund F. R., S. A. Kittelsen, F. Lindseth and D. F. Edvardsen (2006) 'The tax man cometh–But is he efficient?' *National Institute Economic Review* 197, 106–19.

Fuentes R. and A. Lillo-Bañuls (2015) 'Smoothed bootstrap Malmquist index based on DEA model to compute productivity of tax offices', *Expert Systems with Applications* 42, 2442–50.

Fukuyama H. and W. L. Weber (2009) 'A directional slacks-based measure of technical inefficiency', *Socio-Economic Planning Sciences* 43, 274–87.

Mar Molinero C. (1996) 'On the joint determination of efficiencies in a data envelopment analysis context', *The Journal of the Operational Research Society* 47, 1273–9.

Moesen W. and A. Persoon (2002) 'Measuring and explaining the productive efficiency of tax offices: A non-parametric best practice frontier approach', *Tijdschriftvoor Economie en Management* 47, 399–416.

Russell R. R. (1987) 'On the axiomatic approach to the measurement of technical efficiency', in W. Eichhorn (ed.), *Measurement in Economics: Theory and Application of Economic Indices*. Heidelberg: Physica-Verlag, 207–17.

Ruy S. and S. Lee (2013) 'An exploratory study of efficiency in tax jurisdictions', *Advanced Science and Technology Letters* 34, 46–49.

Stevens P. A. (2005) 'Assessing the performance of local government', *National Institute Economic Review* 193, 90–101.

Teresa B. C. M., D. Prior and T. A. Emili (2007) 'On the determinants of local government performance: A two-stage nonparametric approach', *European Economic Review* 51, 425–51.

Thirtle C., B. Shankar, P. Chitkara, S. Chatterjee and M. S. Mohanty (2000) 'Size does matter: Technical and scale efficiency in Indian state tax jurisdictions', *Review of Development Economics* 4, 340–52.

Tone K. and M. Tsutsui (2009) 'Network DEA: A slacks-based measure approach', *European Journal of Operational Research* 197, 243–52.

Tsai P. F. and C. Mar Molinero (2002) 'A variable returns to scale data envelopment analysis model for the joint determination of efficiencies with an example of the UK health service', *European Journal of Operational Research* 141, 21–38.

Tsakas M. and M. Katharaki (2014) 'Impact of environmental factors on the efficiency of tax organizations', *Serbian Journal of Management* 9, 31–43.
Wang E. C. and E. Alvi (2011) 'Relative efficiency of government spending and its determinants: Evidence from East Asian countries', *Eurasian Economic Review* 1, 3–28.
Wang M. S. and Y. H. Tseng (2006) 'An efficiency measurement on operation of own-source revenues of local government in Taiwan: An application of data envelopment analysis', *The Chinese Public Administration Review* 15, 1–29.
Wilson P. W. (1995) 'Detecting influential observations in data envelopment analysis', *Journal of Productivity Analysis* 6, 27–45.
Worthington, A. C. and B. Dollery (2002) Incorporating contextual information in public sector efficiency analyses: A comparative study of NSW local government. *Applied Economics*, 34, 453–64.