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LOCAL GOVERNMENT PERFORMANCE AND ITS ASSOCIATED REWARD POLICIES: THE CONSIDERATIONS OF ECONOMIC GROWTH AND ENVIRONMENT PROTECTION

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ABSTRACT

This paper uses eighteen Taiwanese local governments in 2013 as the decision-making units (DMUs) to evaluate their achievements in economic growth and environmental protection. In particular, we propose performance-based reward policy and slack-based reward policy for encouraging the achievements based on the evaluated efficiency scores and output slacks. Different from previous studies, we consider three undesirable outputs (unemployment, garbage generation, and air pollution) to respond the destructions in economy and environment as governments execute their duties. Empirical results show that most of the local governments are inefficient in three efficiency scores and the technical inefficiency mainly comes from scale inefficiency. All the three undesirable outputs are over-produced relative to a given real disposal income per capita. Ignoring the undesirable outputs will result in biased efficiency evaluations and associated reward policies. In addition, the performance-based reward policy provides a smaller standard deviation of reward share than the slack-based reward policy.

KEYWORDS

environmental destruction, reward policy sharpe ratio, super-efficiency model.

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H11, H23, C44, O44.

1. INTRODUCTION

One of the most debatable issues in economics is the relationship between economic growth and environmental protection (Guo and Ma 2008). While the debate has led to diverse results, the integration of environmental protection into economic growth has become a major concern for many countries and has entered into policy design over the last few years.

Local governments are the basic executive organizations of a country; therefore, their performance in economic growth and environmental protection influences a country's overall operating performance. To improve their operating performance, developed and developing countries such as the US, UK, Japan, and Taiwan have been actively assessing the economic and environmental efficiency of local governments and devising some schemes to induce them to improve the efficiency. Thus, from the policy point of view, evaluating the efficiency of local governments in economic growth and environmental protection and subsidizing their achievements based on the evaluated efficiency indices are helpful for a country to enhance overall operating performance. The objective of this paper is to investigate these two questions.

To achieve this objective, we have to employ an appropriate efficiency evaluation model to measure the operating efficiency of local governments, and then construct available schemes to reward the achievement in the operating efficiency. Data envelopment analysis (DEA) is a well-known nonparametric technique for estimating the relative efficiency of a given set of similar decision-making units (DMUs). The approach does not need to specify a functional form for the relationship between multiple inputs and multiple outputs, and it can calculate various efficiency indices, which makes it possible to conduct a comprehensive evaluation of performance. Thus, the DEA model has been applied to a wide variety of fields, including governmental organization (Worthington and Dollery 2000, Borge et al. 2008,Geys and Moesen 2009, Pan et al. 2011,Wu et al. 2014, Aristovnik et al. 2014), finance (Cummins et al. 2010, Tziogkidis and Siriopoulos 2010,Tsolas and Giokas 2012), education (Moreno and Tadepalli 2002, Pierre and Valerie 2005), and manufacturing (Sufian and Habibullah 2009, Saeidi et al. 2013).

In performing efficiency evaluations of governmental organization, the conventional DEA models (the CCR and BCC models) consider only desirable outputs that generate positive utility. However, undesirable outputs are frequently accompanied with desirable outputs. For example, the undesirable outputs originated from environmental destruction, such as garbage release and air pollution, are produced together with the increase in income, a representative desirable output of economic growth. Fare et al. (1989) indicate that the performance rankings of DMUs are very sensitive to whether undesirable outputs are included in the DEA models. Thus, in measuring a government's operating performance, we have to consider desirable outputs as well as undesirable outputs.

Various methods have been proposed for dealing with undesirable outputs in the DEA models (Tyteca 1997, Scheel 2001, Seiford and Zhu 2002, Silva-Portela et al. 2004, Amirteimoori 2006, Salnykov 2008). Pan et al. (2011) and Wu et al. (2014) argue that these methods encounter some constraints in empirical applications. First, most of them involve complicated mathematical calculations, which cause the application to be inconvenient. Second, they use methods in which undesirable outputs are directly deducted from a specified constant, or undesirable outputs are regarded as inputs, which may ignore the relative importance of desirable and undesirable outputs. Thus, their evaluated efficiency scores are less persuasive. Most importantly, their approaches cannot measure whether undesirable outputs are over-produced relative to desirable outputs. This is particularly important for a country trying to reduce environmental destruction while maintaining economic growth.

Pan et al. (2011) and Wu et al. (2014) employ the concept of the Sharpe ratio, developed in 1966 by William Sharpe, to resolve the above shortcomings in previous studies regarding undesirable outputs. The Sharpe ratio is calculated by dividing the excess return of an investment portfolio by the standard deviation of the portfolio returns (a proxy of investment risk), and it thus represents an investment portfolio's risk-adjusted performance. The desirable output in DEA model corresponds to the excess return in the Sharpe ratio, and the undesirable output is similar to the portfolio risk for risk-averse investors. Thus, the concept of the Sharpe ratio is appropriate for constructing a modified desirable output variable that contains a desirable output/undesirable output pair for use in measuring DEA efficiency indices.

Employing the concept of the Sharpe ratio to construct modified desirable outputs has the following two advantages. First, it integrates any combination of one desirable output and one undesirable output into a new modified (desirable) output, i.e., a modified (desirable) output is expressed as the amounts of desirable output per unit of undesirable output. Thus, a higher the value of the modified desirable output results in a higher the efficiency value under a specific set of inputs. Second, by combining estimated efficiency scores with initial desirable and undesirable outputs and modified output slacks, researchers can easily examine whether an undesirable output is over-produced relative to a specific desirable output under a given set of inputs.

While Pan et al. (2011) and Wu et al. (2014) have provided a good basis for researchers utilizing the Sharpe ratio to deal with the co-existence of desirable and undesirable outputs in the DEA model, they do not state how to construct corresponding subsidy policies to reward local governments' achievements in both economic growth and environmental protection, based on the evaluated efficiency indices and modified desirable output slacks. This paper fills this gap by devising two set of reward policies.

The procedures used to perform our empirical analysis are as follows. First, this paper uses a super-efficiency DEA model to evaluate the relative achievements among local governments. Following Pan et al. (2011) and Wu et al. (2014), the concept of the Sharpe ratio is used for integrating any combination of one desirable output and one undesirable output into a modified (desirable) output. Thus, three modified (desirable) outputs are constructed, i.e., income over unemployment, garbage generation, and air pollution. In the conventional DEA models, an output slack represents the amount of the underlying output that can be increased without altering the efficiency scores of the evaluated DMUs. Thus, a positive modified desirable output slack means that the underlying undesirable output is over-produced relative to the underlying desirable output in the positive modified output. Second, combining the values of the evaluated efficiency scores, modified (desirable) outputs slacks, original desirable outputs, and undesirable outputs, we design two sets of mechanisms for central government to reward the operating performance of local governments.

The proposed reward policies associated with the operating performance of local governments have three traits. First, they consider the achievements of local governments in both economic growth (measured by real per capita disposable income) and environmental protection (measured by unemployment rate, volume of garbage clearance, and air pollution). Thus, the reward policies can balance the economic growth and environmental protection of local governments. Second, they are associated with the evaluated efficiency values, the modified desirable outputs, and the initial inputs and outputs, which satisfy the criteria of efficiency and fairness in resource use. Lastly, the findings in this paper not only contribute to the methodology of performance measurement but have environmental policy implications for central government. To assess the function of this improvement, we use the newest sample of eighteen Taiwanese local governments in 2013.

The rest of this paper is organized as follows. Section 2 briefly introduces the CCR and super-efficiency DEA models. Section 3 presents two sets of reward policies for encouraging the operating performance of local governments, based on the evaluated efficiency indices and initial data set of inputs and outputs. Section 4 describes the selection of input and output variables, the construction of modified (desirable) outputs utilizing the Sharpe ratio, and data sources. Section 5 presents the empirical results and policy implications, and the final section concludes the paper.

2. THE MODELS

This section introduces the DEA models used to evaluate the operating performance of local governments, including the CCR model and super-efficiency model. In the CCR model, the relationship between inputs and outputs is a constant return to scale, and the efficiency of a DMU can be expressed as the maximum ratio of weighted outputs to weighted inputs, subject to the condition that the same ratio for all DMUs must be less than or equal to one. Thus, the CCR model measures an overall efficiency for each DMU, where pure technical efficiency and scale efficiency are aggregated into a single value.

The efficiency score of each DMU_k in a CCR model can be derived from the following model:

$$
\begin{aligned}
&Max\ S_k^{CCR} = \theta + \varepsilon\left(\textstyle\sum_{i=1}^{m} S_{ik}^{-} + \sum_{r=1}^{s} S_{rk}^{+}\right)\\
&s.t.\ \textstyle\sum_{k=1}^{n} \lambda_k x_{ik} + S_{ik}^{-} = x_{ik},\ i = 1,\ldots,m\\
&\textstyle\sum_{k=1}^{n} \lambda_k y_{rk} - S_{rk}^{+} = \theta\, y_{rk},\ r = 1,\ldots,s\\
&\lambda_k, S_{ik}^{-}, S_{rk}^{+} \geq 0,\ k = 1,\ldots,n
\end{aligned} \tag{1}
$$

where S_k^{CCR} is the relative efficiency score of DMU_k; x_{ik}, i =1,…,m and y_{rk}, r =1,…,s are the i-th input and r-th output of DMU_k (k=1,…,n), respectively; S_{ik}^{-} and S_{rk}^{+} represent the i-th input slack and the r-th output slack of the DMU_k, respectively; λ_k denotes the intensity variable of DMU_k, which is used to construct the best practice frontier. ε is an infinitesimal constant. The evaluated unit DMU_k is efficient if the optimal objective value S_k^{CCR} =1, i.e., $\theta = 1$, and inefficient if S_k^{CCR} <1.

The BCC model yields a measure of pure technical efficiency that neglects the impact of the scale size by only comparing a DMU to a unit of similar scale. That is, the BCC model extends the original CCR model to account for technologies that exhibit variable returns to scale. Thus, for a DMU to be considered as CCR efficient, it must have both pure technical efficiency and scale efficiency, and the efficiency score obtained using the BCC model is greater than or equal to the score obtained using the CCR model. In addition, the scale efficiency index can be derived by calculating the ratio of CCR efficiency to BCC efficiency.

Andersen and Petersen (1993) develop a super-efficiency model for ranking the efficient units in the CCR and BCC models. Super-efficiency indicates the extent to which the efficient products exceed the efficient frontier formed by other efficient units. That is, the super-efficiency model involves rerunning the traditional DEA models with the procedures of removing, in turn, each efficient unit and recalculating efficiency score of the resulting change. The super-efficiency scores of a DEA model with constant return to scale are derived from the following model.

$$
\begin{aligned}
&Max\ \ S_k^{SE} = \sum_{r=1}^{s} u_r y_{rk}\\
&s.t.\ \ \sum_{i=1}^{m} v_i x_{il} - \sum_{r=1}^{s} u_r y_{rl} \geq 0 \quad for\ \ l = 1,\ldots,n,\ \ l \neq k\\
&\qquad \sum_{i=1}^{m} v_i x_{ik} = 1\\
&\qquad u_r \geq \varepsilon \quad for\ \ r = 1,\ldots,s
\end{aligned}
$$

$$v_i \geq \varepsilon \quad for\, i=1,\ldots,m \qquad (2)$$

where S_k^{SE} indicates the super-efficiency of DMU*k;* the weights, u_r and v_i, are non-negative. In model (2), the value of S_k^{SE} lies in the interval (1, ∞) for the identified efficiency DMUs, with larger values indicating increasing efficiency, and lies in the interval (0,1] for the identified inefficiency DMUs, with smaller values indicating decreasing efficiency. Super-efficiency scores always benchmark the target DMU on its efficient peers, regardless of its own efficiency level. Thus, this paper employs model (2) to rank the performance of the efficient DMUs in conventional CCR and BCC models. In performing model (2), we consider two inputs (labor and capital, m=2), a desirable output (real disposable per capita income), and three undesirable outputs regarding economic growth and environmental destruction, namely unemployment, garbage generation, and air pollution.

3. REWARD POLICIES ASSOCIATED WITH THE EVALUATED PERFORMANCE

In evaluating the operating performance of local governments, this paper allows for the coexistence of desirable and undesirable outputs, not just desirable outputs as in the specification of the conventional CCR and BCC models. Assume that the desirable outputs and undesirable outputs of DMU$_k$ in the supper-efficiency model are y_{jk}^{D} and y_{hk}^{ND}, *k*=1,…,18*,* $j=1,\ h=1,2,3$, respectively. Employing the Sharpe ratio, the modified (desirable) outputs can be expressed as $y_{hk}^{MD} = y_{jk}^{D} / y_{hk}^{ND}$, $j=1,\ h=1,2,3$. According to models (1) and (2), we can generate the efficiency scores (S_k^{SE} or S_k^{CCR}) and the modified outputs slacks $os_{hk}^{M}(\geq 0)$. If the modified outputs slacks are expressed as the form of percentage ($0 \leq pos_{hk}^{M} \leq 1$).then the optimal undesirable output *h* relative to a given specific desirable output *j* (i.e., the real disposable per capita income in this paper) can be calculated as $y_{hk}^{OND} = y_{hk}^{ND} \times (1 - pos_{hk}^{M})$. That is, the original undesirable output *h* (i.e., unemployment, garbage generation, or air pollution) is over-produced by the amount of $y_{hk}^{ND} \times pos_{hk}^{M}$.

The financial resources of the local governments (municipality, county, or city governments) in Taiwan are composed of the distribution of centrally-allotted tax revenues, grants (general grants and projected-based grants), and several taxes. The former two are so-called the non-self-financing resources, and the last one is the self-financing resources. The general grants from central to local governments include the assistance of basic fiscal deficits of local governments, the imputed assistance of education, social welfare, and infrastructure, and the assistance of the interest differentials of preferential deposits of retired officers. Since local governments have limited abilities in tax collection and in term of their power to set tax rates, the main method of central government has been to use non-self-financing resources: grants and centrally allotted tax revenues, to improve the vertical and horizontal equity in the decentralization system (Huang et al. 2014). Thus, part of the general grants from central to local governments can be designed based on the reward policies proposed by this paper.

If the central government of Taiwan provides a specific amount of reward funds (*SA*) for encouraging the operating performance of local governments, then the reward policies can be designed based on the evaluated efficiency scores S_k and the modified desirable outputs slacks os_{hk}^{M} obtained from model (2). Notably, the evaluated operating performance of local governments in this paper considers achievements in both economic growth and environmental protection. This paper provides two sets of reward policies (Policy A and Policy B) for the reference of central government.

Policy A: Performance-based reward policy

In this policy, all the evaluated local governments can obtain central government's reward based on their relative performance in economic growth and environmental protection of overall local governments. For the *k*-th local government the amounts subsidized from central government are SA_k^{A}:

$$SA_k^{A} = SA \times \left(S_k^{SE} \Big/ \textstyle\sum_{k=1}^{18} S_k^{SE} \right) \qquad (3)$$

where SA is total reward budgets provided by the central government; S_k^{SE} is the technical efficiency score of local government *k* obtained from model (2). Obviously, the higher the performance of local government is, the larger the reward amounts they receive.

Policy B: Slack-based reward policy

This reward policy subsidizes local governments based on the evaluated modified output slacks. For local governments with lower modified outputs slacks, the amounts of reward to encourage their operating performance are higher. Assume that the modified output slack *h* of local government *k* is os_{hk}^{M}, then the subsidy amount of local government *k* is SA_k^{B}, i.e.,

$$SA_k^{B} = r_k^{M} \times SA \qquad k=1,\ldots,18$$

$$r_k^{M} = \left(1 \Big/ \sum_{h=1}^{3} os_{hk}^{M} \right) \Big/ \left(1 \Big/ \sum_{h=1}^{3} \sum_{k=1}^{18} os_{hk}^{M} \right) \qquad (4)$$

where r_k^{M} is the subsidized ratio of the local government *k*.

4. SELECTION OF VARIABLES

The DMUs used in the present paper are 18 Taiwanese local governments in 2013, including New Taipei City, Taipei City, Taichung City, Tainan City, Kaohsiung City, Ilan County, Taoyuan County, Hsinchu County, Miaoli County, Changhua County, Nantou County, Yunlin County, Chiayi County, Pingtung County, Hualien County, Keelung City, Hsinchu City, and Chiayi City. The first five cities are the municipalities in Taiwan. The inputs and outputs (including desirable, undesirable, and modified (desirable) outputs) selected are described as follows.

Inputs

In Economics, production factors include labor, capital, land, and entrepreneurship. Pan et al. (2011) indicate that the executive achievement of a local government can serve as a proxy variable for entrepreneurship and is embedded in its operating performance. In addition, the executive domain of a local government can be considered as the proxy variable for land and is less variable; therefore, it is exogenous to the local government. Thus, the inputs used in benchmark model, model

(1), and model (2) to evaluate the operating efficiency of local governments are labor and capital, which are measured by the number of employment (x_{1k}) and the formation of fixed assets (x_{2k}), respectively.

Outputs

Income is typically regarded as a proxy variable to represent the economic level of a country or region and it represents a desirable output in benchmark model, model (1), and model (2). However, we replace it with real disposable income per capita (y_{1k}^{D}) to exclude the disturbances of taxation, inflation, and population on (nominal) income. To simultaneously include the outputs that represent economic and environmental destructions as local governments conduct their duties, we use three undesirable economic and environmental outputs: unemployment (y_{1k}^{ND}), garbage generation (y_{2k}^{ND}), and air pollution (y_{3k}^{ND}).

To assess the relative importance of the desirable output and the undesirable outputs, to assess whether the undesirable outputs are over-produced relative to the desirable output, and to subsidize the operating performance of local governments, we combine the desirable output and three undesirable outputs to form three modified (desirable) outputs. By employing the concept of the Sharpe ratio, we divide real disposable income per capita (y_{1k}^{D}) by each of the three undesirable outputs to construct three modified outputs: real disposable income per capita with respect to unemployment, garbage generation, and air pollution, which are denoted y_{1k}^{MD} (modified output 1), y_{2k}^{MD} (modified output 2), and y_{3k}^{MD} (modified output 3), respectively. All the data come from the National Statistics of Taiwan, and the measures employed are displayed in Table 1.

TABLE 1: DATA MEASUREMENT

Variable	Symbol	Measurement	Unit
Labor	x_1	Number of employment	Thousands of people
Capital	x_2	Formation of fixed assets	Millions of NT dollars
Income	y_1^{D}	Real disposable income per capita	NT dollars
Unemployment	y_1^{ND}	Unemployment rate	%
Garbage generation	y_2^{ND}	Volume of garbage clearance	Kilos per capita per year
Air pollution	y_3^{ND}	Emissions of ozone and sulfur dioxide	ppm per year

5. EMPIRICAL RESULTS

This section presents the results derived from three constructed DEA models (the benchmark model, model (1), and model (2)) as shown in Table 2. The output used in the benchmark model is the real disposable income per capita, a representative index of economic growth. Three modified outputs in models (1) and (2) are the ratios of real disposable income per capita to unemployment rate, volume of garbage clearance, and air pollution. In addition, technical efficiency can be investigated by decomposing it into pure technical efficiency and scale efficiency.

There are some remarkable findings. First, in the benchmark Model, only Taipei City and New Taipei City reach technical efficiency, whereas Taichung City and Kaohsiung City are the other two local governments with efficiency score over 0.7. These four cities belong to five municipalities in Taiwan. That is, ignoring local governments' undesirable outputs generated from economic growth and environmental destruction, municipalities own the highest operating performance. Second, in the model (1), the average scores of technical efficiency, pure technical efficiency, and scale efficiency are 0.543, 0.799, and 0.651, respectively. That is, most of the city/county governments are inefficient in the three efficiency scores, and the means in the three scores show that the technical inefficiency mainly comes from the scale inefficiency. Third, in model (1), the governments satisfying both technical efficiency and pure technical efficiency are Taipei city, Taoyuan County, and Chiayi City, whereas Hualien County reaches pure technical efficiency. Evidently, once considering the appearance of undesirable outputs and treating the coexistence of desirable and undesirable outputs with the Sharpe ratio, the rankings of efficiency display an extremely different change.

While the evaluation results in model (1) consider the existence of undesirable outputs, the priority rankings of the local governments for both technical efficiency and pure technical efficiency remain unresolved. However, this can be achieved by employing the super-efficiency model, i.e., model (2). From the evaluation results in model (2), we find that Chiayi City has the highest technical efficiency among the three technical efficiency governments. Clearly, the super-efficiency model is useful for ranking the operating performance of local governments with efficiency scores of 1 in the model (1).

TABLE 2: EFFICIENCY SCORES FOR 18 TAIWANESE LOCAL GOVERNMENTS

Evaluation model	Benchmark model	Model (1)			Model (2)
	Efficiency score	Efficiency score			Super-efficiency score
DMU	crse	crse	vrse	scale	crse
New Taipei City	1.000	0.715	0.715	1.000	0.715
Taipei City	1.000	1.000	1.000	1.000	1.123
Taichung City	0.751	0.697	0.697	1.000	0.697
Tainan City	0.123	0.078	0.623	0.126	0.078
Kaohsiung City	0.711	0.713	0.713	1.000	0.713
Ilan County	0.065	0.655	0.932	0.702	0.655
Taoyuan County	0.033	1.000	1.000	1.000	1.009
Hsinchu County	0.046	0.249	0.825	0.301	0.249
Miaoli County	0.078	0.244	0.616	0.396	0.244
Changhua County	0.021	0.126	0.612	0.206	0.126
Nantou County	0.038	0.523	0.816	0.642	0.523
Yunlin County	0.019	0.215	0.599	0.358	0.215
Chiayi County	0.094	0.596	0.827	0.721	0.596
Pingtung County	0.020	0.364	0.714	0.510	0.364
Hualien County	0.024	0.849	1.000	0.849	0.849
Keelung City	0.068	0.579	0.806	0.718	0.579
Hsinchu City	0.109	0.163	0.885	0.184	0.163
Chiayi City	0.046	1.000	1.000	1.000	1.636
Average Efficiency	0.236	0.543	0.799	0.651	

Notes: Model (1) is the CCR model, and model (2) is the super-efficiency model. The inputs in the three evaluation models are the number of employment and the formation of fixed assets. The output in the benchmark model is the real disposable income per capita. However, the outputs in models (1) and (2) are the ratios of real disposable income per capita to unemployment rate, volume of garbage clearance, and air pollution, respectively. crse, vrse and scale denotes technical efficiency from constant return to scale DEA, pure technical efficiency from variable return to scale DEA, and scale efficiency (=crse/vrse), respectively.

The modified output slacks evaluated from super-efficiency model (2) are displayed in Table 3. Evidently, three modified outputs should be increased due to their corresponding positive output slacks. According to the definitions of modified output 1, output 2, and output 3, their corresponding output slacks mean that given a (desirable) real disposal income per capita, undesirable unemployment rate, volumes of garbage clearance and levels of air pollution are over-produced. The overproduction problem is especially obvious for four local governments: Tainan City, Changhua County, Hsinchu City, and Yunlin County. Thus, employing the Sharpe ratio to combine desirable and undesirable outputs and construct new modified outputs allows the relative importance of desirable and undesirable outputs and the overproduction of undesirable outputs to be easily assessed.

Based on the evaluation results in Table 2, we can calculate the rewards of local governments from two different reward policies: Policy A and Policy B. The rankings and distributions of rewards in the benchmark model and Model (2) are extremely different. For the benchmark model, the reward distribution of Policy A is rather uneven and mainly concentrates on four municipalities (Taipei City (23.552%), New Taipei City (23.552%), Taichung City (17.687%), and Kaohsiung City (16.745%)). However, for Model (2), the reward distribution of Policy A is quite even and Chiayi City (15.531%), Taipei City (10.661%), Taoyuan County (9.579%), and Hualien County (8.060%) are the top four reward sharing governments. Evidently, in measuring the operating performance of local governments and its associated reward amounts, ignoring the undesirable outputs (i.e., unemployment rate, volume of garbage clearance, and air pollution) results in a biased reward distribution, and four municipalities (Taipei City, New Taipei City, Taichung City, and Kaohsiung City) occupy most of the reward amounts. For model (2), the reward share of reward policy B shows that Chiayi City (29.579%), Taipei City (12.465%), and Taoyuan County (9.554%) share half of entire reward amounts, whereas Hualien County (8.992%), New Taipei City (8.099%), and Kaohsiung City (6.999%) share half of the remaining reward amounts. That is, the remaining twelve local governments share only one-fourth of entire reward amounts.

In summary, the reward distribution measured by using traditional growth performance model (i.e., the benchmark model) and the performance-based reward policy is biased and displays the largest standard deviation. The reason is that the benchmark model focuses on only one desirable output (economic growth) and ignores the undesirable outputs. In model (2), the performance-based reward policy provides a smaller standard deviation of reward share than the slack-based reward policy (3.825% vs. 7.071%), in spite of their similar rankings of reward share.

TABLE 3: PROPOSED REWARD POLICIES FOR 18 TAIWANESE LOCAL GOVERNMENTS

Reward policy	Policy A		Policy B			
Evaluation model	Benchmark model	Model (2)	Output slack (%)			Model (2)
	Reward share(%)	Reward share(%)	Output 1	Output 2	Output 3	Reward share(%)
New Taipei City	23.552	6.788	0.850	0.830	0.820	8.099
Taipei City	23.552	10.661	0.670	0.580	0.430	12.465
Taichung City	17.687	6.617	1.310	1.280	1.150	5.430
Tainan City	2.897	0.740	20.890	21.050	21.220	0.321
Kaohsiung City	16.745	6.769	1.140	0.900	0.890	6.999
Ilan County	1.531	6.218	1.360	1.430	1.460	4.767
Taoyuan County	0.777	9.579	0.720	0.820	0.610	9.554
Hsinchu County	1.083	2.364	9.590	9.720	9.760	0.696
Miaoli County	1.837	2.316	9.710	9.800	9.840	0.690
Changhua County	0.495	1.196	13.780	14.200	14.020	0.482
Nantou County	0.895	4.965	2.850	2.920	2.880	2.340
Yunlin County	0.447	2.041	12.570	11.540	12.400	0.555
Chiayi County	2.214	5.658	1.640	1.700	1.710	4.010
Pingtung County	0.471	3.455	6.110	6.280	6.210	1.088
Hualien County	0.565	8.060	0.730	0.820	0.710	8.992
Keelung City	1.602	5.496	1.990	1.910	1.980	3.444
Hsinchu City	2.567	1.547	13.580	13.890	13.780	0.491
Chiayi City	1.083	15.531	0.510	0.350	0.120	29.579
Standard Deviation	8.331	3.825				7.071

Notes: The reward sharing ratios are calculated from the technical efficiency scores of local governments. The output slack is expressed as the ratio of the output slack of individual local government to the overall output slack of all local governments. In the slack-adjusted DEA model (1), a weakly efficient DMU will be evaluated as inefficient, due to the presence of input and output slacks; therefore, the output slacks in the table are positive.

6. CONCLUSION

This paper employs the super-efficiency model and Sharpe ratio to evaluate the operating performance of 18 Taiwanese local governments and proposes two sets of reward policies (performance-based reward policy and slack-based reward policy) to encourage the performance. In evaluating the performance, we simultaneously consider local governments' achievements in economic growth and environmental protection. Economic growth is measured by real disposable income per capita and unemployment rate, and environmental protection is measured by the volume of garbage clearance and the emissions of ozone and sulfur dioxide. The Sharpe ratio is used for integrating any combination of one desirable output and one undesirable output into a modified (desirable) output.

Empirical results have the following findings. First, most of the city/county governments are inefficient in the three efficiency scores and the technical inefficiency mainly comes from scale inefficiency. Second, for most local governments, undesirable unemployment rate, volumes of garbage clearance and levels of air pollution are over-produced relative to a given real disposal income per capita. Third, in measuring the operating performance of local governments and its associated reward amounts, ignoring the undesirable outputs (i.e., unemployment rate, volume of garbage clearance, and air pollution) will result in a biased reward distribution, which causes four municipalities share most of the reward amounts. In addition, the performance-based reward policy provides a smaller standard deviation of reward share than the slack-based reward policy.

According to the empirical results, this study proposes the following policy recommendations. First, the super-efficiency model and Sharpe ratio provide available approaches to measure the performance of DMUs with efficiency score 1 in traditional DEA model and undesirable outputs. Second, in designing reward policies to encourage local governments' achievements in their duties, central government needs to consider the undesirable outputs such as unemployment, garbage generation, and air pollution. Third, using the evaluated efficiency scores and/or output slacks to construct reward policies is a proper method to reward local governments' achievements in economic growth and environmental protection.

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