Research Article
The Efficiency of Economic Performance, Electricity Consumption, and Environmental Pollutants in Taiwan

Wen-jie Zou,1 Tai-Yu Lin,2 Yung-ho Chiu,3 Ting Teng,4 and Kuei Ying Huang3

1Institute of Economics of Fujian Normal University, Fuzhou, China
2Department of Business Administration, National Cheng Kung University, No.1, University Road, Tainan City 701, Taiwan
3Department of Economics, Soochow University 56, Kueiyang St., Sec. 1, Taipei 10048, Taiwan
4Business School, Soochow University 56, Kueiyang St., Sec. 1, Taipei 10048, Taiwan

Correspondence should be addressed to Tai-Yu Lin; eickyla@gmail.com

Received 10 January 2020; Revised 5 April 2020; Accepted 17 April 2020; Published 5 May 2020

Academic Editor: Gaetano Zizzo

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Finding the balance between economic development and environmental protection is a major problem for many countries around the world. Air pollution caused by economic growth has caused serious damage to humans’ living environment, and as improving energy and resource efficiencies is the first priority, many countries are targeting to move towards a sustainable environment and economic development. This study uses the modified dynamic SBM (slack-based measure) model to explore the economic efficiency and air pollutants emission efficiency in Taiwan’s counties and cities from 2012 to 2015 by taking labor, motor vehicles, and electricity consumption as inputs and average disposable income as output. Particulate matter (PM$_{2.5}$), nitrogen oxide emissions (NO$_2$), and sulfur oxide emissions (SO$_2$) are undesirable outputs, whereas factory fixed assets are a carry-over variable, and the results show the following: (1) the regions with the best overall efficiency between 2012 and 2015 include Taipei City, Keelung City, Hsinchu City, Chiayi City, and Taitung County; (2) in counties and cities with poor overall efficiency performance, the average disposable income per household has no significant relationship with air pollutant emissions; (3) in counties and cities where overall efficiency is poor, the average efficiency of each household’s disposable income is small; and (4) except for the five counties and cities with the best overall performance, the three air pollutants in the other fourteen counties and cities are high. Overall, the air pollution of most areas needs improvement.

1. Introduction

Taiwan, one of the Asian four dragons, has high energy (electricity) consumption, population, and vehicle density and severe air pollution. This study is going to explore the economic performance efficiency, energy consumption (electricity), and air pollutant emission efficiency of Taiwan.

From the World Health Organization’s [1] national ranking of PM$_{2.5}$ concentrations in September 2011, Taiwan ranks 32nd among 38 survey countries. Among nearly 600 cities worldwide, Chiayi and Kaohsiung made it among the top ten. From the average concentration of PM$_{2.5}$ in 2013, the risk of lung cancer and asthma in children increased to 15%, with the risk from stroke, heart disease, and chronic respiratory disease increasing by 25%. In 2014, more than 6,000 deaths in Taiwan were caused by exposure to PM$_{2.5}$.

Indeed, PM$_{2.5}$ causes damage in Taiwan. The impact of CO$_2$, SO$_2$, and PM$_{2.5}$ cannot be overlooked. Most studies in the literature explore the effects of energy and environmental efficiencies on CO$_2$, SO$_2$, and NO$_2$ emissions. Many researches analyze the energy efficiency of China. Wu et al. [2] use two-stage network DEA (data envelopment analysis) to assess China’s energy conservation and emission reduction efficiency during 2006–2010. Energy saving and emission reduction in the eastern region are better than in the central and western regions. Lin and Du [3] employ the
new nonradial directional distance function to assess regional energy and carbon dioxide emissions efficiency in China from 1997 to 2009. The results show that most of China’s performances in energy use and carbon dioxide emissions are poor. Industrial sector expansion is negatively correlated with China’s regional energy and CO₂ emissions performance. Wang et al. [4] utilize multidirectional efficiency analysis (MEA) to look at regional energy and emissions efficiencies in China from 1997 to 2010. The eastern region is more efficient than the central and western regions. Hebei, Shanxi, Inner Mongolia, Shandong, Henan, and Hubei have higher potentials for energy conservation and emission reduction. Li et al. [5] collect energy data from 2000 to 2009 in China and analyze the impact of three internal factors (economic structure, energy consumption structure, and technological progress) on energy intensity in China using the DEA-based Malmquist method. They convert technology into three components to see the different impacts in various regions. Other researches such as [6–19] also focus on the energy efficiency of China.

Some in the literature analyze the impacts of energy and environmental efficiencies on PM₂.₅ emissions, such as [20–30]. Martínez [20] uses two-stage DEA to assess the energy efficiency of non-energy-intensive industries (NEISs) in Germany and Colombia from 1998 to 2005. The highest energy efficiency in non-energy-intensive industries (NEISs) in Colombia is derived from the cost minimization model, showing that energy prices are not the key to improving energy efficiency. Sueyoshi and Yuan [21] utilize the DEA model to explore regional environmental efficiency performance in China from 2013 to 2014. The Chinese government should allocate economic resources to cities located in the northwestern region (including Lanzhou, Xining, Yinchuan, and Urumqi) and strengthen stricter regulation of energy consumption in major urban environments (such as Beijing, Tianjin, Shanghai, and Chongqing). Ma et al. [22] use the spatial autoregressive model to analyze the spatial diffusion effects of PM₂.₅ in 152 cities in China. PM₂.₅ is significantly affected by geospatial and regional economies. Li et al. [23] utilize the multilevel frontiers DEA model to explore the environmental efficiency of 49 cities in China. Their results present that PM₂.₅ and SO₂ emissions are significantly related to urban population and energy technologies.

There are two contributions of this study. First, we use small economy as the research sample. As can be seen from the above literature, most of the research on air pollutants is based on large economies, such as China. These large economies have rich natural resources and focus on industrial and manufacturing development. However, the problem of air pollution is not limited to large economies, and it cannot be overlooked in some non-industrial-oriented small economies. For example, the Taiwan Environmental Protection Agency’s 2016 and 2017 Air Quality Monitoring Report [31], the annual air quality indicators (AQIs) hit 39.34% and 42.1%, respectively, or out of reach from a good grade of 50%. The other contribution is model modification. Most past models are still dominated by radial (Charnes, Cooper, and Rhodes model, abbreviation as CCR model; Banker, Charnes, and Cooper model, abbreviation as BCC model), nonradial (slack-based measure, abbreviation as SBM), two-stage DEA analysis, and directional distance function. However, these models employ static analysis, lack dynamic considerations, and cannot understand the changes in efficiency of energy and environmental pollutants. Thus, this study employs the modified dynamic SBM to evaluate the situation for each county and city. We utilize 19 counties and cities in Taiwan from 2012 to 2015 with data on the number of employed people, motor vehicles, and electricity consumption and take the average disposable income per household as output, PM₂.₅, nitrogen oxide emissions (NO₂), and sulfur oxide emissions (SO₂) as undesirable outputs (recently, the problem of air pollution has drawn the attention of many scholars; because the issue of CO₂ emission has been analyzed by many researches, this study focuses on the other air pollutants, SO₂, NO₂, and PM₂.₅ in Taiwan), and fixed assets as the carry-over variable). By above input and output variables, this study evaluates the economic performance, electricity consumption efficiency, and air pollutant emission efficiency of Taiwan.

2. Research Methods

2.1. DEA. Farrell [32] proposes the efficiency frontier, but the model is only for a single input and a single output. Charnes et al. [33] extend Farrell’s theory for multiple inputs and multiple outputs, naming it the CCR model. Banker et al. [34] propose their BCC model, which can determine variable returns to scale. For the first time, Tone [35] proposes nonradial and nonoriented estimation methods through slacks, calling it the SBM model. Many efficiency assessment methods have been subsequently proposed, such as super DEA, hybrid DEA, network DEA, two-stage DEA, fuzzy DEA, and three-stage DEA.

2.2. Dynamic DEA. Many research studies utilize static analysis, with dynamic DEA window analysis to analyze dynamic models. Färe et al. [36] offer the Malmquist index, but during two periods, the researchers do not analyze the impact of carry-over. Färe and Grosskopf [37] then offer a new analysis of the dynamic impact of consecutive activities. Chen [38] and K. S. Park and K. Park [39] subsequently present SBM studies of several dynamics, with the dynamic analysis model extended into a slack-based measure by Tone and Tsutsui [40]. In order to carry-over activities as a form of connectivity, they propose the SBM (slack-based measures) dynamic DEA model. Tone and Tsutsui [40] develop the model into SBM dynamic analysis, with carry-over activities as a link, and the existence of activities divided into a four-model analysis: (1) desirable (Z\text{good}⁰); (2) undesirable (Z\text{bad}⁰); (3) discretionary (Z\text{free}⁰); (4) nondiscretionary (Z\text{fix}⁰), with carry-over variables from period t to period t+1.
The following is the nonoriented model:

\[
\rho_0^* = \min \frac{(1/T)\sum_{t=1}^T W^t [1 - (1/m + nbad) \left( \sum_{i=1}^m (u_i^s s^s_{it}/x_{it}) + \sum_{r=1}^{nbad} (v^b_{rt}/z^b_{rt}) \right)]}{(1/T)\sum_{t=1}^T W^t [1 + (1/s + ngood) \left( \sum_{i=1}^s (u_i^s s^s_{it}/y_{it}) + \sum_{r=1}^{ngood} (v^g_{rt}/z^g_{rt}) \right)]} \tag{1}
\]

\[
\sum_{r=1}^n z_{rjt}^a \lambda_j^i = \sum_{j=1}^n z_{rjt}^a \lambda_j^{i+1}, \quad (\forall i; t = 1, \ldots, T - 1). \tag{2}
\]

Equation (2) is the connection equation between \(t\) and \(t+1\).

\[
x_{int}^t = \sum_{j=1}^n x_{jit}^t \lambda_j^i + s^a_t, \quad (i = 1, \ldots, m; t = 1, \ldots, T),
\]

\[
x_{fix}^t = \sum_{j=1}^n x_{fixjt}^t, \quad (i = 1, \ldots, p; t = 1, \ldots, T),
\]

\[
y_{int}^t = \sum_{l=1}^n y_{ljt}^t - s^a_t, \quad (l = 1, \ldots, s; t = 1, \ldots, T),
\]

\[
y_{fix}^t = \sum_{l=1}^n y_{fixlt}^t, \quad (l = 1, \ldots, r; t = 1, \ldots, T),
\]

\[
z_{good}^t - z_{rot}^t = \sum_{r=1}^{n\text{good}} \lambda_j^i - s^a_t, \quad (r = 1, \ldots, n\text{good}; t = 1, \ldots, T),
\]

\[
z_{bad}^t - z_{rot}^t = \sum_{r=1}^{n\text{bad}} \lambda_j^i + s^a_t, \quad (r = 1, \ldots, n\text{bad}; t = 1, \ldots, T),
\]

\[
z_{free}^t - z_{rot}^t = \sum_{r=1}^{n\text{free}} \lambda_j^i + s^a_t, \quad (r = 1, \ldots, n\text{free}; t = 1, \ldots, T),
\]

\[
z_{fix}^t = \sum_{r=1}^{n\text{fix}} \lambda_j^i, \quad (r = 1, \ldots, n\text{fix}; t = 1, \ldots, T),
\]

\[
\sum_{j=1}^n \lambda_j^i = 1 \quad (t = 1, \ldots, T),
\]

\[
\lambda_j^i \geq 0, s^a_t \geq 0, s^a_t \geq 0, z^\text{good}_t \geq 0, z^\text{bad}_t \geq 0 \text{ and } z^\text{free}_t: \text{free (}\forall i, t\text{).}
\]

The most efficient solution is

\[
\rho_0 = \frac{1 - (1/m + nbad) \left( \sum_{i=1}^m (u_i^s s^s_{it}/x_{it}) + \sum_{r=1}^{nbad} (v^b_{rt}/z^b_{rt}) \right)}{1 + (1/s + ngood) \left( \sum_{i=1}^s (u_i^s s^s_{it}/y_{it}) + \sum_{r=1}^{ngood} (v^g_{rt}/z^g_{rt}) \right)} \quad (i = 1, \ldots, T). \tag{4}
\]

2.3. The Modified Dynamic SBM Model. Since this study considers the undesirable output in the dynamic SBM model, Tone and Tsutsui’s [40] dynamic SBM model can be modified to be the undesirable output in the dynamic SBM model. Suppose the observation is a \(J\) (\(J = 1, \ldots, n\)), dimension decision-making unit (DMU) set in which the DMU under evaluation is represented by DMU\(_{ij}\) and subject to DMU\(_{ij} \in J\). The input and output used to compute the efficiency are labeled as \(m\) inputs \(x_{ij} (i = 1, \ldots, m)\) and \(s\) outputs \(y_{ij}\), respectively. Let output \(Y\) be divided into \((Y^d, Y^b)\), where \(Y^d\) is the desirable output, \(Y^b\) is the undesirable output, and \(Z^\text{good}\) is carried over from period \(t\) to period \(t+1\). The following is the nonoriented model:
\[ \theta^*_0 = \min \frac{(1/T)\sum_{t=1}^{T} W_t \left[ 1 - (1/m)\sum_{i=1}^{m} s_{it}^g / x_{it} \right]}{(1/T)\sum_{t=1}^{T} W_t \left[ 1 + (1/s_1 + s_2 + n_{\text{good}}) \left( \sum_{i=1}^{i} s_{it}^g / y_{it} \right) + \sum_{r=1}^{r} s_{rt}^\text{good} / z_{rot}^\text{good} \right]} \]  

(5)

The following six equations show the connection equation between \( t \) and \( t+1 \):

\[ \sum_{j=1}^{n} z_{ij}^a \lambda_{ij}^t = \sum_{j=1}^{n} z_{ij}^a \lambda_{ij}^{t+1}, \quad (\forall i; t = 1, \ldots, T - 1), \]

\[ x_{it} = \sum_{i=1}^{m} x_{ij}^i \lambda_{ij}^t + s_{it}^a, \quad (i = 1, \ldots, m; t = 1, \ldots, T), \]

\[ y_{ot} = \sum_{l=1}^{s} y_{ot}^l \lambda_{ot}^t - s_{ot}^a, \quad (l = 1, \ldots, s; t = 1, \ldots, T), \]

\[ y_{ot} = \sum_{l=1}^{s} y_{ot}^l \lambda_{ot}^t - s_{ot}^b, \quad (l = 1, \ldots, s; t = 1, \ldots, T), \]

\[ z_{rt}^\text{good} = \sum_{r=1}^{n_{\text{good}}} z_{rt}^\text{good} \lambda_{rt}^t - s_{rt}^\text{good}, \quad (R = 1, \ldots, n_{\text{good}}; t = 1, \ldots, T), \]

\[ \sum_{j=1}^{n} \lambda_{ij}^t = 1 \quad (t = 1, \ldots, T), \]

\[ \lambda_{ij}^t \geq 0, s_{it}^a \geq 0, s_{it}^g \geq 0, s_{it}^b \geq 0, s_{rt}^\text{good} \geq 0. \]

The most efficient solution is

\[ \rho_{0t} = \frac{1 - (1/m)\left( \sum_{i=1}^{m} \left( s_{it}^+ / x_{it} \right) \right)}{1 + (1/s_1 + s_2 + n_{\text{good}}) \left( \sum_{i=1}^{i} \left( s_{it}^+ / y_{it} \right) + \sum_{r=1}^{r} \left( s_{rt}^+ / z_{rot}^\text{good} \right) \right)}, \quad (i = 1, \ldots, T). \]  

(7)

In equation (5), \( W_t \) denotes the weight of time and the range of time of this model is from 2012 to 2015. \( x_{it} \) indicates outputs, which are labor, motor vehicle number, and electricity consumption. \( y_{ot}^\text{good} \) denotes desirable output which is disposable income. \( y_{ot}^\text{bad} \) denotes undesirable outputs, which are PM\textsubscript{2.5}, NO\textsubscript{2}, and SO\textsubscript{2}. \( z_{rot}^\text{good} \) is carry over, which is fixed assets. \( s_{it}^a \) indicates input slack. \( s_{it}^g \) indicates desirable output slack. \( s_{it}^b \) indicates undesirable output slack. \( s_{rt}^\text{good} \) indicates undesirable output slack.

This study lists labor, motor vehicle number, and electricity consumption as inputs. Suspended particulate emissions (PM\textsubscript{2.5}), nitrogen oxide emissions (NO\textsubscript{2}), and sulfur oxide emissions (SO\textsubscript{2}) are undesirable outputs. Fixed assets are a carry-over variable. Table 1 lists the details.

The number of motor vehicles, electricity consumption, average disposable income, and NO\textsubscript{2}, SO\textsubscript{2}, and PM\textsubscript{2.5} efficiency indices.

Hu and Wang [19] total-factor energy efficiency index is used to overcome any possible bias in the traditional energy efficiency indicator. For each specific evaluated country, we calculate the number of motor vehicles, electricity consumption, average disposable income, and NO\textsubscript{2}, SO\textsubscript{2}, and PM\textsubscript{2.5} efficiencies from the following equations:

\[ \text{the number of motor vehicles' efficiency} = \frac{\text{target motor vehicles' efficiency input } (i, t)}{\text{actual motor vehicles' efficiency input } (i, t)} \]  

(8)

\[ \text{electricity consumption efficiency} = \frac{\text{target electricity consumption input } (i, t)}{\text{actual electricity consumption input } (i, t)} \]  

(9)
average disposable efficiency = \frac{\text{actual average disposable income output}}{\text{target average disposable output}}, \tag{10}

\text{NO}_2 \text{ efficiency} = \frac{\text{target NO}_2 \text{ undesirable output}}{\text{actual NO}_2 \text{ undesirable output}}, \tag{11}

\text{PM}_{2.5} \text{ efficiency} = \frac{\text{target PM}_{2.5} \text{ undesirable output}}{\text{actual PM}_{2.5} \text{ undesirable output}}, \tag{12}

\text{SO}_2 \text{ efficiency} = \frac{\text{target SO}_2 \text{ undesirable output}}{\text{actual SO}_2 \text{ undesirable output}}. \tag{13}

The efficiency index indicates the ratio of target value and actual value. The target value indicates the most efficient value. Thus, the efficiency index denotes the difference of actual value and target value. The index (ratio) equals to 1 when the actual value reaches the target value, and the actual value is most efficient. The index is more efficient when the value is close to 1.

If the target motor vehicle number and electricity consumption input equal the actual inputs and the NO$_2$, PM$_{2.5}$, and SO$_2$ outputs equal the actual undesirable outputs, then the motor vehicle number, electricity consumption, and NO$_2$, PM$_{2.5}$, and SO$_2$ efficiencies equal 1, indicating no room for improvement on their efficiency. The actual value reaches the target. If the target motor vehicle number and electricity consumption inputs are less than the actual input and the NO$_2$, PM$_{2.5}$, and SO$_2$ outputs are less than the actual undesirable outputs, then the motor vehicle number, electricity consumption, and NO$_2$, PM$_{2.5}$, and SO$_2$ efficiencies are less than 1, indicating the actual value is inefficiency. There is room for improvement on actual value.

If the target average disposable income output is equal to the actual average disposable income output, then the average disposable income efficiency equals 1, indicating overall efficiency. If the actual average disposable income output is less than the target average disposable income output, then the average disposable income efficiency is less than 1, indicating overall inefficiency.

3.1.1. Data Source. This research takes Taiwan as a case study from 2012 to 2015, including New Taipei City, Taipei City, Taoyuan City, Taichung City, Tainan City, Kaohsiung City, Yilan County, Hsinchu County, Miaoli County, Changhua County, Nantou County, Yunlin County, Chiayi County, Pingtung County, Taitung County, Hualien County, Keelung City, Hsinchu City, and Chiayi City. The source is from Taiwan Statistics Department, Taiwan Power Company, and the Environmental Protection Agency of the Executive Yuan. The software used by this research is MaxDEA. This software is a benefit for DEA analysis, especially for model with undesirable output.

3.1.2. Variable and the Structure of Model. This is a dynamic model with several periods, such as period $t$ and period $t+1$. The inputs are labor, motor vehicle number, and electricity consumption. Labor and electricity consumption are used for economic development. Electricity is the main energy consumption of Taiwan. A large amount of air pollutants are generated during the production of electricity (ex: thermal power). Vehicles are a source of air pollutants in daily life.

There are two kinds of output. The desirable output is average disposable income which is an indicator of economic performance. The undesirable outputs are air pollutant which is generated by economic development and citizen’s daily life. The carry-over factor which continues to each period (ex: period $t$ to period $t+1$) is fixed assets. The linkage of variables is shown in Figure 1.

3.2. Statistics of Input and Output Variables. Table 2 summarizes the statistics of Taiwan’s counties and cities from 2012 to 2015. In 2012, the average number of laborers is 569,474, the maximum is 1,892,000 in New Taipei City, and the minimum is 103,000 in Taitung County, with a standard deviation of 523,758. The average number of motor vehicles is 1,166,673, with a maximum of 3,309,078 units in New Taipei City, a minimum of 246,208 units in Taitung County, and a standard deviation of 1,013,652 units. The average electricity consumption is 7.819 billion, the maximum is 22.399 billion in New Taipei City, the minimum is 485.1 million in Taitung County, and the standard deviation is 7.529 billion degrees. The average yearly disposable income is NT$874,514, the maximum is NT$1,278,278 in Taipei City, the minimum is NT$670,017 in Taitung County, and the standard deviation is NT$158,827. The average amount of suspended particulate emissions is 3,941 metric tons, the maximum is 10,696 metric tons in Kaohsiung City, the minimum is 514 metric tons in Chiayi City, and the standard deviation of 2,631. The average sulfur oxide emissions are 6,397 metric tons, with a maximum of 42,929 metric tons in Kaohsiung City, a minimum of 60 metric tons in Chiayi City, and a standard deviation of 10,594 metric tons. The average NOx emissions are 20,213 metric tons, with a maximum of 76,826 metric tons in Kaohsiung City, a minimum of 2,281 metric tons in Chiayi City, and a standard deviation of 19,626 metric tons. The average fixed asset investment for a factory is NT$56,753,880 thousand, the maximum value is
According to Table 2, regardless of the amount of labor, motor vehicles, and electricity consumption, the maximum values are mainly concentrated in New Taipei City and Tainan City. The minimum values are mainly concentrated in Taitung County and Chiayi City. For average disposable income, the maximum value in the 4 years is in Taipei City. The minimum values are mainly concentrated in Taitung County and Chiayi City. The maximum emissions of suspended particulates is mainly in Kaohsiung City, and the minimum emissions are in Chiayi City. The maximum emissions of sulfur oxides are in Kaohsiung City, and the minimum emissions are in Chiayi City. The maximum fixed asset investment for a factory is in Tainan City, and the minimum value is in Taitung County.

3.3. Empirical Analysis. This study explore the overall efficiency of Taiwan’s counties and cities from 2012 to 2015.

3.3.1. Overall Efficiency. As shown in Table 3, the overall efficiency average is 0.8215, and the average efficiency for each year from 2012 to 2015 is, respectively, 0.8360, 0.7984, 0.8199, and 0.8370. The room for improvement is still between 16.3% and 20.2%. The four-year average efficiency maximum is 1 in Taipei City, Taitung County, Keelung City, Hsinchu City, and Chiayi City. The lowest 4-year average efficiency is in Tainan City. The bottom three rankings are Yunlin County, Changhua County, and Tainan City. The average efficiency in 2012 is 0.8360, and the most efficient regions are Taipei City, Taitung County, Keelung City, Hsinchu City, and Chiayi City. The bottom three are Taichung City, Yunlin County, and Tainan City. The average efficiency in 2013 is 0.7984, and the most efficient are Taipei

### Table 1: Definitions of variables.

| Variable       | Definition                                                                                                                                 |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Input          | Labor: Above fifteen-year-old paid worker or engaged in unpaid family work for more than 15 hours (unit: person)                           |
|                | Motor vehicle number: Number of motor vehicles with uniform licenses to the supervision authorities at the end of the year (unit: vehicle) |
|                | Electricity consumption: Electricity sold to the service industry, government schools, agriculture, forestry, fisheries, and industrial sales (unit: degree) |
| Desirable output | Average disposable income: Disposable income/total number of households (unit: NT$)                                                      |
|                | Suspended particulate emissions: Total emissions of suspended particulates (PM2.5) (unit: metric tons)                                    |
| Undesirable output | NOx emissions: Total emissions of nitrogen oxides (including nitrogen monoxide and nitrogen dioxide) (unit: metric tons)              |
|                | Sulfur oxide emissions: Total emissions of sulfur oxides (including sulfur dioxide) (unit: metric tons)                                  |
| Carry-over     | Fixed assets: The amount of fixed assets newly added by the factory in normal operations, including equipment investment (antipollution equipment, machinery and equipment, transportation vehicles, and other equipment), land acquisition, dormitory, factory warehouse office, and other construction projects (unit: NT$1,000) |

### Figure 1: The structure of the model.
Table 2: Description of statistics.

| Variable                              | 2012                          | 2013                          | 2014                          | 2015                          |
|---------------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| **Inputs**                            |                               |                               |                               |                               |
| Labor (people)                        | Maximum 1,892,000 (New Taipei City) | 1,910,000 (New Taipei City) | 1,927,000 (New Taipei City) | 1,945,000 (New Taipei City) |
|                                       | Minimum 103,000 (Taitung County) | 104,000 (Taitung County)     | 104,000 (Taitung County)     | 104,000 (Taitung County)     |
|                                       | Average 569,474                | 574,474                       | 580,736                       | 586,947                       |
|                                       | Standard deviation 523,758     | 529,741                       | 534,914                       | 541,477                       |
| Motor vehicles                        | Maximum 3,309,078 (New Taipei City) | 3,233,275 (New Taipei City) | 3,178,499 (New Taipei City) | 3,183,551 (New Taipei City) |
|                                       | Minimum 246,208 (Taitung County) | 233,394 (Taitung County)     | 230,890 (Taitung County)     | 230,954 (Taitung County)     |
|                                       | Average 1,166,673              | 1,125,181                     | 1,110,507                     | 1,115,854                     |
| Electricity consumption (degrees)     | Minimum 485,166,744 (Taitung County) | 488,240,891 (Taitung County) | 496,469,053 (Taitung County) | 520,574,022 (Taitung County) |
|                                       | Average 7,819,496,456          | 7,988,861,231                 | 8,102,790,831                 | 8,121,363,829                 |
|                                       | Standard deviation 7,529,994,233 | 7,694,682,886             | 7,811,168,091                 | 7,826,312,606                 |
| **Desirable output**                  | Maximum 1,278,278 (Taipei City) | 1,279,195 (Taipei City)       | 1,292,604 (Taipei City)       | 1,314,031 (Taipei City)       |
| Average disposable income (NT$)       | Minimum 670,017 (Taitung County) | 676,390 (Taitung County)     | 667,933 (Chiayi City)         | 636,162 (Taitung County)      |
|                                       | Average 874,514                | 889,033                       | 896,941                       | 895,059                       |
|                                       | Standard deviation 158,787     | 171,147                       | 182,797                       | 167,073                       |
| **Undesirable output**                | Maximum 10,696 (Kaohsiung City) | 10,336 (Kaohsiung City)       | 10,174 (Kaohsiung City)       | 9,893 (Kaohsiung City)        |
| Suspended particulate emissions (PM$_{2.5}$) (metric tons) | Minimum 514 (Chiayi City) | 491 (Chiayi City) | 479 (Chiayi City) | 471 (Chiayi City) |
|                                       | Average 3,941                  | 3,901                         | 3,825                         | 3,742                         |
|                                       | Standard deviation 2,651       | 2,606                         | 2,557                         | 2,487                         |
| Sulfur oxide emissions (SO$_2$) (metric tons) | Maximum 42,929 (Kaohsiung City) | 37,849 (Kaohsiung City)       | 37,132 (Kaohsiung City)       | 35,667 (Kaohsiung City)       |
|                                       | Minimum 60 (Chiayi City)       | 44 (Chiayi City)              | 44 (Chiayi City)              | 43 (Chiayi City)              |
|                                       | Average 6,397                  | 5,960                         | 5,845                         | 5,638                         |
|                                       | Standard deviation 10,594      | 9,614                         | 9,428                         | 9,051                         |
| Nitrogen oxide emissions (NO$_2$) (metric tons) | Maximum 76,826 (Kaohsiung City) | 74,061 (Kaohsiung City)       | 69,934 (Kaohsiung City)       | 65,068 (Kaohsiung City)       |
|                                       | Minimum 2,281                  | 2,283                         | 2,101                         | 1,944                         |
|                                       | Average 20,213                 | 20,213                        | 20,213                        | 18,167                        |
|                                       | Standard deviation 19,626      | 19,228                        | 18,167                        | 16,922                        |
| **Carry over**                        | Maximum 199,155,007 (Tainan City) | 199,637,849 (Taichung City) | 213,935,949 (Tainan City)     | 232,090,820 (Taoyuan City)   |
| Fixed assets (NT$1,000)               | Minimum 324,609 (Chiayi City)  | 264,800 (Taitung County)      | 773,560 (Taoyuan County)      | 903,929 (Taitung County)      |
|                                       | Average 56,753,880             | 55,750,421                    | 62,653,275                    | 65,734,355                    |
|                                       | Standard deviation 66,919,221  | 68,137,797                    | 75,504,497                    | 74,984,091                    |
City, Taitung County, Keelung City, Hsinchu City, and Chiayi City. The bottom three are Tainan City, Changhua County, and Yunlin County. The average efficiency in 2014 is 0.8199, with the most efficient being Taipei City, Taitung County, Keelung City, Hsinchu City, and Chiayi City. The average efficiency in 2015 is 0.8370, with the most efficient being Taipei City, Taitung County, Keelung City, Hsinchu City, and Chiayi City; the worst are Tainan County, Changhua County, and Yunlin County.

3.3.2. Annual Input and Output Variable Efficiencies.
From electricity consumption in Table 4, the four-year efficiency value of 1 covers Taipei City, Hsinchu County, Nantou County, Yunlin County, Chiayi County, Pingtung County, Taitung County, Hsinchu City, and Chiayi City.
Those with efficiency values below the four-year average of 0.8387 are Taoyuan City, Taichung City, Tainan City, Kaohsiung City, Yilan County, and Hualien County. In 2012, there are 9 counties and cities that need to be adjusted. Among them, Taoyuan City, Kaohsiung City, and Tainan City need the greatest improvement, as their efficiency values are 0.4376, 0.4741, and 0.4376. The remaining 10 counties and cities have an efficiency value of 1 and do not need to adjust. In 2013, there are 8 counties and cities that need to be adjusted. Among them, Taoyuan City, Kaohsiung City, and Tainan City need the greatest improvement, as their efficiency values are 0.4312, 0.4690, and 0.4586. The remaining 11 counties and cities have an efficiency value of 1. In 2014, there are 9 counties and cities that need to be adjusted. Among them, Taoyuan City, Kaohsiung City, and Tainan City need the greatest improvement, as their efficiency values are 0.4279, 0.4589, and 0.4716. The remaining 10 counties and cities have an efficiency value of 1. In 2015, there are 9 counties and cities that need to be adjusted. Among them, Taoyuan City, Kaohsiung City, and Tainan City need the greatest improvement, as their efficiency values are 0.4312, 0.4791, and 0.4463. The remaining 10 counties and cities have an efficiency value of 1.

From Table 5 on motor vehicles, the cities with a four-year efficiency value of 1 are Taipei City, Taitung County, Keelung City, Hsinchu City, and Chiayi City. Those with efficiency values below the four-year average of 0.8351 are New Taipei City, Taoyuan City, Taichung City, Tainan City, Kaohsiung City, Changhua County, Yunlin County, Chiayi County, and Pingtung County. In 2012, there are 14 counties and cities with motor vehicles that need to be adjusted. Among them, New Taipei City, Kaohsiung City, and Pingtung County need the greatest improvement, as their efficiency values are 0.5610, 0.5963, and 0.6503. The remaining 5 counties and cities have an efficiency value of 1. In 2013, there are 14 counties and cities with motor vehicles that need to be adjusted. Among them, New Taipei City, Kaohsiung City, and Pingtung County need the greatest improvement, as their efficiency values are 0.5576, 0.6143, and 0.6587. The remaining 5 counties and cities have an efficiency value of 1. In 2014, there are 14 counties and cities with motor vehicles that need to be adjusted. Among them,
New Taipei City, Kaohsiung City, and Taichung City need the greatest improvement, as their efficiency values are 0.5563, 0.6156, and 0.6127. The remaining 5 counties and cities have efficiency values of 0.6497, 0.6611, and 0.6671. In 2013, there are 14 counties and cities that need to be adjusted. Among them, Tainan City, Changhua County, and Yunlin County need the greatest improvement, as their efficiency values are 0.6937, 0.7262, and 0.7393.

From the average disposable income of Table 6, the cities with a four-year efficiency value of 1 are Taipei City, Taitung County, Keelung City, Hsinchu City, and Chiayi City. Those with efficiency values below the four-year average 0.4362 are Taipei City, Taoyuan City, Taichung City, Tainan City, Kaohsiung City, Yilan County, Hsinchu County, Miaoli County, Changhua County, Nantou County, Yilan County, Chiayi County, Pingtung County, and Hualien County. In 2012, there are 14 counties and cities that need to make adjustments for suspended particulate emissions. Hualien County, Kaohsiung City, and Yilan County need the greatest improvement, as their efficiency values are 0.6649, 0.6671, and 0.7115. The remaining 5 counties and cities have an efficiency value of 1.

### 3.3.3. Annual PM$_{2.5}$, SO$_2$, and NO$_2$ Efficiencies.

From Table 7 on PM$_{2.5}$, the cities with a four-year efficiency value of 1 are Taipei City, Taitung County, Keelung City, Hsinchu City, and Chiayi City. Those with efficiency values below the four-year average 0.4362 are Taipei City, Taoyuan City, Taichung City, Tainan City, Kaohsiung City, Yilan County, Keelung City, Hsinchu City, Chiayi City, Miaoli County, Changhua County, Nantou County, Yilan County, Chiayi County, Pingtung County, and Hualien County. In 2012, there are 14 counties and cities that need to make adjustments for suspended particulate emissions. Hualien County, Kaohsiung City, and Yilan County need the greatest improvement, as their efficiency values are 0.0874, 0.1609, and 0.1969. The remaining 5 counties and cities have an efficiency value of 1. In 2013, there are 14 counties and cities that need to make adjustments for suspended particulate emissions. Hualien County, Kaohsiung City, and Yilan County need the greatest improvement, as their efficiency values are 0.0852, 0.1615, and 0.1644.

The remaining 5 counties and cities have an efficiency value of 1. In 2014, there are 14 counties and cities that need to make adjustments for suspended particulate emissions. Hualien County, Kaohsiung City, and Yilan County need the greatest improvement, as their efficiency values are 0.0840, 0.1616, and 0.1673. The remaining 5 counties and cities have an efficiency value of 1. In 2015, there are 14 counties and cities that need to make adjustments for suspended particulate emissions. Hualien County, Kaohsiung City, and Yilan County need the greatest improvement, as their
efficiency values are 0.0829, 0.1635, and 0.1671. The remaining 5 counties and cities have an efficiency value of 1.

From Table 8 on SO₂, the cities with a four-year efficiency value of 1 are Taipei City, Taitung County, Keelung City, Hsinchu City, and Chiayi City. Those with efficiency values below the four-year average of 0.3288 are New Taipei City, Taoyuan City, Taichung City, Tainan City, Kaohsiung City, Hsinchu City, Miaoli County, Changhua County, Nantou County, Yunlin County, Chiayi County, Pingtung County, and Hualien County. In 2012, 14 counties and cities need to make adjustments for sulfur oxide emissions. Hualien County, Yunlin County, and Taichung City need the greatest improvement, as their efficiency values are 0.0188, 0.0209, and 0.0207. The remaining 5 counties and cities have an efficiency value of 1. In 2013, 14 counties and cities need to make adjustments for sulfur oxide emissions. Kaohsiung City, Hualien County, and Yunlin County need the greatest improvement, as their efficiency values are 0.0109, 0.0128, and 0.0144. The remaining 5 counties and cities have an efficiency value of 1. In 2014, 14 counties and cities need to make adjustments for sulfur oxide emissions. Kaohsiung City, Hualien County, and Yunlin County need the greatest improvement, as their efficiency values are 0.0108, 0.0125, and 0.0145. The remaining 5 counties and cities have an efficiency value of 1. In 2015, 14 counties and cities need to make adjustments for sulfur oxide emissions. Kaohsiung City, Hualien County, and Yunlin County need the greatest improvement, as their efficiency values below the four-year average 0.4597 are New Taipei City, Taoyuan City, Taichung City, Tainan City, Kaohsiung City, Yilan County, Hsinchu County, Miaoli County, Changhua County, Nantou County, Yunlin County, Chiayi County, Pingtung County, and Hualien County. In 2012, there are 14 counties and cities that need to make adjustments in NOₓ emissions. Hualien County, Kaohsiung City, and Yunlin County need the greatest improvement, as their
Table 10: Overall score, electricity consumption, motor vehicle emissions, suspended particles emissions, sulfur oxide emissions, nitrogen oxide emissions, and average household disposable income efficiency analysis.

| DMU            | Overall efficiency | Electricity consumption | Motor vehicles | Suspended particles | SOx | NOx | Average household distributable income |
|----------------|--------------------|-------------------------|----------------|---------------------|-----|-----|----------------------------------------|
| New Taipei City| Dropped from 11th place in 2013 to 15th place in 2015 | Maintained 12th or 13th place | In last place all 4 years (19th) | 7th in 2012 and 2013 and dropped to 8th place in 2014 and 2015 | 10th in 2012 and 2014 and dropped to 11th place in 2013 and 2015 | 10th in 2012 and 2014 and dropped to 11th place in 2013 and 2015 | 14th in 2012, progressed to 11th place in 2013, retired to 13th place in 2014, and regressed to 15th place in 2015 |
| Taipei City    | 1st place in the 4 years | 1st place in the 4 years | 1st place in the 4 years | 1st place in the 4 years | 1st place in the 4 years | 1st place in the 4 years | 1st place in the 4 years |
| Taoyuan City   | Continued to improve slightly from 10th in 2012 to 8th in 2015 | Last place in the 4 years (19th place) | 13th in the 4 years | 12th in 2012 and 2013 and progressed to 10th place in 2014 and 2015 | 15th in 2012 and 2015 and progressed to 14th in 2013 and 2014 | 14th in 2012 and regressed to 15th place in 2013, 2014, and 2015 | 10th place in 2012, progressed to 7th place in 2013 and regressed to 8th place in 2014 and 2015 |
| Taichung City  | Continued improving from 17th in 2012 to 13th in 2015 | 4th in 2012, 2013, and 2015 | 16th in 2012 and 2013 and to 17th place in 2014 and 2015 | 15th place in the 4 years | 16th in 2012, 2013, and 2015 and progressed to 15th in 2014 | 15th place in 2012, while 2013, 2014, and 2015 all regressed to 16th place | |
| Tainan City    | Last place in 2012, 2014, and 2015 | Third to last place in 2012, 2013, and 2014 and second to last in 2015 | 15th in the 4 years | 11th in 2012 and 2013 and 12th in 2014 and 2015 | 12th in 2012, 2013, and 2015 and 11th in 2014 | 8th place in 2012, 10th place in 2013, and 9th place in 2014 and 2015 | Last (19th place) in 2012, 2014, and 2015 and 17th in 2013 |
| Kaohsiung City | In 2013 it slipped from 13th | 18th in the 4 years | 18th in the 4 years | 19th in 2012, 2013 and 2015, progressing to 18th place in 2014 | 17th in 2012 and 2015 and 16th place in 2013 and 2014 | 16th in 2012 and 2015, 13th in 2013, and 14th in 2014 |
| Yilan County   | Average 6th place | 6th in 2012 and 2013 and 7th in 2014 and 2015 | 17th place in the 4 years | 13th in 2012, 2013, and 2015 and to 12th in 2014 | 13th in 2012 and 14th in 2013, 2014, and 2015 | Average 7th place | |
| Hsinchu County | Average 7th place | 1st place in the 4 years | 7th in 2012 and 2013 and 8th in 2014 and 2015 | 6th place in the 4 years | Average 7th place | 7th place in 2012, 2013, and 2015 and 11th place in 2014 | 6th in 2012, 2013, and 2014 and 7th in 2015 |
| Miaoli County  | Continued improvement from 11th in 2012 to 9th in 2014 | Average 13th place | 9th place in the 4 years | 10th in 2012 and 2013 and 11th in 2014 and 2015 | 11th in 2012, progressed to 9th in 2013, progressed to 8th in 2014, and returned to 9th in 2015 | 12th in 2012, while 2013, 2014, and 2015 all regressed to 13th | Average 10th place |
| Changhua County| Second to last place in 2012, 2014, and 2015 | 1st in 2013 and 2015, but 11th in 2012 and 2014 | 14th in the 4 years | 9th in 2012, progressed to 8th in 2013, and progressed to 7th in 2014 and 2015 | 9th in 2012 and 2014, but regressed to 10th in 2013 and 2015 | Last place in 2012 (19th), progressed to 9th in 2013, progressed to 8th in 2014, and backtracked to 10th in 2015 | 15th in 2012, while 2013, 2014, and 2015 all regressed to 18th |
| DMU          | Overall efficiency | Electricity consumption | Motor vehicles | Suspended particles | SOx               | NOx               | Average household distributable income |
|--------------|---------------------|-------------------------|----------------|---------------------|-------------------|-------------------|----------------------------------------|
| Nantou County| 11<sup>th</sup> on average | 1<sup>st</sup> place in the 4 years | 10<sup>th</sup> in the 4 years | 13<sup>th</sup> in the 4 years | 6<sup>th</sup> in 2012, 2013, and 2015 and progressed to 5<sup>th</sup> in 2014 | 6<sup>th</sup> in the 4 years | 11<sup>th</sup> on average |
| Yunlin County| 17<sup>th</sup> on average | 1<sup>st</sup> place in the 4 years | 12<sup>th</sup> in the 4 years | 14<sup>th</sup> in the 4 years | 17<sup>th</sup> in 2012, 2013, and 2015 and progressed to 16<sup>th</sup> in 2014 | 16<sup>th</sup> in 2012, 17<sup>th</sup> in 2013 and 2014, and 18<sup>th</sup> in 2015 | 18<sup>th</sup> in 2012, retraced to 19<sup>th</sup> (last) in 2013, progressed to 15<sup>th</sup> in 2014, and regressed to 17<sup>th</sup> in 2015 |
| Chiayi County| 12<sup>th</sup> on average | 1<sup>st</sup> place in the 4 years | 11<sup>th</sup> in 4 years | 11<sup>th</sup> place in 2012 and 9<sup>th</sup> in 2013, 2014, and 2015 | 14<sup>th</sup> on average | 11<sup>th</sup> in 2012 and 12<sup>th</sup> in 2013, 2014, and 2015 | 12<sup>th</sup> in 2012, 15<sup>th</sup> in 2013, 17<sup>th</sup> in 2014, and 11<sup>th</sup> in 2015 |
| Pingtung County| 16<sup>th</sup> on average | 1<sup>st</sup> place in the 4 years | 17<sup>th</sup> in 2012 and 2013 and 16<sup>th</sup> in 2014 and 2015 | 16<sup>th</sup> place in the 4 years | 7<sup>th</sup> in 2012 and 2014 and regressed to 8<sup>th</sup> in 2013 and 2015 | 8<sup>th</sup> on average | 13<sup>th</sup> in 2012, 16<sup>th</sup> in 2013 and 2014, and 14<sup>th</sup> in 2015 |
| Taitung County| 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 | 1<sup>st</sup> place in the 4 | 1<sup>st</sup> place in the 4 | 1<sup>st</sup> place in the 4 | 1<sup>st</sup> place in the 4 |
| Hualien County| 10<sup>th</sup> on average | 15<sup>th</sup> in 2012, 2013, and 2014 | 8<sup>th</sup> in 2012 and 2013 and progressed to 6<sup>th</sup> in 2014 and 2015 | Last place in the 4 years (19<sup>th</sup>) | 18<sup>th</sup> place in 2012, 2013, and 2015 and 17<sup>th</sup> place in 2014 | 18<sup>th</sup> in 2012 and 19<sup>th</sup> in 2013, 2014, and 2015 | 9<sup>th</sup> in 2012, 2013, and 2015 and 11<sup>th</sup> in 2014 |
| Keelung City | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in 2012, 2013, and 2015, but regressed to 19<sup>th</sup> (last) in 2014 | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years |
| Hsinchu City | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years |
| Chiayi City | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years | 1<sup>st</sup> place in the 4 years |
efficiency values are 0.1322, 0.1483, and 0.1582. The remaining 5 counties and cities have an efficiency value of 1. In 2013, there are 14 counties and cities that need to make adjustments in NOx emissions. Hualien County, Kaohsiung City, and Yunlin County need the greatest improvement, as their efficiency values are 0.1289, 0.1329, and 0.1450. The remaining 5 counties and cities have an efficiency value of 1. In 2014, there are 14 counties and cities that need to make adjustments in NOx emissions. Hualien County, Kaohsiung City, and Yunlin County need the greatest improvement, as their efficiency values are 0.1225, 0.1324, and 0.2213. The remaining 5 counties and cities have an efficiency value of 1. In 2015, there are 14 counties and cities that need to make adjustments in NOx emissions. Hualien County, Yunlin County, and Kaohsiung City need the greatest improvement, as their efficiency values are 0.1166, 0.1352, and 0.1365. The remaining 5 counties and cities have an efficiency value of 1.

In order to further understand the counties’ and cities’ electricity consumption, motor vehicles, aerosol emissions, sulfur oxode emissions, nitrogen oxide emissions, and average disposable income per household, this research offers Table 10 for illustration. From Table 10, Taipei City, Taitung County, Hsinchu City, Chiayi City, and Keelung City maintain the highest efficiency values in the 4 years, regardless of overall score, electricity consumption, motor vehicles, fine aerosol emissions, nitrogen oxide emissions, and average per efficiency analysis of household disposable income. From the efficiency analysis of sulfur oxide emissions, Taipei City, Taitung County, Hsinchu City, and Chiayi City still rank first in 4 years. Keelung City also maintains first place in 2012, 2013, and 2015, but in 2014, it ranks 19th (last). In 2014, the Keelung Port Art Exhibition attracted a large number of people from other counties and cities, and the air pollution was serious.

The 19th overall score (last place) is Tainan City. The electricity efficiency value of Tainan City is also in second to last place or third from last place. Its value for motor vehicle efficiency remains in 15th place in the 4 years (5th from last). For its efficiencies of suspended particulate emissions and sulfur oxide emissions, it maintains 11th or 12th place in the 4 years. The average efficiency of each household’s disposable income is last place in 2012, 2014, and 2015 (19th place). In 2013, it improves slightly to 17th (third from last place).

Among the six municipalities, only Taipei City and Taoyuan City rank first and eighth. The remaining 4 municipalities have poor overall scores. In last place (19th) is Tainan City. 15th is Kaohsiung City, 14th is Taichung City, and 13th is New Taipei City.

Among the 13 nonmunicipalities with low overall scores, 18th is Changhua County (second lowest), 17th is Yunlin County (third lowest), 16th is Pingtung County, and 12th is Chiayi County. For nonmunicipalities with middle overall scores, 6th is Hsinchu County, 7th is Yilan County, 9th is Miaoli County, 10th is Hualien County, and 11th is Nantou County.

For the efficiency of electricity consumption, in last place is Taoyuan City for all 4 years. For the efficiency of motor vehicles, in last place is New Taipei City and in 18th is Kaohsiung City for the 4 years (second to last place). For the efficiency of suspended matter emissions, in last place is Hualien County, in 18th is Kaohsiung City (second lowest), in 17th is Yilan County (third from last), and Pingtung County is in 16th place in the 4 years. The undesirable output and desirable output of each county and city have different degrees of progress or regression in the 4 years.

We note that Taipei City, Taitung County, Hsinchu City, Chiayi City, and Keelung City have the best performances. The rest of the counties and cities have a lot of room for improvement. Taiwan’s local governments thus should formulate strong policy interventions in air pollution.

4. Conclusions

During the current situation of global warming and deteriorating environmental conditions, countries around the world are thinking about how to balance economic growth, reduce environmental pollution, and move forward in the direction of sustainable development. Therefore, this article collects data from 19 counties and cities in Taiwan from 2012 to 2015, using the modified dynamic SBM model to explore the change in efficiency of air pollutants in various regions of the country from the economic perspective. The results are as follows:

(1) From 2012 to 2015, the counties with the best overall efficiency performance are Taipei City, Taitung County, Keelung City, Hsinchu City, and Chiayi City. Their average overall efficiency value is 1. The average overall efficiency performances are poor in Tainan City, Changhua County, Yilan County, Pingtung County, and Kaohsiung City, with efficiency values of 0.6488, 0.6716, 0.6756, 0.7032, and 0.7113. In counties and cities with the best overall performance and poor performance, the average disposable income per household has no significant relationship with air pollutant emissions.

(2) In the counties and cities with better overall efficiency from 2012 to 2015, the efficiency values of motor vehicles, average household disposable income, and three air pollutant emissions are all 1. Counties and cities with poor performance have large room for improvement in average disposable income per household.

(3) Regarding the undesirable output of suspended particulate emissions, sulfur oxide emissions, and nitrogen oxide emissions, the efficiency values of Taipei City, Taitung County, Keelung City, Hsinchu City, and Chiayi City are all 1. The efficiency values of the three air pollutants in the remaining 14 counties and cities are far below 0.5, indicating that the air pollution situation there is in urgent need of improvement.

(4) The five counties and cities with the lowest electricity consumption efficiency are Taoyuan City, Kaohsiung City, Tainan City, Taichung City, and Hualien County. The cement industry, mining industry, and tourism industry are concentrated in Hualien
County and need to improve their efficiency. Due to the high demand for industrial electricity, Taoyuan City accounts for more than half of all electricity in Taiwan. The authority must increase the utilization rate of energy use.

Compared with advanced countries, Taiwan has fallen far behind in air pollution control. The prevention of air pollution still only focuses on propaganda and should change to enforcement as soon as possible. More detailed regulations of pollution reduction in different industries are also necessary. This study has pointed out that the efficiency values of the three air pollutants in fourteen counties and cities are far below 0.5. Among the six municipalities directly under the central government with relatively high financial autonomy, only Taipei City and Taoyuan City have higher overall scores. The remaining 4 municipalities of Tainan City, Kaohsiung City, Taichung City, and New Taipei City have poor overall scores. Taiwan must pay attention to the future adjustment of its energy structure such as the use of coal and petrochemical energy and renewable energy development policies. Lastly, Taiwan should face the problem of air pollution without dividing the political parties in order to achieve a steady economy and sustainable development for all involved.

By above results, this research provides the following policy recommendation:

1. Air pollutants move with air flow; thus, the issue of air pollution should be jointly treated with surrounding countries
2. Local governments reduce coal use to generate electricity to reduce air pollution
3. Public sector and private sector should replace petrochemical energy with renewable energy to reduce air pollution
4. The government encourages the public sector and the private sector to use electric vehicles to reduce air pollutant emission by vehicle

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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