A GOAL PROGRAMMING APPROACH TO ASSESSING THE POLICY OF CARBON REDUCTION AND ECONOMIC DEVELOPMENT

[1]WANG HSIAO-FAN, [2]YANGHENG-HSUN

Department of Industrial Engineering and Engineering Management, National Tsing Hua University, Hsinchu, Taiwan, R.O.C.
E-mail: [1]hsiaofanwang@gmail.com, [2]j364916500@gmail.com

Abstract - With the increasing warming of the earth, the United Nations has formulated relevant treaties which require countries to put forward carbon reduction targets, but countries could not take into account both economic development and carbon reduction goals simultaneously, because the economic development often increased additional carbon emissions and there was a lack of objective adjustment between the two. Therefore, this study intends to resolve this dilemma based on a two-stage goal programming approach. At the first stage, an ideal production value of each industry is provided to meet the set carbon reduction and economic growth goals. At the second stage, the individual values of renewable and non-renewable energies will be determined. Through this production of each industry, we can pursue the goal of carbon reduction while enhancing the economic growth. Based on this result, relevant policies are formulated to help industrial transformation to achieve a low-carbon economy and sustainable development. Apreference realization mechanism with weighting and priority tools will be provided to facilitate the decision support and policy assessment procedure.

Keywords - Goal programming, Industry Structure, Carbon reduction, Economic Development, Leontief I-O Model, Cobb-Douglas Production Theory

I. INTRODUCTION

With climate change, the world is facing serious environmental problems. According to the reports, the average surface temperature of the earth has continued to rise in the past 100 years, and it has risen by nearly 1°C compared to pre-industrialization [3]. While facilitating the people's lives after industrialization, countries around the world have gradually aware of the various problems caused by global warming and energy depletion. Therefore, the governments have to take actions to implement green energy policies and to develop green energy industries in order to create a low-carbon economy with sustainable and social development.In response to this impact, the United Nations has formulated international carbon reduction conventions such as the Climate Change Framework Convention [5] and the Paris Agreement [9], requiring all countries to independently propose carbon reduction commitments targeting 2030 and try to limit the temperature increase to 1.5°C to 2°C [9]. However, it has beennotedthat many countries pay more attention to economic development than carbon reduction [7]. Therefore, carbon reduction goals cannot be successfully achieved. In particular, there is a lack of objective quantitative measurement between the two. In other words, to ensure the competitiveness of sustainable industrial economic development, industry structure and industrial transformation are highly critical.Therefore, this study will take Taiwan's industries as a case study to focus on the next stage of the 2030 target and based on the statistics of the Taiwan Energy Bureau of the Ministry of Economic Affairs, to develop GP model based on Leontief Input-Output Equilibrium Theory and Cobb-Douglas Production Theory, to calculate the output value of each industry according to its industry classification. As the energy industry consumes the largest amount of carbon emissions, in addition to adjusting the existing industry structure, we also propose a power generation structure by GP model based on the suggested generation value of the energy sector. Therefore, we shall obtain a new industry structure at the first stage based on the goals set by the government. Then, further analysis is carried out on the energy structure of the energy industry with the portion of renewable and non-renewable energies.

II. METHODOLOGY

2.1. General Goal Programming Model

In the past few decades, Multi-Criteria Decision Analysis (MCDA) has been adopted significantly for different applications with the development of new methods and the improvement of old methods (Velasquez et al., 2013). Among them, Goal programming (GP) is the one to support strategic decision for a head quarter. One of its advantages is that it has the ability to deal with complex problems. That is, it is possible to establish several objective function weights that reflect the priority of many objectives. The flexibility of the GP model allows DM to participate in the solution process by in cooperating DM's preference with various tools [8].
The formulation of GP problem is similar to that of linear programming problems. The major differences are the explicit consideration of goal levels and the various priorities associated with a decision maker's preference. In real life, there is often not only one goal to be pursued, and conflicts may arise when facing with different goals. In complex problems, if there is a trade-off problem, the decision-maker (DM)

usually evaluates the goals based on his/her preference shown by, the weights and/or, prioritizes, or establishes a clear indicator evaluation value to evaluate the conflict alternatives [6].After years of development, GP combines weight and priority to show that a general GP model form can be summarized as follows [ref.]: objective function add 'Z="

$$\text{Lex}\min\left\{\left[\sum_{i\in p_1}(w_i^+d_i^+ + w_i^-d_i^-), \ldots, \sum_{i\in p_k}(w_i^+d_i^+ + w_i^-d_i^-), \ldots, \sum_{i\in p_K}(w_i^+d_i^+ + w_i^-d_i^-)\right]\right\} \quad (1)$$

$$\text{s.t.}\begin{cases} f_i(X) - d_i^+ + d_i^- = g_i, \forall i = 1, \ldots, I \\ d_i^+ d_i^- = 0 \\ d_i^+, d_i^- \geq 0, \forall i \in p_k; k \in \{1, \ldots, K\} \\ X \in F \end{cases}$$

where F is a feasible set, X is a set of unrestricted decision variables, $f_i(X)$is the function of the i^{th} goal,$g_i$is the aspiration level of the i^{th} goal, $d_i^-$and d_i^+ are negative and positive deviations from target value ofi^{th} goal, w_i is the weight of the i^{th} goal.

The weights are ranged in [0,1]with $\sum_i w_i = 1$, p_k represents the index set of goals placed in the k^{th} priority level. It also requires that $d_i^+ d_i^- = 0$ must always hold true.By minimizing the total deviations from the setting goals, the desirable alternatives with Z=0 can be obtained.

2.2. The Proposed First-Stage Goal Programming Model

The Goal Programming Model (GP1) define notation !

In order to achieve the goal, it is necessary to minimize the deviation value and add the deviation value to the goal constraints. Therefore, while the two objective functions defined by (2) and (3), they are transformed into a general GP goal as shown in (4).

Goal 1: Minimize carbon emissions by all sectors

$$\min CO_2 = \sum_j E_j x_j \quad (2)$$

Goal 2: Maximization of the GDP by all sectors

$$\max GDP = \sum_j V_j x_j \quad (3)$$

where $CO_2$is the total CO_2 emissions at target year, E_j is the Carbon emission factor of industry j,$x_j$is the domestic production for industry j. GDPis the GDP at target year, $V_j$is the additional valuefactor of industryj.

Objective Function

$$\text{Lex}\min\left\{\left[\sum_{i\in p_1}(w_1^+d_1^+ + w_1^-d_1^-), \sum_{i\in p_2}(w_2^+d_2^+ + w_2^-d_2^-)\right]\right\} \quad (4)$$

Functional Constraints

$$\sum_j E_j x_j - d_1^+ + d_1^- = CO_2 \quad (5)$$

$$\sum_j V_j x_j - d_2^+ + d_2^- = GDP \quad (6)$$

$$\sum_j C_j x_j \leq B \quad (7)$$

$$\sum_j L_j x_j \leq TL \quad (8)$$

$$d_i^+ d_i^- = 0 \quad (9)$$

$$x_j \geq F_j, \forall j \in J \quad (10)$$

$$x_j, d_i^+, d_i^- \geq 0, \forall i \in I, \forall j \in J \quad (11)$$

Eqs. (5) and (6) show the carbon emission and the economic growth goals, respectively. Eq. (6)is Leontief's input/output equation from the aspect of domestic gross supply.

Based on Cobb-Douglas production function, (7) represents the government's investment budget in the target year. Eq. (8) represents the total number of employed people in the target year.

Eq. (9) ensures that the only one kind of deviation is possible. Eq. (10) represents the industry demand in the target year. Eq. (11) is a non-negative constraint for all variables.

2.3. Scenario Analysis

With the property of a GP, two scenarios are first considered:

Scenario 1. the carbon emission target is first pursued, then followed by the economic growth target;

Scenario 2. the goal of economic growth is first pursued, then followed by the carbon emission goal. Due to different scenarios, the priority index in target formula will be modified as shown in(12) and (13).. .The target formulas are: p in (13) is wrong !! if you swap p, the sequence formula shouldn't change !

Scenario (1). The carbon emission target has a higher priority

Objective Function:

$$\text{Min } Z = p_1(w_1^+ d_1^+ + w_1^- d_1^-) + p_2(w_2^+ d_2^+ + w_2^- d_2^-), \quad p_1 \gg p_2 \tag{12}$$

Scenario (2). Economic growth target has a higher priority

Objective Function:

$$\text{Min } Z = p_2(w_1^+ d_1^+ + w_1^- d_1^-) + p_1(w_2^+ d_2^+ + w_2^- d_2^-), \quad p_2 \gg p_1 \tag{13}$$

2.4. The Proposed second-stage Goal Programming Model

The Goal Programming Model (GP2)

The second stage is to develop the optimal power generation structure, and use the energy output value of the first stage as the only goal to be achieved. . Therefore, the objective function is formulated by(14) below:

Objective Function

$$\text{Min} Z = d_1^+ + d_1^- \tag{14}$$

Functional Constraints

$$p\left(\sum_r \frac{y_r}{PG_r} + \sum_{nr} \frac{y_{nr}}{PG_{nr}}\right) - d_1^+ + d_1^- = \alpha x_1 \tag{15}$$

$$\sum_r \frac{e_r y_r}{PG_r} + \sum_{nr} \frac{e_{nr} y_{nr}}{PG_{nr}} \le ECO_2 \tag{16}$$

$$\sum_r \frac{EC_r y_r}{PG_r} + \sum_{nr} \frac{EC_{nr} y_{nr}}{PG_{nr}} \le EB \tag{17}$$

$$\sum_r y_r + \sum_{nr} y_{nr} = 1 \tag{18}$$

$$\sum_{nr} y_{nr} \ge \beta \tag{19}$$

$$d_i^+ d_i^- = 0 \tag{20}$$

$$y_r \le U_r, \forall r \in R \tag{21}$$

$$y_r, y_{nr}, d_i^+, d_i^- \ge 0, \forall i \in I, \forall r \in R, \forall nr \in NR \tag{22}$$

Eq. (15) shows the target output value, where x_1 is the output value of the energy sector obtained from the first stage, a is the proportion of electricity in the energy sector, multiplied by the two is the required power generation, and p represents the average unit of electricity price.

Eq. (16) shows the carbon emission limit required by the power generation. Eq. (17) shows the budget limit of the power generation. Eq. (18) shows that the total power generation structure is 1. Eq. (19) shows the proportion of base load in the power generation structure for the required stability of power supply. Eq. (21) shows the upper bound of the renewable energy power generation structure due to the land use development conditions [1].Eq. (22) is a non-negative constraint for all variables.

III. CASE STUDY

A case study of policy evaluation to achieve the goals of carbon emission and economic development set by Taiwan in 2030 was adopted to verify the proposed model. On this study, a National Development Plan [4] with Taiwan's Deep Carbon Reduction Policy Proposal [3] was considered and the data from 2006 to 2019 collected by the Taiwan National Statistics Bureau, R.O.C. were used as the basic information. Then according to the Taiwan Bureau of Energy, the national industries are classified into 6 categories [2]: energy sector (j=1), industrial sector (j=2), transportation sector (j=3), agricultural sector (j=4), service sector (j=5), others sector (j=6). Based on our GP module, we first conducted the GP1 with scenario analysis of (1) Prioritize carbon reduction targets, and (2) Prioritize economic growth targets.

At the second stage, we divide the power generation structure into renewable energy and non-renewable energy. Among them, the renewable energy includes solar power (r=1), wind (r=2), other renewable energy (r=3); and the non-renewable energy includes coal (nr=1), gas (nr=2), other non-renewable energy (nr=3).

By adopting the Software Ampl/Knitro (Artleys, 2015), we conduct the analysis of the impact of an industry structure on overall carbon emissions and economic growth from the different target priorities in order to support policy making decisions. The parameter prediction is carried out by the data prediction worksheet of Excel (Microsoft, 2019) to make ETS predictions and establish a 95% confidence interval [ref. your thesis!].

3.1. Numerical Results & Analysis

By substituting the predicted parameters for 2030, the results are shown in Tables 1 to 3, of which Tables 1 and 2 show the priority analysis. Table 3 shows the suggested power generation structure for 2030.

Industry (j)	Output value unit?	Deviation	Output value
Energy (1)	1321740	d_1^+	0
Industrial (2)	18830700	d_1^-	0
Transportation (3)	1123030	d_2^+	0
Agricultural (4)	905296	d_2^-	0
Service (5)	25563100		
Other (6)	348191		

TABLE 1. Scenario (1). Industry Structure by Taking Carbon Emission Target as the 1st Priority

Industry (j)	Output value unit	Deviation	Output value
Energy (1)	1321740	d_1^+	0
Industrial (2)	18830700	d_1^-	0
Transportation (3)	1123030	d_2^+	0
Agricultural (4)	905296	d_2^-	0
Service (5)	25563100		
Other (6)	348191		

TABLE 2.Scenario (2). Industry Structure by Taking Economic Growth Target as the 1st Priority

From the above table, we may note that the two situations in the first stage have the same results. Therefore, at the second stage, we calculate the power generation structure based on the energy output value result of the first stage (x_1=1321740) multiplied by the proportion of electricity (a=0.8) [2] as the goal.

The upper bound of renewable energy and base load capacity (β) for the second stage in 2030 are set as U_1=0.08, U_2=0.1, U_3=0.02, , β=0.85 according to the Taiwan Power Company's forecast (%). Table 3 shows the results of the second stage.

Energy category	Power generation structure	Deviation	Output value
Solar	6.6%	d_1^+	0
Wind	0%	d_1^-	0
Other renewable energy	2%		
Coal	50%		
Gas	33.11%		
Other non-renewable energy	8.29%		

TABLE 3.Results of The Second Stage Model

3.2. For First Stage Deviation Weight Analysis

In the actual situation, although there are already established goals for carbon reduction targets, for decision support sake, pursuing Alternative solution which could reduce more carbon emissions than the established targets would be desirable. In other words, we should search for alternative solution by setting $w_1^+ = 1$, and $w_1^- = 0$, to realize that the increase in carbon emissions is not acceptable, but the reduction in carbon emissions is acceptable.

This leads to a single deviation objective of "minimizing the d_1^+". With the same token, for economic growth goals, $w_2^+ = 0$ and $w_2^- = 1$ are set by "minimizing the d_2^-". That is, for economic growth, GDP can be increased instead of fall. Table 4 summarizes the comparative results of the parameter analysis with those obtained in section 3.1.

Industry (j)	Before (Industry structure)	After (Industry structure)	Difference (After-Before)
Energy (1)	2.76%	2.75%	-0.01%
Industrial (2)	39.30%	39.16%	-0.14%
Transportation (3)	2.34%	2.34%	0%
Agricultural (4)	2.01%	1.88%	-0.13%
Service (5)	52.87%	53.15%	+0.29%
Other (6)	0.73%	0.72%	-0.01%

TABLE 4.The Difference between Before and After Adjusting the Deviational Weight

3.3. For Second Stage Parameter Analysis of the Base Load Capacity

At the first stage, because adjusting the target deviation weight did not change the output value of the energy industry, at this stage, the parameter analysis is carried out with the power generation share of the energy sector (ax_1=1057392) as the target. Since the base load capacity will guarantee the minimum power supply, the important role acquires our further analysis.

The analysis method is to redefine the parameter value of β from the original 85% to the incremental units of 10% to 90%, to provide a new power generation structure.

Then, according to the constraints of the case study, the parameters of U_r and a remain unchanged. To support the policy of power generation structure made for 2030, the ratios proposed by the National Development Plan [4] of 20% for the renewable energy accounted and 80% for the non-renewable energy accounted were adopted, of which MAPE was used to determine the best range of β for the power generation structure. Table 5 shows the results of the analysis.

β	Renewable energy	Non-renewable energy	MAPE
0.1 to 0.4	16.2%	83.84%	12%
0.5 to 0.6	15.33%	84.67%	15%
0.7 to 0.9	8.6%	91.4%	36%

TABLE 5. Parameter Analysis of the Base Load Capacity of Power Generation

IV. DECISION SUPPORT ANALYSIS

In this section, we shall apply the above results for the economic policy proposal on the industry development:

4.1. Energy, Transportation, Agricultural and Other Sector

For energy, transportation, agriculture and other sectors, the change in the industry structure is not obvious (less than 1%). The government only needs to maintain a stable economic level.

4.2. Industrial, Service Sector

According to the data in 2019, the proportion of the industrial sector is accounted for nearly 50%. However, by 2030, that of the service sector is accounted for more than 50%. This means that the government needs to focus on the transformation of the industrial sector. In particular, the government should pay attention to those carbon emission-intensive industries so that they could transform into low-carbon-intensive but high economic growth service industries. Although the industrial structure gap exceeds 10%, there is a lot of room for efforts in the future. .

4.3. Power Generation Structure

According to the power generation structure in 2019, the changes in the power generation structure by 2030 will be relatively large. In particular, if the nuclear power generation retains, to reach the economic development level, both thermal power generation (81.47%) and nuclear power generation (11.79%) accounts for a relatively large proportion [2]. If according to the goal, the renewable energy power generation structure should reach more than 20% by 2030, which is a big challenge for the government. If the government determines a base load capacity between 10% and 40%, it needs to ensure the stability of renewable energy. Otherwise, once renewable energy power generation cannot meet the demand due to sudden extreme environmental factors, the non-renewable energy power generation is needed to make up for the shortfall. However, due to the limitation of base load capacity, the proportion of non-renewable energy cannot be increased any more. In consequence, this will cause the power shortage. In addition, due to geographical environmental factors, nearly 98% of Taiwan’s demand for energy raw materials is imported, which is also heavily affected by international energy prices. In order to reduce this impact, investment and planning for renewable energy will be the urgent development projects.

V. CONCLUSION

Although many governments emphases the economic growth and decouple the economic development from energy saving and carbon reduction, from this study, we have shown that a government can take into account economic development while saving energy and reducing carbon.In this study, in order to achieve the goals of carbon reduction and economic growth, based on the Leontief Input-Output Model, Cobb-Douglas Production Formula and Time Series Analyses, we have developed a GP module to support a strategic plan for a government. The Module includes two sub-models of an Optimal Industry Structure Model (GP1) and an Optimal Power Generation Model (GP2). After the scenario analysis to ensure the feasibility and rationality of this proposed GP1 model for optimal industry structure solution, the second GP2 model for this energy output value has been developed to achieve the best power generation structure.

In order to verify the model, the domestic data of Taiwan in 2019 were adopted, and the Taiwan's targets in 2030 were demonstrated for decision support, of which a new industry structure and power generation structure are provided. The results show that the proposed GP Module is able to provide a new industry structure which can not only achieve the goals of carbon reduction and economic growth, but also increase economic growth by NT$100,000. Moreover, the decision support procedure suggested that the industry and service industries have a major impact on carbon emissions and economic growth. Therefore, in the future, the government can promote the industrial transformation by leading the carbon-intensive industries into service industries.

Although the new power generation structure can meet the government's goal of power generation structure in 2030, the development of renewable energy is crucial to the new power generation structure. Therefore, the government's commitment to the development of renewable energy should be placed on the top priority to ensure the environmental protection and energy supply efficacy. In addition, because the government is the leader on developing a nationwide industrial development plan, many countries have actively established incentives and penalties for carbon emissions (such as carbon taxes, subsidize etc.). The proposed industry and power generation structures can be regarded as a blueprint for a government to develop such plan to give related industries and power generation companies more incentives to reduce energy consumption and carbon emissions.

ACKNOWLEDGMENT

The Authors Acknowledge the financial support from the Ministry of Science and Technology, Taiwan, ROC with project MOST #109-2221-E007-071-MY3. .

REFERENCES

[1] 郭瑾瑋, 周裕豐, 洪明龍, & 劉子衡. (2015). 應用台灣 TIMES 模型進行我國長期電力供需規劃.台灣能源期刊,2(4), 363-382.

[2] 經濟部能源局. (2019). 我國燃料燃燒二氧化碳排放統計與分析.

[3] 中央研究院. (2020). 臺灣深度減碳政策建議書.

[4] 國家委員會. (2020). 國家發展計畫.

[5] Bodansky, D. (1993). The United Nations framework convention on climate change: a commentary. Yale J. Int'l l., 18, 451-473.

[6] Keeney, R. L., Raiffa, H., & Meyer, R. F. (1993). Decisions with Multiple Objectives: Preferences and Value Trade-Offs. Cambridge university press.

[7] Liu, J., Yang, Q., Zhang, Y., Sun, W., & Xu, Y. (2019). Analysis of CO2 emissions in China's manufacturing industry based on extended logarithmic mean division index decomposition. Sustainability, 11(1), 226-253.

[8] Tamiz, M., Jones, D., & Romero, C. (1998). Goal programming for decision making: An overview of the current state-of-the-art. European Journal of operational research, 111(3), 569-581.

[9] UNFCCC, V. (2015). Adoption of the Paris Agreement. I: proposal by the president (Draft Decision). United Nations Office, Geneva (Switzerland).

★★★