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Comparative Analysis of Green Productivity in Selected Asian Countries by AHP Method*

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Abstract: The research aims to assess the status of green productivity(GP) in six Asian countries for which we developed a framework of criteria covering the aspects of environmental sustainability, productivity, and social contribution. Under 3 major criteria, fourteen specific criteria were developed for GP. A total of 367 specialists, citizens and policy makers were participated in the survey from 6 countries. AHP was used in simulation for gaining weighting values. Respondents considered environmental sustainability (0.550) and productivity (0.246) as important elements in GP while social contribution (0.204) as less important. Among all 14 evaluation criteria, the most highly regarded elements were air quality (0.133), followed by water quality (0.111) and the use of renewable energy (0.095), while green label and customer complaints were considered the least important. Applied to the evaluation process were 89 companies that provided actual data for evaluation. These all data were combined with weighting values obtained in the previous survey. by which all companies could be ranked. The CC5 of the Republic of China was ranked as the best company and EC3 of Indonesia and CC15 of ROC were awarded as second and third companies. The research could actually evaluate companies over countries in terms of GP and expects to improve in measurement methodology for GP.
Key Words: Green Productivity, AHP, Multi Criteria Evaluation, Relative Importance, Rank

I. Introduction

Recently, Asian countries have experienced the most rapid economic growth of any region in the world, while they have intensively used energy and natural resources and are becoming the world's largest sources of "black" carbon emissions. The key question

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facing Asian countries is whether this increase will occur in a sustainable manner, or whether it will reproduce the patterns that industrialized countries witnessed in the past. Many researchers acknowledged the necessity of a new path of development, considering economic growth, resource conservation as well as environmental protection in Asia (Pan et al., 2015; Balist et al., 2016; Li and Lin, 2016; Krugman, 2016).

A green productivity (GP) can be generally defined as a business that strives to reduce its negative impact on the environment by incorporating green practices while maintaining a profit. The term Green Productivity was used by the Asian Productivity Organization (APO) (Macial and Freitas, 2019; Pineda-Henson and Culava, 2004; APO, 2006). The concept integrates productivity and quality improvements, in which productivity provides the framework for continuous improvement while environmental protection provides the foundation for sustainable development.

The trends of global environment pollution stemmed from the fast economic growth have highlighted the importance of intensifying the promotion of GP and enforced enterprise's green productivity practices. Recently, APO initiated an award program for green companies for which national experts from Asian countries met and developed an evaluation framework and criteria for GP. Several meetings and intensive seminar for GP in Taipei and Seoul helped in developing the concept and two tiers of specific evaluation framework in the study. And two surveys across 6 Asian countries could be possible from them.

The study reviewed many literatures and developed Asian perspective with APO's help, and finally adopted main framework including environmental sustainability, productivity and social contribution, and specific criteria. The main objective of the paper is to develop an awarding framework of GP not for specific type but for energy and resource intensive type of manufacturing companies in Asia for which evaluation method and criteria were developed.

II. Literature Review

In the face of global environmental crisis, several authors and Asian countries have sought to find a new paradigm of sustainable manufacturing. The conservation of resources and minimization of waste were simultaneously linked to the strategy of better environmental performance and organizational productivity (Pineda-Henson and Culaba, 2004; Li and Lin, 2016). Tuttle and Heap (2007) also clarified the definition of GP with dual focus of business and its macro environment. And Sampattagul et al. and Pan et al. developed an comprehensive and integrated life cycle analysis of eco-impact of machine industries (Sampattgul et al., 2004; Pan et al., 2015).

In order to evaluate the organization as a whole, several authors have developed the Green Productivity Index (GI) and applied to in diverse industries such as oil production, car parts, pepper production etc. (Hur, Kim and Yamamoto, 2004; Gandhi et al., 2006; Cho et al., 2011; Sittichinnawing and Peerapattana, 2012; Marimin et al., 2014; Aprianto et al., 2016). Most of these analysis focused on the case of Asian countries such as Indonesia, Philippine, Pakistan and Republic of Korea, and Thailand.

Beyond the linkage of productivity with environment, the framework of GP are expanded toward social dimensions. The social concern in the generation of products and processes contains the improvement in the quality of customers' life (Macial and Freitas, 2019). The triple concept of GP contributed in the development of evaluation framework in the study. A wide range of criteria or attributes need to be taken into account, not simply focusing on the productivity or cost minimization.

Based on studies of Tangen (2002), Tuttle et al. (2007) and Saxena et. al. (2003), productivity can be defined as being the capacity to produce starting from a certain quantity of resources, where productivity is measured by the relation between the level of production and the resources applied to it, such as labor, energy, water and materials. These became the basic in the construction of indicators in the study.

Environmental impacts can be quantified and measured in terms of the minimum use of resource and the reduction of environmental impacts (Kim and Hur, 2003; APO, 2006). The concept was developed in the study as indicators for dematerialization and detoxification. The intensity of the consumption in raw materials, non-renewable energy, and water resources, and the recycled material, renewable energy and reclaimed water is developed as indicators of dematerailization. The reduction of the discharge of air, water and solid waste generated by the company is also developed as indicators of detoxification.

While corporates have focused on productivities and encouraged the technological innovation and/or cost minimization, societal perspectives require more than economic efficiency and environment and social welfares. The study widens its evaluation framework from the business and the environmental orientations to “shareholders” perspective (Cho et al., 2011; Chavan, 2009). For this, the concept of corporate social responsibility (CSR) need to be integrated. Beyond the conventional approaches, the study integrated CSR in the framework such indicators of social contribution as social investment, safety, consumer and green labeling.

The evaluation of GP in the study are based on concept of productivity, environment and social responsibility. The study developed a metric framework of criteria and indicators to assess GP in the selected Asian countries, assuming the existence of diverse and conflicting values and points of views in the society (Munda, 2003; O'Connor et al., 1996).

Six national experts from six participating countries and staffs from APO have intensively helped together for the development of framework and the extraction of evaluation criteria through two seminars in Taipei and Seoul. Six countries are all of members of APO and experienced in the development of GP criteria. They also supported in conducting survey 1 and survey 2 in each country.

The paper could contribute in the construction GP indicators and framework for a comparison study in Asia by incorporating not only environmental pollution but also energy and social issues with economic growth, all of which are the essentials in Asia's green development.

Ⅲ. Evaluation Method and Framework

1. Evaluation Method

In evaluation of GP, multi-criteria evaluation is an appropriate tool since it allows taking into account a wide range of evaluation criteria, not simply profit maximization but also other considerations (Munda, 2003). Different value and criteria can be conflicting, multidimensional, incomparable and incommensurable. As a tool for conflict management, multi criteria evaluation has demonstrated its usefulness in many green management policies.

Analytic Hierarchy Process (AHP) developed by Satty (1980, 1985) is a method to find an optimal alternative through hierarchical analysis and pairwise comparison of a wide range of criteria or attributes. Because of its simplicity and clearness in comparing companies in green productivity, AHP is appropriate in the study. The extraction of evaluation criteria related to green productivity and in the analysis of relative importance among evaluation criteria can be done. The method can help develop and articulate value judgment in a systematic way that can be used to rank alternatives in the case of development and environmental applications (Hobbs and Meier, 2000).

The research process begins with defining problems, planning goals and generating alternatives through literature review, data survey and expert meetings and interviews and with identifying and extracting hierarchical evaluation criteria; 3 implementing pairwise comparisons of each evaluation criteria with the scale of 7 points.

The surveys consisted of 2 stages: stage 1 to build evaluation framework, evaluation criteria and assessment indicators for GP. Stage 2 to assign the relative importance among the evaluation criteria selected in stage 1. It is anticipated that the respondents have and reveal various interests in GP in the survey response.

In the beginning of AHP, the larger system at upper hierarchy can be developed to comprehend distinct pieces of information and interest, the number of entities. The large system is broken up into subsystems, almost as the schematic of a computer consists of blocks and their interconnections, with each block having a schematic of its own.

Through survey, opinions of respondents on the value of pairwise comparison matrix can be obtained. Analysis of survey data, calculate relative importance and consistency ratio on each alternative. If consistency is not secured, simulate again the 3th stage of analysis until consistency is secured. Finally, driving priorities among alternatives by composing the weights in the hierarchy (Kim et al., 2013).

When many pairwise comparisons are performed, some inconsistencies may typically arise. The AHP incorporates an effective technique for checking the consistency of the evaluations made by the decision maker when building each of the pairwise comparison matrices involved in the process. Consistency Ratio (CR) is important index representing consistency in judging and measuring of survey data. The deviation from consistency can be represented as the consistency index (CI).

$$(CI) = (\lambda_{\max} - n)/(n-1)$$
$$(CR) = (CI/RI) \times 100\%$$

〈Table 1〉 Random Index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Saaty, T., 1980, p.20

The ratio of CI for the same order matrix is called the consistency ratio (CR). A consistency ratio of 0.1 or less is considered acceptable. In particular, CR of 0.2 can be allowed in the case of difficulty in securing indifference among evaluation criteria unfamiliarity of respondents in AHP survey (Park et al., 2000; Ko, 2009).

2. Evaluation Framework

1) Environmental Sustainability

Environmental sustainability is to evaluate the extent to which the applicants reduce their environmental impacts yearly. This dimension has two aspects: dematerialization and detoxification. For the de-materialization aspect, raw material consumption, renewable energy and reclaimed water are important criteria. The discharge of toxic and hazardous materials or wastes are key concept in the detoxification aspect. Air and water quality, solid waste and hazardous waste materials are categorized in the 2nd trial of evaluation criteria. The reduction of GHG emissions is assumed to be included in the criteria of dematerialization.

The indicators for dematerialization and detoxification are expressed in detail in the table 2. The intensity of the consumption in raw materials, non-renewable energy, and water resources, and the recycled material, renewable energy and reclaimed water is developed as indicators of dematerailzation. The reduction of the discharge of air, water and solid waste generated by the company is also developed as indicators of detoxification.

〈Table 2〉 Evaluation framework and criteria

1st Trial evaluation criteria	Aspects	2nd trial evaluation criteria	References
Environmental Sustainability	Dematerialization	Raw material	Kim and Hur (2003) Pineda-Henson and Culabe (2004) Pan et al. (2015) Macial and Freitas (2019)
		Renewable energy(saving)	
		Reclaimed water	
	Detoxification	Air quality	Kim and Hur (2003) Sampattagul et al.(2004) Sittichinnawing and Peerapattana (2012) Pan et al. (2015)
		Water quality	
		Solid waste	
Productivity	General pro-ductivity	Labor productivity	OECD (2001) Kim and Hur (2003) Pineda-Henson and Culabe (2004) Hur et al.(2004) Cho et al.(2011) Sittichinnawing and Peerapattana (2012) Lin et al. (2013) Pan et al. (2015) Li and Lin (2016) Macial and Freitas (2019)
		Energy productivity	
		Water productivity	
		material productivity	
Social Contribution	CSR (Corporate Social Responsibility)	Social investment	Cho et al. (2011) Guo et al. (2015) Macial and Freitas (2019)
		Safety(health)	
		Green label/ certification	
		Customer/ Consumer	

note: specific definition of each criteria are indicated on 〈Table 6〉

2) Productivity

Base on OECD suggestions (2001), the study includes general productivity and material productivity, in which labor productivity is included in the general productivity aspect, whereas energy and water productivities are included in each productivity aspect for analyzing how added value is created by workers, by the energy and by water consumed by the company. The idea behind these criteria is that profitability is the bottom line of a corporation, which thus needs to have high productivity to gain green competitiveness. Hence, all indicators are translated into monetary units to represent a win-win of economic and energy and water efficiency.

Companies should disclose revenue growth for the most recent year, and any new capabilities/factors that demonstrate sustainable growth of the company. Companies should demonstrate continuous improvement in labor, energy, water and material productivity. In this survey, we asked for just one year performance in each element shown in the table 2, because it was difficult to have time series data. The unit of value added used in the following measurement is in US dollars.

3) Social Contribution

Social issues vary for different countries and are sometimes locality and community specific. Even though, the dimension has specific evaluation criteria in which applicants provide the amount of investment towards for contribution. The dimension of safety considering health also asks the enterprises to provide the number of industrial incidence inside and outside. The criteria of green label/certification and customer/consumer are related to current number of label/certification and any channel for customer/consumer number of complaints, each other.

Companies provide a description or explanation of their efforts for social contribution and sustainable development. The magnitude of positive impact on stakeholders of the issues listed in the table 2 is the main consideration for judgment: Data for each criterion in the CSR were not appropriately obtained, so the data for simulation were inputted as number 1 or 0. If a company has investment toward for social contributions, 1 was inputted. If not, 0 was inputted.

Ⅳ. Pairwise Comparisons among Evaluation Criteria and Company Survey

1. Pairwise Comparison

Based on the hierarchical evaluation criteria, the study developed two types of survey questionnaires. Survey 1 for diverse types of respondents is to check the relative importance of criteria by comparing each other in the case of 1st tier and 2nd tier of evaluation criteria each other. All weighting values in each tier could be derived through survey 1. In the survey, 367 respondents are classified as 4 groups of organization, i.e., education and research, company, government and others.

Survey 2 for companies is to fill out actual data for their performance in all questionaries including company's general informations(4), environmental sustainability(13), productivity(4), social contribution(7). Their replied values on questions are integrated and calculated with weighting values that are gained from the survey 1. The final performance and ranking for all companies is determined by the combination of these two surveys.

Our survey for the research has been conducted through 6 countries and the numbers of respondents are as the table 3. Total numbers are 367 for survey 1 and 89 for survey 2.

〈Table 3〉 Number of respondents

Country	Survey1 for weighting	Survey2 for company
Indonesia	35	8
India	50	30
Philippines	17	13
ROK	14	7
Thailand	25	16
ROC	226	15
Total	367	89

The table 4 shows the example of survey questions for evaluating relative importance among 1st tier criteria, and the table 5 shows the example of survey questions for evaluating relative importance among 2nd tier criteria in the case of productivity. Considering criteria, the scale of 7 points are used in pairwise comparisons of each evaluation criteria. Relative importance of evaluation criteria can be expressed in the matrix. Through survey 1, opinions of respondents on the value of pairwise comparison matrix can be obtained. Relative importance of the evaluation criteria for GP can be calculated from the pairwise comparison matrix which is obtained by the second survey. The weights of attributes can be derived by using eigen vector of the pairwise comparison matrices.

〈Table 4〉 Survey I questions for 1st tier evaluation criteria

A	A is more important than B						Equal	B is more important than A						B
	very strongly, strongly, slightly							Slightly, strongly, very strongly						
Environmental sustainability	7	6	5	4	3	2	1	2	3	4	5	6	7	Productivity
Environmental sustainability	7	6	5	4	3	2	1	2	3	4	5	6	7	Social contribution
Productivity	7	6	5	4	3	2	1	2	3	4	5	6	7	Social contribution

〈Table 5〉 Survey I questions for 2nd tier evaluation criteria (Case of productivity)

A	A is more important than B						Equal	B is more important than A						B
	very strongly, strongly, slightly							Slightly, strongly, very strongly						
Labor productivity	7	6	5	4	3	2	1	2	3	4	5	6	7	Energy productivity
Labor productivity	7	6	5	4	3	2	1	2	3	4	5	6	7	Water productivity
Labor productivity	7	6	5	4	3	2	1	2	3	4	5	6	7	Material productivity
Energy productivity	7	6	5	4	3	2	1	2	3	4	5	6	7	Water productivity
Energy productivity	7	6	5	4	3	2	1	2	3	4	5	6	7	Material productivity
Water productivity	7	6	5	4	3	2	1	2	3	4	5	6	7	Material productivity

The table 6 is a sample of survey questionnaire for companies to collect actual data for their performance in GP. Respondents were asked to rate the relative importance of criteria by comparing each criterion with each other as per survey tier 1.

Relative importance of evaluation criteria obtained by survey1 is calculated with the values obtain by survey 2. Simple Additive Weighting (SAW) method is used in the analysis. The SAW method is a commonly known and very widely used method for providing a comparative evaluation procedure in MCDM. SAW uses all criterion values of an alternative and employs the regular arithmetical operations of multiplication and addition (Chen, 2012, pp.1848-1861).

〈Table 6〉 Survey II questions for companies

1. Environmental Sustainability

Criteria	Formula
(1) De-materialization	
Raw material	Total raw material consumption (ton/year)
	Total amount of recycled material (ton/year)
	Total production (Overall production)
Renewable energy (Energy saving)	Percentage of renewable energy to total energy consumption
	Metric ton or equivalent of energy save per ton of product
Reclaimed water	Total water consumption (unit: Unit: m^3 /year)
	Total amount of recycled water Unit: m^3 /year
(2) De-toxification	
Air quality	Sox, NOx, VOC (Y/N) above regulation/ law
	Total amount of emission to air
Water quality	BOD, COD, other toxics (Y/N) above regulation/ law
	Total amount of waste water
Solid waste	Total amount of solid waste Unit: Ton/year
	Amount of hazardous waste Unit: kg/year

2. Productivity

Criteria	Formula
Labor productivity	Production(value added/total employees (y)
Energy productivity	Production(value added/energy consumption (y)
Water productivity	Production(value added/water consumption (y)
Material productivity	Production(value added/ material consumption (y)

3. Social Contribution

Criteria	Formula
Social investment	Amount of investment towards for social contribution (money/year)
	Number of employees and time spent for social service
Safety (Health)	Number of industrial incidence inside and outside (no/year)
	List of safety and health measure implemented/ practiced
Green label and certification	Current number of label/ certification
Customer and consumer	Any channel for Customer/ consumer (Y/N)
	Number of complaints

note: value added in current US dollars; energy in ton of oil equivalent(TOE)

2. Checking Credibility of Survey

Consistency ratio (CR) was obtained by above equations. CR in the 1st tier was 0.028. CR of 1st tier in each country was 0.275 (India), 0.005 (Indonesia), 0.002 (Philippine), 0.01 0 (ROC), 0.012 (ROK), and 0.083 (Thailand) each other. The case of India, the value of CR, 0.275 shows is a little lower level of reliability. If there would be an award program for India companies only within the country, the answer sheet of survey 1 (India case) need to be checked and answer sheets that significantly lack consistency be removed. Within the scope of this research, the Indian sample size was not big enough to make the CR of whole participating countries to the level of unreliable level, i.e. 0.2. Thus, the credibility of CR in this reseach is secured. CR in the 2nd tier was 0.016 (dematerialization). 0.01 (detoxification), 0.046 (productivity) and 0.10 (social contribution) each other. The research used Microsoft Office Excel 2010 in the simulation of the analysis. derived the weighting value among criterion, and finally obtained the priorities among companies by composing the weights in the hierarchy with the values of each company through each criteria.

Ⅴ. Analysis and Result of Survey

1. Analysis of Relative Importance

The table 7 shows the weighing value and order of the criteria of 1st tier and 2nd tier driven by the 367 respondents from 6 Asian countries. On the whole, the respondents gave high priority in order: environmental sustainability, productivity, and social contribution. As shown in the table, the highest value of relative importance in the 1st tier criteria in 6 Asian countries was environmental sustainability (0.550) and productivity (0.246). Social contribution was the lowest value of 0.204. On the whole, respondents consider environmental sustainability as the most important element in the evaluation, while social contribution was regarded as the important issue, implying that people in the region did not give high point to social contribution in green productivity. For the environmental sustainability aspects, respondents gave priority to detoxification (0.554) over dematerialization (0.446).

The number of sample size in survey 1 was big enough in securing the validity of the research, but the case of ROC was relatively very big, comparing with the size of other countries. ROC could be highly influential in driving the weighting values among criteria. So, the study additionally conducted an analysis the wighting pattern by each country (see in the figure 2) and its result showed very similar outcomes as seen in the general. The order of relative importance by each country is exactly same to the order of 6 countries' aggregative relative importance. The study decided to adopt the results of survey 1 because the influential of one country is not enough significant in changing the evaluation framework

while not adjusting the number of respondents from ROC.

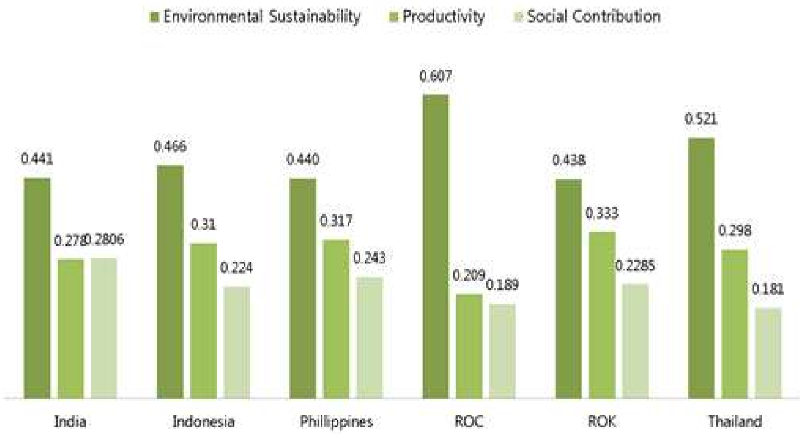
〈Table 7〉 Weight values from survey I

1st tier Criteria		Weight (order)		2nd tier Criteria	Weight (order)	Final weight (order)
Environmental Sustainability	De-Materialization	0.550 (1)	0.446 (2)	Raw material	0.330(2)	0.081(4)
				Renewable energy	0.386(1)	0.095(3)
				Reclaimed water	0.284(3)	0.070(7)
	De-toxification		0.554 (1)	Air quality	0.437(1)	0.133(1)
				Water quality	0.363(2)	0.111(2)
				Solid waste	0.201(3)	0.061(9)
Productivity		0.246 (2)		Labor productivity	0.267(2)	0.066(8)
				Energy productivity	0.314(1)	0.077(6)
				Water productivity	0.222(3)	0.055(10)
				Material productivity	0.197(4)	0.048(11)
Social Contribution		0.204 (3)		Social investment	0.220(2)	0.045(12)
				Safety(health)	0.396(1)	0.081(5)
				Green label/Certification	0.182(4)	0.037(14)
				Customer/Consumer	0.202(3)	0.041(13)

Still, ROC's weighting value in environmental sustainability is high (0.607), while India's and Philippine's weighting values in the same criteria are relatively low (0.441) and (0.440) respectively. the significance of the difference vary by country and by criteria.

The order of The outcome of the evaluation of 2nd tier criteria for GP is as follows. The first, in the criteria of dematerialization, relative importance was shown with priority order of renewable energy (0.386) → raw material (0.330) → reclaimed water (0.284) respectively. In detoxification, relative importance was shown with priority order of air quality (0.437) → water quality (0.363) → solid waste (0.201) respectively. Respondents think maintenance of air quality is the most important in attaining environmental sustainability.

〈Figure 1〉 Relative importance by country



Relative importance in the criteria of productivity was shown with priority order of energy productivity (0.314) → labor productivity (0.267) → water productivity (0.222) → material productivity (0.197) respectively. This means the efficiencies of energy and labor input in production are more important than other elements in the consideration of green productivity .

Relative importance in productivity was shown with priority order of energy productivity (0.314) → labor productivity (0.267) → water productivity (0.222) → material productivity (0.197) respectively. This means the efficiencies of energy and labor input in production are more important than other elements in the consideration of green productivity . Relative importance in social contribution was shown with priority order of safety (health) (0.396) → social investment (0.220) → customer/consumer (0.202) → green label/certification (0.182) respectively. Respondents consider industrial incidence and investment for society are important than labeling and certification policy and customer's or consumer's complaints in pursuing green productivity.

The final weighting value and order by criteria is shown in the last column of the table 7. The values are obtained by multiplying weights in the 1st tier with weights in the 2nd tier in the hierarchy. The most highly regarded elements in all criteria are air quality (0.133), water quality (0.111) and the use of renewable energy (0.095). The consumption of recycled material (0.081) and safety (health) (0.081) are considered as the next important elements in GP. Green label (0.037) and customer/consumer (0.041) are considered as least important.

2. Analysis of Companies

In the second survey, survey companies are confined to be survey candidate only in the case of energy and resource intensive manufactures in 6 countries. National experts from each country anies which were asked to give specific and objective value by each criterion from 2015 to 2016. All values surveyed by criteria and by company are transformed into values of SAW. All values for 89 companies of 6 Asian countries in each criterion are calculated by SAW method and added into four groups such as dematerialization, detoxification, productivity and social contribution.

All participating companies are coded by country: 8 companies of Indonesia from EC1…to EC8, 30 companies of India from IC1…to IC30, 13 companies of Philippines from PC1...to PC13, 7 companies of Korea from KC1...to KC7, 16 companies of Thailand from TC1...TC16, and 15 companies of ROC from CC1…to CC15. All survey 2 data were transformed by 2nd tier criteria by SAW and added into 4 criteria groups respectively.

The table 8 shows ranks of 20 companies among 89 companies from 6 countries. All values of each criterion by each company come from the combination of final weights from the table 7 with corresponding values transformed by SAW. For each country, values by criteria are summed by which all companies are ranked by each sum from the best company to the worst company in GP. In result, CC5 of Republic of China is awarded as the best company in the study. In this way, EC3 of Indonesia and CC15 of Republic of China win the award as 2nd and 3rd companies. Only highly scored 20 companies among 89 companies are listed in the following table.

〈Table 8〉 Evaluation of 89 companies and best 20 companies

Companies	De-materialization	De-toxification	Productivity	Social contribution	Sum	Rank
EC1	0.005	0.244	0.005	0.124	0.378	12
EC3	0.09	0.244	0.001	0.124	0.459	2
EC7	0.023	0.244	0	0.128	0.395	10
IC10	0.013	0.244	0.001	0.128	0.386	11
IC12	0.028	0.244	0.001	0.081	0.354	19
IC16	0.056	0.244	0.001	0.133	0.434	5
IC20	0.096	0.134	0.001	0.126	0.357	17
IC22	0.001	0.244	0.001	0.126	0.372	15
IC23	0.004	0.244	0	0.126	0.374	13
IC26	0.038	0.244	0.001	0.124	0.407	8
IC29	0.038	0.244	0.001	0.124	0.407	8
PC1	0.038	0.244	0.001	0.133	0.416	6
PC7	0.082	0.244	0	0.083	0.409	7
KC1	0.011	0.244	0.09	0.001	0.346	20
TC1	0.004	0.244	0.002	0.124	0.374	13
CC5	0.141	0.244	0.036	0.124	0.545	1
CC8	0.005	0.244	0.072	0.123	0.444	4
CC12	0	0.244	0.001	0.124	0.369	16
CC13	0.007	0.305	0.001	0.042	0.355	18
CC15	0.081	0.244	0.001	0.123	0.449	3

The research divided 89 participating companies into two groups by its output size. The companies were lined in which 44 companies belonged in the large-scale companies and 45 in the small-scale companies, Following the same way of simulation with the previous case, the best 10 companies in each group were shown in the following two tables.

As shown in the table 9, CC5 of Republic of China is the best company in Large-scale Group. In this way, EC3 of Indonesia, CC8 of Republic of China can win the award as 2nd and 3rd companies in Large-scale company group

〈Table 9〉 Best companies within large-scale group

Companies	De-materialization	De-toxification	Productivity	Social contribution	Sum	Rank
IC10	0.013	0.244	0.001	0.128	0.386	7
IC12	0.028	0.244	0.001	0.081	0.354	9
IC16	0.056	0.244	0.001	0.133	0.434	2
IC23	0.004	0.244	0	0.126	0.374	8
IC26	0.038	0.244	0.001	0.124	0.407	4
IC29	0.038	0.244	0.001	0.124	0.407	4
PC7	0.082	0.244	0	0.083	0.409	3
EC7	0.023	0.244	0	0.128	0.395	6
PC3	0.001	0.244	0.001	0.083	0.392	10
CC15	0.081	0.244	0.001	0.123	0.449	1

In ranking among small-scale companies, CC15 of Republic of China is shown in the table 10 as the best company. In this way, 1C15 of India, PC7 of Philippines can win the award as 2nd and 3rd companies.

〈Table 10〉 Best companies within small-scale group

Companies	De-materialization	De-toxification	Productivity	Social contribution	Sum	RANK
IC10	0.013	0.244	0.001	0.128	0.386	7
IC12	0.028	0.244	0.001	0.081	0.354	9
IC16	0.056	0.244	0.001	0.133	0.434	2
IC23	0.004	0.244	0	0.126	0.374	8
IC26	0.038	0.244	0.001	0.124	0.407	4
IC29	0.038	0.244	0.001	0.124	0.407	4
PC7	0.082	0.244	0	0.083	0.409	3
EC7	0.023	0.244	0	0.128	0.395	6
PC3	0.001	0.244	0.001	0.083	0.392	10
CC15	0.081	0.244	0.001	0.123	0.449	1

Ⅵ. Conclusion

The research aimed to evaluate the effectiveness and performance of green productivity in six Asian countries. The study established a comprehensive framework with a set of indicators to rate green companies in the region. The multi-criteria decision making method was adopted and the analytic hierarchy process was used in evaluating theses criteria and in performing pairwise comparison.

The main framework has basically two tiers of each criterion. Environmental sustainability, productivity and social contribution were criteria in the 1st tier under which 14 specific criteria in the 2nd tier were used. In the case of environmental sustainability, two specific criteria of dematerialization and detoxification are additionally used to cover diverse elements of environmental issues.

The survey was conducted through two stages: survey 1 is to collect pairwise comparison data in each criterion from 367 respondents by country; and survey 2 is to collect direct and objective data from candidate companies in energy and resource intensive sectors by country from 2015 to 2016. Based on survey 1, the study derived relative importances (weights) in all evaluation criteria. Then, the study collected actual data from 89 companies through survey 2 and combined wight values and actual data together. The study finally evaluated comparatively 89 companies for their performance in GP.

As a result of survey 1, the people in 6 Asian countries gave the highest value in environmental sustainability (0.550) among three 1st tier criteria. Productivity and social contribution gained much lower weights such as 0.245 and 0.204, respectively. For the environmental sustainability aspects, detoxification (0.554) has a priority over dematerialization (0.446).

In the 2nd stage of analysis, participating companies were ranked by total values in each criterion from the best company to the worst company in GP. SAW method was used in the transformation of all original values into the comparable values. The company name of CC5 from the Republic of China had a highest point (0.545). The rank of other companies was EC3 (0.459), CC15 (0.449), CC8 (0.444), IC16 (0.434) and PC1 (0.416) et cetera. In order to see biases from the county and the size, the study divided 89 companies into diverse companies by the production size and by country, and simulated all companies in each category. The Republic of China and Indonesian companies highly ranked in large-scale group, while in small-scale group, Indian and Philippine companies also ranked highly with Republic of China companies.

The evaluation model has a system both a relative evaluation system and an absolute evaluation system, taking into account the university of indicators and the variety of evaluation objects so it can reflect each company's characteristics as well as overall performance. All indicators are quantitative ones to ensure that the evaluation results can be compared over time and among different companies. Its theoretical contribution comes from improving the previous literatures in terms of specification of resource uses including renewable energy sources, and of corporate social responsibility in GP. The model can be used in evaluating not just the environmental impact of productivity but also the adoption of clean energy technology and social considerations generated by companies.

The study can practically contribute in improving the applicability of GP in the region, because the identification of the specific criteria of GP will allow companies to understand which activities reduce energy and material consumption, environmental impacts and social risk and consequently, increase their efficiency, productivity social reputation.

Finally, considering the relevance of the study, it is necessary to mention some limitations regarding its application: the lack of systemic data about the company, mainly from different products and/or production process. The limit also comes from the initially loose definition of the survey company in which the awarding target companies set bounds to not specific but general type of energy and resource intensive manufacturing sectors. If the study had focused on a specialized area, more accurate and deep comparison of companies could be possible. On the other hand, the resistance on the part of the companies in supplying such informations also presents a limit, especially in the case of an international study. The situation is changing due to the increasing pressures from the global community and green marketing requirement.

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