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Eco-Innovation for Sustainability: Evidence from 49 Countries in Asia and Europe

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Abstract: Following the trend on focusing on a nation's economic-growth, side effects such as resource exhaustion, environmental pollution, and social injustice have begun to appear. As a solution, eco-innovation has received a great amount of attention from European countries and as a result, many efforts to analyze the development of eco-innovation quantitatively have been made. This study aims to evaluate the validity of an eco-innovation index developed to support the sustainable development goal. For this purpose, four factors of eco-innovation—capacity, supportive environment, activity, and performance—were applied to three categories of the Triple-Bottom-Line (TBL) concept in sustainability to compare the eco-innovation development level of 49 Asia-Europe Meeting countries. Factors for eco-innovation and TBL at the country level were organized in quartile and compared to see strength and weaknesses for each nation. In order to test if eco-innovation factors of a nation adequately reflect its sustainability, we used various comparisons of ANOVA. The results of this study are as follows: First, the one-way ANOVA tests present the scores for capacity, supportive environment, and performance as grouped into four quartiles in the same pattern as their economic, social, and environmental scores. The three-way ANOVA tests showed significance for the economic category. Scores for capacity, supportive environment, activity and performance were significant at a nation's economic level. Lastly, the MANOVA test revealed that TBL significantly explains four eco-innovation factors. In addition, the eco-innovation performance level of European nations and Asian nations were compared. The possibility that many nations still have room to be competitive in their eco-innovation efforts was identified. Nations with unbalanced eco-innovation growth are urged to implement new strategies to balance their growth. Therefore, this research contributes to extending research on eco-innovation.

Keywords: eco-innovation; sustainability; Triple-Bottom-Line; factors

1. Introduction

Responding to the worldwide implementation of economic policies heavily focused on each country's national economic growth, the world is contemplating the resultant difficulties from such policies that include but are not limited to resource exhaustion, environmental pollution, and social injustice. To address these difficulties, the concept of sustainable development, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" was introduced [1].

As such, the concept of eco-innovation was put forward. It received attention in Europe and was perceived as one of the critical processes and objectives for reaching worldwide sustainable development goals [2–5]. Eco-innovation is defined as any form of innovation aiming at a significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment or achieving a more efficient and responsible use of resources including both intended and unintended environmental effects from innovation as well as not only environmental technology but processes, systems and services [6].

As a result, having a framework for measuring eco-innovation by each nation's stakeholder began to receive attention [7]. For example, Triebswetter and Wackerbauer [8] addressed the concept by introducing an advanced version of eco-innovation framework and index. Arundel and Kemp [9] also suggested how eco-innovation can be quantitatively measured. Recently, the Eco-Innovation Observatory (EIO) [10] designed a eco-innovation index based on a previous index also from EIO [10] by adding indices for material flow innovation and social innovation to product innovation, process innovation, marketing innovation, and organizational innovation. Meanwhile, the Organization for Economic Co-operation and Development (OECD) and Eurostat [11] measured eco-innovation with four group factors such as cost, knowledge, market, and institutional factor. In addition, Horbach [12] developed a new framework for eco-innovation measurement with demand, supply, and institutional policy.

Despite the great deal of attention given to develop a suitable eco-innovation index, a consensus on this index has not been reached and discussions on this matter are still in progress. In addition, with emphasis on the input/output and static framework, according to EIO [10] the scholars have neglected the inter-relationships among the stakeholders [12,13]. Acknowledging the limitation of previous studies, we will discuss various forms of stakeholder perspectives on eco-innovation from previous studies and introduce a new framework that reflects stakeholder perspective.

Based on existing studies, we found 20 factors proposed that could affect the eco-innovation of a nation and grouped them into four factors using the same weight technique by analytic hierarchy process (AHP). To test the validity, we estimated the relationship between our eco-innovation index and the sustainability goal. According to Elkington [14], sustainable development is "enhancement of the balance between the growth and value in Triple-Bottom-Line (TBL)—economic, social, and environmental". Based on this perspective, the commonly measured categories for evaluating the sustainability have become the economic, social and environmental factors. World Economic Forum (WEF) presents each nation's sustainability score with economic, social, and environmental categories for each year based on the grand data they collect for past years. For our study, WEF's data for the social and environmental category were considered to be adequate. In order to test if our index scores reflect well the TBL perspective, the GDP per capita data and WEF's data scores (of social and environmental category) were compared to our index score.

We believe that there are three major theoretical contributions from this study. First, there have been calls for an eco-innovation index that incorporated various stakeholder perspectives in its development. We provide scientific objectivity to the eco-innovation measurement by analyzing previous studies; Second, unlike previous studies which measured eco-innovation from an economic achievement perspective [4,9,15], this study measured eco-innovation based on a sustainability perspective. Third, the eco-innovation performance of European and Asian nations, which are members of Asia-Europe Meeting (ASEM) were compared and some inferences were made.

The present study report is organized as follows. In the following section, Section 2 the WEF index [16] and the eco-innovation index will be presented. The selection process and structure of our index will be introduced. In Section 3, the research target, factors and data collection will be presented. In Section 4, the results of one-way ANOVA (analysis of variance), three-way ANOVA, and multivariate ANOVA will be presented. The tests will define whether or not the eco-innovation index adequately reflects each category of TBL. The findings will be summarized. ASEM's member countries will be grouped into 4 quartiles and the scores will be measured and compared. In Section 5, the conclusion and recommendations for future research will be proposed.

2. Eco-Innovation and Sustainability

2.1. Theoretical Background for Eco-Innovation

Eco-innovation refers to all forms of innovation: new skills for environmental enhancement, new processes, new products and services, new business forms, *etc.* Moreover, any activities related to reducing negative impacts or enhancing positive influence on the environment while minimizing use of natural resources are all part of eco-innovation [2–4,17–22].

The first concept of eco-innovation was mainly focused on product and process [17]. However, the scope of eco-innovation gradually expanded to equipment and management systems [2], new market creation [20], organization composition [21] and institutions [5].

The majority of the previous studies on eco-innovation were conducted based on the company unit. To understand the trend of eco-innovation studies, we used the Elsevier Scopus research searching engine and reviewed a total of 92 articles that included the terms such as, "eco-innovation" or "ecoinnovation" in Table 1. The study on eco-innovation began in the year 2000 and the number of publications rapidly increased after 2009. Among the 92 articles, 39 included empirical approaches, 32 had a conceptual approach, and the remaining 21 articles included both approaches. The 39 empirical studies were concentrated on companies but more likely large firms than small or medium-sized enterprises. However, few studies looked into the eco-innovation at a national level but most of these studies were performed in and concerned developed nations (*i.e.*, European nations) with an exclusion of Asian countries.

Table 1. Empirical research of eco-innovation classification (Unit: the number of articles).

Nation \ Target Company	Small and Medium Company	Small and Medium Company	Both	Total
Developed countries	21	3	8	32
Developing countries	3	-	2	5
Both	2	-	-	2
Total	26	3	10	39

"-": not recognizable.

In the light of these trends, eco-innovation research on ASEM nations can be an opportunity to compare the eco-innovation level of Europe and Asia and to suggest a way each nation can benchmark other nations with a similar culture or a physically proximity. In applying eco-innovation at the national level and sustainability, we outlined the critical factors that have to be considered by stakeholders. As in Table 2, interactions between the stakeholders and the ripple effects of eco-innovation are important to consider in developing the eco-innovation framework and index used in the present study. For example, interactions between stakeholders are comprised of government, research institutions, industry, firms, and consumers while ripple effect is of a nation's economy, society, and environment. Drawing upon our literature reviews, such two categories explain the extent that a nation can either drive or hinder eco-innovation. The content for each scope is provided in Table 2.

Table 2. Eco-innovation driving factors.

Category	Scope	Contents	Source
Interactions of stakeholders and factors for eco-innovation	Government	Related regulation, Supporting plan, Financial system	[4,23–25]
	Research institute	Technical support for R&D	[26,27]
	Industry	Industrial structure, Inter-enterprise competition	[28]
	Firm	CEO, Vertical systemization, Organizational structure; Value chain, Investment for employees	[29]
	Consumer	Pressure from the world community, Social awareness of the need for clean production	[4,12]
Ripple effect for sustainability	Economy	Green product's market performance, Diversity of technology, Securing of the sustainability of the industrial system	[30,31]
	Society	Create green living, Welfare promotion	[28,32]
	Environment	Increasing efficiency in the use of resources, Restriction on CO_2 emission, Better quality of environment	[33]

Through literature reviews on empirical studies on eco-innovation, we found that most studies have emphasized on how firms can successfully implement eco-innovation. Doran and Ryan [23] reported the positive influence on eco-innovation by enterprise's achievement. They compared the achievement of enterprises where eco-innovation was practiced and the enterprises where eco-innovation was not practiced. Sarkar *et al.* [34] insisted that any types of eco-innovation actions practiced by the enterprises enhanced the development of green environment and that their actions were indispensible for promoting sustainable development worldwide. Ganapathy *et al.* [25] conducted empirical research on manufacturing industries in India and emphasized the possibility of promoting sustainable development in the future by eco-innovation activities. The study found that the eco-innovation could be enhanced through R&D activity and investment for employees related to eco-innovation. Meanwhile, Ganapathy *et al.* [25] elaborated on the possibility of eco-innovation activity expansion when one enterprise successfully implemented eco-innovation. They reported that motivation by the enterprises to implement eco-innovation will most likely rise as ripple effect on the economy is proved to be big for the environmentally friendly enterprises.

Although interactions between each stakeholder and the ripple effects for sustainability were considered central in the studies on eco-innovation, integration of such two perspectives at the national level may provide an opportunity in understanding how a country can improve its sustainability [4,23]. Placing an effort to implement eco-innovation at the national level with our integrated framework, therefore, may extend previously held views on eco-innovation to a more extensive and dynamic influence on a nation's economic, social, and environment [30,33,34]. Under the theoretical and practical considerations referred to above, we aim to develop a eco-innovation index applicable at the national level and also incorporate sustainability to the index by providing the necessary perspective [35,36].

2.2. Eco-Innovation Measurement

Input measures, intermediate output, direct measures, and indirect measures were the most common criteria for measuring eco-innovation using quantitative methods in the reported studies [4,9,15,37]. As shown in Table 3, the eco-innovation index presented in the study applied all four criteria.

Table 3. Summary of eco-innovation measurement criteria used in previous researches.

Criteria	Contents	Source
Input measures	R&D expenditure	[38,39]
Intermediate output	Patents, Publications	[40,41]
Direct measures	Services, Products	[7]
Indirect measures	Resource use efficiency, Productivity change	[1,7]

Drawing upon previous studies, we re-conceptualize the measurement of eco-innovation. Despite the fact that eco-innovation is composed of a gradual evolution towards sustainability, existing studies are highly dependent on the capability of a firm [42–46]. This emphasis has led scholars to neglect potential factors affecting a nation's eco-innovation. Among factors for measuring eco-innovation at the national level, capacity, supportive environment, activity for eco-innovation of the nation, and the national performance in terms of eco-innovation achievement were selected as criteria for our research framework. These criteria were formed based on the findings from previous studies and they are the groupings of major indictors that contain the key concepts and issues for eco-innovation.

The criteria are: (1) "Eco-innovation capacity" as it measures a nation's capacity to achieve and continue sustainable development; (2) "Eco-innovation supportive environment" for it measures the national support system for sustainable development; and (3) "eco-innovation activity" gauges a nation's activity related to eco-innovation. Lastly; (4) "eco-innovation achievement" which measures the current status of a nation in achieving sustainable development.

We sorted the framework of eco-innovation to three steps as in Table 4. The "basic" stage, the first level of our framework includes "capacity" and a "supporting environment". The "basic" stage sustainably influences all the categories in "advance" and "adaptation" stages as well. The knowledge and skills obtained from the "basic" stage are used in the "advance" stage. Therefore, efforts in the "basic" stage must be put into practice to activate the innovation work in "advance" stage. When eco-innovation activity reaches the "advance stage", outputs of "eco-innovation achievement" are brought out and then transferred to the "adaptation stage". All successful cases of the second stage are transferred to the "adaptation stage" and implemented. Finally, when all three levels of the framework are completed successfully, a virtuous cycle is formed that sustainably enhances the basic level (capacity and support environment).

2.3. Sustainability: TBL (Triple-Bottom-Line)

In Elkington's [14] seminal work titled as "Partnerships from cannibals with forks: The triple bottom line of the 21st century business", he pointed out that economic, social, and environmental categories as the three major areas to be considered when measuring the business sector's efforts and achievements for sustainability. Originally, the term "bottom line" referred to the enterprise's net income and it represented the firm's financial achievement. The use of the term Triple Bottom Line (TBL) to measure the business sector's achievement in economic, social and environment has increased as people began to embrace "value maximization" more than "profit maximization". Since Elkington's [14] introduction of TBL for measuring business achievement, institutions such as the Global Reporting Initiative (GRI) and EIO have begun to use TBL as guidelines for national firms. In addition, many managers recognized TBL as practical tool for measuring a group's achievement for sustainability [36].

TBL is popular for measuring multidimensionality of sustainability because it marks the three important aspects for sustainability and has a strong theoretical backing [57]. TBL is a powerful tool that enables one to measure an organization's or an enterprise's achievement not only based on their economic profits but also their influence on social and environmental factors. Because of this reason, we adopted TBL for gauging the sustainability of our eco-innovation index.

Table 4. Eco-innovation index factors and data collection.

Stage	Category	Factors	Research	Obtained Data	Data Source (Year)	Data Formation
Basic	Capacity	Nation's Economic Competitiveness	[47,48]	Global Competitiveness Index (GCI)	World Economic Forum (2014)	Composite Index
		Nation's General Innovation Capacity	[43,49]	Global Innovation Index (GII)	INSEAD (2014)	Composite Index
		Green Technology R&D Institution Capacity	[26,27]	Cleantech	Cleantech group data	Number of green technology R&D institutions, centers and university
		Green Technology possessed/acquired Enterprises	[28]	Cleantech	Cleantech group data	Number of green technology possessed firms
		Awareness of Sustainability Management	[29]	UN Global Compact (UNGC) Business Sector participants	UNGC (2014)	Number of participating enterprise
	Supporting Environment	Government's R&D expenditure in Green Industry	[27]	OECD Statics	OECD (2011)	Size of expenditure
		Implementation of Environmental Regulations	[23,24,30]	WEF Executive Opinion Survey	World Economic Forum (2014)	Composite Index
		Maturity of Investment Setting for Green Technology Industry	[50]	Cleantech	Cleantech group data	Value of investment towards green technology firms
		Investment Scale of Green Technology SMEs	[51]	Cleantech	Cleantech group data	Number of venture capitals and deals made towards green technology SMEs
Advance	Activities	Commercialization Level of Green Technology	[52]	Cleantech	Cleantech group data	Number of companies with green technology widely commercialized
		Enterprises' Participation on Environmental Management System	[12]	ISO 14001 environmental certificates	IMF (2013)	Number of participating enterprise
		Economic Influence of Leading Environmentally Responsive Enterprises	[53]	World's Greenest Companies	Trucost by Newsweek (2014)	Amount of annual sales
		Green Patents	[54]	OECD Environmental technology patent statistics	OECD (2012)	Number of patent
		Activeness of Renewable Energy Utilization	[6]	IEA (International Energy Agency)	IEA (2012)	Measures the contribution of renewable to total primary energy supply
Adaptation	Performance	Level of Environmental Impact on Society	[33,36]	EPI (Environmental Performance index)	EPI (2014)	Composite Index
		CO_2 Emission Intensity	[6]	Key World Energy Statistics	International Energy Agency (2013)	Amount of Carbon dioxide generated
		Country's Energy Sustainability Level	[6]	ESI(Energy Sustainability Index)	World Energy Council (2013)	Composite Index
		Water Consumption Intensity	[6]	IMD (International Institute for Management Development) World Competitiveness Yearbook	IMD World Competitiveness Yearbook (2014)	Water withdrawal for each 1,000 USD of GDP in cubic meter
		Jobs in Green Technology Industry	[55,56]	Cleantech	Cleantech group data	Number of employees
		Green Industry Market Size	[50]	(UK BIS) The UK Department for Business Innovation and Skills	LCEGS (Low Carbon and Environmental Goods and Services) Country Market Size (2011-12)	Green Industry total sales

The primary purpose of measuring an organization's activity based on TBL is to explore the impact of the organization's activities on the world economy, social structures, and environment. This also allows the researchers and policy makers to be one-step closer to sustainable development. To make the proper decision for long-term development, TBL categories must be measured individually and quantified to set an appropriate direction for sustainable development [58]. The present study will conduct an analysis of the eco-innovation index for measuring economic, social and environmental scores of each nation. To do this, each nation's economic, social, and environmental scores will be compared to the nation's scores for supportive environment, eco-innovation activity, and performance. For our index, each nation's GDP per capita was used as a measure of each nation's economic achievement and scores for social achievement and environmental achievement were obtained from WEF [16]. Since 2011, WEF has been reporting these scores annually. In their annual report, each nation's economic achievement scores in addition to other contributors for improving people's quality of life are presented. For the social category, people's happiness relating to the society's welfare, health, and security are measured. In addition, for the environment category, factors relating to the effective resource management for the next generations are included. Table 4 presents the summary of WEF's indices.

3. Materials and Methods

3.1. Nations in the Study

Forty-nine ASEM member nations were targets of this study. Currently, the total population of ASEM member nations constitutes 60.3% of the world's population. Total Gross Domestic Product (GDP) of these countries is up to 55.0% of world's GDP and their amount of trade accounts for 63.2% of world's trade amount [5]. Moreover, ASEM nations play an important role as a cooperating channel for Asia-Europe countries in making major decisions for international issues. Unlike the Asia-Pacific Economic Cooperation (APEC) union, which heavily depends on economic cooperation, the ASEM nations also aim for comprehensive collaboration that takes into account political, economic, social/cultural factors. Therefore, various cooperative projects are promoted within ASEM. ASEM member countries need to actively participate in and respond to the emerging new paradigm of low carbon green growth to prevent further environmental risks and to find new opportunities. Considering this fact, the 49 ASEM member nations were considered adequate targets for the present study.

3.2. Study Factors and Data Collection

A total of 20 factors were originally considered from previous studies. Among these factors, only 12 factors were eventually selected for our study: three factors (Nation's Economic Competitiveness; Nation's General Innovation Capacity; and Awareness of Sustainability Management) were considered for "capacity", two factors (Government's R&D expenditure in Green Industry and Implementation of Environmental Regulations) for "supportive environment", three factors (Enterprises' Participation in Environmental Management System, Economic Influence of Leading Environmentally Responsive Enterprises, and Green Patents) for "activities", and four factors (Level of Environmental Impact on Society, CO_2 Emission Intensity, Country's Energy Sustainability Level, and Green Industry Market Size) for "performance". In the process of selecting factors, data availability was considered. When 49 nations were examined, their complete data only covered 12 factors of the original 20 factors we had originally considered. A detailed explanation of the limitation of this process is provided in conclusion.

For cases with below 5% missing value ratio, the statistical method was applied to replace the missing values. To do this, Expectation-Maximization (EM) algorithm based on likelihood-based procedures was applied in the study. EM uses maximum-likelihood estimation to place missing values with highest probability for highest value based on constant repetition of estimation where

Expectation (E-step) and Maximization (M-step) are repetitively placed to estimate the missing value. Moreover, multiple imputations (MI) were used to estimate missing values. The missing values estimated from 100, 500, and 1000 iterations were the same. The same weight was applied to 12 factors based on EIO [10] suggestion for measuring factors. To make the values comparable, all the extracted values were transposed to standardized values using Min-Max methodology.

3.3. Methods and Variables

To test the validity of our model for measuring a nation's eco-innovation, we implemented ANOVAs comparing the differences of each eco-innovation indexes by countries. In this study, ASEM countries were selected because Europe was the first mover for eco-innovation and Asia followed. For Asian countries, it is important to figure out how large the gap between the two groups is and where is more effort is needed to narrow the gap. However, with many barriers such as constraints for time and lack of available data, it was difficult to compare all European and Asian countries. Therefore, countries with the appropriate social, economic size and the relevant data were selected. In regards to the information we required, ASEM countries were relatively well prepared. In addition, aspects such as politics, economic, and social/cultural handled by ASEM are closely related to the eco-innovation components. Following "Asia-Europe Cooperation Framework 2000" agreement, ASEM countries maintain their political, economic, and social/cultural collegiality and host regular meetings. Assuming the strong relationship between the ASEM countries continues, the Asian countries in ASEM may be able to benchmark the European countries' leadership in this area than those countries not in the ASEM [59,60]. With these considerations, we selected the ASEM countries for our study.

In an empirical analysis, each eco-innovation index such as capacity, supporting environment, activities, and performance, was calculated using the Min-Max method based on the Expectation-Maximization formula; this provided scores that ranged from 0 to 100. Following the OECD and Eurostat Oslo manual for collecting and interpreting innovation data [11], we adopted an equivalent weight when weighting scores for each category since both controlling a nation's various factors and comparing them is difficult in an equation [9]. Next, as suggested by Elkington [14], TBL was set as the sustainable goal for the nations in the study. When we applied and quantified TBL into our study, each economy, society, and environment score based on WEF's annual report was quartiled by rank. For example, Korea's score on economy was 25,976.9 as per capita; on society, it was 5.25 on a composite index and 4.85 on environment also on composite index. Each score was normalized based on the mean for the category and it was transformed into quartiled scores, which meant that a nation's TBL score ranged from 1 to 4 for each categorical variable. Thus, Korea's quartiled position for economy, society, and environment was 2, 2 and 2, respectively. Another example was Japan and its quartiled position of each category was 2, 1 and 1, respectively. By using such quartiled ranking, we quantified TBL scores for all nations in the study in order to understand whether there were differences between countries in terms of eco-innovation.

Since this study aimed to find the differences between countries, the proper method for measurement was a test for checking intra-group and group differences. For this, ANOVA was used to analyze whether there were significant differences for each nation's eco-innovation in TBL category.

4. Results

4.1. Comparisons of Eco-Innovation Index in Terms of TBL Categories

To test if eco-innovation index reflects well the TBL (economic, social, and environmental) of sustainability, a total of three different analyzes were performed. Using the 49 nations of ASEM, the one-way ANOVA was conducted 12 times for each of the 4 eco-innovation index factors (capacity, supportive environment, activity, and performance) as individual dependent variables (DVs) and each of the TBL categories (economic, social, and environmental) as individual independent variables

(IVs). The three-way ANOVA was conducted four times for each factor of eco-innovation index as each individual DVs and the three categories as one IV. Lastly, multivariate ANOVA (MANOVA) was conducted at one time setting for four factors as one DV and 3 categories as one IV. Table 5 lists the descriptive statistics of the present study. Mean scores for eco-innovation factors of capacity, supporting environment, activities and performance were 39.62, 43.47, 20.34 and 36.24, respectively. Since TBL variables were quartiled, mean of three variable was 2.53. Among variables, the activities index showed the widest range and performance index had the smallest range. A correlation analysis was conducted to examine the relationship between the factors under study. All factors statistically correlated to each other at the 5% significance level.

Table 5. Descriptive statistics of eco-innovation and TBL.

Variable		Mean	S.D.	Min	Max	1	2	3	4	5	6	7
Eco-Innovation	1. Capacity	39.62	18.03	2.1	72.3	1						
	2. Supporting Environment	43.47	13.42	14.85	77.96	0.77 *	1					
	3. Activities	20.34	17.79	0	70.34	0.50 *	0.29 *	1				
	4. Performance	36.24	11.67	3.84	54.13	0.80 *	0.65 *	0.56 *	1			
TBL	5. Economy	2.53	1.13	1	4	−0.80 *	−0.66 *	−0.16 *	−0.62 *	1		
	6. Society	2.53	1.13	1	4	−0.86 *	−0.76 *	−0.36 *	−0.72 *	0.82 *	1	
	7. Environment	2.53	1.13	1	4	−0.81 *	−0.70 *	−0.32 *	−0.68 *	0.79 *	0.90 *	1

Note: * $p < 0.05$.

4.2. Differences in Eco-Innovation Factors According to TBL

Eco-innovation supports innovation toward sustainability with three critical concepts: economic, social, and environmental [61]. One-way ANOVA was conducted to confirm that each IV (economic, social, and environmental) significantly distinguished each DV (capacity, supportive environment, activity, and performance). According to the results in Table 6, all factors of eco-innovation except activity, namely capacity, supportive environment, and performance, were significantly distinguished based on the economic, social, and environmental categories ($p < 0.05$). Similar to the result of *t*-test presented above, there was no significant difference between each quartile's activity score.

Table 6. One-way ANOVA results.

IV	DV	R^2	df	MS	*F*-Value	Prob. > *F*
Economy	Capacity	0.68	3	3516.27	31.27	0.00
	Supporting Environment	0.44	3	1274.32	11.87	0.00
	Activities	0.13	3	522.51	2.32	0.09
	Performance	0.45	3	989.55	12.47	0.00
Society	Capacity	0.75	3	3881.11	44.04	0.00
	Supporting Environment	0.61	3	1758.74	23.42	0.00
	Activities	0.10	3	408.99	1.76	0.17
	Performance	0.57	3	1232.70	19.51	0.00
Environment	Capacity	0.67	3	3502.65	30.90	0.00
	Supporting Environment	0.52	3	1507.99	16.43	0.00
	Activities	0.12	3	482.20	2.12	0.11
	Performance	0.54	3	1173.97	17.50	0.00

The differences between eco-innovation factors based on TBL are presented in Table 7. Three-way ANOVA analysis was conducted to examine if the nations' capacity, supportive environment, activity, and performance scores were distinguished based on the IV categories (economic, social, and environment). The result showed that the countries' capacity, supportive environment, activity, and performance scores were significantly distinguished only for the economic category.

Table 7. Three-way ANOVA results.

IV	DV	R^2	df	F	Prob. > F
TBL [a]	Capacity	0.81	9	18.55	0.00
	Supporting Environment	0.64	9	7.68	0.00
	Activities	0.40	9	2.81	0.01
	Performance	0.65	9	7.91	0.00

Note: [a] TBL contains quintile information of each economy, society, and environment.

To test the explanatory power of three IVs (economic, social, environment) on four DVs, MANOVA was conducted. The significant level of Wilks' lambda indicates our model to be adequate. The result showed that the three IVs (economic, social, and environmental) significantly explained the four DVs ($p < 0.06$). However, corresponding to the result of three-way ANOVA conducted for the present study, only economic category significantly distinguished the four DVs when each IV was considered separately. This result indicates the DVs can be significantly distinguished only based on the economic category.

This study determined and analyzed the explanatory power of eco-innovation index factors on TBL (economic, social, and environmental). The one-way ANOVA analysis showed that the IVs (economic, social, and environmental) adequately distinguished each nation's capacity, supportive environment, and performance into the IV quartiles. According to the three-way ANOVA analysis, each nation's capacity, supportive environment, activity, and achievement scores showed a similar pattern of the four quartiles with a nation's economic category. Lastly, MANOVA analysis showed that the model is an adequate fit. The IVs significantly distinguished the DVs. However, when individual differences were considered, the nation's capacity, supportive environment, activity, and performance were significantly distinguished only with the nation's economic score. Such a result may be due to the lack of sufficient data collected from the present study. If this is not the case, eco-innovation index presented in the study may need modification. In such as a case, eco-innovation factors related to social and environmental category must be examined and selected more carefully.

4.3. Comparison of Eco-Innovation Levels for Europe and Asia Groups

Previous studies have reported that the eco-innovation levels differ according to a country's development level. In many cases, developed countries displayed higher eco-innovation than the less developed countries. According to Kemp and Pearson [4], Huppes *et al.* [37] and Arundel and Kemp [9], this is because the amount of additional financial input for implementing eco-innovation differs according to the level of the country's development level. While enterprises in developed countries consider implementing eco-innovation as exploitation of their already existing resources, enterprises in developing countries do not have the same type of resources to implement eco-innovation rapidly. Developing countries are required to put more efforts and finances in order to innovate. Such reasoning is particularly applicable to small-medium sized enterprises. For instance, small-medium sized enterprises in wealthy countries are able to hire scientists or environmental professionals more easily than those in developing countries. Based on this perspective, it is assumed that the eco-innovation level of European countries and Asian countries differ. To examine this assumption, a *t*-test analysis was performed.

As Table 8 demonstrates, the capacity and the performance level was significantly different between European and Asian countries ($p < 0.05$). While the activity level did not differ between the two nation groups, the supportive environment level only partially differed ($p < 0.1$). The activity factor included factors such as Commercialization Level of Green Technology, Enterprises' Participation in Environmental Management System, Economic Influence of Leading Environmentally Responsive Enterprises, Green Patents, and Activeness of Renewable Energy Utilization. While Germany had the highest rank for eco-innovation activity, other Asian countries such as Japan, China, and Singapore were also ranked high. This may be the reason why the grouping analysis showed no significant differences between the European and Asian groups for eco-innovation activity.

Table 8. Results of *t*-test between Europe and Asia.

Variables	Pr (T < *t*)
Eco-innovation Capacity	0.003 **
Eco-innovation Supporting Environment	0.065 +
Eco-innovation Activities	0.122
Eco-innovation Performance	0.000 **

Note: + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$; $N = 49$ (19 Asian nations, 30 European nations).

4.4. Comparison of Eco-Innovation in Europe vs. Asia with Respect to Individual Countries

The relationship between each factor and performance is presented in Figures 1–3. Gray circles represent European countries and yellow circles represent Asian countries. As presented in Figure 1, European countries such as Switzerland, Germany, Britain, Sweden, France, and other nations showed a high level of capacity performance. Asian countries such as Japan, Singapore, South Korea, China, and Malaysia were also part of a high capacity group. Meanwhile, countries such as Myanmar, Cambodia, Laos, Vietnam, and the Philippines were categorized in a low capacity level group.

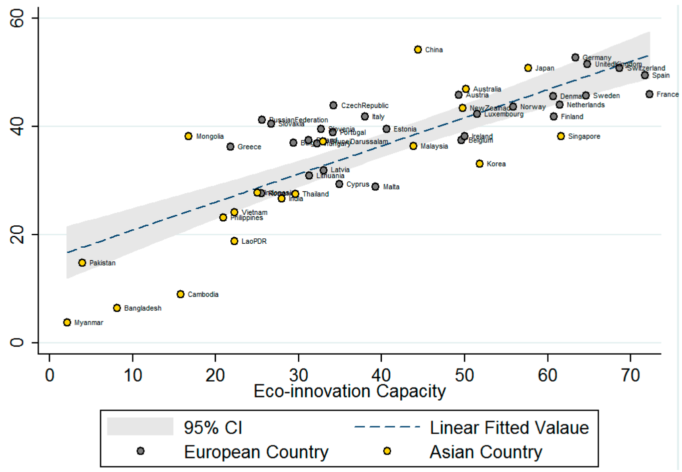

Figure 1. Eco-innovation capacity-performance.

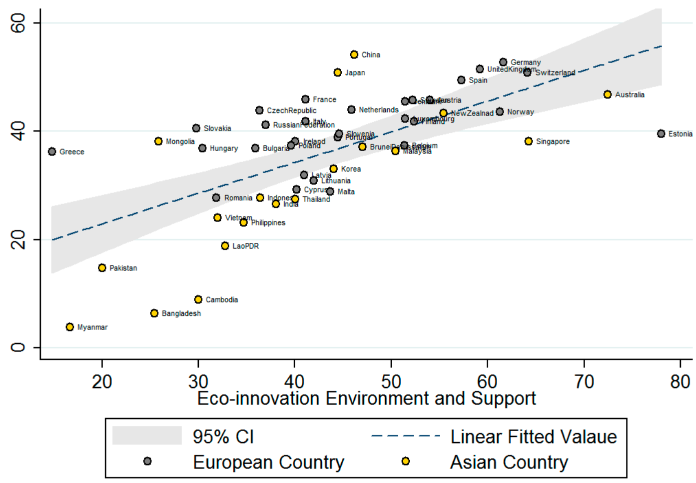

Figure 2. Eco-innovation supporting environment-performance.

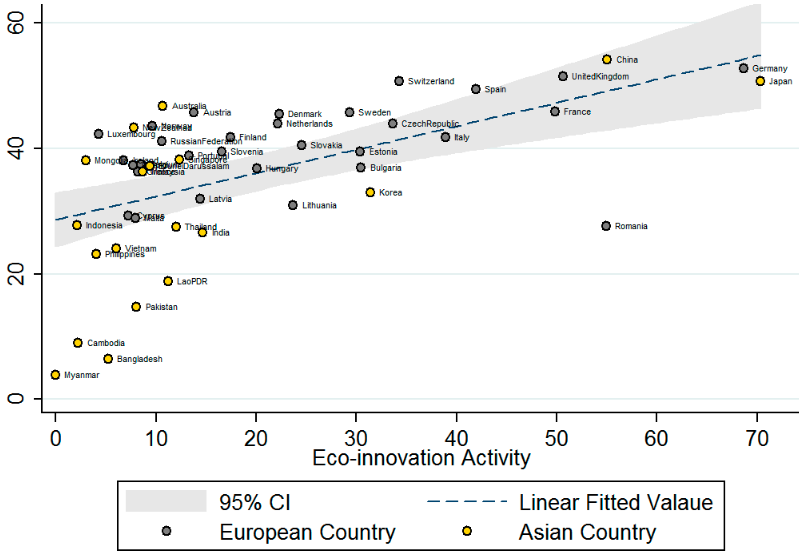

Figure 3. Eco-innovation activity-performance.

Each graph's symmetric placement allows performance comparison for capacity, supportive environment, and activity. While the majority of nations showed a similar trend for their performance and capacity, France, Singapore, and Korea showed a low level of performance compared to their capacity. While China performed well compared to its capacity and supportive environment, Cambodia, Bangladesh, and Myanmar's performance were low compared to their supportive environment. Such results suggest nation's motivations and efforts as other critical factors in determining their eco-innovation performance.

Figure 3 showed a significant difference in European and Asian countries' activity. It seems that countries in Asia are struggling to use their capacity and supportive environment to implement piratical policies. Countries with a low level of activity compared to their supportive environment need to prioritize on using more direct measures such as appropriate technology transfer to promote and increase eco-innovation activities.

5. Discussion and Conclusions

This study aimed to evaluate the validity of the eco-innovation index developed to support sustainable development goals. For this purpose, the eco-innovation factors, which were gleamed from the literature, were applied to Triple-Bottom-Line's (TBL's) three categories (economic, social, and environment) to compare the ASEM nations' eco-innovation development levels and to estimate the explanatory power of each eco-innovation factor for each TBL category.

The results of this research were as follows. First, the index revealed the strengths and weakness of each nation in terms of eco-innovation and areas for additional efforts were discussed by comparing the trend of nationals' eco-innovation index score to their economic, social, and environmental scores.

Second, in order to test whether eco-innovation index scores of a nation adequately can lead to economic, social, and environmental sustainability, one-way ANOVA, three-way ANOVA and MANOVA were conducted 12 times, 4 times, and once, respectively. The result of one-way ANOVA analysis showed that the IV factors (economic, social, and environmental) can adequately be explained by a nation's eco-innovation capacity, supportive environment, and performance into 4 quartiles but not for the level of eco-innovation activity. According to the three-way ANOVA analysis, a nation's capacity, supportive environment, activity, and performance scores showed a similar level of pattern with only the nation's economic category. Lastly, MANOVA analysis showed that the model was adequately fit. The TBL sustainability index significantly distinguished the eco-innovation indices considered. However, when individual differences were considered, a nation's capacity, supportive environment, activity, and performance were significantly distinguished only by the nation's economic sustainability score.

The major contributions of this study to eco-innovation research were three-fold. First, we provided scientific objectivity to the eco-innovation measurement by analyzing previous studies. The indexes developed in the theoretical basis of previous studies were limited as they were developed only based on the input/output (static) framework, disregarding the inter-relationships that might exist among the various stakeholders. Acknowledging the limitation of previously developed eco-innovation indexes, the present study introduces a new eco-innovation index to measure national performance. The eco-innovation index was developed based on a conceptual model that includes capacity, supportive environment, innovative activities, and sustainable performance of eco-innovation.

Second, unlike the previous studies which measured eco-innovation based on the economic achievement perspective [4,15,37], this study measured eco-innovation based on the sustainable perspective. Eco-innovation level of each nation was estimated based on TBL's economic, social, and environmental categories. Furthermore, eco-innovation index presented in this study was based on the perspective of sustainable development. While previous studies only developed and applied their index to their study, we were able to present verify the validity of our eco-innovation index by providing the results of a statistical analysis.

Third, the eco-innovation performance level of the European and Asian nations in the ASEM group were compared and some findings were made. Many nations still had space to develop eco-innovation within their quartile. Nations were identified that had an unbalanced eco-innovation growth, and were in need of new strategies to balance their growth. We suggest that the low ranking nations to benchmark their eco-innovation activities with the high ranking nations in their quartile.

The practical implications of this study are described below. The empirical results of this study can be used as a practical tool for comparing and benchmarking each nation's eco-innovation. Since the eco-innovation index in this study has multifaceted evaluation criteria, such as economy, society, and environment, we expect that the index would be effectively utilized for verifying strength and weakness for each country. In addition, by looking into scores of each eco-innovation segment such as capacity, supporting environment, activities, and performance, policy makers for eco-innovation are able to easily identify the points need to be reinforced, as compared with other countries and allow their country to be in a competitive position in terms of the four categories in eco-innovation. Therefore, this eco-innovation index can be a constructive instrument to advance the efforts of each nation's eco-innovation as compared with other countries.

This study, however, has the following limitations. First, there may be inaccuracies in the TBL scores. Economic, social, and environment scores of each nation were based on the GDP per capita numbers and the raw data from WEF reporting [16]. Such data may not reflect the actual economic, social, environmental aspects for each nation. Therefore, the further study is recommended to elaborate the procedure and methodology in estimating the economic, social, environmental values. The second limitation is the data availability. Problems can arise from the limited availability of the raw data for each nation. Thus, the limitations mentioned above may have been derived from the difficulty in gathering the information on all ASEM 49 member nations. If research cooperation with other nations for eco-innovation is possible, more explicit eco-innovation index that considers each nation's development level can be developed to improve the estimation accuracy. We believe, however, that this study contributes to extending research on eco-innovation on the framework it establishes.

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