Exploring the Nexus between Knowledge Economy and Green Economy

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1 author:

Mohammad Hassan
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Mohammad Hassan

Independent researchers

hssanhanif@gmail.com

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Abstract

This research highlights and empirically tests the relation between knowledge economy and green economy. Researchers per 1 million people, total patent applications and total citable documents published in a year are used as indicators of knowledge economy. Green Perception Index and Green Performance Index of Global Green Economy Index (GGEI) are used as indicators of green economy. With cross sectional data of 48 countries for the year 2014 we applied correlation, OLS and Kernel Non-parametric causality. OLS results suggest a significant positive impact of knowledge economy indicators on green economy indicators the results from Kernel causality test indicate that causality runs from Knowledge indicators to perception index and to performance index. Taken together, these results provide the evidence of a positive association between knowledge economy and green economy and suggest that a knowledge economy can significantly contribute to build a green economy.

Keywords: Correlation, Green economy, Kernel Causality, Knowledge economy, Researchers, Publication.

Background

The concepts of Knowledge Economy and Green Economy are becoming increasingly important and popular among social scientists. World's leaders and politicians are advocating for creation of knowledge economy to accelerate growth, and at the same time, they are urging for a green economy so that the economic growth does not come at the expense of country's natural resources. The term Knowledge Economy, pronounced by OECD in the mid-1990s, is defined as a ‘’type of economy which is directly based on the production, distribution and use of knowledge and information’’ (OECD). UN Environmental Program defined Green Economy as "an economy that results in reducing environmental risks and ecological scarcities, and that aims for sustainable development without degrading the environment" (UNEP 2010).

Although both terms--Knowledge economy and green economy--are independent and display two different scenarios of an economy, a fine link between these two can be established. It is possible to relate knowledge economy with green economy based on the following facts. Firstly, Knowledge is one of the important growth factors (P. M. Romer, 1986). A country with a rich knowledge base would have higher national income. Since environmental cleanness is a luxurious good, a country with higher national income would have more demand for clean environment that can lead them to transform the economy to a green economy. This fact suggests a positive relation between knowledge base and greenness.

Secondly, Knowledge, at the same time, causes an adverse effect on environment through expansion of industrialization. A massive production which lead to increase in greenhouse gases, took place when scientists discovered the machineries and fossil fuels. Moreover, application of chemical fertilizers pesticides, nuclear tests and other arm races in twentieth century seriously damaged the atmospheric, aquatic, and underground environments. These facts establish a negative relation between knowledge base and cleanness of environment. Moreover, A country enriched with scientists and engineers can utilize its own home-made clean technologies with cheaper costs. On the other hand, a country which lacks such people has to import clean technologies. This may incur higher costs for using clean technologies and thus may discourage the country from using them. This again leads us to conclude a positive relation between knowledge base and greenness.

The past studies on these topics mainly viewed them independently and explored their relationship separately with other variables such as relationship between knowledge base and economic growth, knowledge base and employment, economic growth and greenness, trade and greenness etc. The relationship between these two concepts has not been thought yet. The current study is an effort to investigate the linkage between knowledge base greenness.

Knowledge Economy & Green Economy

Knowledge Economy

Knowledge has always been the contributor to economic activities in all forms of generations of human history, from Paleolithic society to nineteenth century industrial periods. The recent decades, however, have witnessed a growing imporatnce of knowdge as a factor of production dominating over phyiscal inputs or natural resourses in European countries (OECD).

Early economic growth theories did not discuss the role of knowdge and technological advances (technology is knowdge; but not all knowdge is technological). The first theory that discussed the technological change is the Solow Swan growth theory. However, the Solow Swan model of economic growth treats the capital and labor as the main inputs of economic growth and the tecnological change as an exogenous trend variable which depends on time only. The change in capital and labor causes the change in output and change in technology causes the shift of output level. On the other hand, The New Growth Theory advocated by (P. M. Romer, 1986), (Lucas, 1988), (Grossman & Helpman, 1990) and others emphasize more on the critical roles the knowledge plays in economic growth and asseerts that economic growth is not function of just labor and capital, rather, it depends also on knowledge and tehnological progress in a society. Seeing the knowledge as a special input and the incremental learining and investment in R&D as the main detrminants of sustainable economic growth (Sabau, 2010), The New growth theories urge for the creation of knowledge to sustain the economic development .

Indicators for Knowledge economy:

Difficulties arise, however, when one attempts to measure the knowledge base in a country. If the measuring of physiscal assets and labor is a laborious task then it seems almost impossible to measure how much knowledge a country has and what is the rate of difissuin of knowledge. Similarly, it is amost impossible to measure the contributions that knowledge brings to the economy. Many researchers attempted to quantify the knowledge. They used sevaeral indicators such as total secondary or tertiary school enrolments, Research and Development (R&D) expenditures, number of academic papers published, number of citations and the number of patent applications. The indicators used in literature can be classified into two groups: input indicators and output indicators of knowledge generating process. R&D investment is considered as an input and the patents and scientific publications are, generally, considered as outputs. Each indicator has its own limitations and cannot provide a clear and absolute picture of the knowledge base in a country. For instance, as mentioned by (Smith, 2000) scientific journal publications inform us very little about innovation process, while ‘patents counts’ can lead us to sporious innovation if the patents are filed for unimporatnt innovations under different names (Smith, 2000). Moreover, scientific journal publications do not include the published books and igonre a part of knowledge output. Thus each indicator is narrower in scope and can provide us only the partial assesment of the knwoldge base in a country.

Green Economy

UN Environmental Programm defined Green Economy as "an economy that results in reducing environmental risks and ecological scarcities, and that aims for sustainable development without degrading the environment" (UNEP 2010). Green economies attempts to invest by governments and citizens in such ways that reduce Green House gas emissions and preserve the biodiversity and ecosystems. (UNEP 2011).

Indicators of Green Economy

Like measuring of knowldge base of a country, It is hard to measure its 'greenness'. Greenness implies reducing of enviroenmental risks. Environmental risks cover a broad range of aspects. Reducing carbon emission to a specific limit, acheiving large portion of renew able energy out of total energy, recycling and preserving biodiversity and forest lands can be indicators of greenness. But none of them alone can provide an overall assessment of greenness. Indicators of green economy are still under development. (Kraemer & Müller-kraenner, 2012) pointed out " of all selected indicators, none was perfect or outperformed the others on all assessment criteria. Therefore, considering several indicators that complement each other and provide a more complete assessment of the sustainability of an industry or product group is suggested. This approach also balances existing methodological challanges and increases explanatory power".

Theories

3.1 Theories that relate knowledge economy to green economy.

Diffusion of innovation models:

the theory of innovation diffusion given by (Rogers, 1995) tries to explains how the innovations and knowledge spread in a society. Diffusion is calssified into two: 1) Intra-industry diffusion or diffusion within sector which implies the dissemination of ideas within one sector and 2) the inter-industry diffusion or diffusion across sectors which implies the dissemination of ideas across heterogeneous sectors. According to (Vernardakis, 2016) the diffusion theory of innovation is applicable for intra-industry diffusion as well as inter-industry diffusion, although the intra-industry diffusion gained much interest of researchers. The ideas flow across heterogeneous sectors of economic system because of their inter-relation through various dimensions. This idea is close to the input-output model developed by Wassily Leontief. Based on the Diffusion of innovation model it is possible to argue that overall progress in technology and science in every sector should have positive impact on the progress of clean technologies.

The new growth theories/Endogenous growth theories

The early growth theories did not discuss the technological changes. The first theory that discussed the technological change is the Solow Swan growth theory. However, the Solow Swan model of economic growth treats te capital and labor as the main inputs of economic growth and the technological change as an exogenous trend variable which depends on time only. The change in capital and labor causes the change in output and change in technology causes the shift of output level. On te other hand, The new growth theory advocated by (P. M. Romer, 1986), (Lucas, 1988), (Grossman & Helpman, 1990) bleives that economic growth is not just the function labor and capital, rather, it also depends on tehnological progress in a society. New growth theories sees the knowledge as a special input and that incremental learining and investment in R&D are main detrminants of sustainable economic growth (Sabau, 2010). The new growth theories or endogenous growth theories hold that although the natural reseourses are finite but the difussion of knowledge and technology will help utilizing finite natural resources in efficient way and lead to use of renewable resources (Development Economics By Gérard Roland). All types of knowledge ‘’from big science to better ways to sew a shirt’’ are non-rival and partly excludable and can be reused with no marginal cost contribute to boundless growth (Sadler, 2010). Moreover, Endogenous growth theories emphasize on government intervention. They argue that for a sustainable growth government ought to spend on R&D and technological progress. ‘’Ultimately, all increases in standards of living can be traced to discoveries of more valuable arrangements for the things in the earth’s crust and atmosphere . . . No amount of savings and investment, no policy of macroeconomic fine-tuning, no set of tax and spending incentives can generate sustained economic growth unless it is accompanied by the countless large and small discoveries that are required to create more value from a fixed set of natural resources’’(P. Romer, 1993)

Social psychological theories:

1) Linear progression model of enviromental knowledge:

This theory posits that enviornmental knowledge leads to pro-environmental behavior. it says that environmental knowledge leads to environmental awareness which may leads to pro environmental beahvior (Kollmuss & Agyeman, 2002). This model , however, centerd its focus on specific knowledge—environmental knowledge. However, it is possible to claim that any type of knowledge may leads to pro-environmnental behavior as well, as more educated people likely to have more environmental knowledge and a country with pro-environmental people will have more demand for clean technologies. This supports the demand-pull perspective of innovations introduced in 1950s and 1960s which stated that increased demand for innovations in market motivates firms to invest in innovation (Kollmuss & Agyeman, 2002).

2) **Model of Responsible Environmental Behavior:**

(Hines, Hungerford, & Tomera, 1987)**;**(Hungerford & Volk, 1990)**;** (Sia, 1984)**.**

They identified some factors that leads to environmental behaviour towards environment including ‘knowledge about environmnetal problems and causes’’ and ‘knowldege about how to mitigate the environmental problems’ (Kollmuss & Agyeman, 2002) (Hassan, 2016). Certainly, knowledge about environmental problems and causes and mitigation methods are included in total knowledge stock. General Citizens will not know these specific environmental knowledges unless there are some experts who know them and spread them to mass. The specific knowledge or information about environments commonly come to them along with overall knowledge and information. Thus, if there are more experts and if the knowledge transfer is wider people will have more ideas and information about environmental problems. And they will, in turn, act to mitigate the environmental problems.

SCT (science comprehension thesis):

This asserts that scientific evidences are erudite and are not comprehensible to public. People who are not engaged with science literacy do not take climate change as serious as scientists do. So there should be a positive correlation between science literacy and concern over climate change. (Kahan et al., 2012)

The theories discussed it is possible to hypothesize that the countries with more knowledge stock and science & technologies likely to produce and adopt more green technologies than their counterparts countries who have less knowledge stock and less science & technologies.

Literature Review

Both the theoretical and empirical studies are very few in numbers. The past studies dealing with these concepts commonly explored the relationship between knowledge economy and other factors and relationship between green economy and other sectors.

(Añón Higón, Gholami, & Shirazi, 2017) estimated the impacts of information and communication technologies (ICTs) on CO2 emission on26 developed countries and 116 developing , for the period spanning from 1995 to 2010. They find an inverted U-shaped relationship between ICT and CO2 emissions. (Wan Lee & Brahmasrene, 2014) examined the relationship between ICT and CO2 emissions on 9 ASEAN countries. They find a significant positive impact of ICT on CO2 emission.

(Kahan et al., 2012) investigated the relationship between science literacy and concern about climate change in United States. They collected data from 1540 United States' adult citizens. The results show that citizens with highest degree of science literacy are not the ones who are concerned about climate change. In other words, a positive correlation between science literacy and concern over climate change is not found. (Finger, 1994) surveyed over 786 and 1004 Swiss citizens to explore the relationships between environmental experience, learning, and behavior the results shows that environmental information, knowledge, and awareness do not have very significant effect on environmental behavior.

(Costantini & Martini, 2010) tested the impact of technological infrastructure on various pollutants. They used number of internet, fixed and mobile telephone lines per 1.000 persons as proxy for technological infrastructure. The findings indicate that technological infrastructure have positive impacts on various pollutants including CO2.

(Qian et al., 2016) conducted a study on citizens of Ningbo, China on relationship between education, environmental attitudes and others. The findings indicate that awareness about air pollution increased significantly if education level has increased.

Methodology

Variables:

Total patent application (patent), total citable published documents (publication), and researchers per 1 million (researchers) people have been used to measure the knowledge base. Green Performance Index (G_{pfi}), Green Perception index (G_{pci}) are used to measure the greenness. The descriptions of these 5 variables are given below.

1) **Patent:** it measure the patent application submitted by residents of a country through ‘’Patent Cooperation Treaty procedure’’ or submitted with national patent office. Patent applications are filed for the purpose of acquiring exclusive right for an innovation. Innovation means a new product or a new process that provides a new way of accomplishing something or provides a new technical solution to an issue. Patent provide legal protection for the invention to the innovator individual or company. Innovators can enjoy a legal protection for usually 20 years.
2) **Researcher:** This variable measure total number of researchers engaged in Research and Development. They are involved ‘’in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned’’ (WDI). Data also covers the Postgraduate PhD students engaged in research and development.
3) **Publication:** This variable measure the number of total citable documents published in a year. Data covers publications in wide range of fields including, Business, Economics, medical engineering mathematics and other social sciences. Citable publications do not necessarily mean that they have already been cited or will be cited in future.
4) **G_{pfi} (Green Performance Index):** This variable include 32 indicators and datasets. 32 indicators are categorized into 4 groups, namely, leadership & climate change, efficiency sectors, markets & investment and environment & natural capital. Leadership & climate change include sub-categories such as Head of State, Media Coverage, International Forums and Climate Change Performance. Markets & investment includes Renewable Energy Investment, Cleantech Innovation, Cleantech Commercialization, Green Investment and Facilitation.

Environment & natural capital includes Agriculture, Air Quality, Water, Biodiversity &Habitat, Fisheries and Forests.

5) **G_{pci} (Green Perception Index):** Green perception index contains the survey data from residents of selected countries. The data were polled on how they perceive national green performance on the four main dimensions of Leadership & Climate Change, Efficiency Sectors, Markets & Investment, and Environment & Natural Capital.

Estimation Techniques:

A preliminary investigation was carried out with Pearson's correlation analysis. Ordinary Least Square then has been performed at second stage along with diagnostic tests. At the last stage the direction of causality is investigated by Kernel non-parametric Causality test.

Correlation Analysis:

Correlation analysis is to check the degree of relationship or association between two random variables. The coefficients of correlation lie between -1 and +1. A correlation coefficient close to -1 indicates a strong negative relationship. On the other hand, a correlation coefficient close to +1 indicates a strong positive relationship between two random variables. And if it is very close to zero, it indicates a weak relationship.

Ordinary Least Square:

OLS allows us to test a relationship hypothesis between the dependent and the independent variable. A total of 6 OLS models have been estimated to check the relationship between knowledge economy and green economy.

Model 1: $\log(G_{pfi})=\beta_1+\beta_2\log(patent_i)+\varepsilon_i$

G_{pfi}=Green performance index

Patent=Number of patent application

Model 2: $\text{Log}(G_{pci})=\beta_1+\beta_2\log(patent_i)+\varepsilon_i$

G_{pci}=Green perception index

Paten=number of patent application

Model 3:

$(G_{pfi})=\beta_1+\beta_2(RES_i)+\varepsilon_i$

G_{pfi}=Green performance

RES= number of researchers per 1 million people

Model 4: $(G_{pci})=\beta_1+\beta_2(RES_i)+\varepsilon_i$

G_{pci}=Green perception

RES_i=Number of researchers per 1 million people

Model 5: $\log(G_{pfi})=\beta_1+\beta_2\log(publication_i)+\varepsilon_i$

G_{pfi}=Green performance

Publication: Number of citable published documents.

Model 6.

$\log(G_{pci})=\beta_1+\beta_2\log(publication_i)+\varepsilon_i$

G_{pfi}=Green perception

Publication: Number of citable published documents.

GE_{pc} stands for green economy performance, GE_{pf} stands for green economy performance and KE stands for Knowledge economy indicators. In each model, β_1, β_2, are the unknown parameters to be estimated. Where, β_1 is intercept and β_2 is slope that quantify effects of knowledge on greenness.

Kernel Causality test:

The Kernel causality developed by Vinod(2017) has its roots in the ‘’instantaneous causality" noted (but not implemented) by Granger. Unlike the standard Granger causality, instentaneous causality does not include the past values. According to the Granger, Y instantaneously causes X if the predictability of current value of X improves if the current value of Y is included in the prediction. Vinod developed a cusality test based on ‘’instantaneous causality’’ applying generalized measures of correlation (GMC) of Zheng et al. (2012).

Let *GMC (Y|X)* the coefficient of determination R^2 of Nadaraya-Watson nonparametric Kernel regression which is given by , $Y=f(X)+e=E(Y|X)+e$ Where $f(X)$, is a non-parametric, unspecified (non-linear) function. By switching X and Y we get *GMC(X|Y)* which is the coefficient of determination of $X=f'(Y)+e'$ where, $f'(Y)$ is a non-parametric, unspecied (non-linear) function.

And let δ =*GMC(X|Y)*- *GMC(Y|X)* that is, the difference between two population coefficient of determinations of each non-parametric regression. The direction of causality then can be determined by the magnitude of δ as follows:

If δ <0; *GMC(Y|X)*> *GMC(X|Y)* then X is the Kernel cause of Y

If δ =0; *GMC(Y|X)*= *GMC(X|Y)* then cause is indeterminate.

and δ >0; *GMC(Y|X)*< *GMC(X|Y)* then Y is the Kernel cause of X.

Vinod (2017) remarked that very small value of δ does not imply the insignificance of Kernel causality , rather it suggest the linearity of the true functions f and f' and. The Kernel causality is simple and easy to be implemented in both time series and cross sectional data. However, vinod stressed that it should be used only when there are exisiting theories and explantions on the causal linkage between the two variables.

Transformation of variables to natural logarithm has been preferred until misspecification test suggest to use non-log forms.

Data:

Data of patent applications researchers have been collected from Word Development Indicators (WDI) compiled by World Bank. Data of Global Green Economy Index have been collected from Dual Citizen LLC

Result

Results and discussion:

Correlation results

Table 1: Correlation results

Knowledge Economy	Green Economy	Correlation	Probability
Researchers	Performance	0.366230*	0.0718
Researchers	Perception	0.645163***	0.0005
Patent	Performance	0.180221	0.3887
Patent	Perception	0.528524***	0.0066
Publication	Performance	0.205052	0.3255
Publication	Perception	0.506501***	0.0098

(*) and (***) indicate that correlation is statistically significant at 10% and 1% level of significance

The pairwise correlation results are reported in table 1. First column and second column of table 1 contain the indicators of knowledge economy and green economy, respectively. All of the indicators were transformed into natural logarithm. The third column 1 lists the correlation coefficients and the fourth column lists the P-values of significance tests of respective correlation coefficients. Table 1 shows that there are some statistically significant correlation between number of researchers and green performance, between number of researchers and green perception, between patent counts and green perception, and between publications and green perception. However, correlation between patent counts and green performance and correlation between publication and green performance are not statistically significant. It can be concluded from table 1 that Knowledge economy indicators are more strongly correlated with green perception than with green performance.

OLS regression results:

Regression Result of model 1:

$\log(G_{pfi})=\beta_1+\beta_2\log(patent_i)+\varepsilon_i$

G_{pfi}=Green performance index

Patent=Number of patent application

Table 2: Regression Result of model 1

	Estimates	Coefficient	Std. Error	t-Statistic	P-value
Intercept	3.763923***		0.083028	45.33309	0.0000
log(patent)		0.021499*	0.012031	1.787042	0.0805
R-squared	0.064918				
Adj R-squared	0.044590				

Diagnostic tests	P-values
Breusch-Pagan-Godfrey: p. $X^2_{(1)}$	0.54 (passed)
Normality JB P. $X^2_{(2)}$	0.368 (Passed)
Fitted^2 (RESET) coef. P-value	0.4694(Passed)

Notes: (*) and (***) represents that coefficient is significant 10% and 1% significance level, respectively. Numbers in () is order of test. P and X^2 denotes p-value and Chi-square, respectively. JB (Jarque–Bera test) examines the normality of residual with null of being residuals are not normally distributed. Breusch-Pagan-Godfrey checks for Heteroskedasticity with null hypothesis of presence of Heteroskedasticity. RESET, stands for Ramsey Regression Equation Specification Error Test, examines the misspecification with the null of the model being correctly specified.

Table 2 displays the estimated results of model 1 which was formulated to check the impact of innovation (proxied by number of total patent application) on Green performance. The coefficient and associated p-value indicate that there is a positive and significant impact of innovation on green performance at 10% significance level. The lower panel of Table 1 displays the results diagnostic tests. The Breusch-Pagan-Godfrey test is used to test Heteroskedasticity. P-value shows that the null hypothesis of Homoskedsticity could not be rejected, indicating no heterskedasticity in the model. Jarque–Bera test is performed to check whether the residuals follow a normal distribution. The associated p-value indicates that null hypothesis of non-normality of residuals could not be rejected, indicating that residuals are normally distributed. The coefficient of fitted square in Remesy RESET test is not significant, implying that evidence of model misspecification is not found.

Regression results of model 2.

$Log(G_{pci})=\beta_1+\beta_2 log(patent_i)+\varepsilon_i$

G_{pci}=Green perception index

Paten=number of patent application

Table 3: Estimated OLS results of model 2

	Coefficient	Coefficient	Std. Error	t-Statistic	p-value
Intercept	-5.724251**		2.812260	-2.035463	0.0476
Log(patent)		3.269562***	0.746781	4.378206	0.0001
R-squared	0.294140				
Adj R-squared	0.278795				

Diagnostic tests	P-values
Breusch-Pagan-Godfrey: p. $X^2_{(1)}$	0.3421(passed)
Normality JB P. $X^2_{(2)}$	0.9346 (Passed)
Fitted^2 (RESET) coef. P-value	0.0603(passed at 5%)

Notes: (**) and (***) represents that coefficient is significant 5% and 1% significance level, respectively. Numbers in () is order of test. P and X^2 denotes p-value and Chi-square, respectively. JB (Jarque–Bera test) examines the normality of residual with null of being residuals are not normally distributed. Breusch-Pagan-Godfrey checks for Heteroskedasticity with null hypothesis of presence of Heteroskedasticity. RESET, stands for Ramsey Regression Equation Specification Error Test, examines the misspecification with the null of the model being correctly specified.

Model 2 was formulated to investigate the impact of innovation on green perception. The results in table 3 suggest that innovation positively affects the green perception in a country. The effect is significant at 1% level of significance. The lower panel of Table 1 displays the results diagnostic tests. The Breusch-Pagan-Godfrey test is used to test Heteroskedasticity. P-value shows that the null hypothesis of homoskedsticity could not be rejected, indicating no heterskedasticity in the model. Jarque–Bera test is performed to check whether the residuals follow a normal distribution. The associated p-value indicates that null hypothesis of non-normality of residuals could not be rejected, indicating that residuals are normally distributed. The coefficient of fitted square in Remesy RESET test is significant at 10% level of significance, implying that the evidence of model misspecification can be present. However, it is not significant at 5% level of significance. Therefore, it is possible to reject the hypothesis of model misspecification at 5% level of significance.

Regression results of model 3

$(G_{pfi})=\beta_1+\beta_2(RES_i)+\varepsilon_i$

G_{pfi}=Green performance

RES= number of researchers per 1 million people

Table 4: Estimated results of model 3

	Estimates	Coefficient	Std. Error	t-Statistic	P-value
Intercept	44.60759		2.477207	18.00721	0.0000
RES		0.002677	0.000639	4.185646	0.0004
R-squared	0.432374				
Adj R-squared	0.407695				

Diagnostic tests	P-values
Breusch-Pagan-Godfrey: p. $X^2_{(1)}$	0.2079 (passed)
Normality JB P. $X^2_{(2)}$	0.7052 (Passed)
Fitted^2 (RESET) coef. P-value	0.0996(Passes at 5%)

Model 3 was formulated to investigate the impact of researchers on green performance. The results in table 4 suggest that researchers positively affect the green performance in a country. The effect is significant at 1% level of significance. The lower panel of Table 4 displays the results of diagnostic tests. The Breusch-Pagan-Godfrey test is used to test Heteroskedasticity. P-value shows that the null hypothesis of homoskedsticity could not be rejected, indicating no heterskedasticity in the model. Jarque–Bera test is performed to check whether the residuals follow a normal distribution. The associated p-value indicates that null hypothesis of non-normality of residuals could not be rejected, indicating that residuals are normally distributed. The coefficient of fitted square in Remesy RESET test is significant at 10% level of significance, implying that the evidence of model misspecification can be present. However, it is not significant at 5% level of significance, so we can reject the hypothesis of model misspecification at 5% level of significance.

Results of Model 4

$(G_{pci})=\beta_1+\beta_2(RES_i)+\varepsilon_i$

G_{pci}=Green perception

RES_i=Number of researchers

Table 5: Estimated results of model 4

	Estimates	Coefficient	Std. Error	t-Statistic	p-value
Intercept	20.09268		5.507346	3.648341	0.0013
RES		0.008803	0.001422	6.191628	0.0000
R-squared	0.625018				
Adj R-squared	0.608714				

Diagnostic tests	P-values
Breusch-Pagan-Godfrey: p. $X^2_{(1)}$	0.1624(passed)
Normality JB P. $X^2_{(2)}$	0.8695 (Passed)
Fitted^2 (RESET) coef. P-value	0.211(Passes)

Model 4 was formulated to investigate the impact of researchers on green perception in a country. The results reported in table 5 suggest that researchers positively affect the green perception in a country. The effect is significant at 1% level of significance. The lower panel of Table 4 displays the results of diagnostic tests. The Breusch-Pagan-Godfrey test is used to test Heteroskedasticity. P-value shows that the null hypothesis of homoskedsticity could not be rejected, indicating no heterskedasticity in the model. Jarque–Bera test is performed to check whether the residuals follow a normal distribution. The associated p-value indicates that null hypothesis of non-normality of residuals could not be rejected, indicating that residuals are normally distributed. The coefficient of fitted square in Remesy RESET test is not significant, implying that evidence of model misspecification is not found.

Results of Model 5.

$\log(G_{pfi}) = \beta_1 + \beta_2 \log(\text{publication}) + \varepsilon_i$

G_{pfi}=Green performance

Publication: Number of citable published documents.

Table 6: Estimated results of model 5

	Estimates	Coefficient	Std. Error	t-Statistic	p-value
Intercept	3.576724		0.141736	25.23511	0.0000
publication		0.034974	0.014871	2.351889	0.0230
R-squared	0.107340				
Adj R-squared	0.087934				

Diagnostic tests	**P-values**
Breusch-Pagan-Godfrey: p. $X^2_{(1)}$	0.1648(passed)
Normality JB P. $X^2_{(2)}$	0.4611 (Passed)
Fitted^2 (RESET) coef. P-value	0.7752(passed)

Model 5 was formulated to investigate the impact of publications on green performance in a country. The results reported in table 6 suggest that publications positively affect the green perception in a country. The effect is significant at 5% level of significance. The lower panel of Table 6 displays the results of diagnostic tests. The Breusch-Pagan-Godfrey test is used to test Heteroskedasticity. P-value shows that the null hypothesis of homoskedsticity could not be rejected, indicating no heterskedasticity in the model. Jarque–Bera test is performed to check whether the residuals follow a normal distribution. The associated p-value indicates that null hypothesis of non-normality of residuals could not be rejected, indicating that residuals are normally distributed. The coefficient of fitted square in Remesy RESET test is not significant, implying that evidence of model misspecification is not found.

Results of model 6.

$\log(G_{pci})=\beta_1+\beta_2\log(publication_i)+\varepsilon_i$

G_{pfi}=Green perception

Publication: Number of citable published documents.

Table 7: Estimated results of model 6

	Estimates	Coefficient	Std. Error	t-Statistic	p-value
Intercept	2.580081		0.180333	14.30733	0.0000
publication		0.124695	0.023703	5.260677	0.0000
R-squared	0.352615				
Adj R-squared	0.338542				

Diagnostic tests	P-values
Breusch-Pagan-Godfrey: p. $X^2_{(1)}$	0.0759(passed at 5%)
Normality JB P. $X^2_{(2)}$	0.277 (Passed)
Fitted^2 (RESET) coef. P-value	0.1883(passed)

Model 6 was formulated to investigate the impact of publications on green perception in a country. The results reported in table 7 suggest that publications positively affect the green perception in a country. The effect is significant at 1% level of significance. The lower panel of Table 7 displays the results of diagnostic tests. The Breusch-Pagan-Godfrey test is used to test Heteroskedasticity. P-value shows that the null hypothesis of homoskedsticity is rejected at 10% level of significance, indicating that heterskedasticity might be present in the model. To this end, HAC standard errors & covariance is used. The regression results reported in table 7 are of modified standard errors by HAC. Jarque–Bera test is performed to check whether the residuals follow a normal distribution. The associated p-value indicates that null hypothesis of non-normality of residuals could not be rejected, indicating that residuals are normally distributed. The coefficient of fitted square in Remesy RESET test is not significant, implying that evidence of model misspecification is not found.

Table 8: Results of Kernel Causality

x	**y**	**r*x|y**	**r*y|x**	**Cause**
Green Performance	Patents	0.263883	0.259324	Patent
Green Performance	Researchers	0.802595	0.56106	Researchers
Green Performance	Publications	0.554824	0.363416	Publications
Green Perception	Patents	0.784211	0.564165	Patent
Green Perception	Researchers	0.827798	0.650635	Researchers
Green Perception	Publications	0.619875	0.629581	Green Perception

The results of Kernel non-parametric causality are reported in table 8. And the directions of causalities are depicted in figure 1. The first column of table 8 contains the indicators of green economy index, namely, Green Performance Index and Green perception index. **r*x|y** **r*y|x** are two coefficient of determination from Nadaraya-Watson nonparametric Kernel regression. If **r*y|x** is less than **r*x|y,** then causality is said to be running from **y** to **x.** For instance, in row 4 of table 8,**r*publication|Green performance** is 0.36341 and **r*Green performance|Publication** is 0.5548. since **r*publication|Green performance** is less than **r*Green performance|Publication**, the causality is running from publication to green performance. The results from table 8 indicate that all of the indicators of knowledge economy used in this study are the causes of green performance. This implies that knowledge base of a country can leads to its good performance in greenness. The higher the knowledge base the greater would be the green performance. Again, results from table 8 suggest that causality is running from knowledge economy indicators to green perception. This implies that knowledge base of a country is cause of green perception. The greater the knowledge base the higher the positive feelings of citizen towards greenness. However, In case of publication and green perception, the causality reversed and is found to be running from green perception to publication. This is an exceptional case among all six cases for which we do not have any convincing explanation.

Direction of causality:

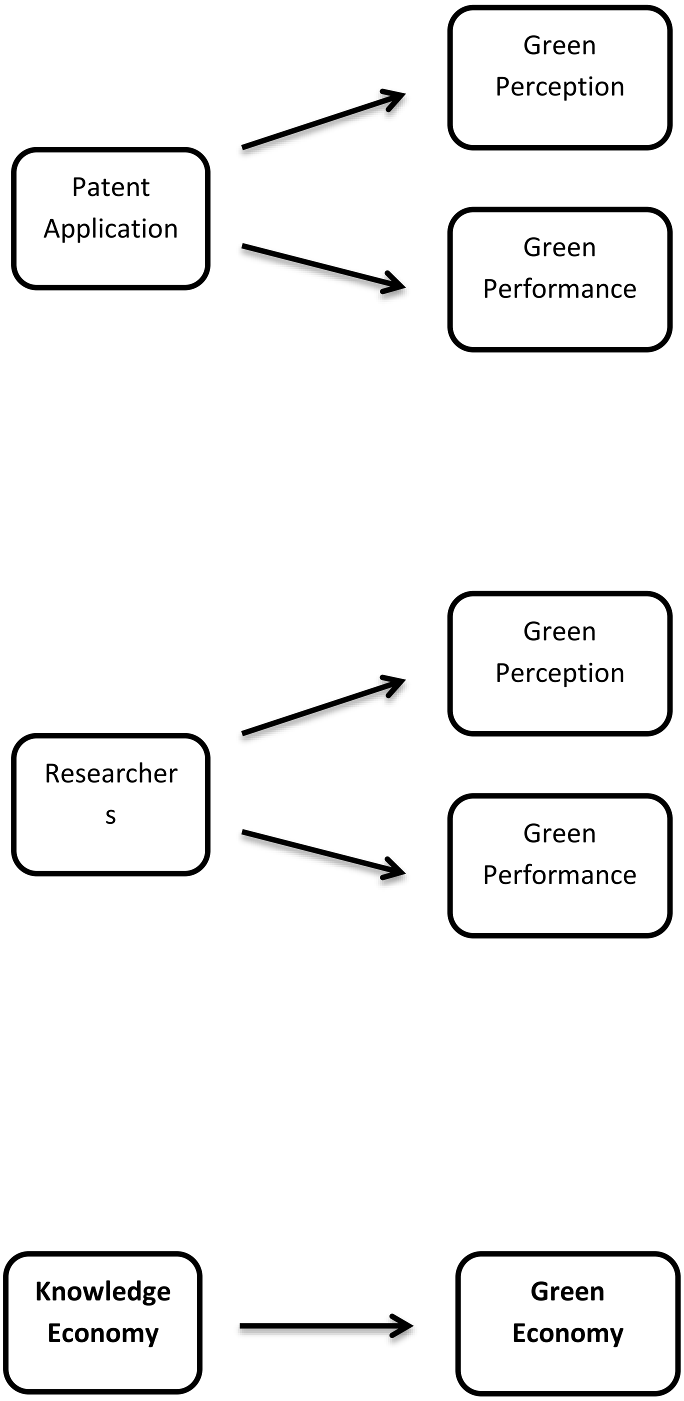

Figure 1: Direction of causality

Findings

Conclusion

The aim of this paper is to explore the relationship between Knowledge Economy and Green Economy. As discussed previously, various economic and psychological theories suggest that knowledge base of a country encourages the environmental friendly activities by its citizens.

We collected data of Green Economy Index

After a preliminary investigation through correlation analysis, a total of 6 different OLS models were formulated to empirically check this relationship. We also applied Kernel non-parametric causality which can determine the direction of causality in cross sectional data.

The obtained correlation coefficients suggest that there was significant positive correlation between knowledge economy indicators and Green Economy Perception and between knowledge economy indicators and Green Economy Performance. However, correlation between patent application and Green Economy Performance and correlation between publications and Green Economy Performance were not significant. The results obtained from OLS regression analysis indicate that knowledge economy indicators significantly affect both performance and perception of green economy. The majority of the tested models were robust to model misspecification, Heteroscedasticity, and non-noramlity of residuals. The results obtained from pairwise Kernel causality suggest that causality runs from knowledge indicators to both green performance index and green perception index.

The overall results suggest that knowledge economies are helpful to build green economies. In other words, an economy where knowledge base is utilized as the main input of production are greener than the countries who do not produce knowledge-intensive products. To ensure the sustainability the knowledge base of should be promoted. Knowledge base is an accelerator of economic growth, and at the same time, it is assistive to preserve the environmental quality. Based on the discussed theories and the empirical findings of this study, we argue that Government and other environment related agencies should consider the promotion of knowledge and literacy among people while formulating the green policies.

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