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A Canonical Correlation Analysis of the Relationship between Income Levels and Resilience to Climate Change

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Abstract

This study aims to examine the relationship between economic growth and income level on climate change resilience. An income-level variable is a group of state income consisting of lower, middle, and upper-income countries. Climate change resilience has dimensions of susceptibility, coping capability, and adaptation capacities. This study estimates 174 countries in the 2019 period. Data were obtained from the World Bank and World Risk Report. Data analysis using canonical correlation. The research findings show that the gap between exposure and vulnerability in low-income countries is more prominent than in other groups. Low-income levels have a relationship with low resilience in terms of susceptibility and lack of coping and adaptation capacities. Another finding shows that economic growth is not correlated with resilience to climate change, where economic growth does not automatically reduce vulnerability but only economic growth followed by appropriate policies.

Keywords: growth, resilience, climate change, income

Introduction

Climate change leads to a decrease in the quality and quantity of economic activity and the loss of the Country's potential output. Climate risks faced in global development are natural disasters and diseases. Mitigation and adaptation are needed to deal with the risks and impacts of climate change. Natural disasters impact infrastructure damage, migration, disease, and human resources. Agriculture is the sector most vulnerable to climate change, while manufacturing is the sector least affected (Akram, 2013). Climate change increases the incidence of pests and diseases, affecting crops, livestock, and humans, extending summer throughout the year, and drying up water sources early (Mtupile & Liwenga, 2017). Climate change endangers fishery life in coastal areas, destroys physical infrastructure, reduces fishing activities, reduces health quality, and reduces food supplies (Herdiansyah, Ningrum, Fitri, & Mulyawan, 2018). The impacts of climate change on fishing households include the difficulty of predicting the season, changes in fishing locations farther from the coast, and reduced and unpredictable fishing frequency (Mutolib et al., 2021).

Several macro-scale studies show the relationship between climate change and economic growth. Changes in temperature, rainfall, and population growth influence economic growth (Akram, 2013). Increasing temperature drives the gross regional product (GRP) in cold regions and decreases GRP in hot regions (Kalkuhl & Wenz, 2020). Rising temperatures reduce the per capita production of countries with relatively high annual average temperatures, including most low-income countries (Kazakova, 2020). Substantially higher temperatures and reduced economic growth in developed countries also have far-reaching effects on agricultural output, industrial output, and politics (Dell, Jones, & Olken, 2012). Many countries simultaneously face a "double danger," namely climate risk and macroeconomic risk (Feyen, Utz, Zuccardi Huertas, Bogdan, & Moon, 2020). In developing countries, the impact of climate change has a more severe risk. Although climate change is a global phenomenon, its negative impacts are more pronounced in underdeveloped countries due to their high dependence on natural resources and limited ability to cope with extreme climate variability (De Silva & Kawasaki, 2018). On the other hand, developing countries have not considered climate change issues when planning local and national development agendas (Ghoneem, 2016).

Vulnerability to climate change can be in the form of susceptibility, coping, and adaptation capacity (Bündnis Entwicklung Hilft, 2020). Susceptibility describes the community's structural characteristics and conditions that allow the community to suffer damage due to extreme natural events. Coping capacity is the ability of a community to minimize the negative impacts of climate risk, including the actions and capabilities available during an incident to reduce damage. The adaptation includes measures and strategies to deal with the negative impacts of natural hazards and climate change in the future.

Literature Review

Several climate change vulnerability studies investigate the group, gender, and region dimensions. Studies generally examine climate change adaptation and mitigation capacity with a research focus on what factors affect community adaptation or mitigation capacity (Acevedo et al., 2020; Assan, Suvedi, Olabisi, & Allen, 2018; Fang, Fan, Shen, & Song, 2014; Mihiretu, Okoyo, & Lemma, 2019; Nggole, Tyas, & Pradoto, 2019; Reckien et al., 2017; Rondhi, Fatikhul Khasan, Mori, & Kondo, 2019; Sedegah, Ajayi, & Adu-Okoree, 2020; Vo, Mizunoya, & Nguyen, 2021; Yang, Wei, & Su, 2020; Zamasiya, Nyikahadzoi, & Mukamuri, 2017). Other studies focus on how affected communities adjust in the face of climate change (Hidayati & Suryanto, 2015; Rasmikayati & Djuwendah, 2015). The latest study (Wilts, Latka, & Britz, 2021) examines income-level and climate change in low- and lower-middle-income countries but only examines the effect of climate change on household types. Few studies still examine the relationship between economic growth and income level on climate change resilience. This study focuses on how economic growth and income levels relate to climate change resilience. The research findings are expected to answer whether income criteria correlate with climate change vulnerability variables such as susceptibility, coping, and adaptation capacities. This study is expected to reveal the agenda to increase resilience to climate change.

Research Method

The study estimates 174 countries for the 2019 period. The research variables consist of:

1) GDP growth rate based on 2010 U.S. constant prices dollars in 2019, earned from Worldbank, 2021.
2) The Exposure Index is climate risk to the natural hazard sphere, from World Risk Report, published by Bündnis Entwicklung Hilft, 2020.
3) The susceptibility, coping, and adaptation capacity index measures a variable set of resilience to climate change, from World Risk Report.
4) Income level is a state income group consisting of 22 low-income countries, 97 middle-income countries, and 55 upper-income countries.

The correlation between economic growth and income level on climate change vulnerability is estimated by canonical correlation analysis. The set of Y is an indicator of vulnerability consisting of Y1 = Susceptibility; Y2= = Lack of Coping capacities; and Y3= = Adaptation capacities. The set of variables X is an indicator of income, consisting of: X_1 = economic growth, X_{D1} = low-income countries, and X_{D2} = dummy upper-income countries. In the variable X_{D1} = low-income countries, the number is 1 for low-income countries; and 0 for others. In the variable X_{D2} = middle-income countries, number 1 is given for middle-income countries; and 0 for others. The canonical equation is presented as equation (1):

$$Y_1, Y_2, Y_3 = X_1, X_{D1}, X_{D2} \tag{1}$$

The characteristics of the random variable vectors X and Y are as follows:

$$E(Y)= \mu_Y; \qquad Cov\ (Y)=\sum_{YY}$$

$$E(X)= \mu_X; \qquad Cov\ (X)=\sum_{XX}$$

$$Cov\ (X,Y)=\sum_{X.Y}= \sum_{Y.X}' \tag{2}$$

The linear combination of the two groups of variables can be written as follows:

$$Var\ (U) = a'X = a_1X_1 + a_2X_{D1+}a_3X_{D2} \tag{3}$$

$$Var\ (V) = b'Y = b_1Y_1 + b_2Y_2 + b_3Y_3 \tag{4}$$

Therefore:

$$Var\ (U) = a'Cov(X)a = a' \textstyle\sum_{X.X} a \tag{5}$$

$$Var\ (V) = b'Cov(Y)b = b' \textstyle\sum_{Y.Y} b \tag{6}$$

$$Cov\ (U,V) = a'Cov(X,Y)b = a' \textstyle\sum_{X.Y} b \tag{7}$$

Vector coefficients a and b for maximum correlation:

$$Cor\ (U,V) = \frac{a' \sum_{X.Y} b}{\sqrt{a' \sum_{X.X} a}\sqrt{b' \sum_{Y.Y} b}} \tag{8}$$

Several steps are estimated for the determinate relationship between income groups and resilience, first performing a multivariate test of significance. If probability < 0.05, reject the null hypothesis, which states that there is no relationship between two groups of variables, or receive the alternative hypothesis, indicating both sets of dependent variables. Second, the analysis function is determined based on the highest significance and criteria for canonical correlation and eigenvalue > 1. Third, Canonical Loading was analyzed for vulnerability and income level variables to determine the strong correlation between variables in a set. Canonical cross-loading was calculated to examine the level and direction of the relationship between the set of resilience and income level variables. Canonical cross-loading was calculated by multiplying canonical loading by the canonical correlation coefficient. Data were transformed by Log10 (k -x), where k is the highest lack of adaptation value plus 1, and x lacks adaptation value for Country i. Therefore, the variable lack of adaptation shows a lower value for a higher lack of adaptation or a higher value for lower adaptation capacities, so the variable lack of adaptation from World Risk Report (2020) changes its meaning to adaptation capacities and has the direction of the negative relationship with the dimension of vulnerability, or the manifestation of climate change resilience. The variables of susceptibility and lack of coping capacities have a positive relationship with the dimension of vulnerability and a negative with climate change resilience.

Results and Discussion

Table 1 presents descriptive statistics of variables based on three income groups: low, middle, and upper-income countries. Based on the average, the highest exposure belongs to the middle-income country group, but the highest average vulnerability belongs to the low-income group. High-income countries have a relatively higher resilience in facing climate risks, while low-income countries are most vulnerable to climate change. Low-income groups have the highest susceptibility and lack coping capacities and adaptation based on vulnerability indicators than middle-income groups. However, the low-income countries group has higher average growth than other income groups in terms of economic performance.

The average vulnerability and exposure in low-income countries differ significantly from other income groups. In other words, although low-income countries have low exposure, it is accompanied by vulnerability to high risk. Climate risks should not harm underdeveloped countries seriously, but because of the limited capacity for risk management, climate change will encourage more severe impacts. In general, the ability to cope with and manage the impacts of climate change between countries in the low-income group is not much different from the middle and high-income groups, indicated by the value of the standard deviation of vulnerability, and the indicator in low-income countries is smaller than other income groups.

Table 1 Variable descriptive statistics

Income Group	Variable	Max	Min	Mean	Stdev	N
Low	Exposure	21.43	8.13	14.4	3.28	22
	Vulnerability	76.34	48.63	68.01	5.54	22
	Susceptibility	70.83	32.00	55.84	8.67	22
	Lack of coping capacities	69.72	36.81	60.51	7.36	22
	Lack of adaptation	93.80	77.09	87.67	4.15	22
	Growth	9.43	-2.28	4.37	2.81	22
Middle	Exposure	86.77	1.85	18.06	13.13	97
	Vulnerability	68.58	33.5	49.93	8.49	97
	Susceptibility	61.54	16.49	30.34	11.28	97
	Lack of coping capacities	63.85	24.81	42.13	9.62	97
	Lack of adaptation	88.76	58.67	77.31	7.04	97
	Growth	18.72	-8.1	2.83	3.55	97
Upper	Exposure	68.92	0.91	14.79	12.23	55
	Vulnerability	69.48	22.81	32.47	8.82	55
	Susceptibility	65.68	8.32	17.47	8.20	55
	Lack of coping capacities	56.21	14.59	24.37	9.09	55
	Lack of adaptation	91.82	37.36	55.57	12.11	55
	Growth	5.55	-2.5	2.16	1.68	55

The normality test results showed that the susceptibility and lack of adaptation data were not normally distributed, so data transformation and retesting were carried out. The result was Kolmogorov-Smirnov Z with a significance value > 0.05. Susceptibility data is transformed by log (10), while lack of adaptation data is transformed by Log10 (*k* -x), where *k* is the highest lack of adaptation value plus 1, and *x* lacks adaptation value for Country i. Therefore, the variable lack of adaptation shows a lower value for higher lack of adaptation or a higher value for lower adaptation capacities, so the variable lack of adaptation from Bündnis Entwicklung Hilft (2020) changes its meaning to adaptation capacities and has the direction of the negative relationship with the dimension of vulnerability, or the manifestation of climate change resilience.

The variables of susceptibility and lack of coping capacities have a positive relationship with the dimension of vulnerability and a negative with climate change resilience.

Table 2 Multivariate test of significance

Test Name	Value	Approx. F	Hypoth. DF	Error DF	Sig. of F
Pillais	0.765	19.393	9	510.00	0.000
Hotellings	2.047	37.914	9	500.00	0.000
Wilks	0.305	28.551	9	409.02	0.000
Roys	0.659				

Estimation of canonical correlation, which begins with F significance testing from Pillais, Hotellings, and Wilks, is presented in Table 2. The F significance test has significant criteria, $p < 0.05$. All tests prove that statistically, there is a significant and positive relationship between the income variable set (X_1, X_{D1}, X_{D2}) and the vulnerability variable set (Y_1, Y_2, and Y_3).

Table 3 Eigenvalues and canonical correlations

Root No.	Eigenvalue	Pct.	Cum. Pct.	Canon Cor.	Sq. Cor
1	1.931	94.307	94.307	0.812	0.659
2	0.107	5.233	99.540	0.311	0.098
3	0.009	0.460	100.000	0.097	0.009

Table 3 presents the three canonical functions, where function 1 shows a correlation of 0.812; the second function is 0.311, and the third function has a canonical correlation of 0.097. Table 4 shows that the first, second, and third canonical variables are <0.05. However, subsequent studies only focus on the first canonical function with the highest canonical correlation and eigenvalue > 1.

Table 4 Dimension reduction analysis.

Root No.	Wilks L.	F	Hypoth. DF	Error DF	Sig. of F
1 To 3	0.305	28.551	9.00	409.02	0.000
2 To 3	0.895	4.829	4.00	338.00	0.000
3 To 3	0.991	1.600	1.00	170.00	0.208

Table 5 presents the raw canonical coefficients variable Y_1 (susceptibility), which has a coefficient of -1,652, indicating that an increase of 1 unit in susceptibility will reduce the resilience of climate change by 1,652 units. Raw canonical coefficients variable Y_2 (lack of coping capacities) of -0.012 indicates that an increase of 1 unit in the lack of coping capacities; will reduce the resistance to climate change by 0.012 units. Raw canonical coefficients variable Y_3 (adaptation capacities) of 0.325 indicates an increase of 1 unit in adaptation capacities; it will increase resistance to climate change by 0.325 units. The correlation between dependent and canonical variables shows that all vulnerability indicators have high coefficients and play a dominant role (> 0.5) in the variables.

Table 5 Canonical weight and loading for vulnerability variables

Variables	Raw canonical coefficients	Standardized canonical coefficients	Correlations between dependent and canonical variables
Y_1	-1.652	-0.352	-0.944
Y_2	-0.012	-0.174	-0.963
Y_3	0.325	0.514	0.971

Using the coefficient values in Table 5, the canonical variables for vulnerability can be written:

$$V = -1.652Y_1 - 0.012Y_2 + 0.325Y_3 \quad (9)$$

Calculating correlations between covariates and canonical variables for the income set (Table 6) shows that the correlation between the independent variables and their constituents has a high role (>0.5) for X_{D1} and X_{D2} but is low for economic growth. The correlation between covariates and canonical variables shows a negative direction for economic growth and is a dummy for low-income groups. However, the correlation between covariates and canonical variables for the dummy high-income group shows a positive direction.

Table 6 Canonical weight and loading for income-level variables

Variables	Raw canonical coefficients for covariates	Standardized canonical coefficients for covariates	Correlations between covariates and canonical variables
X_1	0.007	0.020	-0.188
X_{D1}	-1.528	-0.509	-0.698
X_{D2}	1.594	0.743	0.872

Using the coefficient values in Table 6, the canonical variables for income levels can be written:

$$U = 0.007X_1 - 1.528X_{D1} + 1.594X_{D2} \quad (10)$$

The canonical cross-loading of the dependent and independent variables as presented in Table 7 shows the dimensions of the resilience variable that have the closest correlation with the income level variable, namely Y_3 (adaptation capacities), then Y_2 (lack of coping), and Y_1 (susceptibility). The variable set of income that has the closest relationship with the set of resilience variables is X_{D2} (upper-income group dummy), then X_{D1} (low-income group dummy), while X_1 (economic growth) variable has a low correlation, not reaching 0.5.

Table 7 Canonical cross-loading dependent and independent variable

Variable	Canonical loading	Canonical correlation	Canonical cross-loading
Y_1	-0.944	0.812	-0.767
Y_2	-0.963	0.812	-0.782
Y_3	0.971	0.812	0.788
X_1	-0.188	0.812	-0.153
X_{D1}	-0.698	0.812	-0.567
X_{D2}	0.872	0.812	0.708

The direction of the correlation of each variable can be explained as follows:

1) Variable Y_1 = -0.767 implies that high susceptibility correlates with low-income levels.
2) Variable Y_2= -0.782 implies that a high lack of coping correlates with low income.
3) Variable Y_3= 0.788 implies that high adaptation capacities correlate with high-income levels.
4) Variable X_1 = -0.153 implies that high economic growth correlates with low resilience to climate change.
5) Variable X_{D1}= -0.567 implies a difference in resilience to climate change between low-income countries and other groups, where the resilience of low-income countries is lower than other groups.
6) Variable X_{D2} = 0.708 means a difference in resilience to climate change between high-income countries and other groups, where the resilience of high-income countries is higher than other groups.

The correlation between variables in the resilience set and income level as described in points (1) to (6) implies that low-income levels have a relationship with high vulnerability in terms of susceptibility, lack of coping, and lack of adaptation. The gap between exposure and vulnerability in low-income countries is higher than in other groups. Although the exposure of low-income countries is relatively lower on average than other groups, they have a high vulnerability to natural events. As a result, climate change has a high impact on low-income countries. Middle-income countries own the highest exposure on average. As a result, developing countries also severely impact climate change (Fuentes, Galeotti, Lanza, & Manzano, 2020) without mitigation and adaptation. The results showed a positive correlation between exposure and susceptibility, lack of coping capacities, and lack of adaptation. In the case of repeated exposure, middle-income countries are more difficult to recover due to high vulnerability. Before recovering from one disaster, the next disaster strikes. Because of that, repeated disasters push them further into the poverty trap (Haque, 2020) and threaten the sustainable development goals (SDGs).

Resilience to disasters in coping capacities, adaptation, and control of susceptibility are needed to deal with exposure. Research findings show that low income levels are associated with low climate change resilience for all dimensions. However, it is unfortunate that the role of the public in mitigation and adaptation is still limited (Ghozali, Ariyaningsih, Sukmara, & Aulia, 2016). Many governments, especially in developing countries, are less concerned in prioritizing policies to address climate change even though they have experienced and are vulnerable to disasters caused by climate change, such as floods, droughts, forest fires, and excessive temperature increases (Ghoneem, 2016; Ghozali et al., 2016). Inadequate government action puts the population at high risk (Gran Castro & Ramos De Robles, 2019).

The risk of climate change occurs in both rural and urban areas. Climate change threatens the agricultural and fisheries sectors in rural areas. In low-income countries, the agricultural and fisheries sectors have relatively low productivity compared to other sectors. As a result, people have a low level of welfare and a low level of education. The changing seasons, which are now unpredictable and difficult to anticipate, have further increased vulnerability to climate change. An area may have high-intensity rain in a country, but some areas may have a drought. In the end, climate change is further exacerbated by environmental damage that reduces the quality and carrying capacity of the land so that agricultural productivity drops—coupled with the phenomenon of storms that affect the climate cycle, causing a shift in the planting schedule of agricultural commodities, which increases the chance of crop failure. The impact of climate change on the fisheries sector is more severe in the tropics than in other areas. Climate change, with a continuous increase in temperature, will raise sea levels, directly reducing coastal areas. Developing countries with a high dependence on fisheries are negatively impacted by climate change, so it is necessary to conduct an in-depth economic analysis of the potential economic impact of climate change on global marine fisheries (Lam, Cheung, Reygondeau, & Rashid Sumaila, 2016).

The biggest challenge of climate change in urban areas is the susceptibility of informal and poor settlements. Informal settlements are defined as low-quality houses or huts built outside of formal laws and regulations, where most informal settlements lack piped water or adequate sanitation, drainage, and public services (Satterthwaite et al., 2020). However, most governments in developing countries pay little attention to the urban poor in their policies and investments related to climate change and natural disasters (Haque, 2020). Thus, local urban challenges in informal settlements need to be included in the debate on climate change (Gran Castro & Ramos De Robles, 2019). Policies need to be directed at the impacts and needs of the most vulnerable, such as women living in poverty, for mitigation policies in urban areas (Reckien et al., 2017). Low-income countries are less able to support mitigation efforts, and their distinctive equatorial location makes them less likely to experience natural temperature variability and more remarkable changes in the occurrence of temperature extremes with global warming. This aspect of global warming is well known but ignored in policy agreements on international climate (Herold, Alexander, Green, & Donat, 2017). Research findings show that higher income levels are associated with higher resilience to climate change. Because those high-income countries have advantages in public infrastructure, economic capacity, and better disaster mitigation, thereby increasing their resilience to climate change.

This study also shows that resilience to climate change has a low correlation with economic growth. Growth does not automatically increase resilience or reduce vulnerability. Only proper growth reduces vulnerability (Bowen, Cochrane, & Fankhauser, 2012). Economic growth that can reduce susceptibility and increase coping and adaptation capacities is pursued by such policies encouraging mitigation infrastructure, investment in human resources, and access to finance. Human capital shows a positive correlation with people's livelihood strategies (Fang et al., 2014).

On the other hand, increased access to information on climate change is needed (Kimathi, Ayuya, & Mutai, 2021; Rodríguez & Santos, 2018). Information on climate change increases the adaptation behavior of the community, especially farmers. Understanding the impacts of climate change will lead to positive behavior to support adaptation actions (Zamasiya et al., 2017). Citizens need to be more aware of the causes and impacts of climate change to have a better knowledge base for carrying out adaptation and mitigation actions (Nggole et al., 2019). If the community perceives risk well, it is more likely to become disaster-resistant (Taş, Taş, Durak, & Atanur, 2013). Collaborative approaches to innovation, including empowering and strengthening knowledge on a local scale, are critical to the global goal of sustainable development (Pérez-Escamilla, Cunningham, & Moran, 2020).

Conclusion

Economic growth has not been able to predict the resilience of a country. Economic growth does not automatically reduce vulnerability. Only proper growth reduces vulnerability. High-income countries have advantages in public infrastructure, better economic capacity, and disaster mitigation, thus having better climate change resilience. Low-income groups have vulnerabilities from all aspects, aspects of susceptibility, lack of coping, and lack of adaptation. Low-income countries have a higher risk of climate change than other groups. Although low-income countries have high economic growth, it is not enough to reduce vulnerability due to poor public infrastructure, government capacity, housing conditions, disaster mitigation, nutrition, economic capacity, and income distribution, and levels of health, as well as poverty and dependency.

Low- and middle-income countries have a dominant economic structure in the agricultural sector, so it will have more impact on climate change because the agricultural sector is more vulnerable than manufacturing. Climate change also impacts coastal areas or fishing communities with high susceptibility. Some of the agendas needed, especially for low-income countries, are how to take advantage of economic growth into programs that can increase climate change resilience or growth for resilience, especially in highly impacted areas such as agriculture, fisheries, and the urban poor. Investment in human resources is needed to increase the community's adaptation capacity, especially for coastal areas, informal cities, agricultural communities, the poor, and women.

This study has several limitations, including limited data in conducting data analysis. The analysis period is only one year, and some countries have not been included in the estimate. This model has not been able to estimate the long-term effect between income groups and climate change resilience. Simplify the set of income groups as measured by economic growth and income groups because several measures of income distribution have been included in the vulnerability calculation. Resilience in the face of climate change needs to pay attention to vulnerable economic sectors such as agriculture and fisheries, which are not estimated in this model. Further research is expected to reveal the long-term relationship between a country's income and resilience to climate change by including several income indicators related to the most vulnerable sectors.

Declaration of conflicting interest

The authors declare that there is no conflict of interest in this work.

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