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ENERGY, FORESTS AND ENVIRONMENTAL SUSTAINABILITY: A COMPARATIVE ANALYSIS OF DEVELOPED AND DEVELOPING ECONOMIES

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ABSTRACT

The use of fossil fuels is essential for economic growth, but it also creates environmental hazards that cause 5 million people to die every year. The use of renewable energy is limited because of financial constraints, and there is a need to find ways to decouple fossil fuel consumption and pollution. This study provides a way forward by introducing forest as a moderator. This study has taken data from all countries of the world from 2011 to 2021 and estimated the impact of forests, energy consumption, forest-energy moderator, population, and gross fixed capital formation on the environment. Leveraging the Feasible Generalized Least Squares (FGLS) estimation technique to address heterogeneity and outliers, the study reveals that while the effects of forests and energy consumption align, population density and gross fixed capital formation exert disparate influences on the environment in developing and developed nations. The incorporation of forests as a moderator emerges as a consistently effective measure.

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INTRODUCTION

Man has made incredible advances in almost every aspect of standard of living and social progress, but by doing so, some conflicting consequences are on the road. Damage to the environment is one of such dangerous consequences of human advancement, and pollution is a primary determinant of environmental damage. Pollution (that can be subdivided as air pollution, water pollution, and soil pollution) is the existence of contaminants that force the cycle of adverse impact. Pollution is creating a real threat to the quality of life and is the main source of global warming. It has changed the climate, and the agriculture sector is directly under threat. The toxic ingredients in our surroundings are mostly the results of our activities like consumption of fossil fuels (oil, coal, and gas) and dumping of waste into canals and rivers. The severe impact of pollution on humans, plants, and animals has been vastly studied by different scholars such as Brunette and Nemhauser (2019) emphasizing health urgency to avoid the negative impact of pollution. Brunekreef and Holgate (2002) found the direct impact of pollution ingredients on air and child mortality. Yang et al. (2022) found that PM2.5 caused 2.89 million deaths in 2019. Cheryl (2022) reported that pollution kills 9 million people every year. Environmental hazards pose a significant threat to ecosystems worldwide. From deforestation to pollution, these hazards disrupt the delicate balance of nature, affecting biodiversity and ecosystem stability (Neelam et al., 2023).

Forests play a crucial role in mitigating greenhouse gas (GHG) emissions and pollution. Bukata and Kyser (2007) found that forest has causality with environments. At the same time, Gibbs et al. (2007) found that deforestation is the main source of GHG emissions in most tropical countries. Allen et al. (2010) stated that factors such as drought, heat-induced tree mortality, and deforestation pose risks to forest ecosystems that may lead to the loss of sequestered forest carbon and associated atmospheric feedback.

Hoover (2011) concluded that forests act as carbon sinks, sequestering carbon and reducing atmospheric carbon dioxide levels. Thambiran and Diab (2011) stressed that the forests are a handy opportunity to purify air pollution and reduce GHG emissions. Chen et al. (2016) noted that the consequences of forest on GHG emissions depend on the type of forest, whereas Shah et al. (2017) concluded that there is a need to understand and control the spread of pollutants through forest resources.

Cheng et al. (2020) examined that the forests can cause non-point source (NPS) pollution. Land use affects the spatiotemporal of watershed NPS pollution. Sidabukke et al. (2022) highlighted the impact of forest fire on the environment and concluded that it cause pollution. Amirova et al. (2022) noted that forests absorb greenhouse gases and can contribute to the reduction of GHG emissions. Kumar et al. (2022) suggested that knowledge about the impact of forests on GHG emissions is necessary for managing suitable policies to reduce GHG emissions.

There is a lot of literature about the consequences of energy consumption on pollution. Lin and Sun (2010) noted that fossil fuel consumption is a significant contributor in the emission of greenhouse gas emissions. Carnevale et al. (2018) concluded that the use of alternative means of energy resources has the potential to solve pollution problems. Yan et al. (2019) concluded that the use of energy in production is a primary cause of pollution. Jos et al. (2019) suggested that the current energy policies and CO2 reduction strategies need to consider all greenhouse gas emissions to avoid harmful impact. Golomb (2020) stressed that energy consumption is vital for the economic growth of developing countries.

Shen et al. (2020) observed that the consumption of fossil energy has a direct relation with pollution, and it causes the contamination of sulfur dioxide, dust and smoke. Chandra and Lvaldi (2021) focused on the causality among energy, economic growth and the environment. Yilmaz and Sensoy, (2022) concluded that the use of energy in the form of oil, coal, and gas is the primary cause of GHG emissions and air pollution. The combustion of fossil fuels releases pollutants into the air, causing air pollution. Schernikau and Smith (2022) suggested that the usage of fossil fuels for electricity production is a significant source of CO2 emissions. Zhang and Wang (2022) noted that the use of distributed generators can be used as an effective method to reduce dependency on emissions.

The population has a significant impact on GHG emissions. Mason (2010) stated that higher population densities within countries lead to lower levels of alternative and renewable energy, which suggests that population density has a negative effect on greenhouse gas emissions. Christopher and Kammen (2014) stated that population has a positive relation with carbon footprints until a density threshold is met; later on, it declines.

The effect of changing population on emissions relies on the magnitude of the changes and the initial values, with population changes having a greater effect on emissions than population density (Albert et al., 2014; Daegoon et al., 2016). David et al. (2016) stated that population density affects greenhouse gas emissions by indirectly reducing carbon emissions through factors such as decreased housing size and the use of natural gas heating in cities.

Haroldo et al. (2019) concluded that there is U U-shaped impact on the population for residential emissions and a W-shape impact on total, industrial, and transportation emissions. Pedro et al. (2021) observed that the rising population in cities causes higher energy consumption and pollution emissions. Shunfa et al. (2022) found that the higher population means higher emissions.

Gross fixed capital formation (GFC) or investment can have a positive or negative effect on GHG emissions. Carl-Johan et al. (2018) examined that capital investment in the electricity and gas sector has negative consequences on GHG emissions. Claudiu et al. (2019) noted that developed countries invest in renewable resources, whereas developing countries invest in productions that cause emissions.

Kazen et al. (2021) examined the inverted U-shaped impact of GFC on carbon emissions in G20 countries, whereas Hata et al. (2022) disagreed and concluded that fixed capital formation, in terms of machinery and infrastructure, always increases pollution. Xueying et al. (2022) and Quanliang et al. (2023) concluded that the management of fixed-capital formation is essential to avoid pollution.

In this study, environmental hazards stand as the dependent variable and are limited to greenhouse gas emissions, while forests, population, capital formation, and energy consumption serve as explanatory variables. This setup allows for a comprehensive analysis of the factors influencing environmental hazards. This study aims to analyze the effect of forest and energy moderators on the mitigation of environmental hazards.

Research questions of this study include:

1. What is the effect of forests on greenhouse emissions?
2. What is the impact of energy consumption on the climate?
3. Does the moderator of forest and energy mitigate environmental problems?
4. Does an increase in population density increase environmental degradation?
5. What is the effect of capital formation on the climate?

This study covers the research gap in the dynamic behavior of economic variables in the case of developed and developing nations. This study assumed that the impact of explanatory variables may be different for different types of countries. Most of the researchers do not consider this difference.

There are a lot of studies about the relationship between fossil fuels and environmental pollution, and most conclude that consumption of fossil fuels should be reduced, but it is not feasible for all countries because of financial constraints, so this study attempted to find a way forward to incorporate energy and forest moderator. Moderator of forest with energy consumption is a unique feature of this study. Many developing countries cannot afford to have renewable energy sources so the least cost alternative of this is forestation.

Most of the studies took CO_2 as a proxy for pollution, but that is a limited view of environmental pollution as there are other gases also that are dangerous for human health so this study has taken Greenhouse gas emissions as a comprehensive proxy for environmental pollution. The component of greenhouse gas is given in Figure 1, and Figure 2 illustrates Greenhouse gas emissions by economic sectors.

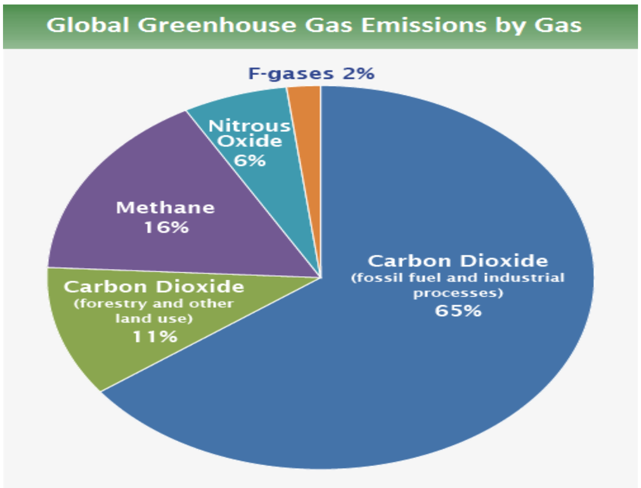

Figure 1. Component of Greenhouse Gas.
Data Source: Environmental Protection Agency.

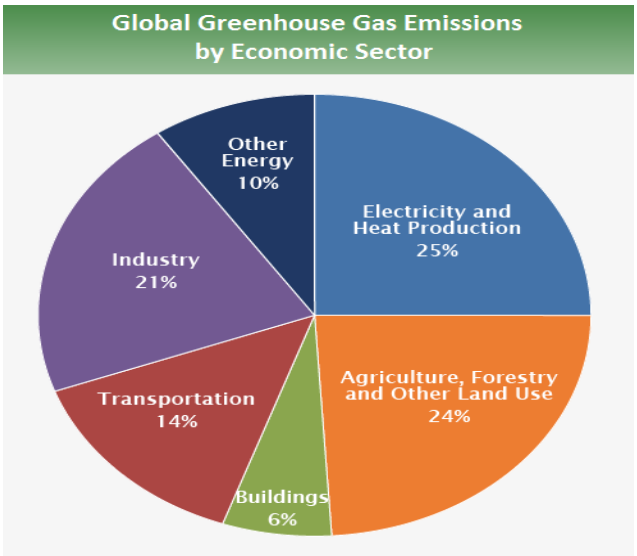

Figure 2. Greenhouse gas emissions by economic sectors.
Data Source: Environmental Protection Agency.

Data from all countries of the world are taken and then these countries are divided into two groups: developed and developing countries. The Human Development Index (HDI) is used as a criterion for the classification. By considering the nature of the data, the Feasible Generalized Least Square (FGLS) method is used to assess the impact of explanatory variables.

METHODOLOGY

Data Framework

The data of all countries are taken for econometrics analysis and then grouped into developing and developed nations on the basis of HDI. Countries whose HDI is higher than 0.8 are placed in developed countries, and others are placed in developing countries (Shabeer, 2022). Model 1 represents developing nations, whereas Model 2 represents developed nations. As this study aims to find whether explanatory variables behave in a similar way or differently in different types of countries, it suggests a way to mitigate pollution that must be applicable in developing as well as developed countries. Some countries do not have sufficient data for the given variables, and such missing data are excluded from econometric analysis. A list of countries is given in Appendix A.

Data from 2011 to 2021 is taken from different sources and detail is given in Table 1. This study is part of a comprehensive study of social progress, and the social progress index is available only from 2011. The current study has the following functional form.

$$GHG_{it} = \beta 0 + \beta 1FOR_{it} + \beta 2ECC_{it} + \beta 3MOD_{it} + \beta 4POP_{it} + \beta 5GFC_{it} + \mu \quad (1)$$

These variables briefly described in Table 1.

Table 1. Description of variable.

Variable name	Symbols	Brief definition	Source
Environment	GHG	Greenhouse Gas Emission	Eurostat, EPA, our world in data
Forest	FOR	Forest area as a percentage of the total area	WDI, the World Bank (2023)
Energy Consumption	ECC	Energy consumption per capita	Eurostat, our word in data
Energy*Forest	MOD	Greenhouse Gas Emission* Forests	WDI, the World Bank (2023)
Population	POP	Population density: Population/Area	WDI, the World Bank (2023)
Gross Fixed Capital Formation	GFC	Total spending on non-current assets. Purchase of business assets	WDI, the World Bank (2023)

It is a panel data study that can eliminate multicollinearity (Shabeer et al., 2021a). Beck (2001) highlights the impact of cross-sections along time series, and it reduces biases (Arshed et al., 2021). Feasible generalized least square (FGLS) estimation is used to address cross-section heteroscedasticity (Abdulhafedh, 2017; Shabeer et al., 2021b; Huang et al., 2023; Wang et al., 2023).

Descriptive Statistics

Descriptive statistics indicates the nature of data at a glimpse. Figures 3 (for developing countries) and 4 (for developed countries) show the mean, standard deviation, minimum and maximum values of each variable. It is also assumed that the data is normally distributed as the number of observations is higher than 30.

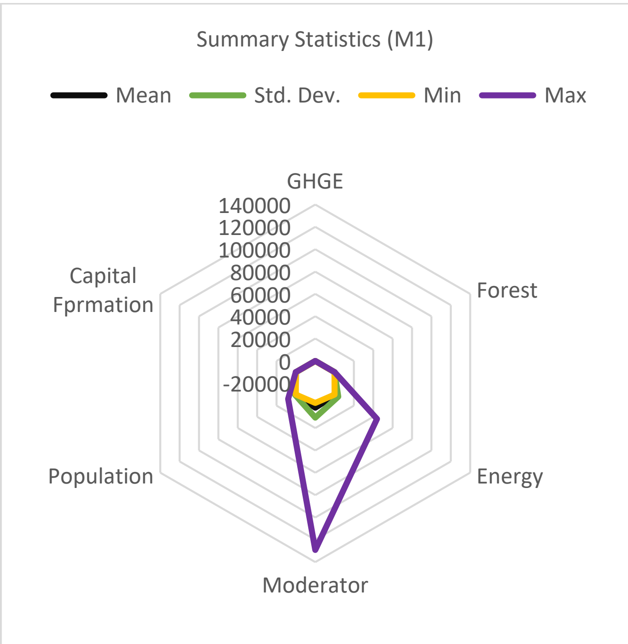

Figure 3. Descriptive statistics of developing nations.

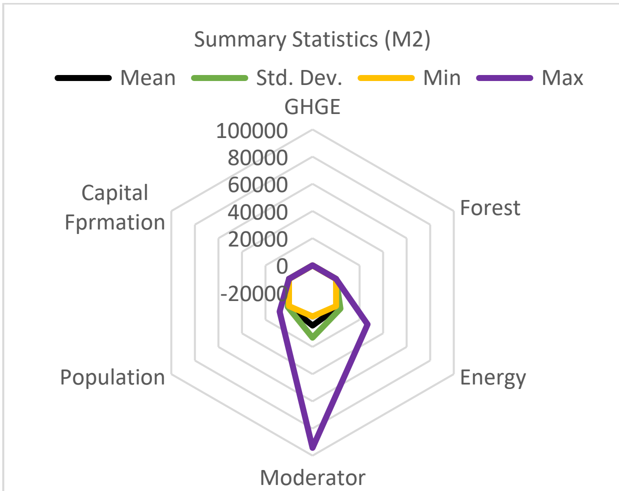

Figure 4. Descriptive statistics of developed nations.

Matrix of Correlation

The relationship among explanatory variables is given in the matrix of correlation charts. Figure 5 (for developing countries) and Figure 6 (for developed countries) indicated the strength of correlation among different variables. More bright colors represent more correlation strengths between variables.

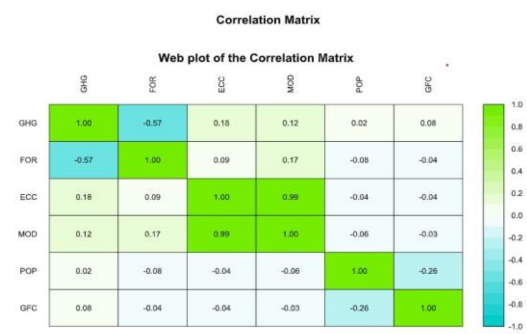

Figure 5. Matrix of correlation (developing countries).

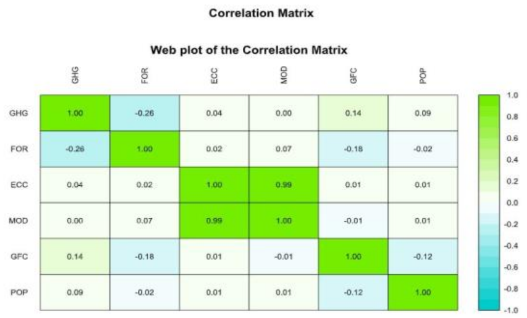

Figure 6. Matrix of correlation (developed countries).

Estimation Technique and Results

The feasible Generalized least square (FGLS) technique is used to incorporate the heteroscedasticity. FGLS hetero might be useful if residuals have unequal values (the variance of the error term is not constant).

According to Table 2, actual observations in Model 1 are 904, whereas in Model 2, observations are 441. The FGLS results show that forest is an effective way to curb environmental hazards by reducing GHG emissions in developing and developed countries. One percent increase in the forest area to total land area decreases emissions by 0.778 percent in the case of developing countries and 2.38 percent in the case of developed countries. Developed countries are more effective in curbing the downside of deforestation, so forestation becomes more effective in reducing emissions in such nations. Forestation reduces emissions because forests mitigate pollution by reducing the concentration of particulate matter (PM) in the atmosphere. Forests and green spaces play an important role in reducing PM levels. Haoran et al. (2022) stated that forests reduce the concentration of major air pollutants such as PM2.5 and PM10. Forests can purify the atmosphere by absorbing and trapping PM particles and reducing their concentration in the air (Chang et al., 2022).

The results of this study are similar to the findings of Hoover (2011), Artur et al. (2017), Labe et al. (2017), Shah et al. (2017), Cheng et al. (2020), Sidabukke et al. (2022), and Kumar et al. (2022). But against the findings of Gibbs et al. (2007), Allen et al. (2010), and Amirova et al. (2022). Impacts depend upon existing levels of forest area and forest management (Bukata and Kyser, 2007; Chen et al., 2016).

Table 2. Feasible Generalized least square (FGLS) results.

Variables	Model 1 (Developing Countries)			Model 2 (Developed Countries)		
GHG	Coef.	Std. Eror	p-value	Coef.	Std. Eror	p-value
FOR	-0.778	0.2	0.000	-2.388	0.201	0.000
ECC	0.004	0.001	0.000	0.002	0.001	0.005
MOD	-0.001	0.000	0.000	-0.004	0.001	0.043
POP	0.001	0.000	0.001	-0.005	0.002	0.068
GFC	0.133	0.045	0.003	-0.014	0.066	0.836
Constant	6.189	0.984	6.29	16.175	1.409	0.000

As expected, energy consumption per capita has a positive significant impact on the environment. One percent increase in energy consumption in the case of developing countries increases greenhouse gas emissions by 0.004 percent, whereas in the case of developed countries, such increase is 0.001 percent. The developed nation has less direct impact because they have sizeable renewable resources in the energy mix. The direct impact of energy consumption is also validated by earlier studies such as Mardiana (2015), Hashimoto (2019), Ossowska et al. (2020), Flammini et al. (2022), Das and Sharma (2023) and Keerthana et al. (2023).

The unique contribution of this study is to assess the moderator impact of forests with energy consumption for mitigation of the harmful impact of energy consumption on the environment. This study confirms that the moderator has the ability to mitigate environmental hazards. Developing countries that do not have sufficient funds to avail renewable energy sources should use forestation policies to mitigate environmental problems. Forestation is also suggested by Thomas et al. (2014), Jianfeng (2016), Labe et al. (2017), Artur et al. (2017), Haoran et al. (2022), and Chang et al. (2022).

Population density has a significant harmful impact on the environment in the case of developing countries where a one percent increase in population causes a 0.001 percent rise in greenhouse gas emissions, whereas in the case of developed nations, the population has a significant negative impact and one percent increase in population density causes GHG emission to fall by 0.005 percent.

Harmful impact of population on on the environment include the depletion of resources, deforestation (Shaw, 2022), pollution (Zhang et al., 2022), and the degradation of natural habitats (Nguyen and Van, 2020). Dutta (2019) concluded that as the population grows, there is an increasing demand for natural resources, leading to their depletion and the destruction of forests. Industrial advancements and pollution from human activities contribute to air and water pollution. The quality of life for communities is negatively affected by these environmental issues. Additionally, population growth amplifies environmental pressures by adding to total economic demand.

The negative impact of population on the environment is found by Albert et al. (2014) and Daegoon et al. (2016). David et al. (2016) stated that population density affects greenhouse gas emissions by indirectly reducing carbon emissions through factors such as decreased housing size and the prevalence of natural gas heating in urban areas.

Gross fixed capital formation has a significant positive impact on the environment in the case of developing countries, where a one percent increase in capital formation causes a 0.133 percent rise in greenhouse gas emissions, whereas in the case of developed nations, capital formation has a significant negative impact and one percent increase in capital formation causes greenhouse gas emission to fall by 0.014 percent.

The harmful impact of capital formation on the environment occurred because of more investment and rapid economic activities that cause pollution. Such results have been validated by Carl-Johan et al. (2018), Gul et al. (2022) and Shiddiq and Wau (2022). A rise in capital formation in the case of developed nations may not have a harmful impact on the environment because of more investment in renewable energy resources that reduce pollution. Such a conclusion has been made by Qaiser et al. (2020) and Hata et al. (2022). Claudiu et al. (2019) noted that in developing countries, capital formation causes pollution, whereas in developed countries, it causes mitigation as such countries invest more in renewable resources. Yan et al. (2015) concluded that capital formation has U shape relationship with population.

CONSULTATIONS AND POLICY IMPLICATIONS

This study concluded that forests have a significant negative impact on greenhouse gas emissions (GHG) and, hence mitigate pollution in case of developing and developed economies. Forests act as crucial carbon sinks and influence NPS pollution. These findings highlight the need for policies that prioritize forestation as a means to mitigate pollution. Policies should focus on preserving acid-sensitive forest soils, reducing nitrogen emissions, minimizing heavy metal emissions, and promoting sustainable forestry practices. Understanding these impacts is essential for developing effective strategies to mitigate GHG emissions and pollution. The impact of energy consumption on greenhouse gas emission (GHG) is positive, and higher energy consumption causes higher pollution. A phaseout of fossil fuel use is necessary to avoid millions of premature deaths from pollution. Moderator of forests with energy consumption mitigates the environmental hazards and countries that face the hurdle of financial constraints can use forestation to reduce GHG emissions. Results show that gross fixed capital formation has a direct impact on GHG emissions in the case of developing nations, but it reduces pollution in the case of developed countries, highlighting that developed countries are making more investments in renewable resources. Developing countries need to make more investments in alternative sources of energy. An increase in population density increases pollution in the case of developing countries and decreases pollution in the case of developed countries so each set of countries can make policy accordingly. It is crucial to limit population growth and use resources efficiently for sustainable development. To mitigate the harmful impacts of population on the environment, it is necessary to change the way we think and develop strategies that balance current needs with the ability to meet the needs of future generations.

Declarations

Conflict of interest: The authors declare that they have no known competing financial/personal interests that could have appeared to influence the work reported in this paper.
Ethics approval: This article does not contain any study that harms animals.

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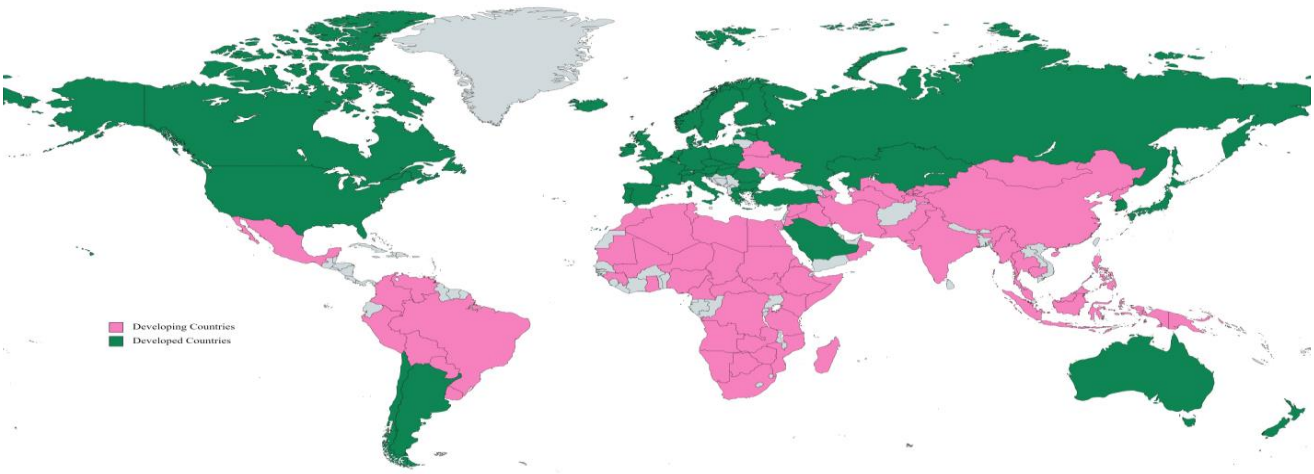
Appendix A. Classification of Countries.



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