Journal of
Environment
(JE)

An Analysis of IPAT Equation in the Face of Technological Advancement in the Philippines

Journal of Environment
ISSN 2789-3863 (Online)
Vol. 4, Issue No. 4, pp 49 – 63, 2024 www.carijournals.org

An Analysis of IPAT Equation in the Face of Technological Advancement in the Philippines

[1]Louis Benedict Gallardo, [1*]Jan Marithe Isorena, [1]Peter Jeff Camaro

[1]Business Economics Department, College of Commerce in Business Administration, University of Santo Tomas

https://orcid.org/0009-0006-6854-6984

Accepted: 20th Nov, 2024, Received in Revised Form: 10th Dec, 2024, Published: 21st Dec, 2024

Abstract

Purpose: This study analyzes the factors contributing to environmental impact using the IPAT equation (Impact = Population × Affluence × Technology). The research aims to explore the dynamics between population, consumption, technology, and environment. The research seeks to provide insights to policymakers and future researchers for developing strategies and policies to mitigate the adverse effects of these factors, with a particular focus on technological progress with sustainable environmental management.

Methodology: The study employs a quantitative research approach to examine the relationship between environmental impact and independent variables: population, affluence, and technological advancement (measured as population growth, GDP per capita growth, and high-technology exports) in the Philippines from 1992 to 2022. The analysis uses secondary data sourced from the World Development Indicator DataBank. Ordinary Least Squares (OLS) regression is applied to evaluate the effect of independent variables on dependent variable.

Findings: The results emphasize the direct contribution of population and affluence to the environmental impact, while the role of technology remains inconclusive.

Unique Contribution to Theory, Practice and Policy: The study contributes to policy by emphasizing the need for measures to address the environmental challenges caused by population growth and economic activities in the Philippines. This study recommends policies to mitigate overconsumption, alongside stricter pollution control measures to foster sustainable production practices. Despite the insignificant relationship between technology and the environment, the study highlights the importance of adopting cleaner technologies. Environmental impact assessments for production technologies and policies supporting green and low-carbon innovations, are proposed to ensure sustainability. These recommendations aim to balance economic growth and environmental protection.

Keywords: *Environment, Technology, IPAT, Economic growth*

Introduction

The environment is relevant to human lives as it supports society and can contribute to the economy. Natural habitats and ecosystems provide a vast range of environmental goods and services that contribute immensely to the people's livelihood and the country's economic growth. Environmental goods and services include climate regulation, nutrient and waste management, flood control, provision of food, fresh water, fuel, medicines, building materials, fertile soils, and clean air, essential for human lives. Environmental resources are significant for production processes, living, and social development, thereby critical for economic growth (Bansal et al., 2021). One of the problems the environment is facing is its gradual degradation. Environmental degradation threatens economic growth and human well-being; it causes various adverse effects on health, resource exhaustion, and natural calamities associated with climate change (Azam, 2016).

The expansion and unsustainable management of agriculture and forestry aggravate land degradation and contribute to climate change; a 2019 study by the United States National Intelligence Council has shown that global deforestation and land degradation each contributed to about 10% of all human-induced greenhouse gas emissions by releasing carbon stored in the trees and the soil. The Lancet Planetary Health (2019) analyzed the combined health risks of air, water, and toxic chemical pollution; the study has shown that pollution is responsible for around 9 million premature deaths each year, or one in six globally, and more than 12 million people around the world die every year because they live or work in unhealthy environments. According to the World Bank (2023), the global economy relies on interconnected supply chains, consuming over 100 billion tons of raw materials annually, which depletes natural resources and causes negative environmental impacts throughout the product life cycle. Besides its effect on climate change, pollution can also promote poverty and inequality in urban and rural areas. As the World Bank stated, since poor people are more prone to the negative effects of pollution, they cannot afford protection from its harmful effects. Environmental degradation promotes poverty and inequality in urban and rural areas; millions of Filipinos rely on agriculture, forestry, and fisheries for their livelihoods; however, ineffective management of the environment threatens these critical natural resources.

Alongside the changing environment is the changing population in the world. The human population has grown remarkably more than tripled since 1950 to nearly 7.8 billion in 2020, with projections surpassing 8.5 billion by 2030, according to the United Nations (2022). This surge in population inevitably leads to increased pressures on the environment, including heightened deforestation, loss of biodiversity, and spikes in pollution and emissions, thereby intensifying climate change. The ongoing population growth throughout this century will further strain the planet, potentially leading to ecological disruption and collapse severe enough to jeopardize life. Every addition in the global population has an effect on the planet's health, as research by Wynes & Nicholas (2017) suggests that reducing family size by one child could lead to a reduction of 58.6 tonnes of CO_2-equivalent emissions per year in developed countries, highlighting the significant impact of population on environmental consumption. The World Bank (2024) projected that the global population will reach 9.7 billion by 2050, resulting in an expected increase in the worldwide demand for food. It is also mentioned that increasing food production is interrelated with agricultural expansion and the unsustainable use of land and resources. As a result, emission levels rise. Currently, one-third of all emissions come from the global agrifood system. Energy consumption from renewable and traditional sources also affects the environment (Jermsittiparsert, 2021). Rapid urbanization and industrialization in the Association of Southeast Asian Nations (ASEAN) economies led to economic growth alongside increased consumption and energy demand. The increasing demand for energy in ASEAN economies is mainly satisfied using energy extracted from traditional sources like fossil fuels, natural gas, coal, and oil. The high demand for energy is regarded as a powerful driver of industrial and economic activities and often causes an increase in CO_2 emission levels (Mustapa et al., 2020).

Journal of Environment

ISSN 2789-3863 (Online)

Vol. 4, Issue No. 4, pp 49 – 63, 2024 www.carijournals.org

On the other hand, it has been widely assumed throughout the decades that technology plays a significant role in fostering innovation. According to Neoclassical theories, technological advancements contribute to increased efficiency in resource utilization, thereby leading to economic growth. While technological innovation is instrumental in promoting economic development by enhancing production capacity, it simultaneously raises concerns about environmental degradation due to natural resource depletion (Mughal et al., 2022). It is crucial to acknowledge that technological progress can promote environmental challenges (Xin et al., 2021). The inquiry into whether technological advancements have a positive or negative impact on the environment remains questionable, particularly in the context of a developing nation such as the Philippines.

Population, affluence, and technological advancement are interrelated. The Environmental Kuznets Curve establishes an inverse relationship between economic growth and environmental degradation. Reduction in population and consumption was recognized as the main method of achieving environmental gains because as the population increases, the demand for and consumption of resources increases, thus more stress on the environment. Because the demand for resources continuously increases, technology continues to advance to search for ways to utilize resources more efficiently and reduce environmental impacts (Stern, 2004). However, alongside an increase in the three aforementioned variables is the increasing environmental challenges. Rapid urbanization, industrialization, overconsumption, increased emission levels, biodiversity loss, and rising pollution are presumably some of the effects brought about by an increase in the three variables.

This research aims to determine the cause of environmental impact using IPAT Equation. Additionally, this analysis seeks to help policymakers and future research endeavors focusing on the intricate dynamics between technology and environmental decline develop policy suggestions that will help lessen environmental degradation brought about by technology and other factors.

1.2. Theoretical Framework

1.2.1. IPAT Equation

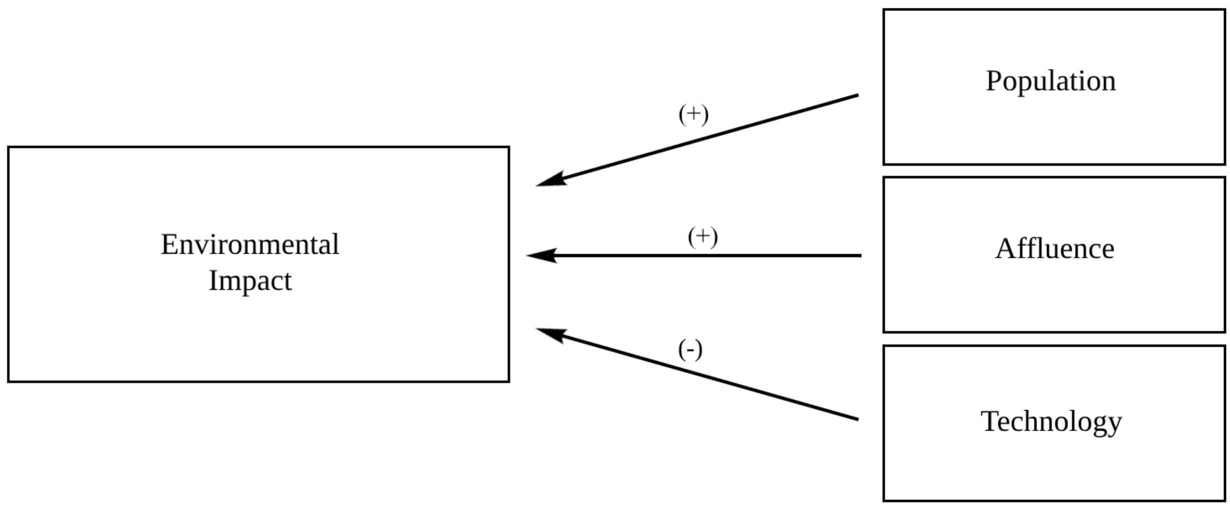
Environmental degradation as an economic-dependent variable has been seen in different models. In the latter part of 1969, biologist Barry Commoner asserted in his speeches and lectures that he had identified the root cause of the environmental crisis. Contrary to popular belief, Commoner argued that neither population growth nor increasing affluence were significant factors. Instead, Commoner pointed to the poor ecological choices in adopting technologies within industrial societies. Paul Ehrlich delved into similar inquiries, exploring the interplay of population dynamics, poverty, affluence, technology, and environmental impact. Commoner's notion that the detrimental impact of a society on the environment could be represented by the simple equation $I = P * F$ gained traction; P represented the population, and F symbolized a function measuring per capita impact. Ehrlich & Holdren (1972) further developed this concept, introducing the equation $I = P \times A \times T$, where environmental impact (I) was affected by population size (P), affluence (A), and technology (T). The IPAT equation has been utilized in recent studies on driving forces of environmental impact. Many scholars have opted for this framework to study population interaction, economic growth, and technological advancements. (Chertow, 2008). The main strength of IPAT is its outlining of the primary factors influencing environmental change and its ability to clearly define the connection between these factors and their impacts (York et al., 2003). One of the methods to build the IPAT model is STIRPAT or Stochastic Impact by Regression on Population, Affluence, and Technology model, which is proposed by Dietz & Rosa (1997). It is a multiple regression model and transforms the variables into natural logarithms.

1.2.2. E-Kuznets Curve

The Environmental Kuznets Curve (EKC) highlights the effect of income on environmental degradation, similar to the IPAT equation. Simon Kuznets demonstrated the relationship between per capita income and income inequality as an inverted U, also known as the Kuznets curve. The

Kuznets curve was modified by Grossman & Krueger (1991), known as the Environmental Kuznets Curve (EKC). EKC shows that there is an increase in pollution emissions, causing the environmental quality to decline in the early stages of economic growth. However, beyond some level of per capita income, the trend reverses so that economic growth leads to environmental improvement at high-income levels. This shows that environmental impacts or emissions per capita are an inverted U-shaped function of per capita income (Stern, 2018). The EKC has a mathematical expression as $y = a + bx + cx2 + \varepsilon$, where y is the level of environmental damage, x is the current level of per capita output, and ε is the unobservable residual. a is constant, and b and c reflect the influences of income level on environmental quality.

1.3. Simulacrum



1.4 Statement of Hypothesis

Ha_1: Population has a significant effect on Environment Impact

Ha_2: Affluence has a significant effect on Environment Impact

Ha_3: Technology has a significant effect on Environment Impact

1. Literature review

2.1 Population on Environmental Impact

Interactions between population and environmental degradation have been studied over the decades. Population growth contributes to environmental degradation (Pham et al., 2020; Khan et al., 2021; Todaro and Smith, 2003, as cited in Ilham, 2021). It significantly contributes to rising carbon emissions (Casey & Galor, 2017; Dong et. al., 2018) and is a significant driver of unsustainability, climate disruption, and other environmental crises (Washington & Kopnina, 2022). Furthermore, population growth increases pressure on the environment's carrying capacity since an increase in population results in an increase in economic activity and demand for natural resources (Babiso et al., 2020; Ilham, 2021). For instance, the growing population rate in Pakistan is causing deforestation due to an increasing need for agricultural land (Ahmed et al., 2015). A growing population significantly contributes to climate change since population growth stimulates energy usage and greenhouse gas emissions (Özokcu & Özdemir, 2017; Khan et al., 2021). Population growth can be favorable in the short run as it boosts economic growth in terms of gross domestic product (GDP). However, it deteriorates the environment in the long run (Pham et al., 2020). The increasing population in urban areas results in rapid urbanization (Johnson & Munshi South, 2017; Wang & Dong, 2019; Rahman & Alam, 2021). This leads to an increase in energy needs and ecological footprint, leading to environmental degradation (Wang & Dong, 2019). Moreover, the rise in urbanization brought about by a growing urban population causes dramatic changes in the environment, including rising temperatures & levels of pollution (Johnson & Munshi South, 2017).

On the other hand, some studies mentioned that population growth helps reduce environmental impact. Population growth may contribute to environmental improvement in the short run (Pham et al., 2020). It brings about technological innovation, decreasing environmental impact (Boserup, 1981, as cited in Hashmi & Alam, 2019). Higher urban density, which refers to the number of people living in a particular urbanized area, contributes to achieving economies of scale, which, in turn, results in lower pollution levels (Shahbaz et. al, 2016).

Some studies reached inconclusive results regarding the relationship between population and environmental degradation in some countries. In Malaysia, the population growth rate does not significantly impact per capita CO_2 emission. Despite the country's decreasing population growth rate, there is still an upward trend of per capita CO_2 emission (Begum et al., 2015). The same is true for Eastern European regions. Even though most of Eastern Europe is facing a population decline, CO_2 emissions continue to rise (Weber & Sciubba, 2019). The relationship between population and CO_2 emissions in countries worldwide may differ because of varying population issues, such as population urbanization and population aging. However, the effects of these issues on CO_2 emissions need to be studied further (Wang & Li, 2021).

2.2. Affluence on Environmental Impact

One of the key driving forces of environmental impacts is affluence (per capita production or consumption) (York et al., 2003). This worldwide growth in affluence has continuously increased resource use and pollutant emissions (Wiedmann et al., 2020). Natural resources are the basic goods and services that sustain human societies, it plays a vital role in fostering economic growth (Mogahzy, 2009). However, natural resource rent and consumption exacerbate pollution (Mesagan & Vo, 2023; Bashir et al. 2023; Onifade 2021) as there is evidence in Africa that it contributes to carbon dioxide emission (Kwakwa et al., 2019). Economic growth also increases environmental pollution emissions, intensifying and inhibiting economic growth (Yan et al., 2022; Wiedmann, 2020). Both per capita energy consumption and per capita GDP have a long-term positive impact on per capita carbon emissions (Begum et al. 2015; Yusuf 2023). The diminishing negative impact of economic growth on deforestation, in the long run, confirms the E-Kuznets hypothesis for deforestation in Pakistan. Moreover, economic growth and energy consumption Granger cause deforestation (Ahmed, 2015).

Furthermore, Ivona et al. (2015) suggest robust and significant relationships between households' expenditure and their environmental impacts, driven by rising demand for nonprimary consumption items; mobility, shelter, and food emerge as the most important consumption categories that contribute to ecological footprints. Economic growth and the accelerating process of urbanization have increased energy needs and, thus, become a source of CO_2 emission that leads to environmental degradation (Wang, 2019; Hassan et al., 2024; Kahouli, 2022; Ozcan, 2020; Wen, 2024). A rapid increase in population or in the consumption of limited resources have ecological consequences. Economic growth, trade openness, and foreign direct investment can cause environmental degradation (Pham, 2020).

On the other hand, Andrée et al. (2020) found that as countries become wealthier, they tend to endeavor to use resources more wisely. Furthermore, in the long run, energy efficiency has a mediating role in mitigating environmental issues (Nuţă et al., 2024). Thus, structural changes in the economy shape environmental output curves. However, it is also essential to consider that overall economic growth still results in increased resource usage.

2.3. Technology on Environmental Impact

The relationship between technology and the environment has been analyzed in several studies. Mughal et al. (2022) assessed economic growth, energy use, and technological innovation within the framework of the environment using Kuznets curve analysis; it is concluded that technological innovation significantly increases environmental degradation in South Asian regions. Another research by Xin et al. (2022) found evidence in China that technological innovation would accelerate CO_2 emissions, resulting in the discharge of wastewater, solid waste, and waste gas

Journal of Environment

ISSN 2789-3863 (Online)

Vol. 4, Issue No. 4, pp 49 – 63, 2024 www.carijournals.org

emissions that lead to environmental degradation. The negative effect of technology on the environment has been further strengthened by other studies, which concluded that technological innovation greatly affects countries with relatively higher emissions, as fossil fuels have the greatest positive effect on emissions (Chen & Lei, 2018; Chen et al., 2024). On the other hand, Iqbal et al. (2022) concluded that even though information, communication, and technology (ICT) has a positive and significant impact on environmental degradation in low-income countries, information technology prevents environmental pollution in high-income countries; this study has been further strengthened by the research of Wu et al. (2021), using Chinese provincial panel data for the period 2006–2017, it is concluded that because of the internet, China's green total factor energy efficiency has improved; therefore, it is concluded that information and communication technology supported by the internet has become a significant driving force that promotes the development of the environment in China. Chen et al. (2022) also concluded from a micro-level perspective using data from Chinese industrial enterprises that technological innovation significantly reduces firms' pollution discharges, holding other variables constant of technological innovation's impact on air pollution. Several studies concluded that information, communication, and technology innovation can mitigate carbon emissions (Yii & Geetha, 2017; Chien et al., 2021). Cheng et al. (2021) emphasized the importance of technological innovation for CO2 emissions reduction. Technological innovation directly reduces CO2 emissions through research and development investment and education expenditure through their heterogeneous analysis using panel quantile regression. There are studies suggesting that technology has the potential to transition towards environmental sustainability, thereby making positive contributions to the environment by imposing green technology and clean technology (Khan et al, 2024; Chien et al., 2021; Sarkodie & Strezov, 2019; Hashmi & Alam, 2019). Green technology is a term used for any environment-friendly technology, from its production line to its usage (Qamar, 2021). Green technological innovation and low-carbon technologies mitigate environmental degradation in Asia (Ahakwa et al., 2023; Ali et al., 2024). Cleaner technology refers to technologies that are efficient enough to minimize waste production and are eco-friendly regarding their environmental impacts (Hussain, 2021). Advanced cleaner technology from international trade would enhance production and mitigate environmental degradation (Shahbaz et al., 2012; Dong et al., 2023). Dubey et al. (2019), through an analysis in India, stated that technology is a fundamental component of environmentally sustainable manufacturing decisions, as it is necessary to lower the resources used in production, which causes less environmental damage.

2. Methodology

3.1 Method of the Study

The study aims to measure the relationship between the independent variables, population, affluence, and technology, with the dependent variable, environmental impact, in the Philippines. Multiple regression is a statistical technique used to analyze the relationship between a single dependent variable and several independent variables. The objective of multiple regression analysis is to predict the value of the dependent variable based on the known values of the independent variables. This technique is widely used to measure the impact of independent variables on a dependent variable (Berry, 2005). Data will be gathered from reliable secondary sources, and the software Gretl will be used for diagnostic tests and analysis.

3.2 Scope and Limitations

The study will be conducted in the Philippines, and the time frame will be from 1992 to 2022. This paper will accomplish its aims through the use of econometric analysis. Econometric software such as Gretl will analyze and measure the interactions between the independent variables, annual population growth, high-technology exports, and annual Gross Domestic Product (GDP) per capita growth, and the dependent variable, CO2 emissions per capita. The annual population growth rate refers to the exponential growth rate of the midyear population, which is expressed as a percentage. High-technology exports refer to products with high research & development intensity (R&D

intensity). The annual GDP per capita growth rate refers to the annual percentage change in GDP based on constant local currency. CO2 emissions per capita are produced by burning fossil fuels, wood and waste materials, and industrial processes such as cement manufacture.

3.3 Data and Sources

The data that will be used are secondary data from the World Development Indicator DataBank – an analysis and visualization tool that contains collections of time series data on various economic indicators. The measurements of the variables gathered are from the years 1992 to 2022. Environmental degradation is measured as CO2 emissions per capita; population is measured as population growth; affluence is measured by GDP per capita growth rate; and technology is measured by high-technology exports (current US$) in billions.

3.4 Model Specification

$$\boldsymbol{CO2E = \beta_0 + \beta_1 POP + \beta_2 GDP - \beta_3 HTE + e}$$

Where:

- $\boldsymbol{CO2E}$ = CO2 emissions per capita
- $\boldsymbol{\beta_0}$ = y-intercept
- $\boldsymbol{POP}$ = Population growth
- $\boldsymbol{GDP}$ = GDP per capita growth rate
- $\boldsymbol{HTE}$ = High-technology Exports
- $\boldsymbol{e}$ = Residual
- $\boldsymbol{\beta_1}$ $\boldsymbol{\beta_2}$ $\boldsymbol{\beta_3}$ = Beta Coefficients

3.5 Diagnostic Tests

The following tests will be conducted to further examine the reliability of the generated Ordinary Least Squares regression model.

Normality residual test	To determine whether sample data has been drawn from a normally distributed population
Breusch-Godfrey test	To test if there is a presence of serial correlation that has not been included in a proposed model structure.
White's test	To analyze the residuals from regression models to check for heteroscedasticity.
Belsley-Kuh-Welsch test	To test the collinearity whether the regression model found the correlation between independent variables
Ramsey Regression Equation Specification Error Test	To test if the model is misspecified by variables, functional form or structure.

4. Result and Discussion

This research determined the cause of the environmental impact in the Philippines using IPAT Equation. By utilizing Ordinary Least Squares regression, this research analyzed the relationship between the dependent variable (environmental impact) and several independent variables (population, affluence, and technology). The study was conducted in the Philippines from 1992 to 2022, with environmental degradation measured by CO2 emissions per capita. Population was represented by the population growth, affluence by GDP per capita growth, and technology by

Journal of Environment
ISSN 2789-3863 (Online)
Vol. 4, Issue No. 4, pp 49 – 63, 2024
www.carijournals.org

high-technology exports. The data used were extracted from World Development Indicator DataBank.

4.1 Econometric Results

Table 1: Ordinary Least Squares (OLS)

Dependent variable: d_$CO2E$

Variable	Coefficient	Std. Error	t-ratio	p-value	
const	0.0337894	0.00975784	3.463	0.0018	***
d_POP	0.611560	0.160491	3.811	0.0007	***
d_GDP	0.00551634	0.00185848	2.968	0.0062	***
d_HTE	0.000277168	0.00241568	0.1147	0.9095	

Mean dependent var	0.017682	S.D. dependent var	0.054211
Sum squared resid	0.050191	S.E. of regression	0.043115
R-squared	0.430707	Adjusted R-squared	0.367452
F(3, 27)	6.809075	P-value(F)	0.001453
Log-likelihood	55.61431	Akaike criterion	−103.2286
Schwarz criterion	−97.49266	Hannan-Quinn	−101.3588
rho	0.052721	Durbin-Watson	1.880154

Table 2 Regression Diagnostic Result

Diagnostic Tests	**p-value**	**Results**
Normality residual test	**0.144242**	P-value is > 0.01
Breusch-Godfrey test	**0.082026**	P-value is > 0.01
White Test for Heteroscedasticity	**0.955354**	P-value is > 0.01
Ramsey Regression Equation Specification Error Test	**0.161**	P-value is > 0.01
Belsley-Kuh-Welsch test	**-**	No evidence of excessive collinearity

Journal of Environment

ISSN 2789-3863 (Online)

Vol. 4, Issue No. 4, pp 49 – 63, 2024 www.carijournals.org

4.1.1 Model

$$\boldsymbol{CO2E} = 0.0337894 + 0.611560\boldsymbol{POP} + 0.00551634\boldsymbol{GD} + \boldsymbol{e}$$

4.2 Results Interpretation

4.2.1 Ordinary Least Squares Interpretation

Table 1 shows the results of the OLS Regression analysis and provides a summary of the relationship between the dependent variable, CO2 emissions per capita, and the independent variables: population growth, GDP per capita growth, and high-technology exports of the Philippines from 1992 to 2022.

d_$\boldsymbol{POP}$ and d_$\boldsymbol{GDP}$ have p-values less than 0.01, with 0.0007 for d_$\boldsymbol{POP}$ and 0.0062 for d_$\boldsymbol{GDP}$, indicating that these are significant for d_$\boldsymbol{CO2E}$. Their coefficients are both positive, showing that population growth and GDP per capita growth have a direct relationship with CO2 emissions per capita. This demonstrates that population and affluence have significant and positive effects on the environmental impact.

On the other hand, the p-value for d_$\boldsymbol{HTE}$ is 0.9095, higher than 0.01, showing that there is no impact on d_$\boldsymbol{CO2E}$. This shows that the relationship between environmental impact and technology is insignificant in the Philippines.

The model shows that for every percent increase in population growth, there is a 0.611560 increase in CO2 emissions per capita; similarly, for every percent increase in GDP per capita growth, there is a 0.00551634 increase in CO2 emissions per capita in the Philippines. The CO2 emissions per capita is 0.0337894 metric tons when there is no growth in population and GDP per capita.

4.2.2 Diagnostic Tests Interpretation

Table 2 shows the results of various diagnostic tests used in the study to assess the validity and reliability of the Ordinary Least Squares regression model. The models that were used are as follows: normality residual test, Breusch-Godfrey test, White's test heteroskedasticity, Ramsey Regression Equation Specification Error Test, and Belsley-Kuh-Welsch test. All of the tests used a 0.01 level of significance.

The normality residual test produced a p-value of 0.144242, which is higher than the 0.01 level of significance, indicating that the residuals are normally distributed. This strengthens the validity of hypothesis tests. The Breusch-Godfrey test produced a p-value of 0.082026, which is higher than the 0.01 level of significance, indicating the absence of autocorrelation in the model. This confirms that the residuals are not correlated.

White's test for heteroskedasticity produced a p-value of 0.955354, which is higher than the 0.01 level of significance, indicating the absence of heteroskedasticity in the model. This means that the variance of the residuals is constant. The Ramsey Regression Equation Specification Error test produced a p-value of 0.161, which is higher than the 0.01 level of significance, indicating that there is no mis-specification in the model. This means that the model is not missing any important variable. Lastly, the Belsley-Kuh-Welsch test yielded a condition index below 10, indicating the absence of excessive collinearity.

5. Conclusion

The study aims to analyze the IPAT equation and determine the effects of technological advancement on the environment in the Philippines. In alignment with this goal, three independent variables were used in the study, namely population growth rate, GDP per capita growth rate, and high-technology exports, and one dependent variable, CO2 emissions per capita. After that, the Ordinary Least Squares regression model was used to analyze the significance of population, affluence, and technology on environmental impact. The results of the regression analysis show that population and affluence have a positive and significant relationship with environmental impact in the Philippines. This means that as population and affluence increase, environmental impact also increases. The results reinforce Pham et al. (2020), Khan et al. (2021), and Todaro & Smith's (2003, as cited in Ilham, 2021) statements, claiming that population growth contributes to environmental degradation. The results also reinforce York et al. (2003), Wiedmann et al. (2020), and Yam et al.'s (2022) statements, claiming that affluence is a key driver of environmental impact. On the other hand, the results show that technology has little to no relationship with environmental impact. According to Iqbal et al. (2023), ICT in low- and middle-income countries has an insignificant effect on carbon emissions compared to high-income countries due to the difference in the level of ICT. ICTs in low- and middle-income countries are less developed, meaning that their ICT isn't as effective when mitigating environmental impact. An example of this is Tunisia, a lower-middle income country, where the level of ICT is insufficient to decrease emission levels (Amri, 2019).

Based on the results of the study, it cannot be determined whether technological advancement has a positive or negative impact on the environment in the Philippines because the tests show that the relationship between technology and environmental impact is insignificant. This could imply that technology in the Philippines is not advanced enough to mitigate environmental impact.

5.1 Policy Implication

The study revealed that population and affluence have a significant and direct relationship with environmental impact. For a country with a growing economy and rapidly growing population like the Philippines, this will give rise to various environmental challenges. For instance, an increase in population leads to an increase in the demand for natural resources. With this in mind, the government should prioritize implementing policies that mitigate overconsumption. Furthermore, since population growth drives urbanization, the government should implement policies and projects that promote sustainable urbanism, like adding green spaces for better air quality. Regarding economic activities, the government should implement carbon-pricing policies to discourage wasteful production and consumption of carbon-intensive goods. This helps reduce greenhouse gas emissions by giving additional costs to those who emit excessively. The government could also implement policies that would incentivize businesses to produce products with eco-friendly designs. On the other hand, research suggested that the relationship between technology and the environment is insignificant. Despite that, the government should still prioritize the advancement and adoption of cleaner technologies. Furthermore, environmental impact assessments should be conducted for technologies used in production processes to ensure sustainability. Governments should also focus on strengthening pollution control policies and implementing standards and measures to protect the environment. To encourage sustainable technology, governments should create policies that support green and clean technological development, aim for a low-carbon economy, and limit the production of carbon-intensive products through stricter environmental regulations.

REFERENCES:

Ahakwa, I., Xu, Y., Tackie, E. A., Odai, L. A., Sarpong, F. A., Korankye, B., & Ofori, E. K. (2023). Do natural resources and green technological innovation matter in addressing environmental degradation? Evidence from panel models robust to cross-sectional dependence and slope heterogeneity. *Resources Policy*, *85*, 103943. https://doi.org/10.1016/j.resourpol.2023.103943

Ahmed, K., Shahbaz, M., Qasim, A., & Long, W. (2015). The linkages between deforestation, energy and growth for environmental degradation in Pakistan. *Ecological Indicators*, *49*, 95-103. https://doi.org/10.1016/j.ecolind.2014.09.040

Ali, E. B., Shayanmehr, S., Radmehr, R., Bayitse, R., & Agbozo, E. (2024). Investigating environmental quality among G20 nations: The impacts of environmental goods and low-carbon technologies in mitigating environmental degradation. *Geoscience Frontiers*, *15*(1), 101695. https://doi.org/10.1016/j.gsf.2023.101695

Amri, F., Ben Zaied, Y., & Ben Lahouel, B. (2019). *ICT, total factor productivity, and carbon dioxide emissions in Tunisia*. Technological Forecasting and Social Change. https://www.sciencedirect.com/science/article/abs/pii/S0040162518307534?via%3Dihub

Andrée, B. P. J., Chamorro, A., Spencer, P., Koomen, E., & Dogo, H. (2019). Revisiting the relation between economic growth and the environment; a global assessment of deforestation, pollution and carbon emission. *Renewable and Sustainable Energy Reviews*, *114*, 109221. https://doi.org/10.1016/j.rser.2019.06.028

Azam, M. (2016). Does environmental degradation shackle economic growth? A panel data investigation on 11 Asian countries. *Renewable and Sustainable Energy Reviews*, *65*, 175-182. https://doi.org/10.1016/j.rser.2016.06.087

Babiso, B., Toma, S., & Bajigo, A. (2020). Population growth and environmental changes: conclusions drawn from the contradictory experiences of developing countries. Int J Environ Monitoring Anal, 8(5), 161. https://doi.org/10.11648/j.ijema.20200805.15

Bansal, S., Sharma, G. D., Rahman, M. M., Yadav, A., & Garg, I. (2021). Nexus between environmental, social and economic development in South Asia: evidence from econometric models. *Heliyon*, *7*(1). https://doi.org/10.1016/j.heliyon.2021.e05965

Bashir, M. F., Shahbaz, M., Malik, M. N., Ma, B., & Wang, J. (2023). Energy transition, natural resource consumption and environmental degradation: The role of geopolitical risk in sustainable development. *Resources Policy*, *85*, 103985. https://doi.org/10.1016/j.resourpol.2023.103985

Begum, R. A., Sohag, K., Abdullah, S. M. S., & Jaafar, M. (2015). CO2 emissions, energy consumption, economic and population growth in Malaysia. *Renewable and Sustainable Energy Reviews*, *41*, 594-601. https://doi.org/10.1016/j.rser.2014.07.205

Bendix, A. (2022). Pollution's fatal threat gains urgency after 9 million died in one year. NBC News. https://www.nbcnews.com/health/health-news/pollution-death-toll-high-studies-rcna29189

Briggs-Goode, A., & Townsend, K. (Eds.). (2011). Textile design: principles, advances and applications.

Casey, G., & Galor, O. (2017). Is faster economic growth compatible with reductions in carbon emissions? The role of diminished population growth. Environmental research letters: ERL [Web site], 12(1), 10-1088. https://doi.org/10.1088/1748-9326/12/1/014003

Chen, F., Wang, M., & Pu, Z. (2022). The impact of technological innovation on air pollution: firm-level evidence from China. *Technological Forecasting and Social Change*, *177*, 121521. https://doi.org/10.1016/j.techfore.2022.121521

Chen, W., & Lei, Y. (2018). The impacts of renewable energy and technological innovation on environment-energy-growth nexus: New evidence from a panel quantile regression. *Renewable energy*, *123*, 1-14. https://doi.org/10.1016/j.renene.2018.02.026

Chen, Y., Subhan, M., Ahmad, G., Adil, M., & Zamir, M. N. (2024). Unveiling the linkages among digital technology, economic growth, and carbon emissions: A resource management perspective. *Resources Policy*, *91*, 104868. https://doi.org/10.1016/j.resourpol.2024.104868

Cheng, C., Ren, X., Dong, K., Dong, X., & Wang, Z. (2021). How does technological innovation mitigate CO2 emissions in OECD countries? Heterogeneous analysis using panel quantile regression. *Journal of Environmental Management*, *280*, 111818. https://doi.org/10.1016/j.jenvman.2020.111818

Chien, F., Anwar, A., Hsu, C. C., Sharif, A., Razzaq, A., & Sinha, A. (2021). The role of information and communication technology in encountering environmental degradation:

proposing an SDG framework for the BRICS countries. *Technology in Society*, *65*, 101587. https://doi.org/10.1016/j.techsoc.2021.101587

Dong, K., Hochman, G., Zhang, Y., Sun, R., Li, H., & Liao, H. (2018). CO2 emissions, economic and population growth, and renewable energy: empirical evidence across regions. Energy Economics, 75, 180-192. https://doi.org/10.1016/j.eneco.2018.08.017

Dong, Y., Wong, W. K., Muda, I., Cong, P. T., Hoang, A. D., Ghardallou, W., & Ha, N. N. (2023). Do natural resources utilization and economic development reduce greenhouse gas emissions through consuming renewable and Clean Technology? A case study of China towards sustainable development goals. *Resources Policy*, *85*, 103921. https://doi.org/10.1016/j.resourpol.2023.103921

Dubey, R., Gunasekaran, A., Childe, S. J., Papadopoulos, T., Luo, Z., Wamba, S. F., & Roubaud, D. (2019). Can big data and predictive analytics improve social and environmental sustainability?. *Technological forecasting and social change*, *144*, 534-545. https://doi.org/10.1016/j.techfore.2017.06.020

Ecological Trends Alliance. (n.d.) Environment and Livelihood programmes. http://www.ecotrendsalliance.org/Environment%20and%20Livelihood%20Programmes.html

Ehrlich, P. R., & Holdren, J. P. (1972). Impact of. *Three Population Resources, and the Environment*, 365. https://faculty.washington.edu/stevehar/Ehrlich.pdf

Environmental Health - Healthy People 2030. (n.d.). https://health.gov/healthypeople/objectives-and-data/browse-objectives/environmental-health#:~:text=Environmental%20pollutants%20can%20cause%20health,and%20some%20types%20of%20cancer.&text=People%20with%20low%20incomes%20are,health%20problems%20related%20to%20pollution

Fernando, J. (2024, April 28). Gross domestic product (GDP) formula and how to use it. Investopedia. https://www.investopedia.com/terms/g/gdp.asp

Hashmi, R., & Alam, K. (2019). Dynamic relationship among environmental regulation, innovation, CO2 emissions, population, and economic growth in OECD countries: A panel investigation. *Journal of cleaner production*, *231*, 1100-1109. https://doi.org/10.1016/j.jclepro.2019.05.325

Hassan, M. U., Tahir, M., Ali, N. O., Qamar, S., Khan, W. U., & Burki, U. (2024). Determinants of Environmental Degradation: Exploring the Unexplored for Brunei Darussalam. *Environmental Challenges*, 100859. https://doi.org/10.1016/j.envc.2024.100859

Hilty, L. M., Arnfalk, P., Erdmann, L., Goodman, J., Lehmann, M., & Wäger, P. A. (2006). The relevance of information and communication technologies for environmental sustainability–a prospective simulation study. *Environmental Modelling & Software*, *21*(11), 1618-1629. https://doi.org/10.1016/j.envsoft.2006.05.007

Holdren, J. P. (1993). A Brief History of IPAT (Impact= Population x Affluence x Technology). *University of California, Berkeley: unpublished paper*, *September*. https://mahb.stanford.edu/library-item/a-brief-history-of-ipat-impact-population-x-affluence-x-technology/

Hussain, C. M., Paulraj, M. S., & Nuzhat, S. (2022). Source reduction, waste minimization, and cleaner technologies. Source Reduction Waste Minimization 23–59. https://doi.org/10.1016/B978-0-12-824320-6.00002-2

Ilham, M. I. (2021). Economic development and environmental degradation in Indonesia: Panel data analysis. Jurnal Ekonomi & Studi Pembangunan, 22(2), 185-200. https://doi.org/10.18196/jesp.v22i2.7629

Iqbal, K., Wang, Y., Danish, Li, N., Khan, S., Mahmood, N., & Shuo, W. (2023). Understanding the relationship between technological innovation and environmental sustainability under the silver lining of education. *Frontiers in Environmental Science*, *11*, 1235376. doi: 10.3389/fenvs.2023.1235376

International Organization for Standardization. (n.d.). Environmental degradation. https://www.iso.org/foresight/environmental-degradation.html

Johnson, M. T., & Munshi-South, J. (2017). Evolution of life in urban environments. Science, 358(6363), eaam8327. https://doi.org/10.1126/science.aam8327

Kahouli, B., Miled, K., & Aloui, Z. (2022). Do energy consumption, urbanization, and industrialization play a role in environmental degradation in the case of Saudi Arabia?. *Energy Strategy Reviews*, *40*, 100814. https://doi.org/10.1016/j.esr.2022.100814

Khan, I., Hou, F., & Le, H. P. (2021). The impact of natural resources, energy consumption, and population growth on environmental quality: Fresh evidence from the United States of America. Science of the Total Environment, 754, 142222. https://doi.org/10.1016/j.scitotenv.2020.142222

Kwakwa, P. A., Alhassan, H., & Adu, G. (2020). Effect of natural resources extraction on energy consumption and carbon dioxide emission in Ghana. *International Journal of Energy Sector Management*, *14*(1), 20-39. https://doi.org/10.1108/IJESM-09-2018-0003

Mesagan, E. P., & Vo, X. V. (2023). Does natural resource rent and consumption interplay worsen Africa's pollution? Heterogeneous panel approach with cross-sectional dependence. *Resources Policy*, *82*, 103562. https://doi.org/10.1016/j.resourpol.2023.103562

Mughal, N., Arif, A., Jain, V., Chupradit, S., Shabbir, M. S., Ramos-Meza, C. S., & Zhanbayev, R. (2022). The role of technological innovation in environmental pollution, energy consumption and sustainable economic growth: Evidence from South Asian economies. *Energy Strategy Reviews*, *39*, 100745. https://doi.org/10.1016/j.esr.2021.100745

Munir, K., & Ameer, A. (2018). Effect of economic growth, trade openness, urbanization, and technology on environment of Asian emerging economies. *Management of Environmental Quality: An International Journal*, *29*(6), 1123-1134. https://doi.org/10.1108/MEQ-05-2018-0087

National Intelligence Council. (n.d.) Structural Forces Environment. https://www.dni.gov/index.php/gt2040-home/gt2040-structural-forces/environment

Nuţă, F. M., Sharafat, A., Abban, O. J., Khan, I., Irfan, M., Nuţă, A. C., ... & Asghar, M. (2024). The relationship among urbanization, economic growth, renewable energy consumption, and environmental degradation: A comparative view of European and Asian emerging economies. *Gondwana Research*, *128*, 325-339. https://doi.org/10.1016/j.gr.2023.10.023

Onifade, S. T., Gyamfi, B. A., Haouas, I., & Bekun, F. V. (2021). Re-examining the roles of economic globalization and natural resources consequences on environmental degradation in E7 economies: are human capital and urbanization essential components?. *Resources Policy*, *74*, 102435. https://doi.org/10.1016/j.resourpol.2021.102435

Opoku, E. E. O., & Boachie, M. K. (2020). The environmental impact of industrialization and foreign direct investment. *Energy Policy*, *137*, 111178. https://doi.org/10.1016/j.enpol.2019.111178

Ozcan, B., Tzeremes, P. G., & Tzeremes, N. G. (2020). Energy consumption, economic growth and environmental degradation in OECD countries. *Economic Modelling*, *84*, 203-213. https://doi.org/10.1016/j.econmod.2019.04.010

Özokcu, S., & Özdemir, Ö. (2017). Economic growth, energy, and environmental Kuznets curve. Renewable and Sustainable Energy Reviews, 72, 639-647. https://doi.org/10.1016/j.rser.2017.01.059

Pham, N. M., Huynh, T. L. D., & Nasir, M. A. (2020). Environmental consequences of population, affluence and technological progress for European countries: A Malthusian view. *Journal of environmental management*, *260*, 110143. https://doi.org/10.1016/j.jenvman.2020.110143

Qamar, M. Z., Ali, W., Qamar, M. O., & Noor, M. (2021). Green technology and its implications worldwide. *The Inquisitive Meridian*, *3*, 1-11.

Rahman, M. M. (2020). Environmental degradation: The role of electricity consumption, economic growth and globalisation. *Journal of environmental management*, *253*, 109742. https://doi.org/10.1016/j.jenvman.2019.109742

Rahman, M. M., & Alam, K. (2021). Clean energy, population density, urbanization and environmental pollution nexus: Evidence from Bangladesh. Renewable Energy, 172, 1063-1072. https://doi.org/10.1016/j.renene.2021.03.103

Raihan, A. (2023). The dynamic nexus between economic growth, renewable energy use, urbanization, industrialization, tourism, agricultural productivity, forest area, and carbon dioxide emissions in the Philippines. *Energy Nexus*, *9*, 100180. https://doi.org/10.1016/j.nexus.2023.100180

Sarkodie, S. A., & Strezov, V. (2019). Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. *Science of the total environment*, *646*, 862-871. https://doi.org/10.1016/j.scitotenv.2018.07.365

Shahbaz, M., Lean, H. H., & Shabbir, M. S. (2012). Environmental Kuznets curve hypothesis in Pakistan: cointegration and Granger causality. *Renewable and Sustainable Energy Reviews*, *16*(5), 2947-2953. https://doi.org/10.1016/j.rser.2012.02.015

Shahbaz, M., Loganathan, N., Muzaffar, A. T., Ahmed, K., & Jabran, M. A. (2016). How urbanization affects CO2 emissions in Malaysia? The application of STIRPAT model. Renewable and Sustainable Energy Reviews, 57, 83-93. https://doi.org/10.1016/j.rser.2015.12.096

Singh, S., Sharma, G. D., Radulescu, M., Balsalobre-Lorente, D., & Bansal, P. (2023). Do natural resources impact economic growth: An investigation of P5+ 1 countries under sustainable management? *Geoscience Frontiers*, 101595.

United States Agency for International Development. (n.d.) Agriculture and Food Security. https://www.usaid.gov/cambodia/agriculture-and-food-security

United States Agency for International Development. (n.d.). Environment https://www.usaid.gov/philippines/environment

Wang, J., & Dong, K. (2019). What drives environmental degradation? Evidence from 14 Sub-Saharan African countries. *Science of the Total Environment*, *656*, 165-173. https://doi.org/10.1016/j.scitotenv.2018.11.354

Wang, Q., & Li, L. (2021). The effects of population aging, life expectancy, unemployment rate, population density, per capita GDP, urbanization on per capita carbon emissions. Sustainable Production and Consumption, 28, 760-774. https://doi.org/10.1016/j.spc.2021.06.029

Washington, H., & Kopnina, H. (2022). Discussing the Silence and Denial around Population Growth and Its Environmental Impact. How Do We Find Ways Forward?. World, 3(4), 1009-1027. https://doi.org/10.3390/world3040057

Weber, H., & Sciubba, J. D. (2019). The effect of population growth on the environment: evidence from European regions. European Journal of population, 35, 379-402. https://doi.org/10.1007/s10680-018-9486-0

Wen, L., & Li, Z. (2019). Driving forces of national and regional CO2 emissions in China combined IPAT-E and PLS-SEM model. *Science of the total environment*, *690*, 237-247. https://doi.org/10.1016/j.scitotenv.2019.06.370

Wen, J., Mughal, N., Zhao, J., Shabbir, M. S., Niedbała, G., Jain, V., & Anwar, A. (2021). Does globalization matter for environmental degradation? Nexus among energy consumption, economic growth, and carbon dioxide emission. *Energy policy*, *153*, 112230. https://doi.org/10.1016/j.enpol.2021.112230

Wiedmann, T., Lenzen, M., Keyßer, L. T., & Steinberger, J. K. (2020). Scientists' warning on affluence. *Nature communications*, *11*(1), 3107.

World Bank. (n.d.). Metadata Glossary. DataBank. https://databank.worldbank.org/metadataglossary/jobs/series/TX.VAL.TECH.MF.ZS#:~:text=High%2Dtechnology%20exports%20are%20products,scientific%20instruments%2C%20and%20electrical%20machiner

World Bank. (n.d.). Metadata Glossary. Databank. https://databank.worldbank.org/metadataglossary/world-development-indicators/series/EN.ATM.CO2E.PC

World Bank. (2023). Pollution. https://www.worldbank.org/en/topic/pollution

World Health Organization. (n.d.). Population. World Health Organization. https://www.who.int/data/gho/indicator-metadata-registry/imr-details/1121

Wu, H., Hao, Y., Ren, S., Yang, X., & Xie, G. (2021). Does internet development improve green total factor energy efficiency? Evidence from China. *Energy Policy*, *153*, 112247. https://doi.org/10.1016/j.enpol.2021.112247

Xin, D., Zhi Sheng, Z., & Jiahui, S. (2022). How technological innovation influences environmental pollution: Evidence from China. *Complexity*, *2022*, 1-9. https://doi.org/10.1155/2022/5535310

Yan, C., Li, H., & Li, Z. (2022). Environmental pollution and economic growth: Evidence of SO2 emissions and GDP in China. *Frontiers in Public Health*, *10*, 930780. https://doi.org/10.3389/fpubh.2022.930780

Yii, K. J., & Geetha, C. (2017). The nexus between technology innovation and CO2 emissions in Malaysia: evidence from granger causality test. *Energy Procedia*, *105*, 3118-3124. https://doi.org/10.1016/j.egypro.2017.03.654

York, R., Rosa, E. A., & Dietz, T. (2003). STIRPAT, IPAT and ImPACT: analytic tools for unpacking the driving forces of environmental impacts. *Ecological economics*, *46*(3), 351-365. https://doi.org/10.1016/S0921-8009 (03)00188-5

Yusuf, A. (2023). Dynamic effects of energy consumption, economic growth, international trade and urbanization on environmental degradation in Nigeria. *Energy Strategy Reviews*, *50*, 101228. https://doi.org/10.1016/j.esr.2023.101228.