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The Impact of Economic Growth and Greenhouse Gas Emissions on Health Costs: The East Asia and The Pacific

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Abstract

The rapid increase of greenhouse gas (GHG) emissions has become a significant impact on health and environment around the globe. Although the impact between economic development and health expenditure has been previously examined, but the influence of GHG emissions on medical spending, particularly in East Asia and the Pacific is under-researched. The goal is to examine the impact of GHG emissions and gross domestic product (GDP) on health expenditures in East Asia, Southeast Asia, and the Pacific Islands from 2000 to 2021. The primary objective is to assess how GHG and GDP affect health expenditures both in the short-run and long-run causality. Using cointegration analysis, the study finds that economic growth and GHG emissions play an important part in driving the increase in health expenditures. Also, notable regional differences in health expenditure and emissions are observed, with East Asia experiencing higher levels compared to Southeast Asia and the Pacific Islands. These findings highlighted the link between GDP growth, environmental health risks, and health costs that emphasizes the need for integrated policy strategies to lessen the global climate change impacts and encourage sustainable growth in the East Asia and the Pacific. These strategies are essential for fostering long-term development and balanced growth, ensuring a healthier and more sustainable environment for future generations.

Keywords: Cointegration Analysis, Economic Growth, Greenhouse Gas Emissions, Gross Domestic Product, Health Expenditure.

Introduction

Greenhouse gases, by definition, increases the global atmospheric temperature. However, given the multitude of systems that exists, there are a lot more conditions they affect, such as bio systems, the environment, the human health, and the economy. An intermediary phenomenon between greenhouse gas (GHG) emissions and the mentioned systems is global climate change. In this era of human development, greenhouse gas emissions are consequences of anthropogenic activities, which make planetary energy balance erratic resulting to global warming (1). Greenhouse gases are the primary pollutants generated by energy production and other industrial processes. In 2021, the United States' greenhouse gas emissions were primarily driven by transportation (28%), electricity production (25%), and industrial production (23%) (2). Both energy consumption and production contribute to the emission of these pollutants. The top global greenhouse gas emitters are China (12,705.1 metric tons CO2 equivalent), United States (6,001.2 MtCO2e), and India (3,394.9 MtCO2e), which make up 42.9% of the accumulated greenhouse gas emissions; while the lowest one hundred countries account for 2.9%, which is around 15 times less than the top three countries (3, 4). The East Asia and Pacific region are crucial to efforts made worldwide to fight the global climate change. Thirteen out of the thirty countries in the region are among the greatest exposed to the impact of global climate change, with one-third of total greenhouse gas emissions, around sixty percent of coal usage (5). Carbon monoxide, nitrogen oxides, and other harmful air pollutants are just some of the many types of pollutants released into the air. Although particulate matter is not a gas because it is a tiny solid, it still matters because it can cause global warming, in which greenhouse gases mainly function as such (6). The impact of greenhouse gases extends beyond climate change. Various health issues might arise

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as a result of GHG exposure. Respiratory and cardiovascular conditions are the health impacts of GHG that manifest most quickly. They are especially worrisome for vulnerable groups like children, the elderly, and people who already have health issues. Young people are highly fragile to climate change-related exposures due to its ongoing development, higher levels of exposure compared to adults, and the potential loss of healthy years in the future (7). Despite forecasting that human life expectancy may increase in the next century under the assumption of improve medical advancements and unaltered environmental conditions, the threats of climate change may disprove this prediction; geriatric health is of importance as elderly adults have great sensitivity to sudden ecological changes and exposure to harmful substances and toxins as they have reduced biological reserve capacity, decreased metabolism function, and weakened the immune system response (8). In addition to respiratory and cardiovascular diseases, greenhouse gases have also been linked to cognitive decline and other neurological disorders. Higher precipitation and increased nutrient loading have been found to accelerate the development of damaging algal blooms, which are triggered by greenhouse gas emissions. These algal blooms produce neurotoxins that accumulate in seafood, increasing the risk of symptoms such as amnesia, epilepsy, dementia, and parkinsonian-like symptoms (9). The interconnectivity of productivity and pollution plays a crucial role towards economic growth and development. GDP is essentially a measure of a country's productivity. However, there are other measures such as labor. Studies indicate that pollution can reduce productivity due to respiratory and other health issues arising from exposure to polluted air. The impact of air pollution on the output of call center employees in China was investigated, revealing that a 10-unit increase in the Air Pollution Index (API) results in a 0.35 percent decrease in the number of calls handled by a worker, indicating a direct correlation between productivity loss and pollution levels (10). For productivity being measured in terms of GDP, greenhouse gas emissions are a result of high economic activity. A study examined the effects of emissions, in terms of CO2, on economic growth of some OECD countries in 1981-1998 (11). Using the semi parametric smooth coefficient model, the output revealed a monotonic direct association among factor productivity development and emissions. This agrees with the balance of material condition, such that increase of production leads to increase in emissions. This may come as counterintuitive with the idea that labor increases GDP. However, higher income may lead to higher demand for environmental protection, such that development for cleaner production and better labor condition may be done (12). Some limitations identified for this study is availability of data. Annual data may not provide as much information as those that are recorded quarterly or monthly. Also, measures on current health expenditure are not available for some countries prior to 2000. This may limit the author's analysis given that a dataset with more time periods may provide better insights. Model diagnostics such as stationarity and correlation are to be employed to assure reliability of estimates. There have been multiple empirical studies that had related greenhouse gas emission, economic productivity, i.e., GDP and growth, and human health, pairwise or altogether. Most of which are time-series analysis and the use of multivariate methods. A paper looked into the impact of greenhouse gas emissions internalized by food tax on chronic diseases in the United Kingdom, in which data from the adult population were used. The paper also estimated the potential government revenue due to the taxation. Chronic diseases considered in this study are obesity, diabetes, cardiovascular disease, and some cancers. The intention of taxation is to reduce intake of food groups that cause such diseases, such as saturated fats and sugar, in which their mass production contribute to increasing greenhouse gas emissions. Two tax situations were considered: £2.72 of tax per metric ton of CO2 per 100 grams of the product was used to all food and drink categories with an above-average of greenhouse gas emissions, while no tax was imposed on those groups with below-average emissions; and the equal tax rate in the first scenario but those groups with below average emissions are subsidized to suppose a tax neutral condition. According to analysis outcomes, an assessment based on the changes in mortality from chronic illnesses following the operation of each tax strategy, the variation in greenhouse gas emissions, and the projected tax revenue.

Estimation of tax revenue uses estimated price elasticities from a Markov Chain Monte Carlo (MCMC) simulation of twelve thousand repetitions and a deletion of 2000. Food area that has the highest GHG emissions per mass of the product (ktCO2e/kg product) are beef (68.8), lamb (64.2), other meats (35.9), and animal fats (35.6), in which they are imposed with taxes; the groups that have the least GHG emissions/mass product are sweets (0.1), sugar and preserves (0.1), and soft drinks (0.1), in which subsidies are provided for their production (13). The results showed that for the first tax scenario, an average of 7,700 deaths could be averted, a reduction in annual greenhouse gas emissions of 18,683 ktCO2e, and an estimated annual tax revenue of £2.02 billion; the scenario of the second tax, in which it is subjected to tax neutrality, average additional deaths are 2,685 with a reduction of annual greenhouse gas emissions of 15,228 ktCO2e. The first scenario saved 7,700 lives each year, generated substantial tax revenue, and reduced greenhouse gas emissions greater than the second scenario. Despite being environmentally favorable, the second scenario does not provide benefits in tax revenue, and can be harmful to human health, as subsidies are applied to food groups that contribute to a bad diet despite emitting GHG below than the average. A study using data from China was conducted to investigate the nexus between health expenditure (out-of-pocket payments), CO2 emissions, and environmental toxins, in terms of an index for both water and waste pollution (14). They hypothesized that both CO_2 emissions and environmental pollution make a positive impact on household health expenditure. Data were collected from the National Health Service Survey, World Health Organization, and World Development Indicators from 1990 to 2019. Nonlinear autoregressive distributed lag (NARDL) and Granger causality were employed for the analysis; in addition, the Zivot and Andrews test for structural breaks was also performed. Their results indicated that both short-run and long-run have positive shocks in CO_2 emissions and environmental pollution have a positive impact on health expenditure. Additionally, there exists a bi-directional relationship among household health expenditure, CO_2 emissions, and environmental pollution, confirming asymmetric relationships among these variables. Their findings also suggest that Chinese residents will incur higher health expenditure as CO2 emissions and pollution on environmental increase. Another study was conducted to examine the relationship between personal health costs and economic growth in the twenty-one OECD countries from 1990 to 2019. Real GDP per capita income was used as the dependent variable to estimate economic progress, while individual health spending, public health costs, out-of-pocket health expenditure, the share of current health expenditures in GDP, and the share of drug expenditures in GDP were used as independent variables to describe health expenditure. The Driscoll-Kraay standard error method was employed to estimate the linear relationships between the independent and dependent variables, addressing potential bias caused by cross-sectional dependence in the panel dataset (15). Their results showed that when real GDP is the dependent variable, all health expenditure measures are positively related to economic growth, such that a one-percent increase in each of health expenditure share in GDP and out-of-pocket expense, an increase of 0.09% and 0.04%, respectively, in real GDP will happen. In the second model, in which the dependent variable is per capita GDP, out-of-pocket expenditure has a negative relationship with per capita GDP, and public health expenditure has a positive effect on per capita GDP. Also, a percent increase in share of current health expenditure in GDP increases per capita GDP by 0.06%. Their findings suggest that investing and spending on public health improves economic productivity brought by better human health conditions, such that a healthier population becomes more productive and drive demand which helps industries thrive. A study was conducted in Iran to investigate the role of environmental quality and income in determining health expenditures from 1967 to 2010. Environmental quality was measured in terms of kilograms of emitted suspended particulate matter (SPM), SO2, and CO, while income was represented by GDP, with health expenditures expressed in dollar PPP terms. The study used autoregressive distributed lag (ARDL) techniques for cointegration to establish both short-run and long-run relationships between health expenditure, income, and environmental quality. The regression model employed was a double-log form, allowing for the estimation of elasticities of health expenditures relative to the considered determinants. The error correction term was used to estimate the speed of adjustment (16). Their findings indicate that the long-run income elasticity of health expenditure is 0.19, meaning that a 1% increase in GDP leads to a 0.19% increase in health expenditure. Both SO2 and CO show positive elasticities with respect to health expenditure, suggesting that exposure to these greenhouse gases can lead to higher health costs. In contrast, SPM has an elasticity of -1.58, indicating that a rise in suspended particulate matter could reduce health expenditures. The error correction term coefficient is significantly negative at -1.10, suggesting that the disequilibrium between health expenditures and the considered determinants is corrected by 1.10% annually, implying that it would take approximately 90 years for the disequilibrium to be fully corrected. Based on these findings, they recommend that health management policies should focus on cleaner fuels, as solely addressing health issues may divert funds from necessary environmental improvements. A similar study was conducted in Sub-Saharan African countries to examine the relationship between health expenditure (per capita, constant 2010 US$), environmental pollution (measured in metric tons per capita of CO2 and NOx emissions), and economic growth (GDP per capita, constant 2010 US$) using annual data from 1990 to 2015. The ARDL technique was employed to estimate both short-run and long-run relationships with health expenditure. Additionally, the vector error correction model (VECM) Granger causality test was conducted to determine the direction of causality—whether health expenditure Granger-causes the determinants, the reverse, or if there is a bidirectional causality. The ARDL technique was employed to estimate both short-run and long-run relationships with health expenditure. Additionally, the vector error correction model (VECM) Granger causality test was conducted to determine the direction of causality—whether health expenditure Granger-causes the determinants, the reverse, or if there is a bidirectional causality (17). The results revealed that the ARDL test indicates a positive impact of economic growth on health expenditure, while CO2 and NOx emissions negatively affect health expenditure in the long run. Specifically, a 1% increase in GDP results in a 0.332% increase in health expenditure, while a 1% increase in CO2 and NOx emissions leads to a decrease of 0.066% and 0.577% in health expenditure, respectively. The VECM Granger causality test shows that health expenditure Granger-causes GDP per capita, while there is a two-way relationship between CO2 emissions and GDP per capita, as well as between health expenditure and CO2 emissions. Another study employing the ARDL approach was conducted on ASEAN countries from 2009 to 2018 using annual data on economic growth (GDP), environmental pollution (metric tons per capita CO2 emission), energy consumption (energy use per capita), and health and research and development (R and D) expenditures, with the last two variables being the dependent variables. They hypothesized that research and development, and health expenditures are positively impacted by environmental pollution as investing on research and development that prevents further pollution while higher pollutions increase the incidence and, in effect, costs on diseases. Also, they believe that economic growth leads to higher research and development, and health expenditure; higher income countries are capable of investing more on development and research, and economic growth may be caused by enhance expenditure on health. Their findings revealed that environmental pollution did not increase health expenditures in the short run as realization of pollution effects on health costs takes time. Economic growth had a short- and long-term impact on research and development expenditure, while only evident on health expenditure in the long-run. Energy consumption was only impactful on research and development and health expenditure in the long-run (18). The effect of environmental pollution (CO2 emissions) and economic growth (GDP per capita) on public health (perinatal mortality) was investigated using panel data from thirty provinces in China from 2007 to 2018. Per capita disposable income, which augments economic growth, and urbanization rate, which supports environmental pollution, were also considered. The Engle and Granger (EG) two-step method was used to test for cointegration. The relationship between perinatal mortality and the determinants was estimated using the individual fixed effect model (19). The body of literature on themes that primarily examine the growth-environment-health connection is expanding globally, with focuses ranging from country-specific to multi-country. It is argued in existing literature that economic growth, in terms of GDP, has a positive relationship with the expenditure on health, as enhanced levels of income tend to result in rising government and private expenditures on healthcare services (15). Greenhouse gas (GHG) emissions—usually linked with industrialization and urbanization—have further been attributed to negative health outcomes, which might augment health-related expenses (20, 21). Therefore, we anticipate that GDP will show a positive correlation with health expenditure, GHG emissions will also exhibit a positive relationship with health spending, especially in regions with high pollution levels. There may be an interrelation between GDP and GHG emissions due to their common links to industrial activity and economic expansion (22). This research paper examines the influence of GHG emissions and GDP on healthcare spending in the East Asia, Southeast Asia, and the Pacific Island. The study is grounded in the interconnectedness of health, environmental factor, and economic growth. Specifically, it addresses the following research questions: What is the relationship between greenhouse gas emissions, GDP, and health expenditure in East Asia, Southeast Asia, and the Pacific Islands from 2000 to 2021? Do greenhouse gas (GHG) emissions and GDP influence health expenditures in the short run and long run? Are there regional differences in the impact of economic growth and environmental degradation on health spending? To answer these questions, the study tests the following null hypotheses:

H_1: GDP has no significant effect on health expenditure. H_2: GHG emissions have no significant impact on health expenditure.H_3: There is no short-run or long-run causality between GDP, GHG emissions, and health expenditure.

Methodology

Theoretical Model

Cointegration approach is a common tool for time-series analysis. It is defined as the constant difference between and independent variable Y_t and its estimator βX_t in which β is a scaling parameter (22). Particularly in this case, a time series analysis on the greenhouse gas emissions and the effects of certain specified variables will be employed. The analysis aims to frame the logarithmic model specified in Equation [1].

$$ln\ ln\ HE = f(ln\ ln\ GHG, ln\ ln\ GDP) \quad [1]$$

For any time-series, the unit root test is initially done to examine the error term stationarity between dependent variable and its covariates as they are time-series data. This avoids spurious regression brought upon by time as an inherent variable (23). If the error term between Y_t and βX_t passes the unit root test, it means that the data is stable, which rejects the hypothesis of having a unit root. Else, the data must be differenced, creating a stationary dataset. Dickey-Fuller Test is employed to test such hypothesis, in which that $\rho = 0$ for the following equation:

$$X_t = \rho X_{t-1} + \varepsilon_t \quad [2]$$

Where a variable at time t is to be regressed to its first lag. After such, the cointegrating relationship between Y_t and X_t will be subjected to an Autoregressive Distributed Lag (ARDL) test, in which the long-term parameters of the model are insignificant, that is, $\beta_i = 0 \; \forall \; i = 1, \ldots, k$ for the equation

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \sum_{i=2} \beta_{i-1} X_{i_{t-1}} + \varepsilon_t \quad [3]$$

The optimal lags are determined with the use of Akaike Information Criterion (AIC), thus testing the said null hypothesis of the ARDL bounds test (24). The error correction model estimates the long-run and short run values. The long run coefficients are estimated as:

$$Y_t = \mu_0 + \sum_{k=1} \mu_{1k} Y_{t-k} + \sum_{l=1} \sum_{k=0} \mu_{l(k+1)} X_{l_{t-k}} + \omega_t = \hat{Y}_t + \omega_t \quad [4]$$

The error correction term represents the difference among the observed and estimated long-term values of the exploratory variables:

$$ECT_t = Y_t - \hat{Y}_t = Y_t - \left(\mu_0 + \sum_k \mu_{1k} Y_{t-k} + \sum_l \sum_k \mu_{lk} X_{l_{t-i}}\right) \quad [5]$$

The short-run values are determined by regressing the first difference of dependent variable to the first differences of each independent variable and the error correction term first lags, that is,

$$\Delta Y_t = \gamma_0 + \sum_{k=1} \gamma_k \Delta Y_{t-k} + \sum_{l=1} \sum_{k=0} \theta_{l(k+1)} \Delta X_{l_{t-k}} + \lambda ECT_{t-1} + \Omega_t \quad [6]$$

The speed of adjustmentλ, which is the coefficient of the first lag defined as the rate per time period in which Y_t and X_{j_t} return to the common trend. If $\lambda < 0$, the error correction term pushes Y back towards the equilibrium, i.e., inducing a negative change in Y towards equilibrium.

The dependent and independent variables included in the paper are defined in Table 1, in which health spending per person is the dependent variable. The hypotheses on the relationships among each independent variable and the mentioned dependent variable are also stated.

Empirical Model

Table 1: Description of Variables and Their Hypotheses

Variable	Notations	Measurement	Hypothesis
Health expenditure	HE	Current health expenditure through out-of-pocket payments per capita (current US$, through out-of-pocket payments).	
Greenhouse gas emissions	GHG	Carbon dioxide emissions refer to those produced from the combustion of fossil fuels and the production of cement (annual total, in metric tons).	(+)
Gross Domestic Product	GDP	Annual real GDP (constant 2015 US$, adjusted for inflation).	(+)

Health cost per capita is expected to increase as GDP per capita increases, as it is logically sound since higher income would make give individuals better access to improving their health. Greenhouse gases positively affect health expenditures, as the effects of greenhouse gases on human health increases costs on health. The data used for the estimation were annual observations for the period 2000-2019 from the World Bank Development Database. The unrestricted regression equation for this paper is specified as:

$$\Delta\, ln\, ln\, HE_t = \theta_0 + \sum_{k=1}^{p} \theta_{1k} \Delta\, ln\, ln\, HE_{t-k} + \sum_{k=0}^{q} \theta_{2k} \Delta\, ln\, ln\, CO2_{t-k} + \sum_{k=0}^{q} \theta_{3k} \Delta\, ln\, ln\, GDP_{t-k} + \beta_0\, ln\, ln\, HE_{t-1} + \beta_1\, ln\, ln\, GHG_{t-1} + \beta_2\, ln\, ln\, GDP_{t-1} + \varepsilon_t$$

The following equation is regressed to test for stationarity:

$$ln\, ln\, HE_t = \alpha_0 + \alpha_1\, ln\, ln\, GHG_t + \alpha_2\, ln\, ln\, GDP_t + \varepsilon_t$$

where the residual ε_t is estimated as $\hat{\varepsilon}_t$ and be subjected to the Dickey-Fuller test. Once stationarity is established, this implies that $ln\, ln\, HE_t$ are cointegrated each with $ln\, ln\, GHG_t$ and $ln\, ln\, GDP_t$. The optimal lag is determined by

$$\ln \ln HE_t = \beta_0 + \sum_{k=1} \beta_{1k} \ln \ln HE_{t-k} + \sum_{k} \beta_{2k} \ln \ln GHG_{t-k} + \sum_{k} \beta_{3k} \ln \ln GDP_{t-k} + \varepsilon_t$$

in which the model with the least AIC score determines the optimal lag. Once the optimal lag is identified for each variable, the error correction can now be estimated. It will be using the specification determined by the optimal lags from the ARDL bound test, which also is the specification for the long-run elasticities.

The ECT is defined as

$$ECT_t = \ln \ln HE_t - \left(\beta_0 + \sum_{k=1} \beta_{1k} \ln \ln HE_{t-k} + \sum_{k} \beta_{2k} \ln \ln GHG_{t-k} + \sum_{k} \beta_{3k} \ln \ln GDP_{t-k} \right)$$

The short-run elasticity is specified as

$$\Delta \ln \ln HE_t = \gamma_0 + \sum_{k=1} \gamma_k \Delta \ln \ln HE_{t-k} + \sum_{l=1} \sum_{k=0} \theta_{l(k+1)} \Delta X_{l_{t-k}} + \lambda ECT_{t-1} + \Omega_t$$

Conceptual Framework

This research examines the interrelationships between economic growth (GDP), greenhouse gas (GHG) emissions, and health expenditure (HE) in East Asia, Southeast Asia, and the Pacific Islands. The framework is based on the recognition that economic and environmental factors are key drivers of health system demand and spending. Economic growth that is measured by gross domestic product (GDP) is hypothesized to have a positive causal relationship with health expenditure. As economies expand, governments and individuals typically allocate more resources toward health services due to increased fiscal capacity, greater demand for quality healthcare, technological advancements, and higher living standards. Previous studies supported these links which suggest that the rising incomes lead to increase per capita heath spending (15, 25, 26). Environmental degradation, especially GHG emissions is characterized to increase health spending by health burdens. Elevated pollution levels contribute to the incidence of respiratory illnesses, cardiovascular diseases, and other chronic health conditions (14, 22). This results in increased demand for medical services and government spending to address pollution-related health impacts. Therefore, GHG emissions are expected to have a positive impact on health expenditure. As economies expand, particularly those based on energy-intensive sectors, GHG emissions tend to rise as a result of increased consumption of fossil fuels and industrial processes. This relationship is extensively documented in the environmental Kuznets curve literature, which implies that emissions first increase with income before falling at higher incomes (12). Understanding this relationship also supports the indirect pathway by which GDP influences health expenditure through environmental externalities.

Figure 1 represents the conceptual model considered in this study. It displays both the direct relationship of GDP and GHG emissions to HE. The diagram highlights the hypothesized positive linkages which result that both economic growth and environmental factor contribute to the increased health spending.

Dataset

The data used in this research is from Our World in Data, a reliable and credible website that aggregates global data from reputable organizations like the World Bank, WHO, and the United Nations. The period from 2000 to 2021 was chosen to register long-term trends in environmental emissions, economic growth, and health expenditure as well as the effect of major worldwide events like the global financial crisis and the pandemic of COVID-19. The areas covered in this paper are East Asia, Southeast Asia, and the Pacific Islands. The Asia-Pacific region includes countries from East Asia like China, Japan, South Korea, and Mongolia; Southeast Asia such as Philippines, Brunei, Singapore, Indonesia,

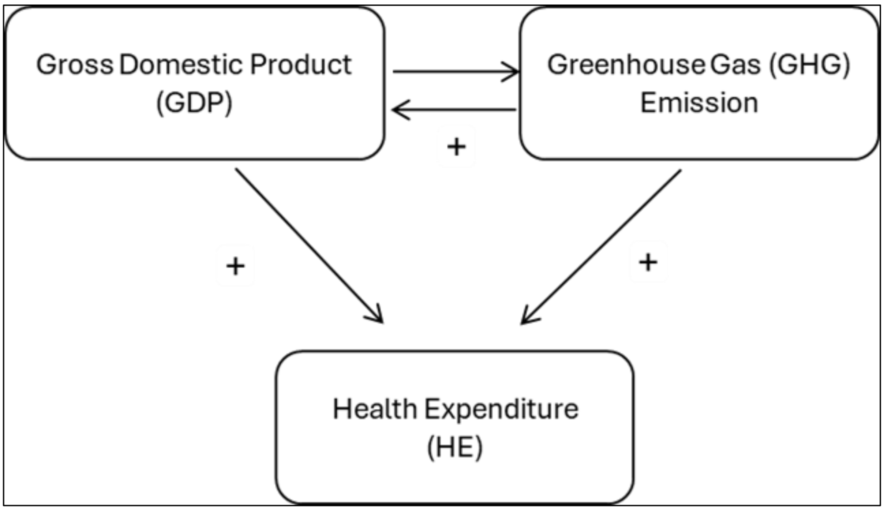

Figure 1: Conceptual Framework Illustrating the Relationship between GDP, GHG, and HE

and the Pacific Islands, which encompass the countries Palau, Samoa, Vanuatu, Tonga, Kiribati, Papua New Guinea, Tuvalu, Micronesia, the Solomon Islands, Fiji, Australia, New Zealand. These selected areas enable a detailed examination of countries with different levels of economic development, health systems, and environmental issues, thereby yielding useful insights into the interconnection between economic and environmental determinants and health expenditure. The chosen variables, such as health expenditure, greenhouse gas emissions, and GDP, are all well-established indicators in health economics and environmental research. In addition, the natural log transformation of the variables helps ensure that the data are normalized and that the analysis is of proportional changes and not absolute values, making it easier to interpret results.

Results and Discussion

Table 2 summarizes the data of health expenditures (HE), greenhouse gas (GHG) emissions, and gross domestic product (GDP) in the East Asia, Southeast Asia, and the Pacific Islands from 2000 to 2021. Average health expenditures are highest in East Asia ($1395.92 per capita), while Southeast Asia has the lowest health expenditure ($330.44). This disparity reflects the differences in economic development, health infrastructure, and government prioritization of health-related funding. Economic development is directly related to health expenditure, that is, as the nation's progress, they compelled to expand public expenditure (27). The Pacific Islands display relatively lower GHG emissions and GDP values compare to the other two areas. Skewness and kurtosis indicate varying levels of asymmetry and peaked, with Southeast Asia's HE being highly skewed and leptokurtic. The Jarque-Bera test outcomes indicate that the entire datasets are approximately normal and the Box-Pierce statistics reveal significant autocorrelation across all variables and regions.

Table 2: Summary Statistics of the Variables

	HE	GHG	GDP	HE	GHG	GDP
		East Asia			Southeast Asia	
Mean	1395.93	$2.96x10^{9}$	$3.47x10^{12}$	330.44	$3.69x10^{8}$	$2.08x10^{11}$
Maximum	5235	$1.37x10^{10}$	$1.58x10^{13}$	3969.89	$2.64x10^{9}$	$1.16x10^{11}$
Minimum	25.92	$1.67x10^{7}$	$3.82x10^{9}$	4.00	$1.15x10^{7}$	$1.07x10^{12}$
Std. Dev.	1552.78	$4.57x10^{9}$	$3.83x10^{12}$	593.73	$5.22x10^{8}$	$1.52x10^{12}$
Skewness	0.95	1	1.50	3.37	2.46	1.65
Kurtosis	-0.46	0	1.88	12.97	5.41	3.27
Jarque-Bera	1.9083	2.1861	1.6169	1.0667	1.2274	1.6900
Box-Pierce	16.315**	16.695**	16.621**	15.182**	12.036**	17.194**
Sample	22	22	22	22	22	22

Year	2000-2021	2000-2021	2000-2021	2000-2021	2000-2021	2000-2021
		Pacific Island			East, Southeast, and Pacific	
Mean	822.00	6.77x10^{7}	4.98x10^{9}	849.46	1.13x10^{9}	1.27x10^{12}
Maximum	848.31	8.27x10^{8}	2.85x10^{7}	3351.07	5.73x10^{9}	6.15x10^{12}
Minimum	20.66	3.70x10^{2}	2.22x10^{11}	16.86	9.42x10^{6}	2.94x10^{9}
Std. Dev.	1549.89	1.91x10^{8}	3.37x10^{11}	1232.13	1.68x10^{9}	1.46x10^{12}
Skewness	2.12	3.01	3.11	2.15	2	2.09
Kurtosis	3.24	7.39	8.27	5.25	4	4.47
Jarque-Bera	1.6982	1.7861	1.4124	1.6487	2.1664	0.3385
Box-Pierce	15.786**	7.5798*	16.731**	16.109**	16.763**	16.658**
Sample	22	22	22	22	22	22
Year	2000-2021	2000-2021	2000-2021	2000-2021	2000-2021	2000-2021

As shown in Figure 2, the map reveals a disparity in health expenditure per capita across the globe from 2019 to 2021, with countries shaded in dark blue representing the highest spending on health, while shaded in light colors represent lower health expenditure per capita. East Asia exhibits a moderate to high health expenditure with countries like Japan and South Korea investing significantly in healthcare (28, 29). While Southeast Asia countries like Singapore and Malaysia have higher expenditure due to strong economic development. However, many other Southeast Asian nations, particularly those with lower income levels have lower spending on healthcare. This can be attributed to factors like limited health resources and infrastructure (25). Lower health expenditure is also observed in Pacific Islands countries, which is due to region's low economies, geographical isolation, and limited resources. Many Pacific Island nations rely heavily on foreign aid to support their healthcare systems (30). There is an upward trend of greenhouse gas emission for all regions, as shown in Figure 3. East Asia, particularly China, significantly contributes more to greenhouse gas emissions compared to Southeast Asian countries and the Pacific region. The total greenhouse gas emissions of East Asia are higher than the average global greenhouse gas emissions around the world. Thus, there is a need to give efforts to low-carbon economies and mitigate climate change impacts (31).

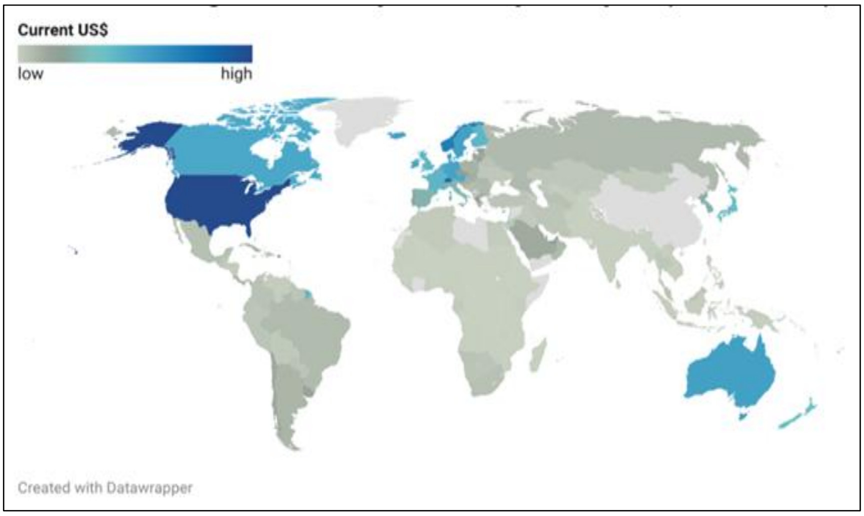

Figure 2: Average Health Expenditure (2019-2021)

As observed in Figure 4, East Asia has consistently maintained the highest GDP among the regions, reflecting strong economic growth over the years. While Southeast Asia has also faced a notable rise in GDP, its growth has been slightly slower compared to East Asia. In contrast, the Pacific region has a relatively lower GDP compared to both East and Southeast Asia, indicating significant economic disparities among the regions.

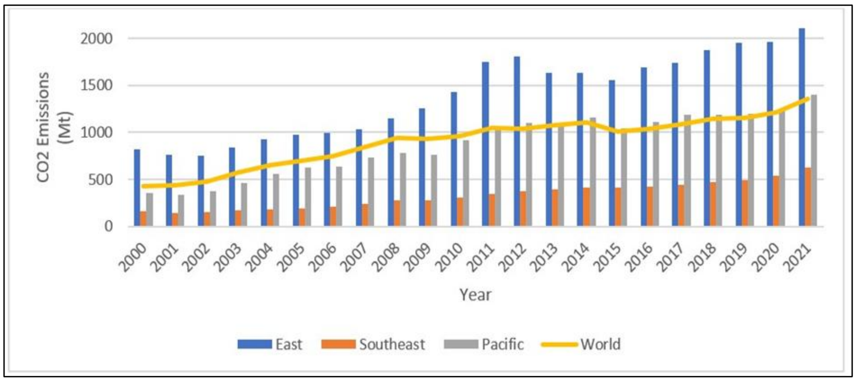

Figure 3: Distribution of Greenhouse Gas (GHG) Emission

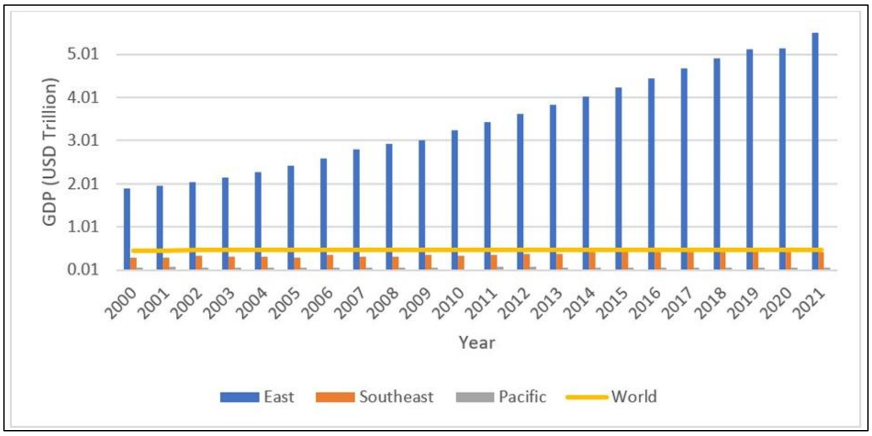

Figure 4: Distribution of Gross Domestic Product (GDP)

Correlation

Figure 5 shows that there is a strong direct association between health expenditure (HE), greenhouse gas (GHG) emissions, and gross domestic product (GDP). As GDP and GHG emissions increase, the health expenditure also increases. Economic expansion often leads to greater investment in healthcare services, while increase in emissions may elevate healthcare costs due to pollution-related diseases and health risks (26, 32, 33).

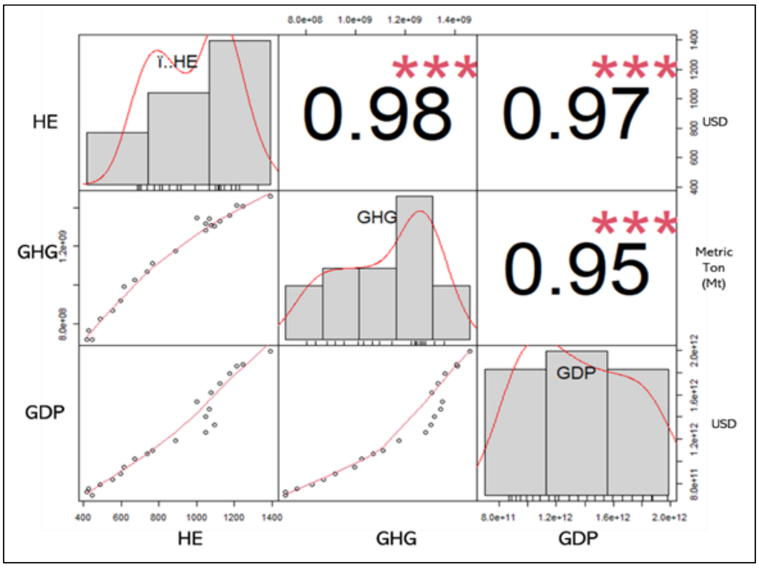

Figure 5: Correlation Result between Dependent Variable (HE) and Independent Variables (GHG and GDP)

Unit Root Test

Understanding the stationarity of the data is essential for using the appropriate models. The unit root test using the Dickey-Fuller (ADF) and Phillips-Perron (PP) tests will be employed to check the stationarity of all variables at their level form. As observed in Table 3, the variables LHE and LGHG are stationary at first difference in both the ADF and PP tests, while the variable LGDP is stationary at the level form without differencing in both tests.

Table 3: Test for Stationarity for All Countries

	ADF		P and P		Order of Integration
	Level	First Difference	Level	First Difference	
LHE	-0.9894	-3.8265*	-0.9894	-3.9389*	I (1)
LGHG	-0.2259	-4.4832*	-0.2362	-4.6632**	I (1)
LGDP	-5.5669**	-8.7857**	-6.8557**	-10.4208**	I (0)

* Significant at 0.05, ** significant at 0.01

Co-Integration Test Results

Table 4 displays the findings of the Johansen Cointegration test to examine the existence of a long-term association among the variables. P-values for the "None" hypothesis is statistically significant at the 1% level for both tests, while the p-value for the “At most 1” hypothesis is statistically significant at the 5% level. Thus, a long-term association exists among the variables analyzed in this study. The Fully-Modified OLS (FMOLS) regression results in Table 5 reveals that there exist a significant association between health expenditure (HE), greenhouse gas emissions (GHG), and GDP across East Asia, Southeast Asia, and the Pacific Island regions. For all regions, GDP has a positive and statistically significant impact on HE, suggesting that as economies grow, health expenditure tends to increase. Greenhouse gas emission in East Asia and the Pacific region has a positive and significant impact on health expenditure, which indicates that, an increase of GHG emissions lead to higher health spending, potentially due to pollution-related health issues. However, in Southeast Asia, the relationship between GHG emissions and HE is negative but not statistically significant.

Table 4: Johansen Cointegration Analysis

	Unrestricted Test		
	Trace Statistics	Rejection	P-value
None*	46.9445	29.7971	0.0002
At most 1*	17.4939	15.4947	0.0247
At most 2	1.2859	3.8415	0.2568
	Unrestricted Cointegration Rank		
None*	29.4509	21.1316	0.0027
At most 1*	16.2080	14.2646	0.0243
At most 2	1.2859	3.8415	0.2568

Table 5: Fully-Modified OLS (FMOLS)

Variable	Coefficient	t-Statistics	Prob
East Asia			
Constant	-10.0854	-12.6265	0.0000***
LGHG	0.8681	3.0331	0.0072***
LGDP	0.3989	1.9323	0.0692*
R-squared		0.9662	
Southeast Asia			
Constant	-11.9442	-8.7882	0.0000***
LGHG	-0.4721	-1.5156	0.1470
LGDP	1.6345	10.7863	0.0000***

R-squared		0.9766	
Pacific Island			
Constant	-36.2849	-6.8264	0.0000***
LGHG	1.3743	2.6957	0.0148**
LGDP	2.5708	12.4277	0.0000***
R-squared	0.9425		
East Asia, Southeast Asia, and Pacific Island (Overall)			
Constant	-12.1606	-25.03	0.0000***
LGHG	1.2692	6.6009	0.0000***
LGDP	0.2912	2.2724	0.0351**
R-squared		0.9870	

* Significant at 0.10, ** significant at 0.05, *** significant at 0.01

Granger Causality Test

The study differentiates between the short- and long-term impacts of economic growth and pollution on health spending through Granger causality. Short-run impacts are a near or instant relationship between variables, typically measured with annual. Though long-run impacts are ongoing, steady relationships over an extremely long time, for instance, stable trends over decades that indicate structural impacts on healthcare expenditure due to shifts in the economy or environment. The Granger causality test results in Table 6 provide insights into the dynamic short-run relationships between health expenditure (HE), greenhouse gas emissions (GHG), and gross domestic product (GDP) across East Asia, Southeast Asia, and the Pacific region. In East Asia, there is significant unidirectional causality among HE, GHG, and GDP, indicating that economic growth and greenhouse gas emissions positively impact health expenditure in the short run. The results for Southeast Asia are less conclusive with all the p-values are not significant, indicates that there is no short-run causal relationship between the variables. In the Pacific region, there is a short-run causal relationship between health expenditure and economic growth, as well as between greenhouse gas emissions and health spending. For the combined regions of East Asia, Southeast Asia, and the Pacific, there is a unidirectional short-run causal relationship between health expenditure and GDP. This suggests that economic growth is a significant driver of increased health expenditure across these regions.

Table 6: Short-Run Granger Causality Effect

Direction of Causality	Statistics	P-value
East Asia		
LHE▼ LGHG	5.6054	0.0606*
LHE▼ LGDP	11.9833	0.0025**
LGHG▼ LHE	0.9319	0.6275
LGDP▼ LHE	0.2176	9.8969
LGHG▼ LGDP	11.3401	0.0035**
Southeast Asia		
LHE▼ LGHG	1.0604	0.3031
LHE▼ LGDP	0.1781	0.6730
LGHG▼ LHE	2.0916	0.1481
LGDP▼ LHE	0.1433	0.9308
Pacific Region		
LHE▼ LGHG	0.3209	0.8517
LHE▼ LGDP	10.3611	0.0056**
LGHG▼ LHE	5.5253	0.0631*
LGDP▼ LHE	1.2035	0.5478
East Asia, Southeast Asian and Pacific (Overall)		
LHE▼ LGHG	1.8975	0.3872

LHE ▼ LGDP	11.2761	0.0036***
LGHG ▼ LHE	0.9305	0.6280
LGDP ▼ LHE	0.1281	0.9380

* Significant at 0.10, ** significant at 0.05, *** significant at 0.01

The long-run causality test results in Table 7 provide insights into the long-term relationships between health expenditure (HE), greenhouse gas emissions (GHG), and GDP across East Asia, Southeast Asia, and the Pacific Island. There exists a bidirectional long-run causality between health spending and GHG emissions, which implies that greenhouse gas emissions significantly impact health spending, and vice versa. Additionally, there is a unidirectional long-run causality from GDP to HE, indicating that economic growth significantly impacts health expenditure. There is a unidirectional long-run causality between HE and GHG emissions in the Southeast Asia region, while in Pacific region, there is a long-run relationship between health expenditure and GDP. Across the three regions, there is a bidirectional long-run relationship between health expenditure and GHG emissions, as well as among health expenditure and GDP.

Table 7: Long-Run Causality Effect

Direction of Causality	Coefficient
East Asia	
LHE ▼ LGHG	-1.7457*
LHE ▼ LGDP	-0.0016
LGHG ▼ LHE	-0.5728*
LGDP ▼ LHE	-611.8032*
Southeast Asia	
LHE ▼ LGHG	59.7423*
LHE ▼ LGDP	-25.0723
LGHG ▼ LHE	0.0167
LGDP ▼ LHE	-0.0400
Pacific Region	
LHE ▼ LGHG	-1.3652
LHE ▼ LGDP	-1.2811*
LGHG ▼ LHE	-0.7325
LGDP ▼ LHE	-0.8906
East Asia, Southeast Asian and Pacific (Overall)	
LHE ▼ LGHG	-1.6239*
LHE ▼ LGDP	-0.1595
LGHG ▼ LHE	-0.6158*
LGDP ▼ LHE	-6.2684*

Conclusion

The findings of the study reveal that there is a significant connection between greenhouse gas (GHG) emissions, economic growth, and health expenditures in East Asia, Southeast Asia, and the Pacific Islands, 2000 to 2021. Cointegration analysis demonstrates that both economic development and GHG emissions contribute to rising healthcare costs in the short and long term. Furthermore, research highlights regional disparities, with East Asia experiencing higher levels of health spending and GHG emissions compared to Southeast Asia and the Pacific Islands.

These findings underscore the growing influence of environmental factors, particularly GHG emissions, on health expenditure trends, emphasizing the need for a comprehensive understanding of these interconnected factors. Given the significant influence of GHG emissions and economic progress on health spending, policymakers should consider integrating climate change mitigation strategies with public health policies. Specifically, regional policies in East Asia, Southeast Asia, and the Pacific Islands should focus on reducing emissions while promoting sustainable economic growth. Governments in these regions must also invest in strengthening healthcare systems to prepare for the long-term health challenges posed by environmental changes. Further exploration is recommended to explore the underlying structures between these variables and to assess the effectiveness of different policy interventions aimed at balancing environmental sustainability and public health outcomes.

Abbreviations

None.

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Author Contributions

Pierre Giuseppe P. Gilles: Introductio, Methodology, Resa Mae R. Sangco: Results, Discussion, Conclusion.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

Ethics Approval

No ethical approval was required for this study since the dataset used is secondary data and readily accessible.

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