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Article

Does economic development influence environmental quality in the Asia-Pacific region? A panel regression analysis

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Abstract: This study delves into the intricate interplay between economic development and environmental quality in Asia-Pacific nations. It examines key economic indicators such as gross domestic product (GDP), gross national income (GNI) per capita, imports and exports, and their influence on environmental metrics like water productivity, carbon dioxide (CO_2) emissions, forest rents, and total resource rents. The results reveal a nuanced relationship: GDP per capita correlates positively with water productivity, suggesting enhanced efficiency, and is associated with lower CO_2 emissions, hinting at potential ecological benefits from economic progress. Conversely, GNI per capita shows a positive link with CO_2 emissions, possibly reflecting income disparities and consumption patterns. While exports show no clear influence on environmental factors, imports are found to have adverse effects on water efficiency. To tackle environmental challenges arising from economic development, the study emphasizes the importance of adopting sustainable development practices and calls for a deeper investigation into the specific variables influencing this relationship at a local level.

Keywords: economic development; environmental quality; water productivity; CO_2 emissions; forest rents; total resource rents; import and export; Asia-Pacific region

1. Introduction

The two main challenges in human development are the economy and good quality of the environment. The impact of economic development on the quality of the environment continues to be unknown. These problems are inextricably linked. The threat of climate change, particularly in poor countries where it threatens the livelihoods and safety of vulnerable populations, is also a threat to social prosperity. Rapid urbanization, increased consumption by a growing middle class, and the need for new infrastructure to sustain high economic growth continue to fuel resource-intensive growth in developing countries of Asia and the Pacific. This growth has come at a high cost: Degraded resources and ecosystems, exacerbated water stress, and increased levels of dangerous waste generated. Public health and people's well-being have been negatively affected by these challenges. The poor are the hardest hit by increased pressure on environmental capacity. These problems are expected to worsen as a result of climate change [1].

If economic growth is taken into consideration, decisions pertaining to environmental quality may prove advantageous. The unsettling reality is that there are extremely few instances of perfect alignment. Consequently, towns and people frequently have to choose between economic growth and environmental protection. The ecology will not perish as a result of economic progress. Developments could lead to an increase in the possibilities available, for instance, through the discovery of new methods and enhanced energy generation. People's willingness to contribute a portion of their income to maintaining a clean environment can also rise with economic development. Financial success is irrelevant, and when people are doing well, it is possible to enhance the environment without sacrificing essential necessities [2].

By 2030, inclusive, safe, resilient, and sustainable cities are the target of Sustainable Development Goal 11. This includes the delivery of basic services, reasonably priced housing, improved traffic safety, and an adaptable transit network. Prioritizing the needs of women, children, the elderly, and people with disabilities also aims to reduce financial losses and promote sustainable population management. The objective also covers minimizing environmental effects, promoting green areas, and cultivating social, economic, and environmental ties. Cities are increasingly putting policies and initiatives that promote inclusivity, resource efficiency, and disaster risk reduction into place since the 2015 Sendai Framework for Disaster Risk Reduction [3,4].

While efforts are being made to address sustainable development, there are also policy issues. Most governments subscribe to issues related to global warming and other climate issues, but this is only sometimes the case. In order to meet the needs of a country or population, policy agendas sometimes do not take into account environmental concerns and sustainability goals. For example, we're promoting and supporting existing fossil fuel industries because they support poor communities and regions. Some communities may be at risk of unemployment and poverty due to the closure or lack of replacement of certain businesses. Changes related to sustainable development initiatives are resisted by a large number of governments in these regions. The support of special interests and groups opposed to the Sustainable Development Goals and incompatible ideologies often brings political parties to power. Fossil fuel companies and activists, for example, are supporting them. When in power, governments have policies that are not compatible with their support base, and it is difficult to change them by means of decision-making [5–7].

Using panel data analysis, this study aims to establish a relationship between economic development and the quality of the environment in selected East Asia and Pacific regions, such as the Philippines, Thailand, Vietnam, Singapore, Japan, Cambodia, Mongolia, Brunei Darussalam, Indonesia and Timor-Leste. Panel data analysis technique, which allows for the analysis of selected economic indicators. The available data from the World Bank website were used for this purpose.

Addressing the interconnected challenges of global poverty reduction, climate change mitigation, and environmental preservation is a critical priority for humanity today. The complex relationship between these issues is evident in low-income nations, where climate change endangers vulnerable communities, putting economic well-being at risk. Moreover, as household incomes rise, enabling greater access to vehicles and larger homes, the carbon footprint escalates. Notably, economic shifts can influence environmental conditions, mirroring the economic repercussions of environmental changes [2].

Environmental sustainability encompasses the preservation of long-term ecosystem health, protection of future productivity, and maintenance of natural resources. When making economic decisions, it is vital to consider not only present costs but also the impact on future generations. Utilizing renewable energy sources like solar and wind power can mitigate the effects of global warming and safeguard the environment. The development of pharmaceuticals and technology underscores the importance of conserving biodiversity. Historically, economic policy has prioritized utility maximization over long-term sustainability. Arthur Pigou's introduction of external costs in 1920 laid the foundation for a framework that incorporates present and potential external costs of environmental sustainability. This approach ensures the availability of natural resources for future generations and empowers them to make informed choices [8,9].

This study seeks to explore the interplay between economic growth and environmental quality, focusing on metrics such as GDP per capita, GNI per capita, exports, and imports of goods and services. Its primary goals include uncovering the key drivers of economic development, identifying essential indicators for gauging environmental quality, examining how economic progress influences environmental conditions in selected Asian countries, and elucidating the notable relationship between environmental quality and economic development within these specific regions. The study focuses only on four selected economic indicators, namely (1) GDP per capita; (2) GNI per capita; (3) exports of goods and services; and (4) imports of goods and services, and environmental indicators such as CO_2 emissions, forest rents, water productivity, and total natural resource rents of selected countries in the Asia-Pacific region, namely: Philippines, Thailand, Vietnam, Singapore, Japan, Cambodia, Mongolia, Brunei Darussalam, Indonesia and Timor-Leste. Furthermore, this work is aligned with Sustainable Development Goals (SDGs) Goal 7 (Affordable and Clean Energy), Goal 11 (Sustainable Cities and Communities), Goal 12 (Responsible Consumption and Production), and Goal 13 (Climate Action).

2. Review of related literature

2.1. Gross domestic product per capita on environmental quality

Grossman and Krueger propose that the EKC hypothesis suggests that GDP per capita income and environmental quality are negatively associated in an inverse U-shape [10]. Nevertheless, another research by Alvarez-Herranz and Balsalobre-Lorente points out an alternative view of life cycle confounding N-shaped relationships between GDP per capita and environmental quality [11]. On the one hand, it has been established that social globalization and financial growth reduce degradation while CO_2 emissions are tied to GDP per capita. Additionally, sustainable development calls for curtailment of hazardous technologies as well as scaling up economic output while engaging in environmentally sound practices [12]. For example, according to some surveys done on this topic, there was a strong positive correlation between 2020 Environmental Performance Index scores and GDP per capita in 2018. However, relative incomes among nations do not match their environmental performance in some cases, implying that there may be factors other than GDP per capita [13]. The study by Wang et al., therefore, examines the intricate relationship between economic development and environmental degradation with particular attention to an inverted U-shaped curve representing the impact of per capita income on environmental deterioration. The different determinants of this variation include governmental regulations [14,15].

2.2. Gross national income per capita on environmental quality

GNI per capita serves as an important measure of a nation's economic health and its connection to environmental quality. An increase in GNI may reflect economic growth, but it can also result in environmental harm if not approached sustainably. Nations with higher GNI usually possess the financial means to invest in safeguarding the environment and adopting sustainable practices. It is vital to find a balance between economic advancement and environmental conservation, and implementing policies that encourage sustainable development and prudent resource management can be beneficial [16–18]. The literature review examines the correlation between Gross National Income (GNI) per capita and environmental quality through the lens of the Environmental Kuznets Curve (EKC) framework. It proposes an inverted U-shaped relationship where early increments in emissions lead to adverse environmental effects. Nevertheless, research findings on the connection between financial development and environmental quality differ, with some studies backing the EKC hypothesis and others yielding inconsistent outcomes [19]. One research project investigates the impact of economic inequality on environmental quality across different sectors. The findings indicated that various sectors respond differently to income inequality concerning sector-specific emissions. The research emphasized the importance of considering sectoral differences when formulating policies aimed at reducing carbon emissions [20].

2.3. Imports of goods and services on environmental quality

In order to control the ecological impact and to eliminate the harm caused by climate change, taking into consideration that loss of biodiversity is one of the main contributions to climate change, requires environmental goods and services. These materials have an impact on the quality of the air and water there. A continuity of the low-carbon economy should be based on the success of eastern greenhouse gases and many energy revolutions. By meeting through multinational agencies and making a framework for multilateral trading, more nations can explore the use of EGS [21]. The items can be used either for environmental or non-environmental uses in the end, the likelihood of pollutant decrease and enhancement of environmental quality are enhanced, indicating a study on the relationship of foreign environmental goods purchases to pollution intensity. If studies showed that stipulations like type A EGs and imported environmental goods consistently fail to enhance the quality of the environment, however, type B EGs, which provide alternatives to primary emitting factors and impel technology improvement, may help anything the opposite. The data from the report revealed that total imported EGs can influence their respective industries and further result in curbing the environment [22]. The finding emerged that the cleansing technologies, as well as products, in every way contribute to environmental regulation and income growth through the process, but importing the end-of-pipe items becomes environmentally cleaner. The results of the study suggest that although trade integration increases the level of water pollution through an income effect, it decreases the level of CO_2 emissions. The paper presented two major results on the conditions of EGs. First, the different kinds of categorization proved to be very important as it affected the findings of the research; second, although the market is globalizing, the perspective of equal rules in trading across the world for EGs is unrealistic [23]. Eco-fertilizer imports could help lower emissions and work best in the context of environmental goals as suggested by the study that looks at CO_2 emissions generated through import intermediates consumption. The article utilizes data from the Chinese prefecture-level statistics between 2000 and 2016, which reveals that the geographic locale, air pollution, sustainable development, as well as the efficiency of the government have a certain role in the outcome. The findings produce a ground for a trade-linked environment to be regularized [24].

2.4. Exports of goods and services on environmental quality

According to the study, panel cointegration techniques were used to examine how enhancing export quality affected environmental sustainability. With a 1% increase in the export quality index translating into a 0.71% increase in CO_2 emissions, it was found that improving export quality raises carbon-intensive emissions. However, the relationship is nonlinear, suggesting that if a certain threshold is reached, improvements in energy use, economic growth, transportation, and trade openness can reduce CO_2 emissions [25]. With global accords like the Paris Agreement calling for the removal of customs taxes on environmentally friendly products, the trade community has been aggressively tackling sustainability and climate issues. Despite continuous debates and sluggish trade liberalization progress, there has been a noticeable increase in the international commerce of environmental commodities. Between 2001 and 2007, the total export value of environmental commodities increased by 100%, according to data from the United Nations Environment Programme (UNEP). In 2014, the UN Environment Programme published a report titled "South-South Trade in Renewable Energy—A Trade Flow Analysis of Selected Environmental Goods". This dataset has made it easier to create tables and maps that show trade trends, top nations, main markets, and possible distinctions between conventional and environmental goods [26]. A study of how international commerce affected the environment in Sub-Saharan Africa (SSA) from 1990 to 2020 found that trade is linked to international commerce has been linked to a reduction in environmental pollution of approximately 0.10% in the short term and 0.79% in the long term, according to a study of the environmental effects of trade in Sub-Saharan Africa (SSA) conducted between 1990 and 2020 [26]. The impact of imports and exports on regional pollution is comparable. The short-term and long-term reductions in pollution were around 0.07% and 0.45%, respectively, for exports and 0.08% and 0.58%, respectively, for imports. According to Duodu and Mpuure (2023), the study highlights the necessity for trade initiatives to concentrate on improving the energy and environmental efficiency technologies associated with the manufacturing and transportation of goods and services that are imported and exported [27].

2.5. Synthesis of the study

According to recent studies, environmental quality and economic growth are positively correlated in Asian countries [17,18,28]. This is consistent with the idea of the Environmental Kuznets Curve, which holds that governments are inclined to make greater investments in ecologically friendly policies as they advance. Strong institutions and environmental policies must be established in order to achieve sustainability. Regional differences may exist in this relationship, but long-term sustainability necessitates striking a balance between economic growth and ecological preservation [17,18,29]. A sustainable future for Asia requires a holistic approach that takes into account the needs of the economy, society, and environment. Because so many things affect it, the relationship between environmental quality and economic growth is complicated. Pollution is directly impacted by population growth since it raises resource consumption, which in turn impacts the ecosystem. Research has shown that population expansion contributes to environmental deterioration, as do resource availability and energy consumption. Public health can be greatly impacted by individual habits, occupations, educational attainment, walkability, availability to green areas, and air and water quality. Although imposing carbon taxes has been successful in reducing CO_2 emissions and improving environmental quality, the economy may suffer as a result. While technology developments can help stop pollution from occurring or being released, environmental improvements can result in a decrease in CO_2 emissions. Importing products and services also helps to reduce environmental damage and manage the ecological imprint. Importing end-of-pipe (EG) products, which contribute to pollution reduction and environmental quality improvement, may be one way to do this. Trade integration can reduce CO_2 emissions while also increasing water pollution because of income implications. Importing eco-fertilizers helps reduce emissions, particularly when it is in line with environmental goals. According to the Yuan et al. study, specific classifications are essential, and rules should be applied consistently to all EGs that are sold worldwide. Geographical location, air pollution levels, sustainable development objectives, and the efficacy of governmental initiatives are some of the variables that affect how trade affects the environment [17,18,24]. Ultimately, creating sustainable development agendas that attempt to lessen the ecological implications of population growth, economic expansion, and environmental quality requires a knowledge of the intricate relationships between these factors.

2.6. Gap bridged

Despite the numerous studies undertaken by various scholars, there have been few focuses within Asia that have unique economic and environmental challenges. The study uses panel regression analysis which combines cross-sectional and time-series data to see if there is a relationship between the governments' policies, technological changes, public awareness and environmental quality. The research offers useful insights for policy-makers, academics and practitioners who are interested in sustainable economic development in the area.

2.7. Theoretical framework

According to the Environmental Kuznets Curve (EKC) theory as shown in **Figure 1**, a country's economic development stages and environmental deterioration are related. There is disagreement over this theory despite plenty of research. According to the EKC hypothesis, when income levels approach a turning point, economic growth improves the environment after initially making things worse. Environmental experts contend that the environment may be endangered by an exclusive concentration on economic growth. According to the argument, the most effective approach to remedy environmental degradation is through economic growth [30–32].

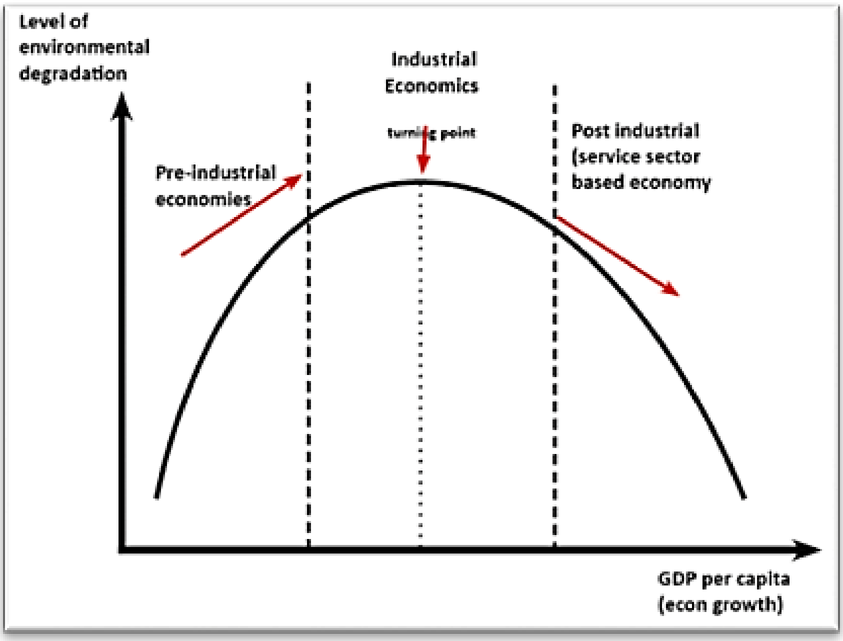

Figure 1. Environmental Kuznets Curve (EKC) theory.

2.8. Conceptual framework

Conceptual framework as shown in **Figure 2** demonstrates the relationship between economic development and environmental quality. It illustrates how independent variables influencing environmental quality include GDP per capita, GNI per capita, exports, and imports of commodities and services. The quality of the environment deteriorates when any of these factors rise. The strain on the environment increases as a country's economy develops.

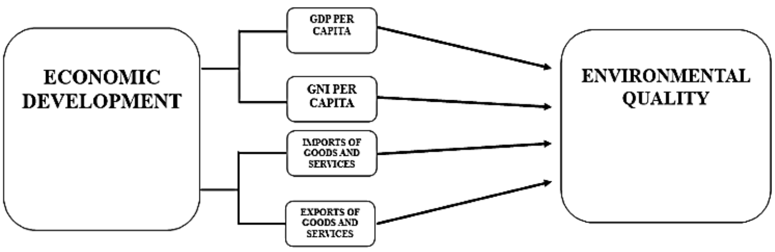

Figure 2. Conceptual framework of the study.

2.9. Definition of terms

Economic Development—economic transformation of a country or an area that results in the improvement of the well-being and economic capacity of its population [17,18,33].

GDP Per Capita—is the total value added by all resident producers, including any product taxes or subsidies not included in output valuation, divided by the mid-year population [17,18,34].

GNI Per Capita—is a measure used to compare the average income earned by a country's population, providing insights into the standard of living and economic well-being, enabling comparison of economic development and prosperity levels [17,18,34].

Import of Goods and Services—include the value of goods and market services received from the rest of the world, including merchandise, freight, insurance, transport, travel, royalties, license fees, and services, excluding employee compensation, investment income, and transfer payments [17,18,34,35].

Exports of Goods and Services—Exports involve transactions between residents and non-residents, including sales, barter, gifts, and grants. They impact a country's economy, profitability, worker wages, global competitiveness, and economies of scale. Exports are calculated as a percentage of GDP by dividing exports by GDP [17,18,34,35].

Environmental Quality—Environmental quality refers to the natural resources of the planet, free from artificial impurities or waste products, and is subjective and affects the satisfaction of wants and needs [16–18,34,35].

Carbon Dioxide (CO_2)—a colorless gas with a sour taste and a little harsh smell. It is among the most significant greenhouse gases connected to climate change [34–36].

Forest Rents—are the products of local pricing and a local rental rate multiplied by the roundwood harvest [34,35].

Water Productivity—is the quantity of value produced in terms of advantages and services for each volume of water used [34,35].

Total Natural Resources Rents—The total of the following is the rent for natural resources: Oil, natural gas, hard and soft coal, minerals, and forest resources [34,35].

3. Methodology

The paper conducted statistical tests on the influence of economic development and environmental quality in the Asia-Pacific region over the period 2011–2020. The data were gathered from the World Bank website. Panel regression analysis was a component of our research design that enabled us to examine both cross-sectional and time-series data.

3.1. Research design

The researchers will use a quantitative method in this study. The causal-explanatory design was chosen to elucidate the effect of economic development on environmental quality. This design allows us to establish a cause-and-effect relationship and understand how changes in economic development indicators (independent variables) influence environmental quality (dependent variable).

3.2. Source of data

The study utilized data spanning from 2011 to 2020. Secondary data was sourced from reputable organizations such as the World Bank. These organizations supply comprehensive and reliable data regarding various environmental and economic factors for countries in the Asia-Pacific region. To gather essential and dependable information, the researchers employed data mining techniques, which were then used as inputs for the panel regression analysis. Only ten (10) countries data from 2011–2020 were included because other countries lacked data on the a priori variables utilized in this study. The exclusion of these countries was necessary to maintain the integrity of the analysis and prevent potential distortion caused by missing or incomplete data [37–39].

3.3. Data gathering procedure

The World Bank website was the source of the secondary data. Microsoft Excel was used to obtain and filter the study's four required variables. The data was arranged appropriately using Microsoft Excel. Additionally, the researchers used econometric methods for data analysis and treatment.

3.4. Research instruments

The World Bank provided secondary data that the researchers could obtain and analyze. Computer software was used for data evaluation, while econometric tools and Microsoft Excel were used for statistical analysis.

3.5. Ethical considerations

The research committed to academic honesty and proper citation, using secondary data available to the public. Employing panel regression analysis, it investigated the connection between economic development and environmental quality in the Asia-Pacific Region, offering insightful information that transcends national boundaries. This work utilizes secondary data; therefore, ethical clearances do not apply and are not necessary.

3.6. List of variables

Table 1 shows the code, description, and measures of the dependent and independent variables of the study. The list of variables used in the study was gathered from the World Bank website, with a coverage of 10 years, from 2011 to 2020.

Table 1. List of variables.

Variables	Code	Description	Measures
Dependent Variables	EnQ	Environmental Quality	Carbon Dioxide (CO_2), Forest Rents, Water Productivity, Total Natural Resources Rents.
Independent Variables	GDP PerC	Gross Domestic Product Per Capita	Gross Domestic Product Per Capita (constant 2015 US$) data was collected from the World Bank.
	GNI PerC	Gross National Income Per Capita	Gross National Income Per Capita (constant 2015 US$) data was collected from the World Bank.
	EXGOSE	Exports of Goods and Services	Exports of Goods and Services (constant US$) data was collected from the World Bank.
	IMGOSE	Import of Goods and Services	Imports of Goods and Services (constant US$) data was collected from the World Bank.

3.7. Data analysis

The researcher employed panel linear regression. It was utilized to reveal the influence of (1) GDP per capita; (2) GNI per capita; (3) exports of goods and services; and (4) imports of goods and services and the environmental quality of the ten countries involved. The econometric model below was used for panel regression analysis. Moreover, this work employed causal-explanatory research design. Causal analysis is an econometric design that is concerned with establishing cause and effect between given variables [17,18].

$$\mathrm{d} = \beta_0 + \beta_{1i} + \sum_{m=1}^{m} \delta_m r_m$$

The following multiple linear regression model with multiple independent variables was used in the study:

$$\mathrm{CO2} = \beta_0 + \beta_{1GDP\ PerC} + \beta_{2GNI\ PerC} + \beta_{3EXGOSE} + \beta_{4IMGOSE} + \varepsilon$$

$$\mathrm{FR} = \beta_0 + \beta_{1GDP\ PerC} + \beta_{2GNI\ PerC} + \beta_{3EXGOSE} + \beta_{4IMGOSE} + \varepsilon$$

$$\mathrm{WP} = \beta_0 + \beta_{1GDP\ PerC} + \beta_{2GNI\ PerC} + \beta_{3EXGOSE} + \beta_{4IMGOSE} + \varepsilon$$

$$\mathrm{TNRR} = \beta_0 + \beta_{1GDP\ PerC} + \beta_{2GNI\ PerC} + \beta_{3EXGOSE} + \beta_{4IMGOSE} + \varepsilon$$

where:

CO_2—dependent variable.

FR—dependent variable.

WP—dependent variable.

TNRR—dependent variable.

β_0—is the intercept term, representing the value of the dependent variable when all independent variables are zero.

$\beta_{1\mathrm{GDP\ PerC}}$—is one of the independent variables represented by *GDP PerC* and its coefficient β_1.

$\beta_{2\mathrm{GNI\ PerC}}$—is one of the independent variables represented by *GNI PerC* and its coefficient β_2.

$\beta_{3\mathrm{EXGOSE}}$—is one of the independent variables represented by *EXGOSE* and its coefficient β_3.

$\beta_{4\text{IMGOSE}}$—is one of the independent variables represented by *IMGOSE* and its coefficient β_4.

$\sum_{m=1}^{m} \delta_m r_m$—represents the sum of multiple independent variables, each term is the product of a coefficient δ_m and a variable r_m.

m—represents the index of the variables in the summation, ranging from 1 to m.

δ_m—is the coefficient associated with the m-th independent variable r_m.

r_m—represents the m-th independent variable in the regression model.

3.7.1. Fixed-effects model

Fixed-effects regression is employed in this study to analyze the impact of economic development on environmental quality in the Asia-Pacific Region. This statistical method controls for unobserved heterogeneity, addressing country-specific and time-invariant factors. The analysis incorporates variables such as environmental quality, GDP per capita, GNI per capita, exports, and imports, facilitating a more precise examination of the interplay between economic indicators and environmental outcomes.

The following fixed-effects regression model was used in the study:

$$CO_{2it} = \beta_0 + \beta_{1GDP\ PerCit} + \beta_{2GNI\ PerCit} + \beta_{3EXGOSEit} + \beta_{4IMGOSEit} + \alpha_i + \varepsilon_{it}$$

$$FR_{it} = \beta_0 + \beta_{1GDP\ PerCit} + \beta_{2GNI\ PerCit} + \beta_{3EXGOSEit} + \beta_{4IMGOSEit} + \alpha_i + \varepsilon_{it}$$

$$WP_{it} = \beta_0 + \beta_{1GDP\ PerCit} + \beta_{2GNI\ PerCit} + \beta_{3EXGOSEit} + \beta_{4IMGOSEit} + \alpha_i + \varepsilon_{it}$$

$$TNRR_{it} = \beta_0 + \beta_{1GDP\ PerCit} + \beta_{2GNI\ PerCit} + \beta_{3EXGOSEit} + \beta_{4IMGOSEit} + \alpha_i + \varepsilon_{it}$$

where:

CO_{2it}—CO_2 emissions for country i in year t.

FR_{it}—Forest rents for country i in year t.

WP_{it}—Water productivity for country i in year t.

$TNRR_{it}$—Total natural resources rents for country i in year t.

$GDPPerC_{it}$—GDP per capita for country i in year t.

$GNI\ PerCit_{it}$—GNI per capita for country i in year t.

$EXGOSE_{it}$—Exports of goods and services for country i in year t.

$IMGOSE_{it}$—Imports of goods and services for country i in year t.

α_i—This represents the fixed effect for each country (i). It captures the time-invariant characteristics of each country that are not included in the independent variables.

β_0—This is the intercept term.

β_1—his represents the coefficient for each independent variable.

ε_{it} −error term for i country in year t.

3.7.2. Random-effects model

The random-effects model is an effective method for analyzing panel data, which involves repeated observations of the same individuals or groups over time. It enhances generalizability by accounting for unobserved heterogeneity and is capable of incorporating time-invariant variables. The model operates under the assumption that unobserved factors influencing the dependent variable are randomly allocated across the population, thereby enabling inferences regarding the average impact of independent variables. Additionally, it integrates time-invariant variables such as geographic location, gender, race, and education level.

The following random-effects regression model was used in the study:

$$CO_{2it} = \beta_0 + \beta_{1GDP\ PerCit} + \beta_{2GNI\ PerCit} + \beta_{3EXGOSEit} + \beta_{4IMGOSEit} + u_i + \varepsilon_{it}$$

$$FR_{it} = \beta_0 + \beta_{1GDP\ PerCit} + \beta_{2GNI\ PerCit} + \beta_{3EXGOSEit} + \beta_{4IMGOSEit} + u_i + \varepsilon_{it}$$

$$WP_{it} = \beta_0 + \beta_{1GDP\ PerCit} + \beta_{2GNI\ PerCit} + \beta_{3EXGOSEit} + \beta_{4IMGOSEit} + u_i + \varepsilon_{it}$$

$$TNRR_{it} = \beta_0 + \beta_{1GDP\ PerCit} + \beta_{2GNI\ PerCit} + \beta_{3EXGOSEit} + \beta_{4IMGOSEit} + u_i + \varepsilon_{it}$$

where:

CO_{2it}—CO_2 emissions for country i in year t.

FR_{it}—Forest rents for country i in year t.

WP_{it}—Water productivity for country i in year t.

$TNRR_{it}$—Total natural resources rents for country i in year t.

$GDPPerC_{it}$—GDP per capita for country i in year t.

$GNI\ PerCit_{it}$—GNI per capita for country i in year t.

$EXGOSE_{it}$—Exports of goods and services for country i in year t.

$IMGOSE_{it}$—Imports of goods and services for country i in year t.

β_0—This is the intercept term.

β_1—his represents the coefficient for each independent variable.

u_i —Random effect for country *i*. This term captures the unobserved heterogeneity across countries, but it’s treated as a random variable drawn from a distribution with a mean of zero.

ε_{it} −error term for i country in year t.

3.7.3. Hausman test

The Hausman test is a statistical method that evaluates and compares coefficient estimates from fixed-effects and random-effects models. It tests the null hypothesis asserting that the random-effects model provides consistent and unbiased estimates. A rejection of this hypothesis suggests that a fixed-effects regression is preferable. To conduct the Hausman test, one must obtain coefficient estimates and variance-covariance matrices from the chosen statistical software, calculate the H statistic, and compare the results against the critical value [17,18,37–39].

Fixed-effects model:

$$CO_{2it} = \beta_0 + \beta IV_{it} + \alpha_i + \varepsilon_{it}\ (fe)$$

Random-effects model:

$$CO_{2it} = \beta_0 + \beta IV_{it} + u_i + \varepsilon_{it}\ (re)$$

4. Results and discussion

4.1. Economic development of Asia-Pacific region from 2011 to 2020

Figure 3 shows the gross domestic product per capita of Asia-Pacific countries from 2011–2020. Singapore possesses the highest GDP per capita, followed by Japan, Brunei Darussalam, and Thailand, while the Philippines, Vietnam, and Timor-Leste record the lowest figures. The chart illustrates the GDP per capita for ten nations from 2011 to 2020. Over the last decade, GDP per capita has generally risen across the region, although there have been significant differences in growth rates between countries. A similar report by the Asian Development Bank indicates that Southeast Asia's GDP per capita has been consistently rising, with Singapore, Malaysia, and Thailand standing out as the top three countries in the region. This result underscores significant economic disparities within Asia-Pacific region, with countries like Singapore and Japan leading in GDP per capita while others like the Philippines, Vietnam, and Timor-Leste lag behind. The overall upward trend in GDP per capita across the region highlights economic dynamism but also emphasizes the need for targeted policies to bridge the gap between high- and low-performing countries [17,18,40].

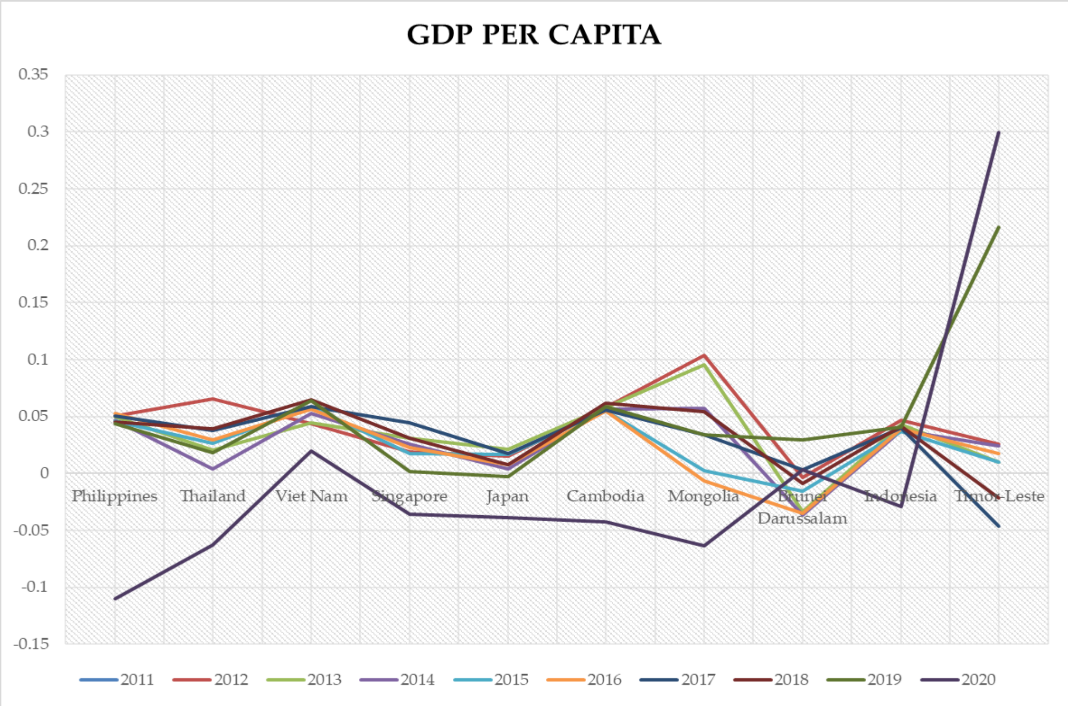

Figure 3. Gross domestic product per capita of Asia-Pacific region (2011–2020).

Figure 4 illustrates gross national income per capita of Asia-Pacific countries from 2011 to 2020. Singapore boasts the highest GNI per capita, followed by Brunei Darussalam, Japan, and Thailand among the ten nations from 2011 to 2020. Conversely, Timor-Leste, Vietnam, and the Philippines report the lowest figures. Throughout the last decade, there has been a general increase in GNI per capita across the region, although there are significant differences in growth rates among various countries. A relevant report from the World Bank titled "Poverty and Shared Prosperity in Southeast Asia" highlights this steady growth and attributes it to robust economic advancement in several nations, particularly Singapore, Malaysia, and Thailand. The trends showcase significant disparities, with countries leading in economic prosperity and others lagging behind. Despite an overall increase in GNI per capita, varying growth rates suggest uneven progress. Policymakers should focus on reducing disparities, stimulating growth, and enhancing shared prosperity across the region [17,18,41,42].

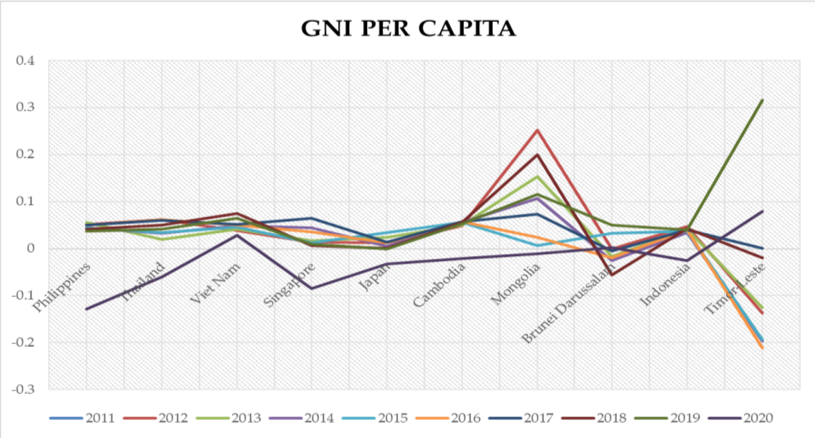

Figure 4. Gross national income per capita of Asia-Pacific region (2011–2020).

Figure 5 reveals the imports of goods and services among Asia-Pacific countries from 2011–2020. Singapore ranks first among countries in terms of imports, followed by Thailand, Vietnam, and Indonesia. In contrast, the countries with the lowest rankings are the Philippines, Cambodia, Mongolia, and Timor-Leste. The chart illustrates the imports of goods and services for ten countries from 2011 to 2020. While growth rates vary significantly among these nations, overall imports in Southeast Asia have been on the rise over the past decade. This growth is primarily attributed to robust economic progress in several countries, with Singapore, Malaysia, and Thailand at the forefront, according to research conducted by the United Nations Conference on Trade and Development (UNCTAD). The import trends highlight disparities in trade activity and economic development across the region. With Singapore leading in imports and countries like Thailand, Vietnam, and Indonesia following closely behind, there is a clear indication of varying levels of trade intensity. The lower import rankings of the Philippines, Cambodia, Mongolia, and Timor-Leste suggest challenges in trade engagement. Despite this, the overall increase in imports signifies growing economic interconnectedness. Policymakers can leverage successful strategies from leading importers to promote trade engagement, foster economic development, and work towards greater regional integration for sustained growth and prosperity [17,18,43].

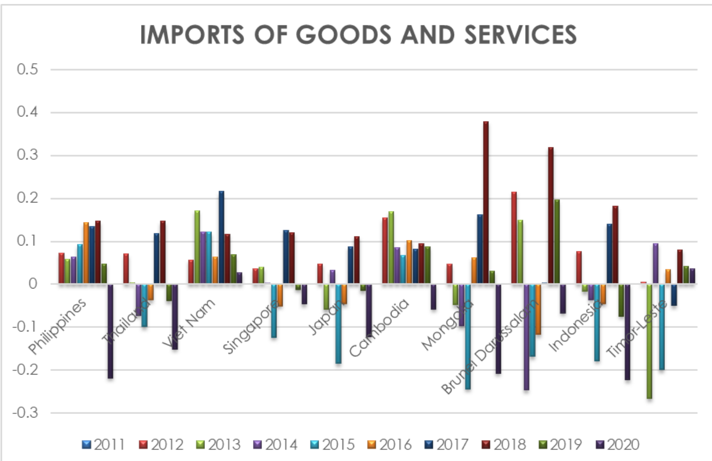

Figure 5. Imports of goods and services among Asia-Pacific countries (2011–2020).

Figure 6 reveals the exports of goods and services among Asia-Pacific countries from 2011–2020. Singapore leads as the top exporter, with Thailand, Vietnam, and Indonesia following closely behind, according to data reflecting exports of goods and services among ten Asian countries from 2011 to 2020. Conversely, the countries with the lowest export performance include Timor-Leste, Cambodia, the Philippines, and Mongolia. Although growth rates vary among the nations, overall exports in the region have risen in the past decade. A report from the World Trade Organization (WTO) indicates that this export growth has been driven by strong economic development, particularly evident in Singapore, Malaysia, and Thailand. Policymakers can leverage successful export strategies from leading nations to boost trade performance, drive economic growth, and enhance regional integration for sustained prosperity in Asia-Pacific [17,18,44].

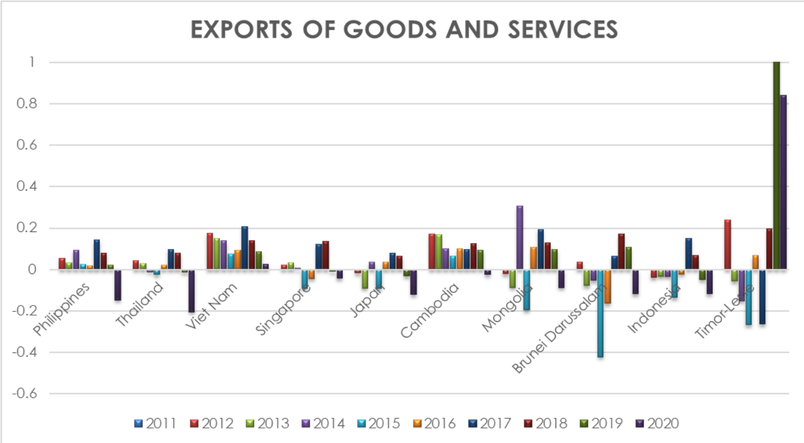

Figure 6. Exports of goods and services among Asia-Pacific countries (2011–2020).

4.2. Environmental quality of Asia-Pacific region from 2011 to 2020

Figure 7 illustrates CO_2 emissions from 2011 to 2020 among Asia-Pacific countries, showing that Indonesia has the highest emissions, followed by Thailand, Vietnam, and Singapore. Conversely, the countries with the lowest emissions include Timor-Leste, Cambodia, Mongolia, and the Philippines. Overall, CO_2 emissions across the region have been rising, although the rate of growth among the different countries has varied. This pattern is emphasized in supplementary research by the International Energy Agency (IEA), which links the increase to strong economic growth, particularly in Thailand, Vietnam, and Indonesia. The correlation between emission growth and economic development underscores the need for sustainable policies to address climate change challenges. It is imperative for policymakers to prioritize environmental sustainability and adopt greener economic strategies to ensure a cleaner and healthier future for the Asia-Pacific region [17,18,45].

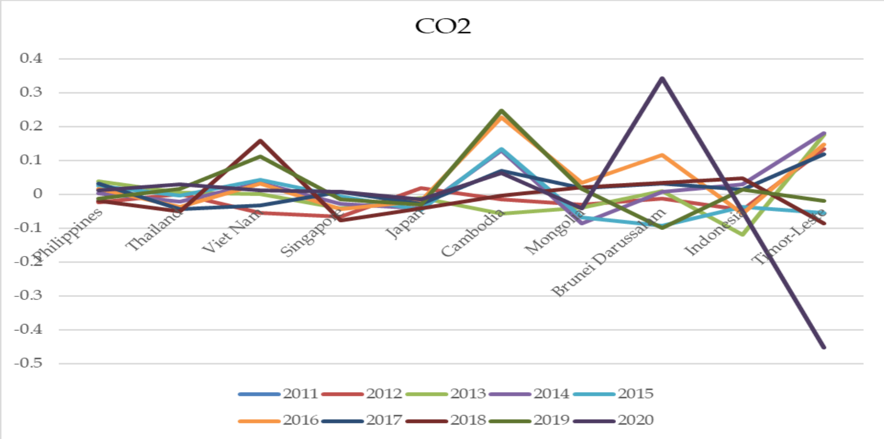

Figure 7. Carbon dioxide emissions among Asia-Pacific countries (2011–2020).

Figure 8 shows the forest rents among Asia-Pacific countries from 2011–2020. Cambodia has the highest values, closely followed by Brunei Darussalam, Mongolia, and Indonesia. On the other hand, the countries with the lowest forest rents include Timor-Leste, Japan, Thailand, Vietnam, Singapore, and the Philippines. Although growth rates differ greatly among these countries, forest rents have generally increased during the last ten years. Furthermore, this trend is supported by research called "State of the World's Forests 2020" by the Food and Agriculture Organization of the United Nations (FAO), which identifies strong economic growth as a major factor contributing to the increases, especially in Cambodia, Mongolia, and Brunei Darussalam. To maintain sustainable forest management, countries should focus on conservation efforts, balancing economic growth with environmental preservation, enacting and enforcing policies for responsible forest management, fostering international cooperation, and engaging local communities in conservation initiatives [14,15,17,18].

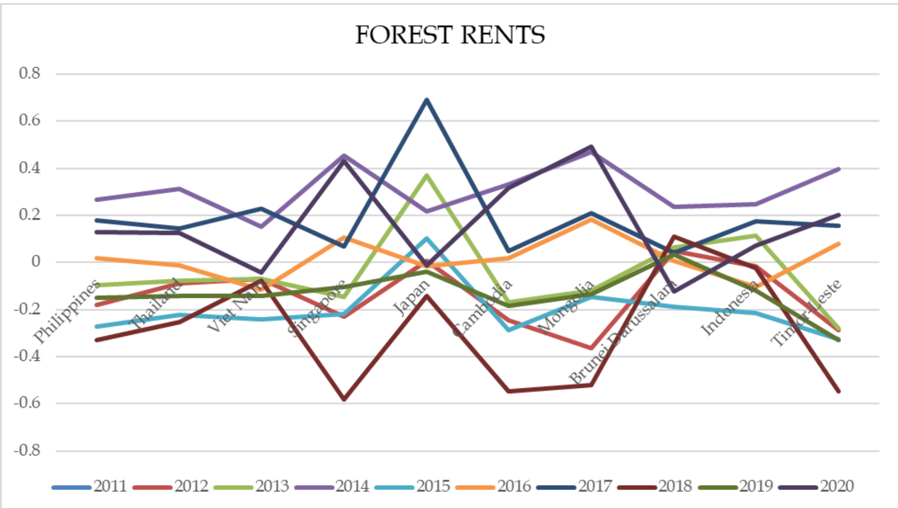

Figure 8. Forest rents among Asia-Pacific countries (2011–2020).

Figure 9 depicts the water productivity among Asia-Pacific countries from 2011–2020.Singapore is at the forefront of water productivity, followed by Japan, Thailand, and Vietnam, while the Philippines, Cambodia, Mongolia, Brunei

Darussalam, Indonesia, and Timor-Leste rank the lowest. Despite significant variations in growth rates among different countries, the overall water productivity in the region has seen a marked increase over the past decade. This ongoing improvement is further corroborated by a related study from the World Resources Institute known as the “Aqueduct Water Risk Atlas”, which emphasizes the significant contributions of Singapore, Malaysia, and Thailand. To sustain and enhance water productivity levels, countries should focus on efficient water management practices, prioritize water conservation initiatives, invest in water-efficient technologies, and promote cross-border collaborations to address water-related challenges collectively [17,18,46].

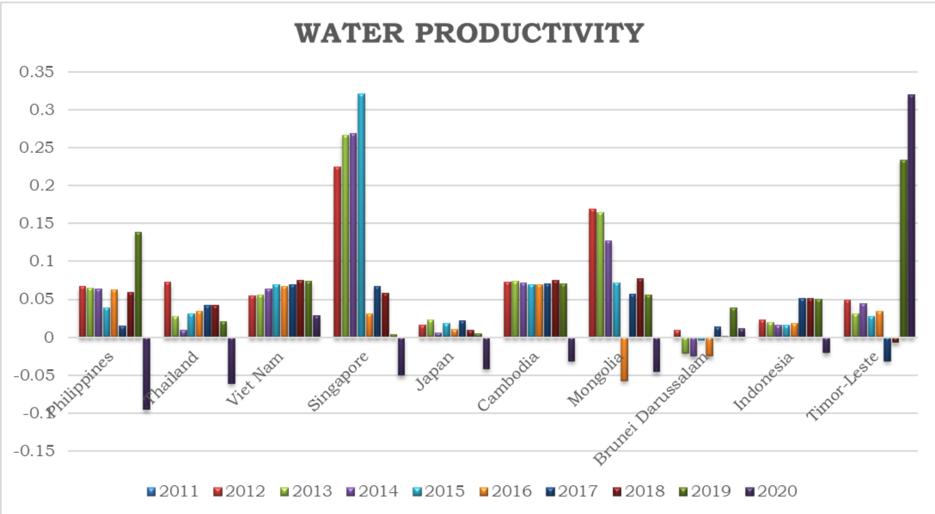

Figure 9. Water productivity among Asia-Pacific countries from 2011–2020.

Figure 10 reveals the total natural resources rents among Asia-Pacific countries from 2011 to 2020. Brunei Darussalam possesses the highest total natural resource rents, with Thailand, Indonesia, and Mongolia following behind, while the Philippines and other countries experience the lowest rates. Over the past decade, these rents have generally risen, although the growth rates differ significantly among nations. According to a related report from the International Monetary Fund, robust economic performance in the region, particularly in Brunei Darussalam, Mongolia, and Indonesia, has been a key factor driving this growth. To ensure sustainable management of natural resources, countries should consider implementing policies that promote responsible resource extraction, invest in diversifying their economies, prioritize environmental conservation, and collaborate on regional initiatives to address the challenges associated with natural resource management collectively [17,18,47].

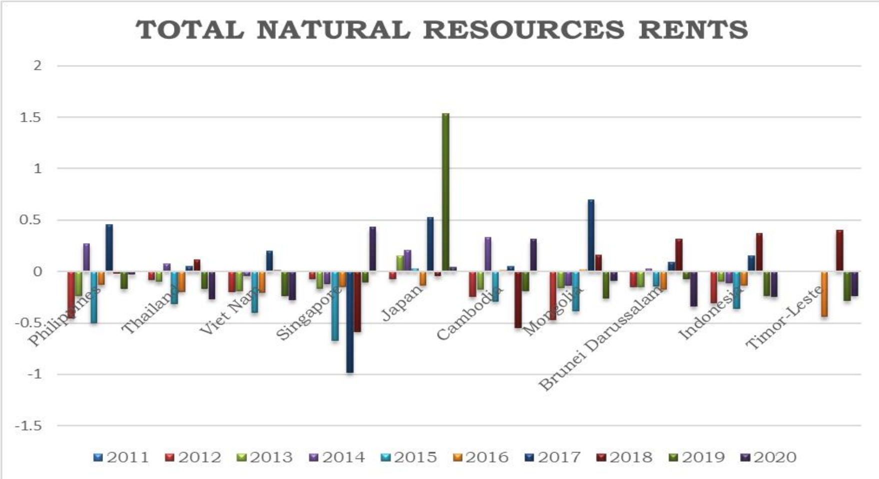

Figure 10. Total natural resources rents among Asia-Pacific countries (2011–2020).

4.3. Panel analysis on environmental quality as influenced by economic development in Asia-Pacific region

4.3.1. Carbon dioxide emissions

Table 2 illustrates the results of panel analysis on factors influencing carbon dioxide emissions among Asia-Pacific countries by employing fixed effects. The coefficient analysis indicates notable connections between CO_2 emissions and various economic metrics. More specifically, there is a statistically meaningful negative relationship between GDP per capita and CO_2 emissions, suggesting that as GDP per capita rises, CO_2 emissions generally decline. Conversely, there exists a statistically significant positive correlation between GNI per capita and CO_2 emissions, implying that CO_2 emissions are likely to increase alongside GNI per capita. Nonetheless, no statistically significant relationship has been identified between CO_2 emissions and the imports and exports of goods and services. The variance components analysis indicates a significant intraclass correlation coefficient, which suggests that differences between groups contribute significantly to the overall variability in CO_2 emissions. Additionally, the F-test for random effects reveals considerable variation across years, underscoring the importance of accounting for these fluctuations when studying CO_2 emissions. The Environmental Kuznets Curve (EKC) from Stern illustrates the interaction between GDP per capita and CO_2 emissions, showing that emissions initially rise as GDP per capita increases but then decrease when nations achieve higher economic growth levels [48]. In contrast, Guo et al. identified a positive association between GNI per capita and CO_2 emissions, which may be linked to increasing income inequality that leads to higher levels of production and consumption [49]. This finding underscores the need for sustainable development strategies to balance economic growth and environmental protection, while conflicting findings on income inequality's impact on emissions highlight the importance of inclusive growth policies that promote sustainability amidst rising production and consumption levels [17,18,50].

Table 2. Panel analysis on factors influencing carbon dioxide emissions among Asia-Pacific countries (fixed effects).

CO_2	Coef.	Std. Err.	*t*	*p* > t	[95% Conf.	Interval]
GDP Per Capita	−0.0899	0.0134	−6.7200	0.0000	−0.1164	−0.0633
GNI Per Capita	0.0004	0.0001	4.8300	0.0000	0.0002	0.0005
Imports of Goods and Services	−0.1264	0.2110	−0.6000	0.5510	−0.5459	0.2931
Exports of Goods and Services	−0.0065	0.0242	−0.2700	0.7890	−0.0545	0.0416
_cons	0.0442	0.0221	2.0000	0.0480	0.0004	0.0881

Table 3 shows the panel analysis on factors influencing carbon dioxide emissions among Asia-Pacific countries by applying random effects. The coefficients derived from the regression analysis imply that a rise in GDP per capita corresponds to a reduction in CO_2 emissions. On the other hand, the connection between GNI per capita and CO_2 emissions exhibits greater complexity. Furthermore, an increase in imports of goods and services is anticipated to result in a decline in CO_2 emissions, while the association with exports lacks statistical reliability. The link between GDP per capita and the dependent variable is shaped by various elements. GDP carries a negative coefficient, whereas GNI per capita holds a positive coefficient, indicating that as GDP per capita rises, the dependent variable tends to fall, and as GNI per capita increases, the dependent variable appears to rise (). These findings underscore the importance of considering multiple factors influencing emissions patterns. Understanding the nuances of GDP and GNI per capita's impact on emissions is crucial, with GDP indicating a reduction and GNI suggesting an increase. GNI per capita may signal increased global engagement, potentially linked to improved social outcomes from equitable income distribution. Contextual understanding is key to interpreting these results accurately; higher GDP per capita may signify increased industrial activity and pollution, while elevated GNI per capita could signal greater investment in environmental protection. Tailoring interventions based on these insights can help shape effective policies that balance economic growth with environmental sustainability [34,35,48,51].

Table 3. Panel analysis on factors influencing carbon dioxide emissions among Asia-Pacific countries (random effects).

CO_2 Emssions	Coef.	Std. Err.	z	*p* > z	[95% Conf.	Interval]
GDP Per Capita	−0.0739	0.0130	−5.6900	0.0000	−0.0993	−0.0484
GNI Per Capita	0.0004	0.0001	5.1200	0.0000	0.0002	0.0005
Imports of Goods and Services	0.1901	0.1518	1.2500	0.2100	−0.1074	0.4876
Exports of Goods and Services	−0.0072	0.0237	−0.3000	0.7600	−0.0537	0.0392
_cons	0.0243	0.0214	1.1400	0.2550	−0.0176	0.0662

The results of the Hausman test indicate that the coefficient b is consistent under both the null hypothesis (Ho) and the alternative hypothesis (Ha), as obtained from xtreg. On the other hand, the coefficient B is found to be inconsistent under the alternative hypothesis but efficient under the null hypothesis, also obtained from xtreg. The test conducted aimed to assess whether there is a systematic difference in coefficients. The calculated chi-squared statistic was 18.54, with a corresponding probability value of 0.0010. It is worth noting that the variance-covariance matrix difference (V_b–V_B) is not positive definite. **Table 4** reveals significant differences between fixed-effects (FE) and random-effects (RE) regression models, accounting for unobserved, time-invariant factors affecting the dependent variable. The results suggest that unobserved factors might be influencing the dependent variable. FE models assume unobserved factors are specific to each group, such as each year, useful for studying the impact of education on income across different countries. RE models assume random unobserved factors, potentially leading to biased estimates. Therefore, FE is a more suitable choice for understanding independent variable effects within each group [17,18].

Table 4. Hausman test on the results of panel analysis (fixed and random effects).

Variables	Coefficients *(p = 0.0010)*		
GDP Per Capita	−0.1637	−0.0160	0.0032
GNI Per Capita	0.0004	−5.8800	0.0000
Imports of Goods and Services	−0.1264	−0.3165	0.1465
Exports of Goods and Services	−0.0137	0.0008	0.0046

4.3.2. Forest rents

Table 5 reveals the fixed effects results of panel analysis on factors influencing forests among Asia-Pacific countries. The regression analysis indicated that the model points to a negative association between GDP per capita and the dependent variable, while no notable correlations were observed for the other variables. In summary, the analysis reveals a substantial negative association between GDP per capita and the dependent variable, with other variables not showing any significant connections. Research has demonstrated that economic growth, as indicated by GDP per capita, may result in heightened environmental degradation, which could account for the negative correlation between GDP per capita and the dependent variable in the table. Furthermore, research has indicated that economic growth may lead to increased income inequality, especially in developing nations, which might clarify the negative connection between GDP per capita and the dependent variable in the table. The regression model shows a noteworthy negative correlation between GDP per capita and the dependent variable, evidenced by a p-value of 0.002. Nevertheless, no significant correlation was observed between GNI per capita, imports of goods and services, exports of goods and services, and the dependent variable. The model indicates a negative relationship between GDP per capita and the dependent variable; however, no significant associations were identified for GNI per capita, imports of goods and services, exports of goods and services, and the dependent variable. This suggests that as GDP per capita rises, the dependent variable tends to decline. Based on the regression analysis indicating a negative association between GDP per capita and the dependent variable, potentially linked to environmental degradation and income inequality, it is recommended to further explore the impacts of economic growth on these aspects. Policy measures addressing sustainable development and income equality should be considered alongside additional research to better understand and mitigate these effects [17,18,52,53].

Table 5. Panel analysis on factors influencing forest rents among Asia-Pacific countries (fixed effects).

Forest Rents	**Coef.**	**Std. Err.**	**t**	***p* > t**	**[95% Conf.**	**Interval]**
GDP Per Capita	−2.6357	0.8273	−3.1000	0.0000	−4.2806	−0.9909
GNI Per Capita	−0.0050	0.0047	−1.0000	0.2900	−0.0143	0.0044
Imports of Goods and Services	−15.1965	13.0505	−1.1000	0.2400	−41.1444	10.7513
Exports of Goods and Services	0.1501	1.4942	0.1000	0.9200	−2.8208	3.1210
_cons	3.2835	1.3653	2.4000	0.0100	0.5690	5.9979

Table 6 shows the results of panel analysis on factors influencing forest rents among Asia-Pacific countries by utilizing random effects. The values for GDP per capita, GNI per capita, imports of goods and services, and exports of goods and services were evaluated. All coefficients were found to be statistically not significant, suggesting that there is no substantial link between these economic indicators and the dependent variable. Additionally, the findings highlighted the possible environmental consequences of international trade and income inequality on environmental deterioration.

Table 6. Panel analysis on factors influencing forest rents among Asia-Pacific countries (random effects).

Forest Rents	**Coef.**	**Std. Err.**	**z**	***p* > z**	**[95% Conf.**	**Interval]**
GDP Per Capita	−1.0883	0.8750	−1.2000	0.2100	−2.8032	0.6266
GNI Per Capita	−0.0042	0.0049	−0.8000	0.3900	−0.0139	0.0054
Imports of Goods and Services	14.5199	10.2344	1.4000	0.1500	−5.5392	34.5791
Exports of Goods and Services	−0.1982	1.5987	−0.1000	0.9000	−3.3316	2.9351
_cons	1.4339	1.4411	1.0000	0.3200	−1.3905	4.2583

4.3.3. Water productivity

Table 7 depicts the fixed effects results of panel analysis on factors influencing water productivity among Asia-Pacific countries. The findings indicated a notable positive correlation between GDP per capita and water productivity, an insignificant connection between GNI per capita and water productivity, and a significant negative association between imports of goods and services and water productivity. The variance components revealed that a minor proportion of the overall variation in water productivity was due to random effects among groups. The *F*-test demonstrated a highly significant fluctuation across the years, underscoring the importance of accounting for these differences when discussing water productivity. A positive relationship between GDP per capita and water productivity is supported by research conducted by. This is consistent with the data presented in the table, which suggests that economic expansion can enhance water use efficiency. Conversely, a rise in imports, particularly in the agricultural sector, may result in decreased water productivity. The table also emphasizes the substantial negative effect of imports on water productivity. To accurately describe water productivity, the model must take into account variations over the years, as indicated by the existence of significant random effects. Given these findings, it is advisable to incorporate temporal variations when analyzing water productivity trends. Policies aimed at improving water productivity should consider the impact of economic growth and import patterns on water efficiency. Strategies promoting sustainable water management practices, particularly in sectors affected by imports, could help mitigate the negative effects on water productivity. Further research into the nuanced relationships between economic indicators and water productivity over time would enhance understanding and inform targeted interventions to optimize water resource utilization [17,18,54,55].

Table 7. Panel analysis on factors influencing water productivity among Asia-Pacific countries (fixed effects).

Water Productivity	Coef.	Std. Err.	t	*p* > t	[95% Conf.	Interval]
GDP Per Capita	3.4019	0.1665	20.4000	0.0000	3.0708	3.7330
GNI Per Capita	0.0003	0.0009	0.3400	0.7300	−0.0016	0.0022
Imports of Goods and Services	−6.0770	2.6268	−2.3100	0.0200	−11.2997	−0.8543
Exports of Goods and Services	−0.0700	0.3008	−0.2300	0.8100	−0.6680	0.5279
_cons	0.1935	0.2748	0.7000	0.4800	−0.3529	0.7398

Table 8 reveals the random effects results of panel analysis on factors influencing water productivity among Asia-Pacific countries. The independent variables include GDP per capita, GNI per capita, imports and exports of goods and services, and consumption. The findings reveal a highly statistically significant positive correlation between GDP per capita and water productivity, indicated by a *p*-value of 0. This suggests that as GDP per capita rises, there is a substantial uptick in water productivity. In contrast, no statistically significant association is found between GNI per capita and water productivity. The coefficients for imports of goods and services in relation to water productivity point to a marginally significant negative correlation, with a *p*-value of 0.059. The analysis underscores the critical role of GDP per capita in driving water productivity, supported by existing research. Importantly, the lack of significant correlation between GNI per capita and water productivity suggests a more nuanced relationship. The negative association between imports of goods and services and water productivity, echoing prior studies, warrants caution in managing trade dynamics to sustain water efficiency. Policymakers should prioritize strategies that leverage economic growth to enhance water productivity while carefully monitoring and potentially mitigating the adverse impacts of increased imports on water efficiency, particularly within the agricultural sector. Further research could explore the complex interplay between economic indicators and water productivity to inform targeted interventions and sustainable resource management practices [17,18,54–56].

Table 8. Panel analysis on factors influencing water productivity among Asia-Pacific countries (random effects).

Water Productivity	Coef.	Std. Err.	z	*p* > z	[95% Conf.	Interval]
GDP Per Capita	3.4157	0.1512	22.5000	0.0000	3.1192	3.7121
GNI Per Capita	−0.0001	0.0009	−0.1500	0.8800	−0.0018	0.0015
Imports of Goods and Services	−3.3340	1.7691	−1.8800	0.0500	−6.8014	0.1335
Exports of Goods and Services	−0.0741	0.2764	−0.2700	0.7800	−0.6157	0.4676
_cons	0.0654	0.2491	0.2600	0.7900	−0.4228	0.5536

4.3.4. Total natural resources rents

Table 9 illustrates the fixed effects results of panel analysis on factors influencing total natural resource rents among Asia-Pacific countries. The findings revealed a negative relationship between GDP per capita and total natural resources, suggesting that as GDP per capita rises, total natural resources are likely to decline. In contrast, there was a positive correlation between GNI per capita and total natural resources, indicating that an increase in GNI per capita is associated with a rise in total natural resources. Additionally, the research indicated that there was no significant correlation between imports and exports of goods and services and total natural resources. According to Stijns, previous studies have highlighted a mixed relationship between GDP per capita and natural resource availability, which may reflect the concept of the "resource curse" [57]. Conversely, a positive correlation exists between GNI per capita and natural resource availability. The intricate nature of the relationship between economic indicators and total natural resources emphasizes the necessity of considering variations from year to year. This implies that while greater GNI per capita is linked to increased natural resources, higher GDP per capita shows a negative correlation with natural resources, which may point to the resource curse phenomenon. Given the complex relationships observed, policymakers should adopt a nuanced approach in managing natural resources. Strategies should aim to leverage the positive correlation between GNI per capita and total natural resources while mitigating the potential adverse effects of the negative relationship between GDP per capita and natural resources, possibly linked to the resource curse phenomenon. Continuous monitoring and adaptive policies that account for yearly variations are essential to ensure sustainable resource management practices in the Asia-Pacific region. Further research could delve into the underlying mechanisms driving these relationships to inform targeted interventions and policy decisions [17,18].

Table 9. Panel analysis on factors influencing total natural resource rents among Asia-Pacific countries (fixed effects).

Total Natural Resource Rents	Coef.	Std. Err.	t	*p* > t	[95% Conf.	Interval]
GDP Per Capita	−2.0843	0.5865	−3.5500	0.0010	−3.2514	−0.9172
GNI Per Capita	0.0076	0.0034	2.2500	0.0270	0.0009	0.0143
Imports of Goods and Services	−4.0603	9.7496	−0.4200	0.6780	−23.4625	15.3420
Exports of Goods and Services	−0.1444	1.0360	−0.1400	0.8900	−2.2060	1.9173
_cons	2.2493	0.9949	2.2600	0.0260	0.2695	4.2291

Table 10 shows the fixed effects results of panel analysis on factors influencing total natural resource rents among Asia-Pacific countries. GDP per capita, exports of goods and services, and the constant term did not exhibit statistically significant connections, but there was a statistically significant positive link between GNI per capita and imports of goods and services with total natural resources. Furthermore, the variance components analysis revealed significant variation over time, highlighting the need to take these variations into consideration when attempting to explain the overall number of natural resources. The availability of natural resources and GNI per capita are positively correlated, according to a study of the literature.

Additionally, it was noted that increased trade might affect natural resources in both positive and negative ways. Higher income levels are associated with greater natural resource availability. In light of these results, policymakers should prioritize strategies that capitalize on the positive correlation between GNI per capita, imports of goods and services, and total natural resources. It is imperative to recognize the nuanced impact of increased trade on natural resources, which can have both positive and negative implications. While higher income levels are generally linked to greater natural resource availability, the potential repercussions of escalating imports on resource demand, as highlighted by Copeland and Taylor (2004), warrant careful consideration. Building on the existing literature, future research should delve deeper into the multifaceted dynamics between economic indicators, trade activities, and natural resource management to inform sustainable policies and practices in the Asia-Pacific region [17,18,58,59].

Table 10. Panel analysis on factors influencing total natural resource rents among Asia-Pacific countries (random effects).

Total Natural Resource Rents	Coef.	Std. Err.	z	$p > z$	[95% Conf.	Interval]
GDP Per Capita	−0.7215	0.6274	−1.1500	0.2500	−1.9511	0.5083
GNI Per Capita	0.0092	0.0036	2.5700	0.0100	0.0021	0.0162
Imports of Goods and Services	15.6257	7.7731	2.0100	0.0400	0.3906	30.8606
Exports of Goods and Services	−0.2865	1.1422	−0.2500	0.8000	−2.5251	1.9522
_cons	0.7983	1.0658	0.7500	0.4500	−1.2906	2.8873

4.4. Panel summary

Table 11 shows the panel summary statistics of variables in analyzing the causation between environmental quality and economic growth among Asia-Pacific countries from 2011 to 2020. Economic data reveal significant disparities across countries in terms of imports, exports, GDP per capita, and GNI per capita. Countries with low levels of economic development are reflected in the relatively low average GDP per capita. The dataset's substantial variation in GDP per capita suggests varying degrees of economic development. The fact that the average GNI per capita is greater indicates that certain nations experience both significant variability and high levels of national income. Moderate variability may be seen in imports and exports, with more variation within a single nation than between them. The dataset includes measurements for total natural assets, water resources, forest cover, and CO_2 emissions. The moderate overall mean and standard deviation for CO_2 emissions reflect a combination of both high and low emitters. While the moderate mean for forest cover shows a mix of wooded and deforested regions, the moderate overall mean and standard deviation for CO_2 emissions show a mix of high and low emitters. The overall natural resources and water availability show substantial variability but reasonable averages. Given the observed disparities and variations, policymakers should adopt tailored approaches to address the unique economic and environmental challenges faced by different Asia-Pacific countries. Strategies aimed at sustainable development should consider the diverse economic landscapes and environmental conditions within the region. Mitigating CO_2 emissions, preserving forest cover, and ensuring the sustainable use of natural resources and water reservoirs are paramount. Collaborative efforts focusing on both economic growth and environmental conservation are essential to foster long-term prosperity and ecological resilience across the Asia-Pacific region. Continued monitoring and data-driven decision-making will be crucial in guiding effective policies that balance economic advancement with environmental sustainability [17,18].

Table 11. Panel summary statistics of variables in analyzing the causation between environmental quality and economic growth among Asia-Pacific countries (2011–2020).

Variable		Mean	Std. Dev.	Min	Max		Observations
GDP Per Capita	overall	0.2225	1.6007	−0.9729	14.1291		N = 99
	between		0.6739	−0.0060	2.1593		*n* = 10
	within		1.4775	−2.9098	12.1922	T	bar = 9.9
GNI Per Capita	overall	33.6951	328.8641	−0.9968	3272.4270		N = 99
	between		117.1203	−0.0254	370.3921		*n* = 10
	within		310.9653	−337.6940	2935.7300	T	bar = 9.9
Imports of Goods and Services	overall	0.0514	0.1623	−0.2663	0.9021		N = 99
	between		0.1257	−0.1026	0.3250		*n* = 10
	within		0.1123	−0.2351	0.6284	T	bar = 9.9
Exports of Goods and Services	overall	0.1337	0.8604	−0.4209	8.4530		N = 99
	between		0.2746	−0.1064	0.8754		*n* = 10
	within		0.8192	−0.7913	7.7113	T	bar = 9.9
CO_2	overall	0.0293	0.2628	−0.8447	1.3144		N = 99
	between		0.0767	−0.0106	0.2437		*n* = 10
	within		0.2532	−1.0591	1.1000	T	bar = 9.9
Forest Rents	overall	1.7691	13.4437	−0.9996	128.5275		N = 99
	between		6.2081	−0.2913	19.6079		*n* = 10
	within		12.1883	−18.8383	110.6887	T	bar = 9.9
Water Productivity	overall	0.6398	5.8420	−0.9746	58.0015		N = 99
	between		2.0504	0.0016	6.5339		*n* = 10
	within		5.5334	−6.8687	52.1074	T	bar = 9.9
Total Natural Resource Rents	overall	1.7714	10.6140	−0.9846	88.5475		N = 94
	between		6.8709	−0.3367	21.6427		*n* = 10
	within		8.6898	−20.7860	68.6763		T = 9.4

5. Conclusion and recommendations

The analysis of the relationship between economic development growth and environmental quality in the Asia-Pacific region offers valuable insights. While a negative correlation between GDP per capita and CO_2 emissions suggests a potential shift toward cleaner technologies driven by economic progress, the positive association between GNI per capita and CO_2 emissions reflects heightened consumption and industrial activity accompanying increased income levels. Notably, GDP per capita's positive link with water productivity signals enhanced efficiency in water usage practices. Conversely, the adverse impact of imports on both CO_2 emissions and water productivity, particularly in the agricultural sector, stands in contrast to the negligible influence of exports on environmental indicators. These diverse outcomes underscore the necessity of tailored development approaches to address the unique environmental challenges faced by each country. By recognizing and addressing these nuanced relationships, policymakers can formulate targeted strategies that promote sustainable economic growth while safeguarding environmental well-being, aligning with sustainable development.

The findings illuminate a complex relationship where economic development exhibits dual effects on environmental aspects. While it is associated with enhanced water productivity, it also coincides with elevated CO_2 emissions, aligning with the inverted U-shaped curve hypothesis posited by the EKC. The observed positive correlation between Gross National Income (GNI) per capita and CO_2 emissions suggests a scenario where rising income levels might contribute to environmental degradation, possibly due to factors like income inequality and consumption patterns. This correlation reflects a stage where economic growth initially worsens environmental quality before eventual improvements are seen as economies advance further. Importantly, the adverse impacts of imports on both water productivity and CO_2 emissions underscore the environmental repercussions associated with global trade practices. This highlights the significance of considering the environmental costs of international trade activities. However, the limited impact of exports on these environmental factors hints at a more nuanced relationship that necessitates further exploration. By acknowledging these intricate dynamics and their alignment with the EKC theory, this study underscores the importance of tailored environmental policies and sustainable development strategies to navigate the complexities of economic growth and environmental conservation in the Asia-Pacific region. Continued research efforts are essential to deepen our understanding of these relationships and inform targeted interventions that promote both economic prosperity and environmental sustainability.

Economic growth can yield positive outcomes, yet it also poses environmental challenges that necessitate comprehensive policies. Key recommendations include advancing green technologies, implementing green procurement policies, investing in renewable energy research, establishing clear environmental regulations, enhancing resource efficiency, and fostering a circular economy. International collaboration is crucial to address environmental issues transcending borders. Sustainable practices can be promoted through initiatives such as green bonds, a carbon pricing system, and educational programs. In the Philippines, significant environmental threats encompass deforestation, pollution, and climate change. The government must enact legislation favoring green technologies, improve resource efficiency through enhanced waste management, conserve water, and reduce plastic waste to strike a balance between economic development and environmental sustainability. Securing climate finance for these endeavors will enhance environmental assessments, encourage public-private partnerships, and support a national green economic agenda. Specific measures could involve enforcing stricter mining regulations, promoting ecotourism, practicing sustainable agriculture, and bolstering education and community conservation efforts. Strengthening governance and enforcing environmental laws will ensure participatory decision-making. Future research topics related to this study could include investigating the influence of green technological innovation on economic growth and environmental sustainability in developing countries. Another area of exploration could focus on assessing the effectiveness of cross-border collaboration in addressing transboundary environmental challenges. Additionally, research could delve into the challenges and opportunities surrounding policy implementation and enforcement for environmental conservation, particularly examining the case of the Philippines to understand how legislative measures can promote green technologies and sustainable practices while balancing economic development and environmental protection.

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