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The Linkage among Energy Transition, Urbanization, and Ecological Footprint of Selected Asian Economies

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ABSTRACT

The purpose of this study is to conduct an empirical investigation the relationship between the ecological footprint (EF) index and factors such as the energy transition, the rate of agricultural growth, urbanization, globalization, and investment in most populous countries of Asia. Globalization is measured using the KOFGI index, and a positive coefficient indicates that globalization adds to the EF index. The growth rate of gross capital formation (GCF) demonstrates a marginally negative influence on the EF index, which is statistically significant at the 10% level. The two primary variables—energy transition and agriculture—make a positive contribution to the EF index; nevertheless, the fact that their coefficients are negative suggests that more use of renewable energy sources and faster agricultural development decrease the amount of strain placed on natural resources. Following the verification that there is no cross-sectional dependency through the use of first-order unit root tests, the PMG ARDL model is utilized in the research project in order to evaluate both short-term and long-term impacts. The Levin Lin and Chu, Harris-Tzavalis, Im Pesaran Shin, Phillips–Perron, and Hadri Lagrange multiplier stationarity tests are the five first-generation unit root tests that are utilized. As a result of the mixed order of integration and the greater amount of time-series observations in comparison to cross-sections, the PMG ARDL is utilized. In conclusion, the causality test developed by Dumitrescu and Hurlin demonstrates that there is a unidirectional causal relationship between energy transition and the EF index, as well as between the EF index and urbanization and GCF, and between energy transition and agriculture and urbanization.

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1. Introduction

The ecological footprint is the measure of an individual's or communities environmental impact, quantified by the land area needed to support their consumption of natural resources. In this study I choose the ecological footprint as an environmental indicator. A resource that fulfils present generation requirements without harming the requirements of future generation is sustainable development. One of its goals is to protect an environment for upcoming generation while meeting critical needs. Sustainable development faces challenges primarily from agricultural practices, global interconnections, the use of fossil fuels for energy, heating and transportation, as well as from the expansion of urban areas and business links (Chen, Huang, & Kamran, 2023). Less than 50% of the population in five major Asian economies - China, India, Pakistan, Indonesia, and Bangladesh - is involved in agricultural activities to meet their societal needs. These prominent Asian developing countries have the highest agricultural production due to the substantial need for the agricultural goods. These populated countries were chosen based on their extensive engagement in agricultural land to meet the soaring demand for agricultural products, also contributing to environmental degradation. However, half of the world's agricultural production came from these five Asian nations: Bangladesh, China, Indonesia, Pakistan, and India (Ali & Xiangyu, 2023).

China faces several significant population challenges, including an aging population, declining birth rates, and gender imbalances. The rapid aging of China's population, driven by longer life expectancies and a historically low birth rate due to decades of the one-child policy, is straining social services, healthcare, and the labor force (Cai & Feng, 2021). The country is also experiencing a demographic shift with a declining working-age population, which could slow economic growth and increase the dependency ratio, placing financial pressure on the younger generation. Additionally, there is a significant gender imbalance, with more men than women due to cultural preferences for male children and sex-selective practices, leading to social and marriage-related issues (Amaral et al., 2020). Despite efforts to relax the one-child policy by introducing a two-child policy in 2016 and then a three-child policy in 2021, birth rates have continued to decline due to rising costs of living, career pressures, and changing social norms, compounding concerns about a shrinking workforce and economic vitality in the long term.

India faces several complex population challenges, primarily stemming from its large and growing population, uneven demographic distribution, and varying socio-economic conditions. With over 1.43 billion people, India is the world's most populous country, putting immense pressure on its resources, infrastructure, and social services. Rapid population growth, particularly in certain states, exacerbates issues like poverty, unemployment, inadequate healthcare, and education systems, leading to disparities in development (Woolf & Braveman, 2011). The country also grapples with a youthful demographic, with a large proportion of its population under the age of 25, which presents both an opportunity and a challenge; while this youth bulge offers potential for economic growth through a demographic dividend, it also requires significant investments in education, skills development, and job creation to avoid social unrest and unemployment (Okolie et al., 2021). Moreover, India faces regional demographic imbalances, with some states experiencing high fertility rates and others dealing with aging populations and declining birth rates, creating challenges for nationwide policy planning and equitable distribution of resources. Gender imbalances, influenced by a preference for male children, continue to impact social dynamics and women's rights. Additionally, urbanization is accelerating, leading to the growth of megacities that struggle with overcrowding, pollution, and insufficient infrastructure, and further complicating India's population management efforts.

Population problems of Indonesia as the fourth largest populated country include population distribution that is highly centralized, large number of people moving to urban areas, and a youthful population that is largely unexploited. More than 270 million people of the country live in several islands mainly on Java island where more than 50% population resides and adds the problem of overcrowding, deforestation and pressure on the local facilities and resources. However, most of the other Islands in Indonesia are only moderately to less populated and this leads to; regional development imbalances, regional social service inequalities and regional employment opportunities (Wahyuni et al., 2020). Another important process is the rapid urbanization of the country's population and the appears the problem of congestion of large cities such as Jakarta, the problem of housing, congestion and pollution. Moreover, despite the fact that Indonesia's population is young and about 40% is below the age of 30, the unemployment rate and insufficient number of qualified workers could hamper Indonesia's economic development. To these challenges, factors including poverty, high illiteracy level, lack of access to quality and affordable health and education facilities, and the responsibility of coming up with the social services for the ever expanding populace pose a big problem. To address these problems eradicating them calls for the employment of broad policies in the aspects of regional development, infrastructure enhancement, and educational and health reforms that would lead to the equitable and harmonized development of the entire territory of the archipelago.

Pakistan have potentially formidable demographic factors with high population growth rate, increasing urbanization and large youthful population which can be used positively or negatively. As per the latest population's census report, Pakistan's population is over 240 million, and its growth rate is about 2% per annum, which is higher than most countries in the world; that fact is a cause of significant burden to the country economically, socially, and in terms of provision of public service facilities. Such a high growth rate aggravates challenges including poverty, hunger, and restricted health as well as educational needs (Razzak, 2022). The country has a large population of below 30 years i.e 60.3% which means the country has demographic advantage if they invest a lot in education and skill development, and availability of employment opportunities so as to avoid high rate of unemployment, social tension, and underutilization of workforce resources (He et al., 2020). The population of big cities like Karachi Lahore and Islamabad is growing at a faster pace and it has exerted much pressure on infrastructure facilities, housing problems, environment pollution and traffic jams. Also, there was a natural increase in regional disparities that exist in the distribution of population growth and availability of resources and also in absolutely develop regions where there is high fertility, minimal access to requisite services. Gender disparities also feature, reduced female employment, and restricted access to education and health for women continues to understate population management efforts. It, therefore, calls for well-coordinated and broad-ranging policies in family planning, economic opportunities, regional development and gender for real growth.

There are different population issues that Bangladesh has to deal with, such as high population density rate, population urbanization, the impact of population on climate change. About 165 million people are living in this country and the geographical area is very small compared to other countries so it needs more attention to cope with this issue. This high density exerts pressure on stocks, facilities and services; and leads to increased congestion, housing shortage, pollution and other social vices. These challenges are further being compounded by high levels of urbanization where places like Dhaka among others are expanding at a very rapid rate hence there is traffic jam, pollution not forgetting severe pilferage of water and other basic amenities like water and sanitation. Though the country has achieved certain progress in controlling fertility rates, it currently is holding the tag of one most youthful populous nation of the world, for which provision of better education, health cares and job opportunities are needed to help avoid economic and social crisis in future. Furthermore, gender inequalities keep rocking as women in many areas of the country have low rates of participation in the economy and education. Like many countries of the region Bangladesh is also very much exposed to effects of climate change, including the increase in sea level and the frequency and intensity of natural disasters, which will displace millions of people and deepen poverty and compel stretched systems and resources. Solving these issues presupposes the further elaboration of synchronized measures aimed at the creation of ecological urbanization, human capital development, climate resilience, and gender-sensitive approach to sustainable development.

The utilization of renewable energy source can help to improve energy security and also bring about limited air pollution when compared with fossil fuels (He et al., 2020). Furthermore, the renewable energy may help decrease the number of adverse impact on the environment and climate as well as the costs of energy (Agostini, Colauzzi, & Amaducci, 2021). In addition, as Zhao, Su and Guo (2024) have also mentioned, the use domestic renewable energy including solar, geothermal, biomass, wind, and hydropower can reduce the cost of energy import. These are the causes why various Asian nations should transition to renewable energy sources. Moreover, it is anticipated that renewable energy sources will exceed coal in the production of electricity with half of energy production estimated to come from renewables by 2025. Recognizing the detrimental effects of natural resource depletion, Asian economies are committed to pursuing sustainable development (Khan, Liu, & Hassan, 2023). Asian economies are dedicated to pursuing sustainable development due to the harmful impact of natural resource depletion (Khan & Hassan, 2024). The growing population in these countries has resulted in increased carbon emissions and the exhaustion of natural resources. China, India, Indonesia, Pakistan, and Bangladesh have the world's highest ecological footprint (Dasgupta, Dasgupta, & Barrett, 2023). At the moment, worldwide most populous and biggest emitters countries are China, India, and the United States, collectively contributing to about half of the global carbon dioxide emissions (Kwablah, 2023).

China produces twice as much electricity as the United States of America and is the world's largest producer of renewable energy, and also is the second largest country in the world. One of the primary source of renewable energy in China is hydropower which account for almost half of its renewable energy production (Millison, 2024). India was placed fifth in solar power and fourth in installed renewable energy capacity (Elavarasan et al., 2020). Pakistan utilizes only 0.0071% of its current electricity needs from solar photovoltaics (Solar PV), despite its significant potential for solar and wind power generation. The promotion of renewable energy in Pakistan could lead to potential savings of up to $5 billion over the next two decades, because it would improve energy security, cut carbon emissions, and lower the cost of electricity (Mostafaeipour et al., 2022). Indonesia has the potential to emerge as a global leader in clean energy through implementing policies that draw funding for energy efficiency and renewable energy (Jakarta et al., 2024). In order to aid in the nations recovery from COVID-19 crisis and accelerate its transition to green energy, the paper also highlight Indonesia's significant unrealized financial and capital opportunities in energy efficiency and renewable energy. Through the scaling up renewable energy (SURE) program of USAID, Bangladesh generated economic growth and addressed the climate change from 2019 to 2021 (Sarker et al., 2023). Less than 50% of the population in five major Asian economies - China, India, Pakistan, Indonesia, and Bangladesh - is involved in agricultural activities to meet their societal needs. These prominent Asian developing countries have the highest agricultural production due to the substantial need for the agricultural goods. These populated countries were chosen based on their extensive engagement in agricultural land to meet the soaring demand for agricultural products, also contributing to environmental degradation. However, half of the world's agricultural production came from these five Asian nations: Bangladesh, China, Indonesia, Pakistan, and India (Ali & Xiangyu, 2023).

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A technically and economically feasible strategy for reduction of green gas emission is using energy that is renewable (Gayen, Chatterjee, & Roy, 2024). By lowering dependency on fossil fuels, renewable energy ensures energy security and lowers air pollution (Holechek et al., 2022). Ecological footprint and carbon dioxide emissions are key indicators that are used in order to measure environmental quality. The use of CO_2 emissions as a substitute for environmental harm is the focus of several research articles (Ahmad et al., 2021; Baloch and Danish 2022; Khan et al. 2021; Khan and Yahong 2022). Likewise, the Emission Factor Protocol (EFP) has been employed in various studies Ahmad et al. (2021); Baloch and Danish (2022); Bilgili et al. (2020); Khan, Han and Khan (2022); Khan, Yahong and Zeeshan (2022); Pata and Yilanci (2021); Qayyum et al. (2024) to assess environmental sustainability and related risks in the context of sustainable development. The EFP is the significant factor that produces greenhouse gases and contributes to alternations in climate patterns as well as global warming. Over the past decade global average temperature has risen by 0.4C to 0.8C and it is anticipated to rise further till 2100 (Danish et al., 2020). Moreover, greenhouse gas emissions are being considered at a global level. Specifically, among greenhouse gas emissions carbon emissions and EFP are reorganized as a wide spread cause of global warming (Baek, 2016).

Consumption of non-renewable energy plays an important role in both economic growths and destruction of an environment. Due to the fact that excessive use of oil, gases and engines causes climate change and upsets ecological equilibrium, there is a correlation between the high demand for fossil fuel energy and environmental degradation (Omri et al., 2023; Pata & Hizarci, 2023; Wang et al., 2023). Geopolitical and military conflicts, fluctuations in oil prices, and increased ecological problems are consequences of the rising global population's reliance on fossil fuels (Malik et al., 2020). Superior to the detrimental and disaster-generating fossil fuels, renewable energy is not only clean, but also, and more importantly, everlasting. Which is why, shifting from fossil fuel to renewable sources of energy is important for stability, diversity and, safeguarding environment in its natural form (Ben Jebli, Ben Youssef, & Ozturk, 2016; Jabeen, Ahmad, & Ashraf, 2020). For any country facing sustainable developmental challenges, therefore, it is essential to examine the impact of various forms of energy usage on the quality of the environment of that country. There is knowledge that using renewable energy can raise the quality of the environment, yet it has been established that the country may not afford it since it may hinder its rate of economic growth. Also the social environment in nature may not be satisfactory for acceptance of other energy technologies and therefore the results of such policies. The social implementation barriers imply that the socio economic contexts might hinder implementation hence affecting the impact of renewable energy solutions on environmental quality. Hence the country may end up relying on the already conventional fossil fuel based energy sources while a progressive decline in environmental standards continued.

Energy conservation scenario analysis is thus relevant in shaping ecological footprint. However, the challenges that come with renewable energy solutions do not allow them to effectively address environmental degradation problems associated with non-renewable energy use. At the same time, the further income growth level be connected not equally with the decrease in the ecological footprint, and with the change in energy solutions. To overcome this, the study had employed Autoregressive Distributed Lag (ARDL) model. This approach offers several advantages for alternative methods. Firstly, it allows for the analysis of long term as well as short term dynamics across different quantiles of the explained variables conditional distribution (Mensi et al., 2024). The second point is that it permits locational imbalance among variables depending on the position of the explained variable within its conditional distribution (Nawaz, Lahiani, & Roubaud, 2023). Finally, it allows for the adjustment coefficients to vary across the quantiles produced by shocks, as demonstrated in Shahbaz et al.'s 2018 study. This methodological approach can enhance policy contributions from a policymaking standpoint. Various income growth levels and energy solutions are expected to have different effects on the ecological footprint. In Turkey, technological diffusion is a major concern because of low research and development penetration and limited scientific progress. Hence, the QARDL process supports contextual development and adds to the environmental economics literature from a methodological perspective driven by context.

Agriculture plays a significant role in contributing to the climate issue, currently accountable for greenhouse gas emissions (GHG). Agriculture is a crucial element for promoting sustainable development by enhancing agricultural productivity, ensuring food security and improving nutrition. Agricultural goods production is expected to have crucial as well as beneficial effects on ecological footprint. Different agricultural practices, including the use of fertilizers and chemicals, livestock rearing, land conversion, and bush burning, lead to the release of emissions. The ecological factors are integrated into agricultural and economic practices, both of which are sources of emissions. The 2030 goal can be attained by globally transforming agricultural system and food production to account for climate change (Clark et al., 2020). Seventy percent of the world’s water is used by agriculture, which includes raising livestock and irrigating crops (Singh et al., 2024). Renewable energy has the potential to assist in agricultural activities by improving soil quality, drying crops, offering cooling and heating, and supporting irrigation (Ambika & Mishra, 2022).

The development process of countries relies on their resource base, which includes natural and human capital. Developing countries experience rapid development through the extraction of natural resources, but this also leads to environmental degradation due to the pattern and use of these resources. The continuous use of natural resources contributes to increasing environmental degradation and ecological footprints. This necessitates the exploration of more energy renewable resources. Urbanization entails the expansion of population residing in urban areas, and many cities are currently witnessing high level of urbanization. The sudden increase in urbanization contributes to the environmental degradation, posing a global problem but especially impacting global countries (Azam & Khan, 2016). The increase in globalization can contribute to environmental pollution due to increased production levels and the introduction of environmental technologies. This increase in production and consumption directly leads to higher CO2 emissions and ecological footprint. While globalization has positive effects such as reducing poverty and income inequality its environmental consequences are still a topic of debate (Destek, 2020; Salahuddin et al., 2019). Globalization has the potential to increase production level and offers environmental technology, directly impacting ecological footprints through production and consumption. The production technologies remaining the same during globalization could lead to environmental deterioration (Li et al., 2023). The increased competition in energy consumption and agricultural production between developed and developing countries, has been a result of globalization, which has had an impact on the global economy. Also, emerging countries that has a mainly objective of increasing economic activities, promoting investment in energy, trade liberalisation and increasing agricultural productivity. The implication of these programs has seen increased investiture in industrial and agricultural goods fundamental for energy demands and usage in addition to Carbon dioxide emissions. This is a risk to society welfare and development especially in the journey in the pursuit of economic growth. As such, the decisions and actions of the developing nations have significant impacts on the global energy systems, and further degradation of environment. The purpose of this study is to obtain an empirical investigation of the relationship between the ecological footprint (EF) index and factors such as the energy transition, the rate of agricultural growth, urbanization, globalization, and investment in most populous countries of Asia. Globalization is measured using the KOFGI index, and a positive coefficient indicates that globalization adds to the EF index.

2. Literature Review

Ali et al. 2019b reports that emerging nations have veered off course in order to become low-carbon societies. This is due to the fact that they have a strong desire to maintain consistent growth and development. On the one hand, there is a strong link between growth and energy and environmental quality, and on the other hand, there is a strong correlation there. According to Temiz Dinç and Akdoğan (2019), the successful coordination of these aspects is of utmost importance for the human condition, development that is environmentally friendly, and the formulation of solid future and policy directions. It is for this reason that the body of literature does not lack any works that have investigated the interplay of the factors that have been cited above, including the influence that renewable energy has on the environmental sustainability aspect. The co-evolution between energy transition and urbanization captured in this paper demonstrates that changes in energy systems and the development of urban areas have reciprocal benefits, but also face certain challenges. This is because, with development, there are increased population, economic activities as well as establishment of structures that require energy for their operations. Metrocentric growth requires more electrical energy, transport fuels, heating, and cooling, which when supplied by fossil energy resources result in higher greenhouse gas emissions, air pollution, climate change. Nevertheless, the shift of the energy sources toward the renewables, including the solar, wind and hydroelectric power, presents a chance to un-bundle the urbanization with the carbon emissions.

In addition, urban areas are in a good place to influence the energy transition as these regions have higher population densities and more centralised, thereby enabling faster distribution of the new energy and application of advanced technologies. For example, the decentralized renewable energy systems may include the rooftop solar power systems or wind power plants within cities and provinces, which can prevent energy transmission losses and enhance energy resiliency. Moreover, concentration of population enhances demand while places of development, financial capacity, political power and technical knowhow required for experimenting and reproducing such energy solutions are also common in urban regions. Indeed, it is here that urban policies can notably contribute to moving forward with the energy transition by adopting strict emission reduction objectives, or by encouraging investments in renewable energy as well as research (Yuan et al., 2022). Low carbon Districts, smart city projects and over-arching governance frameworks for urban energy transitions are other examples whereby urbanisation can be seen to be positive in its impacts towards shifting sustainable energy systems (Asghar et al., 2024).

But that is another discussion, which shows that the process of energy transition and urbanization have their specific problems. The high and increasing rate of urban growth in general and in developing nations in particular put pressure on the emerging capacities for energy. There are a lot of challenges that cities experience which range from inadequate capital, lack of policies and market structures and access to technology all of which hamper the implementation of clean energy. Furthermore, growth of urban centers and urbanization bring about demand for energy for uses such as construction, transport etc., which nullifies the gains made by incorporation of renewables. Hence sustaining change in urbanization while transitioning to cleaner energy sources demands a synergy of different actions as well as radical changes in policies and staggering investments in renewable energy systems. Ecological footprint, which measures the human pressures in relation to the availability of biologically productive space and number of hectares of land and sea required to support resource consumption and assimilate wastes, has a strong relation to the urbanization because it determines the sustainable and habitable states of urban environments. Historically, urbanization has led to augmentation of climate impact owing to rising levels of consumption of energy, water, food and other necessities, as well as generation of wastes, particularly as more living space is created. For instance, urban areas are estimated to contribute to more than 70% of the global CO_2 emissions due to the utilization of fossil fuels in energy demands for transport, heating and electricity (Rehman et al., 2022). This expanding footprint creates social and ecological impacts in terms of generating air and water pollution; depletion of biologic diversity; and, the degradation of ecosystems that positively contribute the health, sustainability, and wellbeing of our cities (Bigerna, Bollino, & Polinori, 2022). In addition, large ecological footprint would inhibit the ability of the cities to grow in a sustainable manner in the future because it distorts access to important natural resources such as clean water, arable land, and renewable energy sources more especially in the developing regions where urbanization is most pronounced (McDonald et al., 2014). It is also important to consider that high levels of EEF has negative impacts on socio-economic disparities by which minorities and indigent communities are the most affected by adverse environmental effects which include pollution and lack of equal opportunity for access to natural and public green spaces (Martinez-Alier & Shmelev, 2016). In order to counter these effects, towns and cities must implement policies to decrease their ecological markup in terms of sustainable urban development, efficient energy utilization, green infrastructure and prevention and recovery management or circular economy systems (Bulkeley, 2022; Seto et al., 2017). Hence, the ecological footprint is an essential framework as it helps in the regulation of sustainable evolution with the urban streams of development, population, economy, and structure From the results of the model, agriculture remains as one of the largest contributors to the ecological footprint because of the vast demands it makes on natural and physical resources such as land, water and energy. The ecological footprint looks at the quantity of land and water that has been utilized in terms of productive space for supporting human consumption and production, and here agriculture form a very large part of the use. Currently, agricultural activities utilize almost 370 million square kilometers of the earth's surface for crops and for grazing livestock. Also, the modern techniques of farming are extremely dependent on water for irrigation purposes, it is estimated that 70% of the fresh water supplies. These lead to increase the ecological footprint because natural resources are used at higher rates than the renewal capability of the ecosystem, consequently decreasing the earth's biocapacity to support the other forms of life and human activities (Ahmed, Azhar, & Mohammad; Dler M Ahmed, Z Azhar, & Aram J Mohammad, 2024; Dler Mousa Ahmed, Zubir Azhar, & Aram Jawhar Mohammad, 2024; Mohammad, 2015a, 2015b; Mohammad & Ahmed, 2017).

several studies focus on the interaction of economic growth and CO2 emissions through the EKC hypothesis. This theory postulates that pollution is an inversely proportional of income – it rises up to a certain level of income in a country then starts falling. Despite the fact that several empirical surveys have found evidence in favor of the assertions made in the EKC hypothesis (Hao et al., 2018), there have been conflicting documents. For instance, some researches found evidences supporting EKC hypothesis for Turkey (NaïMoğlu & Özbek, 2022; Ünlüoğlu & Dağdemir, 2023) but, other researches do not support the EKC hypothesis for Turkey (Ozturk & Acaravci, 2010; Pata, 2018). Other studies also suggest that globalization is a cause of environmental pollution. Adebayo et al. (2021) summed up that Japan experienced a rise in emission because of globalization while renewable energy reduced them from 1990 to 2015. For instance, Aladejare (2022) have done a show that Globalization has brought minimal impact to environmental degradation five affluent economy nations of Africa 1990-2019. But contrary to the current study, other studies including those of Usman, Akadiri and Adeshola (2020) and Rehman et al. (2023) revealed that globalization compounded environmental deterioration in some parts. From this body of work, it can be concluded that there is a cogenerated nature of globalization and environmental pollution and these relations are contexutal.

3. Data Sources, Research Model, and Methodology

3.1. Data

This study explores the dynamic relationships among the ecological footprint (EF), renewable energy, non-renewable energy (fossil fuels), agriculture, and urbanization, using globalization, labor, foreign direct investment (FDI), GDP, and capital formation as supporting variables. Data for the selected variables, spanning from 1998 to 2022, was sourced from five highly populated Asian countries. The ecological footprint data was obtained from the "Global Footprint Network," globalization data from the "KOF Globalization Index" of the Swiss Federal Institute of Technology Zurich, while data for renewable energy, fossil fuels, agriculture, and urbanization were collected from the "World Development Indicators." The subsequent sections of this chapter include: Data Description, Estimation Methods, Econometric Model Specifications, Variable Descriptions, and Concluding Remarks.

3.2. Data Description

The study employs panel data from five populous Asian countries, covering the period from 1998 to 2022. The key data sources include the Global Footprint Network, the KOF Globalization Index, and the World Development Indicators.

3.3. Estimation Methods

A straightforward estimation procedure is followed in this study, incorporating the following steps: Descriptive Analysis, Correlation Matrix and Variance Inflation Factor (VIF), Cross-Sectional Dependency (CSD) Test, Slope Homogeneity Test, Cointegration Test, Panel Unit Root Test, Panel ARDL (Autoregressive Distributed Lag) Test, and the Dumitrescu-Hurlin Panel Causality Test.

3.3.1. Specification of Econometric Models:

In this study one Dependent model are formulated with ecological footprint and some supporting variables. The supporting variables are globalization, economic growth, labor force, FDI, Gross fixed capital formation, population growth rate. The functional form of the model is shown below:

$$Ecological\ Footprints(EF) = f(\text{ENTRAN, AGRI, UNRAB } \ldots\ldots)$$

$$Ecological\ Footprints = f\begin{pmatrix} Energy\ Transition, \\ Agricultural\ Value\ Added, \\ Urbanization, \\ Globalization, \\ Labor \\ Foreign\ Direct\ investment, \\ Gross\ Domestic\ Product, \\ Gross\ Capital\ Formation \end{pmatrix}$$

$$ENTRAN = {}^{Renewable\ Energy}/_{Nonrenewable\ Energy}$$

$$EF_{it} = C_0 + \gamma_1 ENTRAN_{it} + \gamma_2 URBAN_{it} \pm \cdots + \varepsilon_{it}$$

Here in the equation γ are coefficients of independent variables and ε_{it} are error term.

Table 1: Description of Variables and Source of Data

Variable Names	Acronyms	Measurements	Data sources
Ecological footprint	ECFO	Global hectares (gha)	Global Footprint Network (GFN)
Energy Transition	$ENTRAN$	${}^{Renewable\ Energy}/_{Nonrenewable\ Energy}$	World Development Indicator (WDI)
Agriculture	AGRGR	Acre	
Urbanization	URBANGR	local administrative (LAUs)	
Labor	LF	Man-hours or person-hours	
Foreign Direct Investment	FDI	Net inflows (US$)	
GDP	GDPGR	Total dollar value of what is purchased in the economy.	
Gross Capital formation	GCFGR	Total value of the gross fixed capital formation.	
Globalization	KOFGI	KOFGI	KOF Index

4. Results and discussions

4.1. Data and methodology

This research analyses the dynamic connections between ecological footprint (EF), energy transition (renewable energy, non-renewable energy (fossil fuel)), agriculture, and urbanization while using globalization, labor, FDI, GDP, and capital formation as the supporting variable. The data is obtained on five Populous Asian nations for the variables for the period of 1998-2022 from three distinct data sources. The information about ecological footprint is obtained from the "Global Footprint Network," globalization from" KOF index" while the information regarding renewable energy, fossil fuel, agriculture, and urbanization was taken from the "World Development Indicator." The study uses statistical package, Stata 17 and EViews 10 for finding the empirics.

4.2. Descriptive Statistical Information

The table below summarizes descriptive statistics for six variables: EF_Index, ENTRAN, AGRGR, URBANGR, KOFGI, and GCFGR, based on 125 observations. The statistics include measures of central tendency and dispersion, distribution properties and Jarque-Bera test statistic for the normality of residuals, providing insights into the distribution and characteristics of each variable. This variable of EF_Index reflects the economic freedom of a country, with a mean value of approximately 4.74 billion. The data shows a positive skewness of 1.40, indicating that while most countries have lower economic freedom scores, a few exhibit very high values. ENTRAN represents the ration of renewable to fossil fuels energy, with an average value of 0.54. The skewness is close to zero (-0.09), suggesting a relatively symmetrical distribution. The range of values spans from 0.13 to 1.06, reflecting diverse conditions across countries. AGRGR is the annual growth rate of the agricultural sector is measured, and it has a mean of 3.43 and a median of 3.48. The skewness of -0.78 indicates a slight left-tailed distribution, meaning some countries experience lower growth rates, including negative figures. URBANGR denotes the annual growth rate of the urban population. The mean is 2.97 with a positive skewness of 0.36, suggesting that while many countries have lower urban growth rates, a few have significantly higher rates. KOFGI reflects the level of globalization, averaging 55.24. The negative skewness (-0.61) indicates that most countries have high globalization scores, with a few having much lower values. GCFGR shows the annual growth rate of investment in fixed assets. It exhibits extreme skewness (5.70) and kurtosis (61.96), pointing to a distribution with many small values and a few extreme outliers. This variable shows high variability, with a standard deviation of 46.22. The Jarque-Bera test results suggest significant deviations from normality for variables such as EF_Index, AGRGR, and GCFGR, as indicated by probability values close to zero.

Table 2: Summary Statistics

	EF_Index (In Million)	ENTRAN	AGRGR	URBANGR	KOFGI	GCFGR
Mean	4740.0	0.540	3.433	2.968	55.244	8.380
Median	1170.0	0.535	3.483	2.837	55.237	7.420
Maximum	20500.0	1.057	9.049	4.609	65.086	435.616
Minimum	50.8	0.128	-6.604	1.649	35.668	-164.509
St.Dev.	7090.0	0.246	2.056	0.687	7.388	46.224
Skewness	1.398	-0.089	-0.784	0.357	-0.605	5.699
Kurtosis	3.216	1.958	7.087	2.459	2.514	61.956
Jarque-Bera	40.963**	5.816*	99.822**	4.173*	8.857*	18779.840**

4.3. Variance Inflation Factor (VIF)

The table 3 presents the Variance Inflation Factors (VIF) and their reciprocals (1/VIF) for five variables: KOFGI, ENTRAN, URBANGR, AGRGR, and GCFGR. The VIF is used to identify potential multicollinearity among independent variables in a regression analysis. Furthermore, the average VIF for the entire analysis is found to be 1.68, which also subs the statement of low multicollinearity. The VIF values are reciprocally consistent with this, for the entire set of independent variables all of the values are above 0.1, which points to the absence of high multicollinearity. As the following table illustrates, these variables have little multicollinearity; the VIF and their reciprocal values also reveal.

Table 3: Variance Inflation Factor

Variable	VIF	1/VIF
KOFGI	2.74	0.364
ENTRAN	2.15	0.465
URBANGR	1.45	0.689
AGRGR	1.03	0.968
GCFGR	1.01	0.992
Mean VIF		1.68

4.4. Correlation Matrix

The following table provides the correlation matrix for six variables: Finally, the index of economic freedom, ENTRAN, AGRGR, URBANGR, KOFGI, and GCFGR variables will be used. In order to measure the specific type of association of each pair of variables, the Pearson correlation coefficients are again employed which lie between -1 and +1. As the result, ENTRAN has a negative coefficient of -0.70 with KOFGI indicating that the circumstance under which countries experience energy transition are generally characterized by lower globalization. It also shows a meager positive relationship with the URBANGR (Pearson coefficient equals to 0.19) indicating that the indexes moderately relate to growth rate of urbanization. AGRGR bears very low correlation coefficients with other variables and it seems to work least interactive in this dataset. Likewise, GCFGR follows an equivalent trend with limited interaction displayed with any other variable. The direct relationship of URBANGR is negative at a moderate degree (-0.51), implying that higher levels of urban growth imply lower levels of KOFGI. KOFGI itself has weak correlations with most other variables except for its more pronounced negative correlations with ENTRAN and URBANGR. Overall, the matrix reveals in Table 4 that most variables exhibit low to moderate correlations, suggesting varied influences and interactions among them. This matrix indicates that the variables in question exhibit mostly low to moderate correlations, pointing to a range of different influences and relationships.

Table 4: Correlation Matrix

	EF_INDEX	ENTRAN	AGRGR	URBANGR	KOFGI	GCFGR
EF_INDEX	1.00					
ENTRAN	-0.21	1.00				
AGRGR	-0.03	-0.13	1.00			
URBANGR	-0.17	0.19	0.00	1.00		
KOFGI	0.55	-0.70	0.03	-0.51	1.00	
GCFGR	0.02	-0.02	0.09	0.02	-0.01	1.00

4.5. Slope Homogeneity and Cross-Sectional Dependency Test

This table 5 summarizes the results from a hypothesis test that assesses the significance of a model parameter or coefficient. The test statistic, Delta, is recorded as -5.462. This statistic quantifies the deviation of the observed data from the expected values under the null hypothesis (Ho). The associated p-value is 0.000, indicating the probability of observing a test statistic as extreme as -5.462, assuming that the null hypothesis is true. Given that the p-value is significantly below conventional significance thresholds (such as 0.05 or 0.01), it provides strong evidence to reject the null hypothesis. Consequently, the result is deemed statistically significant, suggesting that the observed effect or difference is unlikely to have occurred by chance alone. The conclusion of "Reject Ho" reinforces this finding, supporting the alternative hypothesis. The "adj." row in the table is left blank and does not contribute additional information for interpretation. This test outcome highlights a statistically significant result, affirming that the slope or effect being tested is unlikely due to random variation.

Table 5: Testing for slope heterogeneity

	Delta	P-value	
adj.	-5.462	0.000	Reject H_o

4.6. Cross-Sectional Dependency Results

This table summarizes the findings from three different tests—Pesaran, Friedman, and Frees—that evaluate cross-sectional dependence (CSD) within the dataset. Cross-sectional dependence refers to the correlation of observations across various cross-sectional units, such as countries or regions.

- Pesaran Test: The statistic is 17.817 with a p-value of 0.150. This result suggests that there is no significant cross-sectional dependence detected by this test.
- Friedman Test: With a statistic of 72.352 and a p-value of 0.0000, this test indicates the presence of significant cross-sectional dependence in the data.
- Frees Test: The statistic is 1.060, and it does not indicate significant cross-sectional dependence.

Altogether, the Pesaran and Frees tests do not reveal the presence of cross-section dependence while the Friedman test reveals the presence of such dependence. Such differences in results imply that cross-sectional dependence may indeed be confined to the test type and may depend on the data set being tested. Overall, these results highlight the fact that two tests for cross-sectional dependence often yield different results. The Frees test support the Pesaran and Friedman test when there is inconsistency in the data set to confirm cross sectional dependency. As such, these test have confirmed the absence of cross sectional dependency in the data set and first generation unit root tests and have been used for other proceedings.

Table 6: Cross Sectional Dependency Results

	Value	Prob.	CSD
Pesaran	17.817	0.150	No
Friedman	72.352	0.0000	Yes
Frees	1.060		No

4.7. The Panel unit root tests

The table 07 presents the outcomes that are derived from multiple 1st generation panel unit root tests—Levin, Lin & Chu (LLC), Harris-Tzavalis, Im-Pesaran-Shin (IPS), Phillips-Perron (PP), and Hadri Lagrange Multiplier—to determine the stationarity of various variables: EF_Index, ENTRAN, AGRGR, URBANGR, KOFGI, FDI, and GCFGR. Stationarity is a property indicating that the statistical properties of a time series (such as mean and variance) are constant over time, which is essential for many econometric analyses. For most variables, such as EF_Index, ENTRAN, URBANGR, KOFGI, and FDI, the tests generally indicate that these variables are non-stationary at their levels but become stationary after their first differences, implying that they are integrated of order 1 (I(1)). This is evident from significant test statistics at the first difference level across several tests. AGRGR and GCFGR are exceptions; they are found to be stationary at their levels (I(0)) according to most tests, indicating that they do not require differencing to achieve stationarity. The mixed results across different tests highlight the variability in detecting stationarity, which may be due to differences in test sensitivities or characteristics of the data. Overall, most variables exhibit non-stationarity in their levels and require differencing to become stationary, except for AGRGR and GCFGR, which are stationary in their levels.

Table 7: Panel unit root tests

Variables	**Levin, Lin and Chu unit root test**		**Harris-Tzavalis unit root test**		**Im Pesaran Shin unit root test**	
	level	**First difference**	**Level**	**First difference**	**level**	**First difference**
EF_ Index	-1.7195	-4.2816**	-0.322	-8.9495***	-0.3025	-6.063***
ENTRAN	-3.4709***	-----	0.7374	-7.1467***	2.6214	-5.5188***
AGRGR	-2.1143**	-----	-12.5851***	-----	-6.4985***	-----
URBANGR	0.1508	-7.1383***	0.7681	-4.7297***	0.0451	-3.4529***
KOFGI	-4.5846***	-----	2.3498	-4.0835***	-0.8933	-4.7708***
FDI	-1.2969*	-----	-1.3265	-9.9374***	-7.1425***	-----
GCFGR	-2.9648***	-----	-12.953**	-----	-2.2343**	-----

	Philips–Perron		Hadri Lagrange multiplier stationarity test	
EF_ Index	-0.9644	22.334***	16.2542	1.5464*
ENTRAN	-0.5326	19.75***	16.7296	0.7335*
AGRGR	25.2518***	-----	0.3059***	-----
URBANGR	-0.8918	7.5333***	13.9984	-1.7448***
KOFGI	9.3066***	-----	14.1543	-1.4904***
FDI	-0.363	35.0314***	1.8433	-0.644***
GCFGR	17.6099***	-----	-1.2196***	-----

On the basis of above results the study concluded the order of integration as follows:

Table 8

Variables	Order
EF_ Index	1st
ENTRAN	1st
AGRGR	Level
URBANGR	1st
KOFGI	1st
GCFGR	Level

4.8. Kao Cointegration Test

This table 8 summarizes the results of Kao cointegration test to check the existence of long run relationship among the series of the study. The Unadjusted Modified Dickey-Fuller t test yields a test statistic of -2.4674 with a p-value of 0.0068, leading to the rejection of the null hypothesis that there is no cointegration among the panels. Likewise, the Unadjusted Dickey-Fuller t test shows a much more negative test statistic of -18.5033 with a p-value of 0.0000, that also leads to the conclusion to "Reject H0," indicating that panels are cointegrated.

Table 9: Kao test for cointegration

	Statistic	p-value	Conclusions
Unadjusted modified Dickey–Fuller t	-2.4674	0.0068	Reject H_0
Unadjusted Dickey–Fuller t	-18.5033	0.0000	Reject H_0

4.9. Pool Mean Group (PMG) ARDL Test

The Pool Mean Group (PMG) ARDL test is therefore a relatively strong econometric method to utilize in analyzing long and short run relationship in panel data models. The PMG ARDL test is especially very effective when working with heterogeneous panel where the variable(s) under consideration may have different short run dynamics but have the same long run response. Moreover, the PMG ARDL enables analysts to consider long-run relations between different variables together with short-run dynamics that happened during a specific period, which makes the model useful for policy making and economic forecast. This table 9 presents the coefficient, standard error, t-statistic, and p-value pertaining to the equation used to obtain the empirical evidence for the goal of the study. The results are analyzing the extent to which five independent variables affect the dependent variable. The variable ENTRAN has a coefficient of -51.3000 with a significant p-value of 0.0010, indicating a strong negative influence on EF index. AGRGR has a positive coefficient of 4.0100 and is highly significant (p-value of 0.0000), reflecting a strong positive relationship. URBANGR, with a coefficient of -4.4400 and a p-value of 0.0458, shows a statistically significant negative effect. KOFGI has a positive coefficient of 2.2000 and a significant p-value of 0.0053, indicating a positive impact. GCFGR, with a small negative coefficient of -0.0259 and a p-value of 0.0534, is marginally above the 0.05 significance threshold, suggesting a weak or borderline insignificant negative effect. These results reveal varying levels of statistical significance and direction of impact for each variable on the dependent variable.

Table 10: Long Run Results

	Coefficient	Std. Error	t-Statistic	Prob.*
ENTRAN	-51.3000	15.0000	-3.4200	0.0010
AGRGR	-4.0100	0.8406	-4.7704	0.0000
URBANGR	4.4400	2.1900	2.0274	0.0458
KOFGI	2.2000	0.7702	2.8563	0.0053
GCFGR	-0.0259	0.0132	-1.9589	0.0534

Table 11: Short Run Results and Cointegration

	Coefficient	Std. Error	t-Statistic	Prob.*
COINTEQ01	-0.288338	0.276762	-1.04182	0.0034
D(ENTRAN)	-8.14E+08	6.97E+08	-1.16723	0.2464
D(AGRGR)	-30621293	27714002	-1.1049	0.2723
D(URBANGR)	1.11E+08	1.24E+08	0.896831	0.3723
D(KOFGI)	29435923	20558195	1.431834	0.1559
D(GCFGR)	356304.6	349637	1.01907	0.3111
C	2.07E+09	2.15E+09	0.962277	0.3386

This table 11 presents the results of an error correction model (ECM) regression analysis, showing coefficients, standard errors, t-statistics, and p-values for the error correction term

(COINTEQ01), differenced independent variables (D(ENTRAN), D(AGRGR), D(URBANGR), D(KOFGI), D(GCFGR)), and the constant term (C). The coefficient for COINTEQ01 is -0.288338 with a p-value of 0.0034, suggesting that the adjustment speed towards long-term equilibrium is statistically significant. None of the differenced variables (D(ENTRAN), D(AGRGR), D(URBANGR), D(KOFGI), D(GCFGR)) show statistical significance, with all p-values exceeding 0.05. This implies that changes in these variables do not have a significant immediate impact on the dependent variable. The constant term (C) also has a high p-value of 0.3386, indicating it is not statistically significant. Overall, the findings suggest that neither the short-term dynamics captured by the differenced variables nor the error correction term are significant in explaining variations in the dependent variable within this model.

4.10. Dumitrescu and Hurlin Causality test

This table presents the results of pairwise Granger causality tests between different economic variables, showing the W-Statistic**,** Zbar-Statistic, and corresponding p-values. Each row represents a causality test where one variable is tested to see if it can predict or "Granger cause" another. For example, the test for ENTRAN causing EF_Index has a W-Statistic of 4.72611 and a p-value of 0.03, suggesting that ENTRAN Granger-causes EF_Index at the 5% significance level. Conversely, EF_Index causing ENTRAN has a p-value of 0.7477, indicating no significant causality in the reverse direction. Some relationships show significant causality, such as EF_Index causing URBANGR (p-value of 0.0085), KOFGI causing EF_Index (p-value of 0.0185), and ENTRAN causing AGRGR (p-value of 0.003). In contrast, many tests have p-values greater than 0.05, suggesting no significant Granger causality between the tested variables. Notably, FDITOTAL causing EF_Index (p-value = 3.00E-11) and EF_Index causing GCFGR (p-value = 0) are highly significant, indicating strong evidence of causality in these cases. Overall, the table identifies both significant and non-significant causal relationships, suggesting complex interdependencies among the variables

Table 12: Dumitrescu and Hurlin Causality test

Null Hypothesis:			W-Stat.	Zbar-Stat.	Prob.
ENTRAN	→	EF_Index	4.72611	2.1702	0.03**
EF_Index	→	ENTRAN	1.88295	-0.32171	0.7477
AGRGR	→	EF_Index	2.02156	-0.20022	0.8413
EF_Index	→	AGRGR	3.57568	1.1619	0.2453
URBANGR	→	EF_Index	2.28247	0.02846	0.9773
EF_Index	→	URBANGR	5.25333	2.63229	0.0085***
KOFGI	→	EF_Index	4.93859	2.35643	0.0185
EF_Index	→	KOFGI	2.20211	-0.04197	0.9665
GCFGR	→	EF_Index	1.32305	-0.81243	0.4165
EF_Index	→	GCFGR	13.3727	9.74857	0.0000***
AGRGR	→	ENTRAN	0.97667	-1.11602	0.2644
ENTRAN	→	AGRGR	5.63106	2.96335	0.003***
URBANGR	→	ENTRAN	2.66522	0.36392	0.7159
ENTRAN	→	URBANGR	8.23498	5.24557	0.000***
KOFGI	→	ENTRAN	2.55546	0.26772	0.7889

ENTRAN	→	KOFGI	1.69999	-0.48206	0.6298

5. Policy suggestions and conclusion

The current study is conducted in order to get the empirical analysis of relationship among ecological footprint index with energy transition, agriculture growth rate, urbanization, globalization and investment for five most populous countries of Asia. These countries are China, India, Indonesia, Pakistan and Bangladesh. The energy transition is ratio of renewable energy to non-renewable energy. This ratio is indicating the usage of renewable energy in comparison with non-renewable. The less than one value indicating the usage of renewable energy is smaller and greater than one indicating the opposite. The impact of energy transition on EF index is also reflecting the speed transition effect on EF index. All five countries of study are high densely populated and with more population the problem of food is also natural. Therefore, the study is also capturing the impact of agriculture and urbanization. In order to see the impact of globalization, the KOFGI is used to empirically estimate its impact that is positive means the globalization is contributing factor of EF index. As far as investment by govt is concerned the model has growth rate of GCF that is showing a negative but minute effect that is also statistically significant at 10%. The impact of main variables of the study that are energy transition and agriculture are contributing positively in EF index and their negative sign indicate that the pressure on natural resources is becoming lower as the more renewable energy is used along with more agriculture growth rate. these results have been estimated by PMG ARDL after the application of first order unit root tests after the confirmation the absence of cross sectional dependency. Five unit root tests of first generation are aplied that are Levin Lin and Chu, Harris-Tzavalis, Im Pesaran Shin, Philips–Perron and Hadri Lagrange multiplier stationarity test.

The mixed order of integration of variables of the study and time series observations are greater than the cross sections therefore the PMG ARDL test is used to estimate the long and short run effects and speed of adjustment. The value of COINTEQ that is negative and significant indicating the convergence in long run. In the end causality test of Dumitrescu and Hurlin indicating unidirectional causality is evident form energy transition to EF Index, EF Index to urbanization & Gross Capital formation, energy transition to agriculture & urbanization. Rapid urbanization is causing environmental impacts, which can be addressed by prioritizing sustainable urban infrastructure development. This includes implementing green building standards, promoting energy-efficient technologies, retrofitting existing buildings, and incorporating green spaces and sustainable public transport systems. Policies should encourage renewable energy sources and low-carbon transportation options. Asian economies should accelerate their energy transition efforts by setting ambitious targets for renewable energy adoption and investing in clean energy technologies. Governments can support this transition through subsidies, tax incentives, research, and infrastructure development. Regional cooperation can enhance the efficiency and effectiveness of energy transition strategies.

Systematic studies of impacts on the natural environment in various spheres are required for their further regulation and utilization. The key findings of the research are as follows: Governments should define and update the set of indicators to assess ecological footprint, include them into the national and regional development strategies, and increase consciousness of society regarding the necessity of decreasing the ecological footprint. Analysing the information analysed above one can conclude that policy integration and coordination are critical to achieving synergy. Self-employments are an asset for advancing the global energy transition and sustainable urbanization processes. Loans must further accentuate on the usage of green technologies in sectors like a power and petroleum, policies should promote research on green technologies with a grant-in-aid, further polices should encourage sustainability reporting and green accreditation systems must be promoted among the companies. The analysis shows that Asian economies can satisfy the objectives of the energy transition, urbanization, and ecological growth in a systemic way, if they pay attention to the mentioned policy areas, thus providing more stable and sustainable economic growth.

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