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ZEESHAN ARSHAD

O papel das variáveis macroeconómicas na modelização energética e ambiental: evidências econométricas dos países asiáticos

The Role of Macroeconomic Variables in Energy and Environmental Modelling: Econometric Evidence from Asian countries

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Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Ciências Económicas e Empresariais, realizada sob a orientação científica da Professora Doutora Margarita Matias Robaina, Professora Auxiliar, e da Professora Doutora Anabela Botelho Veloso, Professora Catedrática, ambas do Departamento de Economia, Gestão, Engenharia Industrial e Turismo da Universidade de Aveiro

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Dedicated to my beloved family.

o júri

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I would like to start by praising Allah Almighty without whose approval nothing is possible. I would like to thank Him for all the mercy He always bestowed upon me.

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palavras-chave Desflorestação, Crescimento Económico, Urbanização, Emissões de CO_2, TIC, EKC, Análise de Clusters, Econometria, Energia Renovável, Energia Não Renovável, Recursos Naturais, Países Asiáticos

Resumo

Esta tese é composta por três ensaios enquadradosna área daEconomia da Energia e do Ambiente, com foco particular no impacto das variáveis macroeconómicas nas emissões de dióxido de carbono (CO_2) nas economias do Sul e do Sudeste Asiático (SSEA).

O ensaio 1 estuda os efeitos da desflorestação, crescimento económico e urbanização nos níveis de emissões de CO_2 nas regiões do SSEAno período 1990–2014. Os resultados sugerem que a desflorestação e a urbanização podem agravar a poluição ambiental nessas regiões e afetar ainda mais o desenvolvimento sustentável a longo prazo. Além disso, o método mais adequado e eficiente para minimizar as emissões de CO_2 é o aprimoramento das atividades florestais.

O ensaio 2 estima o efeito das Tecnologias de Informação e Comunicação (TIC), do comércio, do crescimento económico, do desenvolvimento financeiro e do consumo de energia nas emissões de carbono nas regiões SSEA para o período de 1990 a 2014. A Análise de Clusters foi usada para identificar dois grupos (países potenciais e países avançados, com base no seu nível de desenvolvimento social). Os resultados revelam que o uso do desenvolvimento financeiro e das TIC deteriora a qualidade do ambiente na região do SSEA. Pelo uso crescente do “standby mode” e dos dispositivos auxiliares de Wi-Fi, recomenda-se a rápida implementação da legislação que regule essas tecnologias para torná-las mais eficientes.

O ensaio 3 examina o papel do crescimento económico, consumo de energia renovável, energia não renovável e recursos naturais nas emissões de dióxido de carbono no período de 1990 a 2014. Os resultados mostram que o consumo de energia não renovável e renovável impulsiona as atividades económicas. Além disso, os recursos naturais impedem o crescimento económico nas regiões da SSEA. Mas por outro lado, os resultados demonstram que o crescimento económico e a energia não renovável aumentam as emissões de CO_2, enquanto o consumo de energia renovável diminui as emissões de carbono. No entanto, os recursos naturais também contribuem para as emissões de CO_2 no caso dos painéis do sul da Ásia e do painel completo, além de melhorar a qualidade ambiental na região do sudeste asiático. Os resultados sugerem que um melhor uso dos recursos naturais, a atenção especial do governo à educação e a redução de atividades ilegais melhoram o crescimento económico nas áreas estudadas.

Keywords

Deforestation, Economic Growth, Urbanization, CO_2 Emissions, ICT, EKC, Cluster Analysis, Econometrics, Renewable Energy, Non-renewable Energy, Natural resources, Asian Countries

Abstract

Three essays in this dissertation revolve around the area of energy and environmental economics, with particular focus on the impact of macroeconomic variables on carbon emissions in the South and Southeast Asian economies.

Essay 1 examines the effects of deforestation, economic growth, and urbanization on carbon dioxide (CO_2) emissions levels in the South and Southeast Asian (SSEA) regions for the 1990–2014 periods. Our results suggest that deforestation and urbanization can aggravate environmental pollution in these regions and can further affect sustainable development in the long run. Moreover, the most appropriate and cost-effective method to minimize CO_2 emissions is found to be through the improvement of forest activities.

Essay 2 estimates the effect of ICT, trade, economic growth, financial development, and energy consumption on carbon emissions within the South and Southeast Asian regions for the period of 1990-2014. Cluster analysis was used to identify two groups (potential and advanced countries, based on their social development score). Results revealed that the use of financial development and ICT deteriorated the environment quality in the SSEA region. The increasing use of standby mode and Wi-Fi assistive devices require the rapid implementation of legislation regulating these technologies to make them more efficient.

Essay 3 examines the role of economic growth, renewable energy consumption, non-renewable energy, and natural resources in carbon emissions over the period of 1990-2014. The outcomes show that non-renewable and renewable energy consumption increase economic activities. Furthermore, natural resources impede the economic growth in the SSEA regions. Additionally, the results demonstrated that non-renewable energy and economic growth increase CO_2 emissions, whereas renewable energy consumption lessens the carbon emissions. However, natural resources also contributed to CO_2 emissions in the case of South Asian and full countries panels while improving the environmental quality in the Southeast Asian region. Findings suggest that the better use of natural resources, governments' special attention to education and curbin gun lawful activities improve the economic growth in the selected studied areas.

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List of Abbreviations

ADF	Augmented Ducky-Fuller
ASEAN	Association of South East Asian Nations
CIS	Commonwealth of Independent States
DH	Dumitrescu-Hurlin
DOLS	Dynamic Ordinary Least Squares
EKC	Environmental Kuznets Curve
EU	European Union
FAO	Food and Agriculture Orgnization
FMOLS	Fully Modified Ordinary Least Squares
GHG	Green House Gas
ICT	Information and Communication Technology
IUCN	International Union of Conservation of Nature
MENA	Middle East and North African
MG	Mean Group
OECD	Organization for Economic Cooperation and Development
PMG	Pooled Mean Group
SD	Sustainable Development
SSEA	South and Southeast Asian Countries
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WDI	World Development Indicators

Chapter I

Introduction

1 Introduction

1.1 Context

Sustainable Development (SD) is the organizing principle for meeting human development goals while at the same time sustaining the ability of natural systems to provide the natural resources and ecosystem services upon which the economy and society depend. Central to the concept of SD or Triple Bottom Line (TBL) is the balance between three main pillars of the economy, society and environment (Janeiro and Patel, 2015; Schlör et al., 2015).

The United Nations organized a summit in New York in September 2015 on global sustainable development, where countries set 17 goals and 169 targets (Hák et al., 2016). Some of the goals were highly debatable, like goal 12, which proposes the principle of sustainable consumption and production. In this summit, it was consensual the relevance of informing people about global warming and preparing them for incoming environmental shocks and disasters by 2030 (United Nations, 2015a). All the participants intended to achieve the legally binding and universal agreement on climate by keeping global warm below 2^0 C (United Nations, 2015b). To tackle the environment, many countries have agreed to submit an annual national inventory report to the United Nations Framework Convention on climate change (UNFCCC).

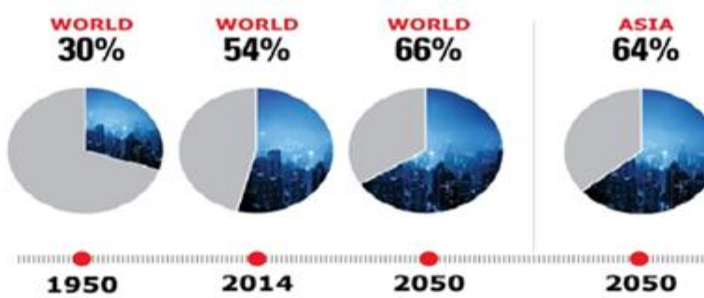
Climate change has been a core issue for all the Nations from the last few decades. While forest is one of the best solutions to control climate change (IUCN, 2017), carbon dioxide (CO_2) is one of the primary cause of it. According to the International Union of Conservation of Nature (IUCN) (2017), approximately 2.6 billion tons of CO_2 is absorbed by forests every year and one-third of the CO_2 releases from burning fossil fuels. In 1990, the world had 4128 million hectares (ha) of forest, and this area decreased to 3999 million ha in 2015. The volume of forest tends to decline as human populations keep growing and demand for food and land increase. In fact, over 3 percent of the rate of net forest area has been lost during 1990-2015 (Nations, 2018).

Deforestation, or forest conversion to other lands, may have the effect of cooling the atmosphere (Bala et al., 2007), but it also results in biodiversity loss, disturbed water regulation, and the destruction of livelihoods for a few of the world's poorest countries (Williams, 2003). Slowing down, or even reversing, deforestation is complicated by using a couple of causal factors, along with conversion for agricultural uses, infrastructure extension, wooden extraction (Geist and Lambin, 2002; Kaimowitz et al., 1999) and agricultural product (Douglas C et al., 2006).

Earlier, forests were used only for timber production; however, in recent times, non-production functions of forests grow to be more and more significant (Ciesielski and Stereńczak, 2018). The benefits of the forests are long term, and they facilitate the environment in many ways. It provides numerous benefits to humankind (Kishor and Belle, 2004), by improving environmental quality, economic opportunities and aesthetic standards (Coletta et al., 2016; Marziliano et al., 2013). Forest behaves as biodiversity vaults (Christopoulou et al., 2007) and climate change is being affected by carbon storage represented as an ecosystem regulator (Delphin et al., 2016). Tropical deforestation is considered the most significant source of greenhouse gas emissions (UNEP, 2007) and predicted to remain a substantial emission source for the near future (Eco system and human well- being, 2005).

Urbanization is also one of the variables that can impact climate change. In the last few decades, urbanization has been overgrowing. Half of the population of the whole world resides in urban areas. According to the UN estimate in 2050, 64% of the population of developing countries will be urbanized (see Figure 1. 1).

Figure 1. 1: Projected World Urban Population



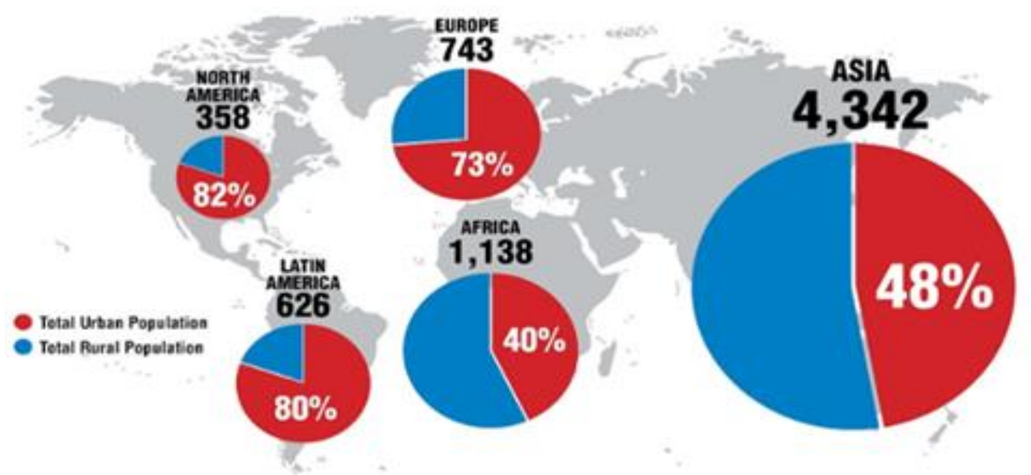
Source: UN World Urbanization report, 2014

A lack of job opportunities in the rural areas led to high migration rates, feeding further into the growth of urbanization. Mostly, rural jobs are seasonal related to wheat and rice crops. After harvesting, people wait until next cropping season for jobs. Educated persons also migrate to cities for employment opportunities and better education. Investors (local and foreign) choose locations based on the availability of needed skills and access to sound infrastructure. This increased investment raises the demand both for skilled and unskilled labor, which further stimulates the urbanization.

The world urban population was 1.73 billion in 1980 (39% of the total population) which steadily increased to 3.29 billion in 2007 and 3.968 billion in 2015, and which is projected to be 6.419 billion in 2050 (66%of the total population)(Urbanet, 2018).

The current population of Asia is 4.64 billion with the density of 150 P/km^2 in 2020 based on the latest United Nations estimates, which is equivalent to 59.76% of the entire world, standing at first position among all the continents ordered by population ("Population of Asia (2020) - Worldometer," 2020). In 1955, the estimated population of Asia was about 1.54 billion, with a density of 50 P/km^2. The urban population was 19.2 % in 1955. Between 1955 and 2014, urban population increased to 48% (see Figure 1. 2).

Figure 1. 2: World Urban Population in Millions



Source: UN World Population Situation and Urbanization report, 2014

Moreover, the urban population is 50.90% of the Asian region (2.36 billion or 128 people per mi^2) in 2020, ("Population of Asia (2020) - Worldometer," 2020). Among the most populous countries of Asia are China, India, Indonesia, Pakistan, and Bangladesh. It will reach 525 billion, with a density of 169 P/km^2 and the share of the urban population will be 63% of the total population in 2050 (Worldometer, 2018).

This migration to cities has led to the deterioration of environmental standards in Asia as well as to a higher demand for electricity, which translates into more CO_2 emissions. This rapid increase in urbanization will generate more pressure on existing urban infrastructure, e.g., health, education, power, transportation, pollution, water, and sanitation, along with new housing needs.

This might lead to deforestation, to fulfil the requirement of new houses, land, and other materials, which ultimately is one of the causes of global warming.

Moreover, the economic theory predicts that urbanization is caused by economic growth and social modernization (Martínez-Zarzoso and Maruotti, 2011; Poumanyvong and Kaneko, 2010). Poumanyvong and Kaneko (2010) noted that urbanization means the shift of rural labour force from the agricultural sector to the industrial sector, which is mostly situated in urban areas. This may also be called the renovation of rural population into the urban population, i.e. conversion of rural areas into urban areas.

Furthermore, the relationship between environmental pollution and economic growth has also been discussed in the existing literature. The relationship between economic growth and environmental degradation was explored by Grossman and Krueger (1991) by investigating the potential effects of the North American Free Trade Agreement (NAFTA) and known as Environmental Kuznets Curve (EKC). The EKC posits that environmental degradation increases with a rise in per capita income and as passing a threshold point, the environmental quality improves as the economy matures.

In recent years, many researchers have been significantly interested in the factors that affect the emission of carbon dioxide associated with energy use, and many impressive results were obtained. Poumanyvong and Kaneko (2010) examined the urbanization effect on energy use and on CO_2 emissions for 99 countries for 1975-2005, and noted that this impact varies across the stages of development. The results suggested that urbanization decreases the energy consumption in the lower-income countries whereas it has an upward direction in the middle- and high-income countries. Concerning CO_2 emissions, they noted that the urbanization deteriorated the environmental quality in all the income groups.

The above discussion about the role of forest and urbanization in environmental degradation indicates that a continuous increase in urbanization and deforestation will have a significant impact on environmental degradation through an energy consumption effect.

Notwithstanding, the relationship between urbanization, deforestation and migrations is not yet clear because the literature has not established the relationship of these variables with other essential factors. In fact, limited research focused on the damaging effect of economic activities on forest and decreased recreational opportunities (Christopoulou et al., 2007).

In the modern era, Information and Communication Technology (ICT) plays a vital role in economic growth and social development; however, it also harms the quality of the environment (Park et al., 2018) and has a substantial impact on climate change. ICT products and services need electricity for operation. ICT use in general and massive growth in internet use is expected to exert increasing pressure on electricity consumption, via which it is likely to cause emissions. The increase in CO_2 emissions is undisputedly one of the critical causes of global warming and climate instability.

Research on the environmental implications of ICT is relatively recent. Cohen et al. (1998) and Jokinen et al. (1998) have been a few of the authors who first tested such relationships from theoretical and conceptual perspectives. Although their findings have been inconclusive, they set the stage for further studies. Later, Roome and Park (2000) provided a framework to cope with records, conversation, computing and electronic technologies (ICCE), concluding that such technologies have both positive and negative implications for sustainability.

The world has witnessed a good-sized boom in the growth of Information and Communications Technology use over the last three decades (Chavanne et al., 2015). Although this fast growth in ICT utilization is believed to lead to upgrades in productivity and strengthen efficiency, its consequences on the environment are still inconclusive. Some research supported that ICT has a relevant role in mitigating the greenhouse gasoline emissions (Ishida, 2015; Mathiesen et al., 2015), while others indicate that ICT use exerts pressure on electricity use via the ensuing increase in electricity intake (Moyer and Hughes, 2012), one of the key causes of global CO_2 emissions (Hamdi et al., 2014). Collard et al. (2005) evaluated the electricity use and the development of ICT in the service sector of France, and showed that once controlled for technical progress, the electricity intensity of production increases with computer and software uses, while it decreases with the diffusion of the communication devices.

Conversely, Cho et al. (2007) indicated that ICT investment in the service and manufacturing industries increased electricity consumption in Korea. Another study by Sadorasky (2012) also confirms that the use of ICT raised the energy consumption in the emerging economies. In addition, the use of the internet and economic growth both stimulate energy consumption in Australia (Salahuddin and Alam, 2015). Van Heddeghem et al. (2014) demonstrated how electricity consumption progressed in three categories of ICT, namely: communication networks, personal computers, and data centres. Their estimated results show that the annual growth of all three individual ICT categories is higher than the growth of global electricity consumption from 2007 to 2012.

On the contrary, Ishida (2015) indicated that ICT improved environmental quality through energy efficiency in Japan. Recently, Dehghan Shahbani and Shahnazi (2019) investigated the relationship between ICT, energy consumption and CO_2 emissions for 2002-2013 in Iran. Their findings showed that the usage of ICT increased the CO_2 in the industrial sector but improved the environmental quality in the transportation and service sectors. Moreover, their results suggested that a bidirectional causality link exists between ICT and CO_2 in the sectors of industrial and transportation, whereas unidirectional causal linkages were confirmed in the service sector.

Research on the environmental impact of financial development and trade constitutes another important contribution to field of climate change (Park et al., 2018). The relationship between financial development, trade openness and CO_2 emissions has been greatly discussed in the relevant literature. Tamazian et al. (2009) found that financial development improves environmental conditions, as well as Jalil and Feridun (2011), who concluded that financial development reduces CO_2 emissions in China. Lu (2018) investigated the impact of ICT, economic growth, financial development and energy consumption on CO_2 emissions in 12 Asian countries, concluding that financial development causes CO_2 emissions over the period of 1993-2013. Park et al. (2018) also reported that financial development and trade openness have a diminishing negative impact on CO_2 emissions in the European economies. Conversely, financial development stimulates the level of CO_2 emissions in emerging economies (Danish et al., 2018). For Turkey, Ozturk and Acaravci (2013) examined a causal relationship between financial development, CO_2 emission, trade, economic growth and energy consumption over the period of 1960-2007. The bounds F-test for cointegration supported along-run relationship between the variables. Their findings suggested that trade increases carbon emissions, whereas there is an insignificant effect of financial development on CO_2 emissions in the long run.

To sum up, the existing literature about the “ICT-financial development-CO_2 emissions” nexus reveals mixed results for different countries and economies. Moreover, the ICT impact on energy consumption also remains an open empirical question, so further investigation is justified since such association has important implications for environmental sustainability around the globe.

In addition, the existing literature also examines the nexus “economic growth and natural resources” , similarly providing mixed (positive and negative) results concerning the impacts of natural resources' availability on economic growth (Satti et al., 2014). Sachs and Warner (1995) indicate that economies with abundant natural resources do not perform as well as the natural resource-scarce nations. For instance, Korea, Singapore, Japan, Hong Kong and Switzerland, performed very well and recorded high economic development with no or limited access to natural resources (Krueger, 1998). The GDP per capita of natural resource-poor countries has increased approximately three times faster than natural resource-abundant economies (Auty, 2001; Sachs and Warner, 1995). Shaw (2013) further indicates that natural resource abundance is the only reason for low economic growth in Azerbaijan.

Conversely, some South American countries took the benefits from the natural resource boom in the 19^{th} century to improve economic growth. Notably, Ecuador increased its GDP per capita during the boom period of natural resources (Sachs and Warner, 1999). Moreover, the resources of ore and coal in England and Germany were the significant ingredients behind the industrial revolution in Europe (Sachs and Warner, 1995). The exploitation of natural resource abundance was also behind the success story of Norway to achieve a high level of income prosperity with proper economic planning (Gylfason, 2001).

Furthermore, natural resources are also included in different studies to investigate their impact on environmental quality. Recently, Bekun et al.(2019) analyzed the causal interaction between economic growth, natural resource rent, renewable and non-renewable energy consumption in carbon emissions for EU 16 countries based on a balanced panel data covering the period of 1996-2014, using PMG-ARDL models. The Kao cointegration techniques supported the long-run relationship between the variables, and the study suggested that natural resources' rent have a significant positive impact on CO_2 emissions. This result implies that overdependence on the natural resources rent has negative effects on environmental sustainability if proper management is ignored. The study also noted that non-renewable energy and economic growth increase, whereas renewable energy consumption decreases, CO_2 emissions. The causality results reveal a feedback effect between non-renewable, renewable energy and economic growth. Further, the study also found feedback causality between natural resources' rent and economic growth. The review of the limited existing literature on this theme also reveals conflicting results concerning the specific association between these variables, thereby requiring further empirical research aiming at clarifying these associations (Balcilar et al., 2018).

1.2 Problem Statement

The South and Southeast Asian countries are in a phase of industrialization and have been facing rapid population growth. Moreover, Asian countries are still based on agriculture, and are already facing agriculture-related carbon emissions. In addition, the emerging markets, cheap labor, governments' concern about employment, ease of doing business and lenient environmental policies have all motivated foreign and local investors to invest in the South and Southeast Asian region, mainly in Pakistan, India, Bangladesh, Indonesia, Malaysia, Vietnam, etc. Furthermore, the upcoming strict policies and taxes seeking to clean the environment from the Western World also encouraged investors to move their businesses towards Asia. The combination of all these factors increased the urbanization, energy demand, and deforestation in the region to handle the accommodation of newly urbanized people and other wood-related use in the buildings, which altogether put more pressure on environmental quality. To meet the unique challenges concerning energy demand, South and Southeast Asian countries raise their dependence on non-renewable energy sources such as fossil fuel, rather than renewable energy sources, which is also one of the significant causes to raise their carbon emissions. In the modern era, the use of information communication technology is an essential part of human life, which also increases energy demand, ultimately having a positive impact on CO_2 emissions. Adding to these circumstances, and despite the abundance of natural resources, Asian countries are also facing corruption problems, low level of education, the so-called Dutch disease[1], etc., which also contribute to worsen the environment.

1.3 Research Question

Given the current dynamics of the South and Southeast Asian countries, the need to achieve the sustainable development goals proposed by United Nations until 2030, and the state-of-the-art of the relevant literature as previously summarized, the present study formulates and purports to contribute with answers to the research question "What is the role of macroeconomic variables in energy and environmental modelling?" by providing econometric evidence from Asian countries.

[1]The popular term "Dutch disease" as used in Economics refers to a causal relationship between the economic growth of a specific sector of the economy (e.g. natural resources) and a simultaneous growth reduction in other sectors of the economy (e.g., manufacturing, agriculture, etc).

1.4 Aim & Objectives of the study

The present study has the following specific objectives:

i) To examine the impact of urbanization on environmental degradation in the form of massive carbon emissions in the panel of Asian countries.

ii) To analyze the impact of energy demand on environmental degradation in Asian countries.

iii) To explore the relationship between deforesting and emissions on Asian countries.

iv) To examine the inverted U-shaped (Environmental Kuznets Curve) relationship between economic growth and CO_2emissions in Asian countries.

v) Compare the empirical evidence from the sampled countries.

vi) To examine the ICT energy efficiency in the sampled countries.

vii) To analyze the impact of trade openness, financial development, economic growth, and ICT on CO_2emissions in the sampled countries from a short and long run perspectives.

viii) To analyze the impact of renewable energy, non-renewable energy, natural resources, and economic growth on CO_2emissions in the sampled countries from a short and long run perspectives.

ix) Identify which of the factors-Renewable energy, Non-renewable energy, and Natural resources-has a stronger impact on CO_2emissions.

1.5 Data Sources

The current study uses a panel data over the period of 1990-2014 (annual frequency) of the South and Southeast Asian countries. The selection of the countries and time-period was based on the availability of the data. The sources used were the World Development Indicators (World Bank, 2019, 2018), and the United Nations Data Bank.

1.6 Thesis Organization

Following the introductory chapter, which comprises the general introduction, this thesis is organized into three independent essays addressing the specific objectives of the present work. All the essays have been published in (indexed) international scientific journals and are presented in chapters 2-4. The contents of each essay are summarized below, and their respective citation is presented at the end of each summary. The fifth and final chapter presents a general conclusion and global policy implications.

1.6.1 Essay 1

The effect of deforestation and urbanization on sustainable growth in Asian countries

This study aims to determine the effects of deforestation, economic growth, and urbanization on carbon dioxide (CO_2) emissions levels in the South and Southeast Asian (SSEA) regions for the 1990–2014 periods. The data was divided into five sub-panels. Three of them are income-based groups (namely low-, middle- and high-income panels), and the remaining two are South and Southeast Asian regions. The Pedroni cointegration test confirms a long-run relationship between deforestation, economic growth, urbanization, and CO_2 emissions in the SSEA regions. Further, empirical results reveal the existence of a U-shaped relationship between CO_2 emissions and economic growth for all panels (excepting low-income countries). However, some U-shaped relationships are inverted U-shaped relationships. This means that these countries can grow in a sustainable path, but they must be aware of long-term risks of this economic growth, as this sustainable path could be compromised when reaching the turning point of the "U". Moreover, our results suggest that deforestation and urbanization can aggravate environmental pollution in these regions and can further affect sustainable development in the long run. Besides, the most appropriate and cost-effective method to minimize CO_2 emissions is found to be through the improvement of forest activities.

Citation:

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Journal indexed in WOS and SCOPUS (Q_2 as per the last available 2019 metrics.

1.6.2 Essay 2

The role of ICT in energy consumption and environment: an empirical investigation of Asian economies with cluster analysis

The development of societies has led information and communication technology (ICT) to play a gradually important role in people's lives, transforming the way societies and economies function. ICTs are often associated with the path to reducing CO_2 emissions; however, do they lead to that path? Or are they themselves a growing source of energy consumption and emissions?

The current study estimates the effect of ICT, trade, economic growth, financial development, and energy consumption on carbon emissions in South and Southeast Asian (SSEA) region for the period of 1990–2014. Moreover, the study also tried to validate the environmental Kuznets curve (EKC) hypothesis between GDP per capita and CO_2 emissions. Cluster analysis was used to identify two groups (potential and advanced countries) based on their social development score. The long-run connection between the variables was examined and the long-run elasticity's of ICT, financial development, energy consumption, trade, and economic growth with respect to CO_2 emissions were estimated. Besides, individual country-wise long-run coefficients were found. Results show that financial development and ICT deteriorated the environment quality in the SSEA region, suggesting ICT goods and services are not energy-efficient in both potential and advanced countries and that most of the financial investment was made in non-friendly environmental projects, in potential countries. On the contrary, in advanced countries, financial Development mitigates CO_2 emissions. In addition, results also confirmed an inverted U-shaped relationship for all the considered three panels such as potential, advance, and full-countries panels, confirming EKC. Causality findings showed bidirectional causality between CO_2 emissions and energy consumption as well as unidirectional causality from trade, economic growth, financial development, and ICT to CO_2 emissions. Policymakers should be aware of the ICT impact on energy consumption and strengthen the regulation of their manufacture to facilitate the integration of energy efficiency into user routines. Due to the increasing use of standby mode and Wi-Fi assistive devices, the rapid implementation of legislation regulating these technologies to make them more efficient is recommended.

Citation:

Arshad, Z., Robaina, M., Botelho, A., 2020. The role of ICT in energy consumption and environment: an empirical investigation of Asian economies with cluster analysis. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-020-09229-7.

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1.6.3 Essay 3

Renewable and Non-renewable energy, Economic growth, and Natural resources impact on environmental quality: Empirical evidence from South and Southeast Asian countries with CS-ARDL Modelling.

This study aims to estimate the effects of economic growth, renewable and non-renewable energy consumption, and natural resources on carbon emissions for the period of 1990-2014, in 11 countries, using 3 panels: (i) full countries panel, (ii) South Asian countries and (iii) Southeast Asian countries. For all panels, the long-run elasticity's were estimated. The results suggest that non-renewable and renewable energy consumption increase economic development in the three panels. Besides, natural resources impede the economic growth in South Asian and full countries panels while natural resources increase the economic activities in Southeast Asian countries. Non-renewable, and economic growth increase CO_2 emissions whereas, renewable energy consumption lessens the carbon emissions. Natural resources also contributed to CO_2 emissions in the case of South Asian and full countries panels while improved the environmental quality in the Southeast Asian region. It was also observed that there is cointegration among the variables in all three panels. Policy recommendations can be made, in the sense that renewable energy sources should be preferred to decrease CO_2 emissions, and education and corruption should be improved to stimulate the economic growth in the studied areas.

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References

Auty, R.M., 2001. The political state and the management of mineral rents in capital-surplus economies: Botswana and Saudi Arabia. Resources Policy 27, 77–86. https://doi.org/10.1016/S0301-4207(01)00008-3

Bala, G., Caldeira, K., Wickett, M., Phillips, T.J., Lobell, D.B., Delire, C., Mirin, A., 2007. Combined climate and carbon-cycle effects of large-scale deforestation. PNAS 104, 6550–6555. https://doi.org/10.1073/pnas.0608998104

Balcilar, M., Ozdemir, Z.A., Ozdemir, H., Shahbaz, M., 2018. The renewable energy consumption and growth in the G-7 countries: Evidence from historical decomposition method. Renewable Energy 126, 594–604. https://doi.org/10.1016/j.renene.2018.03.066

Bekun, F.V., Alola, A.A., Sarkodie, S.A., 2019. Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. Science of The Total Environment 657, 1023–1029. https://doi.org/10.1016/j.scitotenv.2018.12.104

Chavanne, X., Schinella, S., Marquet, D., Frangi, J.P., Le Masson, S., 2015. Electricity consumption of telecommunication equipment to achieve a telemeeting. Applied Energy 137, 273–281. https://doi.org/10.1016/j.apenergy.2014.10.027

Cho, Y., Lee, J., Kim, T.-Y., 2007. The impact of ICT investment and energy price on industrial electricity demand: Dynamic growth model approach. Energy Policy 35, 4730–4738.

Christopoulou, O., Polyzos, S., Minetos, D., 2007. Peri-urban and urban forests in Greece: obstacle or advantage to urban development? Management of Environmental Quality: An International Journal 18, 382–395.

Ciesielski, M., Stereńczak, K., 2018. What do we expect from forests? The European view of public demands. Journal of environmental management 209, 139–151.

Cohen, S., Demeritt, D., Robinson, J., Rothman, D., 1998. Climate change and sustainable development: towards dialogue. Global Environmental Change 8, 341–371.

Coletta, V., Lombardi, F., Altieri, V., Bombino, G., Marcianò, C., Menguzzato, G., Marziliano, P.A., 2016. Environmental resources conservation through sustainable forest management. Procedia-Social and Behavioral Sciences 223, 758–763.

Collard, F., Fève, P., Portier, F., 2005. Electricity consumption and ICT in the French service sector. Energy Economics 27, 541–550.

Danish, Khan, N., Baloch, M.A., Saud, S., Fatima, T., 2018. The effect of ICT on CO_2 emissions in emerging economies: does the level of income matters? Environ Sci Pollut Res 25, 22850–22860. https://doi.org/10.1007/s11356-018-2379-2

De Chant, T., Gallego, A.H., Saornil, J.V., Kelly, M., 2010. Urban influence on changes in linear forest edge structure. Landscape and Urban Planning 96, 12–18.

Dehghan Shabani, Z., Shahnazi, R., 2019. Energy consumption, carbon dioxide emissions, information and communications technology, and gross domestic product in Iranian economic sectors: A panel causality analysis. Energy 169, 1064–1078. https://doi.org/10.1016/j.energy.2018.11.062

Delphin, S., Escobedo, F.J., Abd-Elrahman, A., Cropper, W.P., 2016. Urbanization as a land use change driver of forest ecosystem services. Land Use Policy 54, 188–199.

Douglas C, M., Ruth S, D., Yosio E, S., 2006. Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. PNAS 103, 14637–14641. https://doi.org/10.1073/pnas.0606377103

Geist, H.J., Lambin, E.F., 2002. Proximate Causes and Underlying Driving Forces of Tropical Deforestation Tropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations. BioScience 52, 143–150. https://doi.org/10.1641/0006-3568(2002)052[0143:PCAUDF]2.0.CO;2

Grossman, G.M., Krueger, A.B., 1991. Environmental Impacts of a North American Free Trade Agreement (Working Paper No. 3914). National Bureau of Economic Research. https://doi.org/10.3386/w3914

Gylfason, T., 2001. Natural resources, education, and economic development. European Economic Review, 15th Annual Congress of the European Economic Association 45, 847–859. https://doi.org/10.1016/S0014-2921(01)00127-1

Hák, T., Janoušková, S., Moldan, B., 2016. Sustainable Development Goals: A need for relevant indicators. Ecological Indicators 60, 565–573. https://doi.org/10.1016/j.ecolind.2015.08.003

Hamdi, H., Sbia, R., Shahbaz, M., 2014. The nexus between electricity consumption and economic growth in Bahrain. Economic Modelling 38, 227–237. https://doi.org/10.1016/j.econmod.2013.12.012

Ishida, H., 2015. The effect of ICT development on economic growth and energy consumption in Japan. Telematics and Informatics 32, 79–88.

IUCN, 2017. Forest and Climate Change. The International Union for Conservation of Nature, Gland, Switzerland.

Jalil, A., Feridun, M., 2011. The impact of growth, energy and financial development on the environment in China: A cointegration analysis. Energy Economics 33, 284–291. https://doi.org/10.1016/j.eneco.2010.10.003

Janeiro, L., Patel, M.K., 2015. Choosing sustainable technologies. Implications of the underlying sustainability paradigm in the decision-making process. Journal of Cleaner Production, Decision-support models and tools for helping to make real progress to more sustainable societies 105, 438–446. https://doi.org/10.1016/j.jclepro.2014.01.029

Jokinen, P., Malaska, P., Kaivo-oja, J., 1998. The environment in an information society': A transition stage towards more sustainable development? Futures 30, 485–498.

Kaimowitz, D., Thiele, G., Pacheco, P., 1999. The Effects of Structural Adjustment on Deforestation and Forest Degradation in Lowland Bolivia. World Development 27, 505–520. https://doi.org/10.1016/S0305-750X(98)00146-6

Kishor, N., Belle, A., 2004. Does improved governance contribute to sustainable forest management? Journal of Sustainable Forestry 19, 55–79.

Krueger, A., 1998. Why Trade Liberalisation is Good for Growth. The Economic Journal 108, 1513–1522. https://doi.org/10.1111/1468-0297.00358

Lu, W.-C., 2018. The impacts of information and communication technology, energy consumption, financial development, and economic growth on carbon dioxide emissions in 12 Asian countries. Mitig Adapt Strateg Glob Change 23, 1351–1365. https://doi.org/10.1007/s11027-018-9787-y

Martínez-Zarzoso, I., Maruotti, A., 2011. The impact of urbanization on CO2 emissions: Evidence from developing countries. Ecological Economics 70, 1344–1353. https://doi.org/10.1016/j.ecolecon.2011.02.009

Marziliano, P.A., Lafortezza, R., Colangelo, G., Davies, C., Sanesi, G., 2013. Structural diversity and height growth models in urban forest plantations: A case-study in northern Italy. Urban forestry & urban greening 12, 246–254.

Mathiesen, B.V., Lund, H., Connolly, D., Wenzel, H., Østergaard, P.A., Möller, B., Nielsen, S., Ridjan, I., Karnøe, P., Sperling, K., Hvelplund, F.K., 2015. Smart Energy Systems for coherent 100% renewable energy and transport solutions. Applied Energy 145, 139–154. https://doi.org/10.1016/j.apenergy.2015.01.075

Moyer, J.D., Hughes, B.B., 2012. ICTs: Do they contribute to increased carbon emissions? Technological Forecasting and Social Change 79, 919–931. https://doi.org/10.1016/j.techfore.2011.12.005

Nations, F. and A.O. of the U., 2018. Global Forest Resources Assessment 2015: How are the world's forests changing? Second edition. Food & Agriculture Org.

Ozturk, I., Acaravci, A., 2013. The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Economics 36, 262–267. https://doi.org/10.1016/j.eneco.2012.08.025

Park, Y., Meng, F., Baloch, M.A., 2018. The effect of ICT, financial development, growth, and trade openness on CO 2 emissions: an empirical analysis. Environmental Science and Pollution Research 25, 30708–30719.

Piussi, P., Farrell, E.P., 2000. Interactions between society and forest ecosystems: challenges for the near future. Forest Ecology and Management 132, 21–28.

Poumanyvong, P., Kaneko, S., 2010. Does urbanization lead to less energy use and lower CO2 emissions? A cross-country analysis. Ecological Economics 70, 434–444. https://doi.org/10.1016/j.ecolecon.2010.09.029

Population of Asia (2020) - Worldometer [WWW Document], 2020. URLhttps://www.worldometers.info/world-population/asiapopulation/#:~:text=Subregions%20in%20Asia&text=The%20current%20population%20of%20Asia,%22)%2C%20ordered%20by%20population. (accessed 7.5.20).

Roome, N., Park, J., 2000. Global Sustainability and Information Economy: Old Challenges, New Perspectives [WWW Document]. Greener Management International. URL https://link.galegroup.com/apps/doc/A76996486/AONE?sid=lms (accessed 1.11.20).

Sachs, J.D., Warner, A.M., 1999. The big push, natural resource booms and growth. Journal of Development Economics 59, 43–76. https://doi.org/10.1016/S0304-3878(99)00005-X

Sachs, J.D., Warner, A.M., 1995. Natural Resource Abundance and Economic Growth (Working Paper No. 5398). National Bureau of Economic Research. https://doi.org/10.3386/w5398

Sadorsky, P., 2012. Information communication technology and electricity consumption in emerging economies. Energy Policy 48, 130–136.

Salahuddin, M., Alam, K., 2015. Internet usage, electricity consumption and economic growth in Australia: A time series evidence. Telematics and Informatics 32, 862–878.

Satti, S.L., Farooq, A., Loganathan, N., Shahbaz, M., 2014. Empirical evidence on the resource curse hypothesis in oil abundant economy. Economic Modelling 42, 421–429. https://doi.org/10.1016/j.econmod.2014.07.020

Schlör, H., Fischer, W., Hake, J.-F., 2015. The system boundaries of sustainability. Journal of Cleaner Production, Sustainable Development of Energy, Water and Environment Systems 88, 52–60. https://doi.org/10.1016/j.jclepro.2014.04.023

Shaw, D.L., 2013. Good governance in the post-Soviet south: testing theories of the resource curse in Azerbaijan. Journal of Politics & International Studies 9, 520–561.

Tamazian, A., Chousa, J.P., Vadlamannati, K.C., 2009. Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. Energy Policy 37, 246–253. https://doi.org/10.1016/j.enpol.2008.08.025

United Nations, 2018. United Nations Report.

United Nations, 2015a. Home - 2019 [WWW Document]. United Nations Sustainable Development. URL https://www.un.org/sustainabledevelopment/ (accessed 1.11.20).

United Nations, 2015b. Climate change [WWW Document]. UNEP - UN Environment Programme. URL http://www.unenvironment.org/explore-topics/climate-change (accessed 1.11.20).

Urbanet, 2018. News and Debates on Municipal and Local Government, Sustainable Urabn Development Decentralisation.

Van Heddeghem, W., Lambert, S., Lannoo, B., Colle, D., Pickavet, M., Demeester, P., 2014. Trends in worldwide ICT electricity consumption from 2007 to 2012. Computer Communications 50, 64–76.

Williams, M., 2003. Deforesting the Earth: From Prehistory to Global Crisis. University of Chicago Press.

World Bank, 2019. World development indicators.

World Bank, 2018. World development indicators.
Worldometer, 2018. Worldometers.

Chapter II

The effect of deforestation and urbanization on sustainable growth in Asian countries

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2 The effect of deforestation and urbanization on sustainable growth in Asian countries

2.1 Introduction

Forest is one of the essential factors of the earth and survival of humanity (Ciesielski and Stereńczak, 2018). The role of the forest evolved over the centuries. Earlier, forests were used only for timber production; however, in recent times, non-production functions of forests grow to be more and more significant (Ciesielski and Stereńczak, 2018). The benefits of the forests are long term, and they facilitate environment in many ways. It provides numerous benefits to humankind (Kishor and Belle, 2004), by improving environmental quality, economic opportunities, and aesthetic standards (Coletta et al., 2016; Marziliano et al., 2013). Forest behaves as biodiversity vaults (Christopoulou et al., 2007), and climate change is being affected by carbon storage represented as an ecosystem regulator (Delphin et al., 2016). For all these reasons, forest protection should be considered about political nature, habit, social, and economic conditions (Piussi and Farrell, 2000).

In 1990, the world had 4128 million hectares (ha) of the forest, and this area had decreased in 2015 to 3999 million hectares (ha). The volume of the forests sector is declining as human population keeps growing and demand for food and land increases. The rate of the net forest area has been lost over 3% since 1990 (Nations, 2018). Moreover, there are nearly three million premature deaths related to pollution from firewood (World Energy Outlook, 2017). Concisely, forest areas are at risk as a result of climate change, pests, diseases, exploitation, industrialization, and urbanization. Industrialization leads to urbanization by creating economic growth (Liu and Bae, 2018). Industrialization influences on the quality of human life and damages the natural environment (Awan et al., 2018).

Shahbaz et al. (2016) explained the urbanization as social and economic capabilities moved from rural to urban areas. Martinez-Zarzoso and Maruotti (2011) focused on the influence of urbanization on carbon dioxide (CO_2)emissions and noted the presence of an inverted U-shaped relationship between CO_2 emissions and urbanization. The global urban population was 1.73 billion in 1980, 39% of total population which gradually increased to 3.29 billion in 2007 and 3.97 billion in 2015 (almost 54%) which is projected to be 6.42 billion in 2050 (66%) (Urbanet, 2018). In 2018, these numbers turned to 4.54 billion with a density of 146 P/km^2, which is equivalent to 59.7% of the total world, standing at first position among all continents. Urban population was 49.7% (a rise of 48.6% since 1955). It will reach 525 billion with a density of 169 P/km^2, and the share of the urban population will be 63% of total population in 2050 (Worldometer, 2018). Among the most populous countries of Asia are China, India, Indonesia, Pakistan, and Bangladesh. Half of the population of the whole world resides in the urban regions. According to the UN estimate in 2050, 64% of the people of developing countries will be urbanized. Urbanization will increase the demand for necessary infrastructure such as transportation, building, energy which ultimately increases the level of CO_2 emissions (Liu and Bae, 2018).

However, it is a universal consensus that the increasing atmospheric gases (GHG) especially CO_2 emissions are the primary cause of climate change (Wang et al., 2013). Worldwide mesh human-caused CO_2 emissions might need to drop by about 45 percent from 2010 levels by 2030, attaining 'net zero' around 2050. Robust implementation of CO_2 emissions reduction from the air is essential for mitigating global climate change (*Intergovernmental Panel on Climate Change 2018, report Working Group 1 Report*, 2018).

In summary, the growing world population, rapid industrialization, and urbanization of human environment collectively with social and economic changes contribute to rising demands on forest areas. The state of affairs forced the responsible bodies of the forest management to pay some special attention to the recreational of forest mainly located near the urban areas (Gołos, 2013). Moreover, media and political commentaries, by NGOs and in educational literature, the possible adverse environmental effects of growing urbanization had been mentioned see (Lean and Smyth, 2010; Mishra et al., 2009).

This study examines the relationship between economic growth, urbanization, deforestation, and CO_2 emissions, taken as a case study of the South Asian and ASEAN regions (SSEA). The SSEA regions are known as one of the highly urbanized areas in the world, struggling underneath the intensity of environmental degradation, CO_2 emissions, and GHG hassle (Behera and Dash, 2017). This study moves further than preceding research in several aspects: (i) we examine the impact of deforestation on CO_2 emissions, explicitly addressing the issue of cross-sectional dependence for South and Southeast Asian countries; (ii) the Augmented Dicky-Fuller unit test is applied to check the stationarity properties of the variables and the second generation panel unit root (Pesaran, 2007) test is also applied to assess the robustness of stationarity properties of the variables; (iii) the Pedroni (2001a) and Westerlund (2007) cointegration tests are employed to examine the presence of cointegration between the variables; (iv) to examine, short-run and long-run impact of deforestation, urbanization, and economic growth on CO_2 emissions, we apply the Pooled Mean Group (PMG) regression method, followed by the estimation of error correction approach. The strength of long-run coefficient is determined by Dynamic Ordinary Least Squares (DOLS) and Group Mean Fully Modified Ordinary Least Squares (GM-FMOLS) methods, and (v) the Dumitrescu-Hurlin causality test is applied for examining causal relationship.

We observe that cointegration exists among the variables. Moreover, the relationship between CO_2 emissions and economic growth found to be a U-shaped in middle- and high-income countries, deforestation, economic growth, and urbanization are adding in CO_2 emissions. Following policy implications can be considered: (1) the improvement of forest activities is the most cost-effective method to mitigate the CO_2 emissions level; (2) the South and Southeast Asian countries must take the initiative of cross-country settlement to maintain a certain threshold level of pollution and environmental degradation; besides, a vigorous interference for trans-border movement should be applied to regulate the air pollutants and (3) the upcoming projects must declare some green space nearby to offsetting the carbon emissions.

2.2 Literature Review

Existing literature intends to explain environmental pollution (as CO_2 emissions) can be divided into three strands: linkage between urbanization and CO_2 emissions, economic growth, and CO_2 emissions, and, deforestation and CO_2 nexus.

2.2.1 Urbanization and CO_2 Emissions

The economic theory predicts that urbanization is caused by economic growth and social modernization (Martínez-Zarzoso and Maruotti, 2011; Poumanyvong and Kaneko, 2010). Cities grow because of the continuous flow of human beings into cities. While these flows stop, urbanization involves a standstill (Chaolin et al., 2012). On similar lines, Pacione (2003) states that a boom in city population accompanies urbanization observed using urban increase and urbanism a period regarding the city's existence style and social, behavioral functions. A comparative take a look at the procedure of urbanization in different well-known countries shows the truth that the direction of urbanization followed by way of different nations is based totally on their cultural, historical past, and tiers of development (Berry and Lobley, 1973). Glaeser and Kahn (2010) surveyed a big frame of literature on urban-pollutants nexus. They focused on city-specific studies, with more recognition of metropolis-precise studies associated with urbanization and air pollutants.

The existing literature shows that researchers reached on different conclusion. Several studies found a positive and negative relationship between CO_2 emissions and urbanization, while some of them also described the inverted U-shaped relation. For instance, He et al. (2017) established the inverted U-shaped relationship between urbanization and CO_2 emissions, while using the provincial level panel estimation in China. They suggested that CO_2 emissions rise with the expansion of urbanization, they declined after reaching a turning point, afterwards maintaining an inverse relation with urbanization. Moreover, Zhang et al. (2014) concluded that there is a unidirectional causality moving from urbanization to CO_2 emissions. According to Wang and Zhao (2015), there is a direct relationship found between urbanization and CO_2 emissions in developing, under developing and developed areas in China and the elasticity coefficients vary in different economic regions. In another study, Miao (2017) suggested that the urban population in a built-up area is one of the contributors to residential CO_2 emissions. Meng et al. (2018) also concluded that urban density contributes to mitigating CO_2 emissions. Besides, Wang et al. (2018b) discussed all form of urbanization like economic urbanization, population urbanization, land urbanization, social urbanization, and explained that economic urbanization and land urbanization directly affects emissions due to the transformation from under develop to develop areas and wealth growth respectively. In contrast, population urbanization wields an inverse effect on CO_2 emissions while social urbanization decreased emissions due to awareness of energy-savings in the surroundings of Pearl River Delta in China. Therefore, it is essential to create a civic sense such as citizenship education, civic awareness, and civic participation in the society about sustainability issues (Awan et al., 2014).

However, Sharma (2011) illustrated an inverse relationship between CO_2 emissions and urbanization in the panel of 69 countries of different income groups around the globe. Ali et al. (2017) also found a negative relationship between CO_2 emissions and urbanization while stated a favorable condition between urbanization and CO_2 emissions in Singapore. Furthermore, the high level of urbanization resulted in a more friendly environment (Chikaraishi et al., 2015). Existing literature also described the urbanization as one of the essential pillars and play a crucial role in social development along with the forest resources (Ünal et al., 2019). Nevertheless, the relationship between urbanization, deforestation, and migrations is not clear because literature lacks the relationship of these variables with other essential factors. Urbanization may require special intentions due to its conversion of forestland into other advancements (De Chant et al., 2010). Limited research focused on the damaging effect of forest on economic activities and decreased recreational opportunities (Christopoulou et al., 2007). Although, Defries et al. (2010)explored that deforestation driven by urban population growth and agriculture trade in 41 countries. Their empirical results show that forest loss is positively related to urban population growth and agriculture products exports. In a recent study about Turkey, Ünal et al. (2019) explored a positive linear temporal relationship between urbanization and deforestation. There is a significant negative relation between forest area and the rural population, which means that the decline of rural population resulted in afforestation.

2.2.2 Economic Growth and CO_2 Emissions

At the first level, the relationship between environmental pollution and economic growth has been discussed. The economists are analyzing the relationship between per capita income and CO_2 emissions to control the possible anthropogenic CO_2 emissions in the atmosphere since 1991(Gene M. Grossman and Krueger, 1991). For instance, Grossman and Krueger (1991) developed a connotation between economic growth and environmental degradation. They noted the inverted-U shaped relationship between the variables, which is well represented as the Environmental Kuznets Curve (EKC). The EKC hypothesis suggests that during the initial stage of income growth, ecological degradation and per capita income increase in parallel and then after achieving the threshold level, environmental degradation decreases with further per capita income (Alvarez-Herranz et al., 2017; Wang et al., 2018a). The EKC has been more significant to understand the effect that economic development has on the environment quality based on past circumstances and present situation to achieve future sustainable development (Uchiyama, 2016). EKC reveals importance of analysis of specific context of regions or countries, as it evaluates how the economy has developed from the clean agricultural economy to polluted industrial economy, and to clean services economy. On the other hand, it may also allow us to see the tendency of higher yielding regions to have a higher preference for environmental quality

(Dinda, 2004). In practical terms, the EKC results have shown that economic growth could be compatible with environmental improvement if appropriate policies are taken (Dinda, 2004).

Several contradicting results have been found on such relationship particularly among developed and developing countries. For example, Moomaw and Unruh (1997) reported that the EKC relationship for CO_2 emissions is well defined in countries that are part of the Organization for Economic and Development (OECD). In 106 countries of the different income groups, Antonnakakis et al. (2017) verified the existence of EKC because of a continuous process of growth from 1971-2011. Koirala et al. (2011) demonstrated the presence of an EKC relationship for CO_2 emissions in high-income countries. Recently, Xie and Liu (2019) also confirmed the inverted U-shape EKC in the region level study of China throughout 1997-2016 by extented STIRPAT model.

In short, several studies confirmed the existence of EKC hypothesis some of them are (Md. M. Alam et al., 2016; Apergis, 2016; Ben Jebli et al., 2016; Le and Quah, 2018; Li et al., 2016; Ouyang and Lin, 2017; Shahbaz et al., 2015; Zaman and Moemen, 2017) etc.

On the other hand, some of the studies rejected the validity of the EKC hypothesis. For instance, Richmond and Kaufmann (2006) illustrated the invalidation of EKC in the case of non-OECD countries. Al-Mulali et al. (2016) failed to confirm the EKC in Kenya because of urbanization trade openness, GDP, and fossil fuels. Adu and Denkyirah (2018) also found insignificant results in the long run between CO_2 emissions and economic growth in the West African countries with the same income groups, which confirmed the non-existence of EKC. A low level of turning point is a hassle in this case. Moreover, Amri (2018) unable to find the inverted U-shaped relationship between CO_2 emissions and economic growth because of not attaining the requested level of total factor productivity in the Tunisian economy.

2.2.3 Deforestation and CO_2 Emissions

Relationship between deforestation and CO_2 emissions is investigated by applying various methods, but few studies have econometric approaches with empirical findings. For instance, Koirala and Mysami (2015) investigated the effect of forest resources on CO_2 emissions in the USA and estimated that forest degradation dominate CO_2 emissions. In the case of Pakistan, Ahmed et al. (2015) developed the relationship between deforestation, economic growth, energy consumption, trade openness, and population and found that there exists a long-run relationship between the mentioned variables. Moreover, the study also found the Granger causality among the variables. According to De Sy et al. (2015), one of the significant sources of CO_2 emissions is the land use changes in the region of South America. The drivers and indicators of anthropogenic CO_2 emissions is a critical aspect of global climate change commitment. However, few countries monitor the lack of national-level information on deforestation drivers is one of the vital elements. Their results also indicate that remote sensing time series in a systematic way provides the basis for the deforestation and carbon losses drivers in the region of South America. Hewson et al. (2019)also demonstrated the land change to investigate the impact of expert-informed scenarios on deforestation, GHG emissions, particularly CO_2 emissions in the Corridor in eastern Madagascar. Their results illustrate that carbon emissions could be reduced through adequate forest protection and management, whereas infrastructure advancement in new areas causes a reduction in forest areas. Their results also indicate how the land change modelling can enrich the forest policy which ultimately leads the countries to make a settlement among the economic development, forest up gradation, and climate change commitments.

Recently, Gokmenoglu et al. (2019) developed a relationship between CO_2 emissions and deforestation, energy consumption, urbanization, and fossil fuel energy consumption in ten countries throughout 2000-2015. These long-run equilibrium relationships among the mentioned variables are well established. EKC hypothesis is supported by fully modified ordinary least squares' (FMOLS), and pair-wise DH Granger causality test also proposed the causal relationship among the variables. Their results also confirmed different policies like afforestation grant, exemptions of taxes along with the tariffs on imports regarding forest products are of paramount importance in the reduction of CO_2 emissions in host countries. For different 86 countries Parajuli et al. (2019) also investigated the effects of forest land and agriculture on CO_2 emissions throughout 1990-2014. They proved that the forest is an important determinant to lessen CO_2 emissions globally with dynamic panel data method. The most recent study by Andrée et al. (2019) found inverted U-shapes in deforestation, Air pollution, and carbon intensities followed by a J-shape in per capita carbon output.

Several studies have been done to examine the relationship between environmental pollutants and their determinants (Wang et al., 2016) and we summarize studies in Table 2.1 demonstrating the association between energy consumption, deforestation and CO_2 emissions, and urbanization in developing and developed countries. Table 2.1shows numerous studies on environmental issues, but a limited number of studies, which especially analyzed the relationship among, forestation, urbanization, and CO_2 emissions in South Asian and ASEAN countries.

2.3 Methodology and Data Description

2.3.1 Data

The South Asian[2] and ASEAN[3], consisting of a panel of 17 countries covering the period of 1990-2014, has been analyzed. The data is divided into six panels: (i) all countries[4]; (ii) lower income[5] countries; (iii) middle income[6] countries; (iv) high income[7] countries (as suggested by (World Bank, 2019) economic list); (v) South Asian region and (vi) Southeast Asian region. The data for CO_2 emissions (metric tons per capita), real GDP per capita (constant 2010 U.S. dollar), forest area (Km^2), urban population, is collected from World Development Indicators (CD-ROM, 2018). The series of total population is used to convert urban population and deforestation area km^2 into per capita units (See Figure 2.1in Appendix A).

2.3.2 Empirical Models

This essay examines the relationship between deforestation, economic growth, urbanization, and CO_2 emissions. The general form of the function model is as follows:

$$CO_2 = f(GDP, Forest, Urban) \quad (1)$$

Where, CO_2 is carbon dioxide emissions per capita, GDP measures economic growth via real GDP per capita, forest is forest area per 1000 person, and urban represents urban population per capita. To estimate the air pollution rate in a country, CO_2 is the most appropriate way to calculate it. The emerging economies with high growth rate could enable the high air pollution in

[2] Pakistan, India, Bangladesh, Nepal, Maldives, Iran, Bhutan, and Sri Lanka
[3] Indonesia, Malaysia, Thailand, Cambodia, Philippines, Vietnam, Myanmar, Laos, Brunei Darussalam
[4] Pakistan, India, Bangladesh, Nepal, Maldives, Iran, Bhutan and Sri Lanka, Indonesia, Malaysia, Thailand, Cambodia, Philippines, Vietnam, Myanmar, Laos, Brunei Darussalam
[5] Pakistan, Bangladesh, Myanmar, Nepal, Laos, Cambodia
[6] India, Sri Lanka, Indonesia, Bhutan, Vietnam, Philippine
[7] Malaysia, Thailand, Brunei Darussalam, Iran, Maldives

South Asian and ASEAN regions. An increase in urbanization, high level of manufacturing, and high-level import of energy can facilitate the growth rate of a country (Behera and Dash, 2017).

Table 2.1: Summary of Existing Studies

No.	Study	Method	Country/ies (period)	Findings
1	Narayan and Narayan (2010)	Panel cointegration and the panel long-run estimation techniques.	43 countries/1980-2004	rise in income the carbon dioxide emission is fallen in South Asia and Middle East panel when the long run income elasticity is smaller than the short run
2	Poumanyvong and Kaneko (2010)	STIRPAT	99 countries/1975 – 2005	Urbanization reduces the energy consumption in low-income countries, while, the urbanization increases the energy consumption in middle and high-income groups. In the case of urbanization on emission is similar in all the sample countries but the middle-income group is higher than the other income groups.
3	Martínez-Zarzoso and Maruotti (2011)	STIRPAT model	88countries/1975-2003	an inverted U-shaped relation between CO_2 emissions and urbanization
4	Li et al. (2012)	STIRPAT model	China province/1990-2010	GDP and urbanization have a higher influence on CO_2 emission
5	Al-Mulali et al. (2012)	FMOLS	East, Pacific, Central and South Asia, East Europe, Latin America and the Caribbean, Middle East and North Africa, Sub- Saharan Africa, and Western Europe countries/1980-2008	84% of countries have the positive long-run relationship between urbanization; energy consumption and carbon dioxide emission and the remaining have the unclear results
6	Zhu et al. (2012)	STIRPAT model, semi-parametric, fixed effect model	20 emerging economies/1992-2008	urbanization has a nonlinear association ship with CO_2 emission
7	Al-Mulali et al. (2013)	Dynamic OLS technique, panel cointegration and panel Granger causality	MENA countries/1980-2009	urbanization, energy consumption and CO_2 emission have a short and long-run positive relationship
8	Heidari et al. (2015)	panel smooth transition regression model (PSTR)	ASEAN countries/1980-2008	The energy increases the CO_2 emission in the first and second regime. EKC hypothesis and its validity
9	Begum et al. (2015)	ARDL, DOLS and Sasabuchi–Lind–Mehlum U tests	Malaysia /1980-2009	the GDP per capita and energy consumption have a long-run positive impact on CO_2 emission
10	Saidi and Hammami (2015)	simultaneous equation method	58 countries /1990-2012	Impact of energy consumption on economic growth is positive. Economic growth is negatively affected by CO_2 emission.
11	Rafiq et al. (2016)	STIRPAT and EKC (Environmental Kuznets curve), second-generation heterogeneous linear panel model, nonlinear techniques	22 emerging economies/1980-2010	population density and affluence increase emissions and energy intensity while renewable energy seems to be dormant in these emerging economies, but non-renewable energy increase CO_2 emissions and energy intensity
12	Li and Lin (2015)	STIRPAT model and dynamic threshold regression model	73 countries/1971-2010	The energy consumption decreases, and carbon dioxide emission increases due to industrialization and urbanization increase the carbon dioxide emission and consumption of energy
13	Shahbaz et al. (2016)	STIRPAT model	Malayshia/1970 Q_1 -2011 Q_4	economic growth is a first-rate contributor to CO_2 emissions, the relationship between urbanization and CO_2 emissions are U-shaped
14	Wang et al.(2016)	FMOLS, Pedroni panel co-integration	ASEAN countries/1980-2009	urbanization, energy consumption and CO_2 emission have a positive long-run relationship
15	Sheng and Guo (2016)	STIRPAT model, mean group (MG), pooled mean group (PMG), and dynamic fixed (DFE)	China provinces/1995-2011	rapid urbanization increases CO_2 emissions both in the short and long run
16	Abdallh and Abugamos(2017)	STIRPAT	MENA countries/1980-2014	the continuation of the urbanization procedure, carbon emissions per capita decreased
17	Zhang et al. (2017)	STIRPAT	141 countries/1961-2011	Inverted U-shaped relationship between urbanization and CO_2 emission. excessive urban attention can declare the benefits of high-level urbanization

In addition, these economies are highly dependent on oil, and others import to stable their economic growth and development. There exist several approaches to find the relationship between urbanization, CO_2 emissions, and economic growth along with the EKC hypothesis. For example Narayan and Narayan (2010)with a panel cointegration and panel long run estimation, Shahbaz et al. (2016) using a STIRPAT model and Zhang et al. (2017) applying IPAT model. However, we follow Grossman and Kruger (1995), Heil and Selden (2001), and Koirala and Mysami (2015)approach to model; our empirical model as following:

$$CO_{2it} = \alpha_{1it} + \alpha_{yit} GDP_{it} + \alpha_{y^2it} (GDP)^2_{it} + \alpha_{Uit} \ Urban_{it} + \alpha_{fit} \ Forest_{it} + \epsilon_{it} \qquad (2)$$

We are going to use log-linear specification for empirical analysis. The standard EKC model represents the quadratic income function provides the base for the inclusion of square GDP in the model (Hui et al., 2007). Furthermore, ϵ_{it} is an idiosyncratic error term, independent, and identically distributed. It represents the standard normal distribution with unit variance and zero mean. Whereas i represent the country, t stands for a time period, α_{1it} is intercept, while α_{yit}, $\alpha_{Uit}, \alpha_{fit}$ are the long run elasticity's estimates of CO_2 emissions per capita with respect to the explanatory variables, such as real GDP per capita, urbanization, and deforestation respectively. The coefficient α_{y^2it} shows the shape of EKC curve in the panel countries. After estimation the following scenarios could be used to analyze EKC hypothesis: if $\alpha_{yit} = 0 \ and \ \alpha_{y^2it} = 0$ imply no relationship; $\alpha_{yit} > 0 \ and \ \alpha_{y^2it} = 0$ imply a monotonically increasing relationship; $\alpha_{yit} < 0 \ and \ \alpha_{y^2it} = 0$ imply a monotonically decreasing relationship; $\alpha_{yit} > 0 \ and \ \alpha_{y^2it} < 0$ imply an inverted U-shaped relationship, i.e. EKC hypothesis; $\alpha_{yit} < 0 \ and \ \alpha_{y^2it} > 0$ imply U-shaped relationship (Koirala and Mysami, 2015). However, the relationship between CO_2 emissions and explanatory variables cannot be estimated at this stage.

2.3.3 Econometric Approach

There are five acquainted steps of a comprehensive analysis concerning an econometric point of view. Unit root testing, cointegration, Pooled mean regression group, FMOLS, DOLS, and Dumitrescu- Hurlin (DH) causality test, we use for empirical analysis.

2.3.3.1 Unit Root Testing

The first step employed in this research is known as a stochastic method which could be determined by investigating unit root problem in the variables of the panel. The panel unit root test is used to determine the presence of the stochastic trends, which is broadly designed to elaborate on the postulation of cross-sectional dependence. Due to several different testing strategies, the aim to apply several unit root tests in the panel is to analyze the reliability of empirical results. Mainly, ADF Fisher and PP Fisher tests have been employed to determine the issues of stationarity. Also, many factors like the trans-border movement of pollutant, general residual interdependence, unobserved common factors, omitted observed common factors, and pollution cross-ways in South Asia and South Asian regions can cause the increased in cross-sectional dependence cross-ways the cross-section units (Behera and Dash, 2017). For that reason, to handle the trouble of cross-sectional dependence, it is instructive to use the panel unit root test proposed by Pesaran (2007).

2.3.3.2 Cointegration Testing

2.3.3.2.1 Pedroni Test

Many panel cointegration tests are suggested by Pedroni (2004). The long-run information in the pool and short-run dynamics of cross-sectional unit is the significant benefit of cointegration techniques. The pooling can be executed both by employing within and between the dimensional statistics. Pedroni (2001a, 2001b) presents seven-panel cointegration statistics, out of which four considered within dimension statistics and three between-dimension statistics. The computation of the residuals of the hypothesized cointegrating regression by Pedroni (2004) is as follows:

$$Y_{i,t} = \alpha_0 + \alpha_{1,i}X_{1i,t} + \alpha_{2,i}X_{2i,t} + \dots\dots\dots\dots\dots\dots. + \alpha_{Z,i}X_{Zi,t} + e_{i,t} \qquad (3)$$

In equation-3, t denotes the number of observations, Z denotes the number of independent variables, and N represents the number of panel members. It was supposed that a variation between the slope coefficients $\alpha_{1i}, \alpha_{2i} \dots\dots. \alpha_{Zi}$ and the member specific intercept α_0 can occur across each cross-section. The relevant panel cointegration test statistics could be computed through panel cointegration regression equation 2. The existed difference between estimated residuals and original series to compute the panel–ρ and panel-t statistics are represented in the following regression:

$$Y_{i,t} = c_{1i}\ \Delta x_{1i,t} + c_{2,i} x_{2i,t} + \ \ldots\ldots\ldots\ldots\ldots\ldots . + c_{Z,i} \Delta x_{Zi,t} + \hat{\varphi}\ _{i,t} \quad (4)$$

The Newey-West (1987) estimator represented the residuals of the regression, the variance represented by $\hat{\varphi}\ ^{2}_{i,t}$ and symbolized as per $\hat{L}^{2}_{11i}$ was calculated as:

$$\hat{L}^{2}_{11i} = \frac{1}{T}\sum_{t=1}^{T} \hat{\varphi}\ ^{2}_{i,t}\ + \frac{2}{T}\sum_{s=1}^{k_i}\left(1 - \frac{s}{k_i+1}\right) 1/T \sum_{t=s+1}^{T} \hat{\varphi}\ _{i,t}\ \ \hat{\varphi}\ _{i,t-s} \quad (5)$$

The regression is estimated for both panel–ρ and group–ρ statistics by using $\hat{\varepsilon}_{i,t} = \hat{\gamma}_i \hat{\varepsilon}_{i,t-1} + \tilde{\mu}^{2}_{i,t}$, using the residuals $\hat{e}_{i,t}$ from the cointegration equation-2. After that, the long-run variance($\tilde{\sigma}^{2}_{i}$) and contemporaneous variance ($\hat{s}^{2}_{i}$) of $\hat{\mu}_{i,t}$ were computed, where:

$$\hat{s}^{2}_{i} = \sum_{t=1}^{t} \hat{\mu}_{i,t} \text{ And}$$

$$\hat{\sigma}_{i}^{2}\ = \frac{1}{T}\sum_{t=1}^{T} \hat{\mu}_{i,t}\ + \frac{2}{T}\sum_{s=1}^{k_i}\left(1 - \frac{s}{k_i+1}\right) 1/T \sum_{t=s+1}^{T} \hat{\mu}_{i,t}\, \hat{\mu}_{i,t-s} \quad (6)$$

Where, $k_i$stands as lag length and additionally, authors also calculated the term:

$$\tau_i = \frac{1}{2}(\hat{\sigma}^{2}_{i} - \hat{s}^{2}_{i})$$

However, for panel-t and group–t again using the residuals of $\boldsymbol{\hat{\varepsilon}}_{i,t} of \boldsymbol{\hat{\varepsilon}}_{i,t}$ cointegration regression-1, we estimated $\hat{\varepsilon}_{i,t} = \hat{\gamma}\ _i\ \hat{\varepsilon}_{i,t-1}\ + \sum_{t}^{k} = 1\hat{\gamma}\ _{ik}\ \Delta\hat{\varepsilon}_{i,t-1}\ + \hat{\mu}^{*}_{i,t}$. In this study, the step-down procedure and the Schwarz lag order selection criteria have been applied to determine the lag truncation order of ADF t-statistics.

$$\hat{s}_i^{*2} = 1/T \sum_{t=1}^{T} \hat{\mu}_{i,t}^{*\,2}, \sim \hat{s}_{i,t}^{*\,2} \equiv 1/Nt = 1N\hat{s}_i^{*2}$$

The next move was the computation of the relevant Pedroni panel cointegration statistics based on within dimension using the following expressions:

a) Pedroni v-statistic**:**

$$Z_v = \left(\sum_{i=1}^{N} \sum_{i=1}^{T} \hat{L}_{11i}^{-2} \hat{\varepsilon}_{it-1}^{2} \right)^{-1}$$

b) Panel statistic:

$$Z_p = \left(\sum_{i=1}^{N} \sum_{i=1}^{T} \hat{L}_{11}^{-2} \hat{\varepsilon}_{it-1}^{2} \right)^{-1} \sum_{i=1}^{N} \sum_{i=1}^{T} \hat{L}_{11}^{-2} \hat{\varepsilon}_{it-1}^{2} (\hat{\varepsilon}_{it-1} \Delta \hat{\varepsilon}_{it} - \hat{\tau}_i)$$

c) Panel pp-statistic:

$$Z_t = \left(\hat{\sigma}^2 \sum_{i=1}^{N} \sum_{i=1}^{T} \hat{L}_{11}^{-2} \hat{\varepsilon}_{it-1}^{2} \right)^{-1/2} \sum_{i=1}^{N} \sum_{i=1}^{T} \hat{L}_{11}^{-2} \hat{\varepsilon}_{it-1}^{2} (\hat{\varepsilon}_{it-1} \Delta \hat{\varepsilon}_{it} - \hat{\tau}_i)$$

d) Panel ADF statistic:

$$Z_{*p} = \left(\hat{S}^{*2} \sum_{i=1}^{N} \sum_{i=1}^{T} \hat{L}_{11}^{-2} \hat{\varepsilon}_{it-1}^{2} \right)^{-\frac{1}{2}} \sum_{i=1}^{N} \sum_{i=1}^{T} \hat{L}_{11}^{-2} \hat{\varepsilon}_{it-1}^{*2} (\hat{\varepsilon}_{it-1}^{*2} \Delta \hat{\varepsilon}_{it})$$

For Pedroni panel cointegration statistics based on between dimensions, it was used the following expressions:

a) Group-p statistic

$$\bar{z}_p = \sum_{i=1}^{N}\left(\sum_{i=1}^{T}\hat{\varepsilon}_{it-1}^{-2}\right)^{-1}\sum_{i=1}^{T}\hat{\varepsilon}_{it-1}^{2}\,(\hat{\varepsilon}_{it-1}\,\Delta\hat{\varepsilon}_{it} - \Delta\,\hat{\tau}_i)$$

b) Group pp-statistic

$$\bar{z}_t = \sum_{i=1}^{N}\left(\hat{\sigma}^2\sum_{i=1}^{T}\hat{\varepsilon}_{it-1}^{-2}\right)^{-1/2}\sum_{i=1}^{T}\hat{\varepsilon}_{it-1}^{2}\,(\hat{\varepsilon}_{it-1}\,\Delta\hat{\varepsilon}_{it} - \hat{\tau}_i)$$

c) Group ADF statistic:

$$\bar{z}_t^{\,*} = \sum_{i=1}^{N}\left(\sum_{i=1}^{T}\hat{S}^{*2}\hat{\varepsilon}_{it-1}^{-2}\right)^{-1/2}\sum_{i=1}^{T}\hat{\varepsilon}_{it-1}^{*}\,(\hat{\varepsilon}_{it-1}\,\Delta\hat{\varepsilon}_{it})$$

In the end, to have a standard normally distributed statistics, the appropriate variance and mean adjustment has been applied to each panel cointegration. $\frac{\chi_{N,T}-\mu\sqrt{N}}{\sqrt{v}} => N(0,1)$ where $\chi_{N,T}$ are the properly standardized technique and functions of moments of the underlying Brownian motion functional.$H_0 : \hat{\gamma_i} = 1$, for all, I represent the null hypothesis as no cointegration. Whereas, alternative hypothesis has two conditions: first, between-dimension-based and second, within-dimension-based panel cointegration test. Condition one $H_a\!: \hat{\gamma_i} < 1$ for all i. whereas, common value $\hat{\gamma_i} = \hat{\gamma}$ is not required. However, in the case of within-dimension-based $H_a\!: \hat{\gamma} = \hat{\gamma_i} < 1$ for all I, but the common value $\hat{\gamma_i} = \hat{\gamma}$ is required in this case.

2.3.3.2.2 Westerlund Cointegration Approach

To have validated and more reliable results, Westerlund (2007) test of cointegration has been applied. This test enables the researchers to estimate the diverse forms of heterogeneity along with p-values. Westerlund (2007)test strengthens the cross-sectional dependence through bootstrapping. Four test statistics are planned in this cointegration test. First, two tests out of four are designed to consider the cointegrated as whole panel. Second, the remaining two tests are intended to examine the cointegrated panel with at least one cross-sectional unit. The first explained two test statistics based on whole cointegration are referred to as group statistics and denoted by (G_τ and G_α); whereas, the other two are referred to panel statistics which are denoted by (P_τ and P_α). The null hypothesis of this test is no error-correction. It means that if the null hypothesis is rejected, cointegration exists among variables. The Westerlund (2007)tests are based on the following error correction model:

$$\Delta y_{it} = \delta' d_t + \alpha_i \left(y_{it-1} - \beta_i' x_{it-1}\right) + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{it-j} + \sum_{j=-q_i}^{p_i} \gamma_{ij} \Delta x_{it-j} + e_{it} \quad (7)$$

In equation-7 t=1,… , T and i=1,……., N stand as time-series and cross-sectional units respectively, while d_t contains the deterministic components.

2.3.3.3 Pooled Mean Group Regression

The mentioned cointegration tests well validate the cointegration relationship between the variables. In a third step, we apply the pooled mean group regression (PMG) recommended by Pesaran (1997) and Pesaran et al. (1999), which enables convergence speed and short-run adjustment to measure the heterogeneity of each country. Pesaran et al. (1999) suggested that this model takes the cointegration form of the simple ARDL model and adapts it for a panel set by allowing the intercepts, short-run coefficients, and cointegrating terms to differ across cross-sections. It further executes the restrictions of the cross-country homogeneity on the long-run coefficients. Hence, the ARDL (p, q) model is as follows:

$$\Delta(I_i)_t = \sum_{j=1}^{p-1} \rho_j^i \Delta(I_i)_{t-j} + \sum_{j=0}^{q-1} \delta_j^i \Delta(x_i)_{t-j} + \theta^i\left[(I_i)_{t-1} - \alpha_1^i (X_i)_{t-j}\right] + e_{it} \quad (8)$$

Where, $(I_i)_{t-j}$ and $(I_i)_{t-1}$ describe short and long-run standards regarding CO_2 emissions, respectively; while ρ_j^i and δ_j^i are the short-run coefficients; θ^i is the error correction term; $(x_i)_{t-j}$ and $(X_i)_{t-j}$ are the values of short-run and long-run variables, α_1^i are the long-run coefficients; and $e_{it} = \mu_i + v_{it}$; whereas μ_i and v_{it} represents country specific fixed and time variant effects respectively.

2.3.3.4 Dumitrescu- Hurlin (DH) Causality Test

A few policy implications can be defined through the analysis of short-run and long-run connection without prior knowledge regarding the causal association between them (Shahbaz et al., 2013b). Therefore, in a fourth step, we applied the Dumitrescu and Hurlin (2012) causality test, as this is an appropriate method and represents the more advantages as compare with traditional Granger (1969) causality test. The DH presents the two important domains of heterogeneity known as the heterogeneity of the regression model and heterogeneity of the casual relationship.

2.3.3.5 DOLS and GM-FMOLS

Having evidence of both cointegration Pedroni and Westerlund tests on the empirical model, the estimation of the parameters presented in the empirical model is the next and last step. Nevertheless, the desired results may find by applying ordinary least squares (OLS) method on panel data. Also, fixed effect, random effect, and GMM approach could be a cause of inconsistency and misleading coefficients when applied to cointegrated panel data (Ahmed et al., 2017). To avoid the type of inconsistency concerning the OLS, fixed effect, random effect, and GMM methods, it is instructive to use the Group Mean Fully Modified Ordinary Least Squares (GM-FMOLS) proposed by Pedroni (2001b) and dynamic ordinary least square (DOLS) introduced by Stock and Watson (1993). To test the strength of the long-run coefficient through PMG method, the GM-FMOLS and DOLS methods are considered the most appropriate techniques. FMOLS is believed to eliminate the hassle of endogeneity in the regressors, and serial correlation within the errors, which might also result in consistent estimate parameters in a relatively small sample. Likewise, the problem of endogeneity, multicollinearity, and serial correlation is solved by using the DOLS estimator. Moreover, DOLS method gives the cointegrating vector.

2.4 Results and their Discussion

Table 2. 8 (see in Appendix A) represent the statistics summary of being selected variables presented throughout1990-2014. According to these statistics, the highest CO_2 emissions (in metric tons per capita) was in Brunei (24.60) in 2011, while the lowest level was in the Maldives (0.6703) in 1991 in the high-income countries list. The average value of CO_2 emissions was in high-income countries (6.98). In the Middle-income countries, the maximum of CO_2 emissions was in Indonesia (2.55) in 2012, and the minimum was in Sri Lanka (0.2232).

Moreover, the average emissions were 0.92 in the middle-income economies. In the case of low-income countries, the maximum value of CO_2 emissions was in Pakistan (0.9910) in 2007 and a minimum in Nepal (0.033835) in 1990 with an average of 0.30. Furthermore, in the case of South Asian and Southeast Asian region, the highest value of CO_2 emissions was in Iran (8.2830) in 2014 and Brunei (24.60) in 2011, respectively. The minimum value of CO_2 emissions in South, Southeast region, was in Nepal and Maldives. The mean value of CO_2 emissions was 1.90 and 6.98, in South and Southeast Asian regions, respectively.

The highest value of real GDP (in US dollars constant 2010) was in Brunei (37838.32) in 1992, while the lowest value of real GDP was in Myanmar (193.24 32) in 1991. The average real GDP was 4274.18 over the period 1990-2014 of the selected countries. Regarding the level of forest (Km^2) per thousand people, Bhutan has the highest forest area (49.64) in 1995, while the lowest area was covered by Maldives (0.024495) in 2014. The most top urbanized country per capita was Brunei (0.7633) in 2014, and minimum migration was in Nepal (0.0885) in 1990. The average value of urbanization per capita was 0.3518. The matrix correlation between our analysis variables shows that CO_2 emissions are positively correlated with GDP and urbanization in all panels.

On the other hand, CO_2 emissions are positively correlated with forest in high-income countries and Southeast Asian region while, negatively correlated in low, middle-income countries and the South Asian region. Furthermore, forest is positively correlated with urbanization in high-income countries and Southeast Asian region and has a negative relationship in low, middle income, and south Asian regions. This empirical research estimation begins with the application of several panel-unit root tests to analyze the stationarity properties. ADF Fisher and PP-Fisher test are used in the variables to measure the integration property.

Along with CO_2 emissions of a country which can affect environmental conditions of another country, the countries of the South and Southeast Asian regions are also suffering from the cross-country heterogeneity, cross-sectional dependence, and transborder pollutants effect (Behera and Dash, 2017). A well-known Pesaran (2007) unit root test has been used to manage the ambiguity of cross-sectional dependence.

The results of the PP-Fisher and ADF Fisher panel unit root tests are presented in Table 2.9 (see in Appendix A). In all the cases of different panels of the countries, almost all the variables are non-stationary at the level.

However, variables are stationary at first difference rejecting the null hypothesis at 5% level of significance. This result shows that the variables contain a panel unit root. The literature illustrated that to manage the cross-sectional dependence, the ADF test is not enough. Therefore, the presence of cross-sectional dependence is controlled by applying the Pesaran (2007) unit root test.

Table 2.2: Unit Root Analysis with Cross-Sectional Dependence

Economies	Variables	Without trend T-bar	Without trend Z-t-tilde-bar	Without trend P-value	With trend T-bar	With trend Z-t-tilde-bar	With trend P-value
Low	**co_2**	-0.6987	2.3588	0.9908	-2.0527	1.4039	0.0802
	Δco_2	-14.0299	-9.0816	0.0000	-13.8212	-8.6214	0.0000
	for	-8.9129	3.8533	0.0001	-0.6736	3.9803	1.0000
	Δfor	-3.3e+02	-8.6182	0.0000	-6.2e+02	-7.5096	0.0000
	gdp	2.5579	9.8721	1.0000	-1.5299	0.4287	0.6659
	Δgdp	-38.7851	-7.9674	0.0000	-41.7996	-7.7702	0.0000
	urban	-8.2941	-2.4824	0.0065	-1.2090	2.3034	0.9894
	Δurban	-5.0e+02	8.5900	0.0000	2.5e+03	-8.2457	0.0000
Middle	**co_2**	-1.0941	1.1761	0.8802	-1.9038	-1.0813	0.1398
	Δco_2	-15.9851	-9.4507	0.0000	-15.1513	-8.8493	0.0000
	for	-3.6954	-2.3114	0.0104	-1.1728	2.6901	0.9964
	Δfor	-2.5e+02	-8.7721	0.0000	-4.0e+02	-8.1931	0.0000
	gdp	0.8125	6.7456	1.0000	-1.7013	-0.1289	0.4487
	Δgdp	-62.0221	-8.6555	0.0000	-64.2276	-8.1657	0.0000
	urban	-2.9564	1.3850	0.9170	1.5991	6.6557	1.0000
	Δurban	-4.3e+02	-8.4632	0.0000	-5.1e+02	-8.2850	0.0000
High	**co_2**	-1.8202	-0.7409	0.2294	-2.9692	-3.0330	0.0012
	Δco_2	-18.5212	-9.2953	0.0000	-17.7057	-8.7487	0.0000
	for	-6.7752	-0.0350	0.4860	-1.1105	2.1584	0.9846
	Δfor	-4.0e+02	-8.5070	0.0000	-4.5e+02	-8.3008	0.0000
	gdp	-1.1662	0.7887	0.7849	-2.5264	-2.1930	0.0142
	Δgdp	-31.3966	-9.1109	0.0000	-29.1606	-8.5159	0.0000
	urban	-3.4455	-0.5939	0.2763	-0.6620	2.2967	0.9892
	Δurban	2.5e+03	-8.2457	0.0000	-5.0e+02	8.5900	0.0000
All panels	**co_2**	-1.1681	1.6982	0.9569	-2.2697	-3.1213	0.0009
	Δco_2	-16.7288	-8.5252	0.0000	-15.9202	-8.0469	0.0000
	for	-6.4427	-3.6814	0.0001	-0.9783	5.1333	1.0000
	Δfor	-4.7e+02	-7.3951	0.0000	-5.4e+02	-7.3420	0.0000
	gdp	0.8466	10.3001	1.0000	-1.8834	-1.0112	0.1560
	Δgdp	-23.9342	-8.0785	0.0000	-22.2837	-7.5857	0.0000
	urban	-4.9841	-0.9740	0.1650	-0.5700	6.5680	1.0000
South Asia	**co_2**	-0.9365	1.8881	0.9705	-2.2592	-2.0900	0.0183
	Δco_2	-20.3392	-10.7264	0.0000	-19.2348	-10.0229	0.0000
	for	-4.0489	0.7307	0.7675	-0.4151	3.6659	0.9999
	Δfor	-5.2e+02	-10.5298	0.0000	-7.5e+02	-9.2918	0.0000
	gdp	1.1654	8.0253	1.000	-1.9150	-0.7964	0.2120
	Δgdp	-48.4027	-4.0792	0.0000	-46.8773	-9.4085	0.0000
	urban	-3.1497	0.2438	0.5963	0.2639	4.9373	1.000
	Δurban	-2.7e+02	-10.3959	0.0000	-4.2e+02	-9.9389	0.0000
Southeast Asia	**co_2**	-1.3741	0.5539	0.7102	-2.2790	-2.3193	0.0102
	Δco_2	-22.9334	-11.288	0.0000	-22.0027	-10.534	0.0000
	for	-8.5706	-5.7484	0.0000	-1.4858	3.5989	0.9998
	Δfor	-88.0121	-11.0417	0.0000	-1.6e+02	-10.6638	0.0000
	gdp	0.5232	6.5898	1.0000	-1.8554	-0.6361	0.2624
	Δgdp	-70.8814.	-10.8381	0.0000	-80.3528	-10.1641	0.0000
	urban	-6.6148	-1.5685	0.0584	-0.3423	4.3720	1.0000
	Δurban	-1.1e+03	-11.9676	0.0000	-6.6e+03	-11.6531	0.0000

Note: we report (T-bar) and Z (t-tilde-bar) statistics in the table.

The result in Table 2.2 also shows that all the variables are non-stationary at the level and they are stationary at first difference. Therefore, we can declare that both first-and second-generation unit root tests have similar findings. Hence, after the first order integration of variables, the next step is to analyze the cointegration among different variables. For this reason, we have used two cointegration tests name Pedroni (2004) and Westerlund (2007) known as second-generation.

Table 2.3: Pedroni Panel Cointegration Analysis

Economies		**Low**		**Middle**		**High**	
		Without trend	**With trend**	**Without trend**	**With trend**	**Without trend**	**With trend**
Within - dimension	Panel v-Statistic	0.1589 (0.4369)	0.109186 (0.4565)	0.386035 (0.3497)	-0.217626 (0.5861)	-1.338080 (0.9096)	-1.687644 (0.9543)
	Panel rho-Statistic	-0.03845 (0.4847)	0.3222 (0.6264)	0.917718 (0.8206)	1.377053 (0.9158)	-0.108724 (0.4567)	-0.567505 (0.2852)
	Panel PP-Statistic	-1.9560 (0.0254)	-2.4866 (0.0064)	0.500729 (0.6917)	-0.140307 (0.4442)	-1.355198 (0.0877)	-4.640831 (0.0000)
	Panel ADF-Statistic	-1.5606 (0.0593)	-3.5751 (0.0002)	-0.525094 (0.2998)	-1.960120 (0.0250)	0.226538 (0.5896)	-1.944049 (0.0259)
Between-dimension	Group rho-Statistic	0.5647 (0.7139)	0.7923 (0.7859)	1.814839 (0.9652)	2.321699 (0.9899)	0.582150 (0.7198)	0.292276 (0.6150)
	Group PP-Statistic	-2.9326 (0.0017)	-4.2184 (0.0000)	0.728121 (0.7667)	0.522206 (0.6992)	-1.466860 (0.0712)	-12.05880 (0.0000)
	Group ADF-Statistic	-2.7258 (0.0032)	-3.9835 (0.0000)	-0.364402 (0.3578)	-1.193842 (0.1163)	-0.368968 (0.3561)	-3.673069 (0.0001)
Regions		**South Asia**		**Southeast Asia**		**All Countries**	
Within - dimension	Panel v-Statistic	-0.154997 (0.5616)	-0.097587 (0.5389)	-0.325699 (0.6277)	-0.923213 (0.8221)	-0.337266 (0.6320)	-0.743840 (0.7715)
	Panel rho-Statistic	-0.026388 (0.4895)	0.145972 (0.5580)	0.542221 (0.7062)	0.891522 (0.8137)	0.355065 (0.6387)	0.753451 (0.7744)
	Panel PP-Statistic	-1.829361 (0.0337)	-4.521192 (0.0000)	-0.812772 (0.2082)	-1.387085 (0.0827)	-1.895021 (0.0290)	-3.939011 (0.0000)
	Panel ADF-Statistic	-0.098174 (0.4609)	-3.302581 (0.0005)	-1.650802 (0.0494)	-3.164292 (0.0008)	-1.291757 (0.0582)	-4.535434 (0.0000)
Between-dimension	Group rho-Statistic	0.748567 (0.7729)	1.050942 (0.8534)	1.671094 (0.9526)	1.769631 (0.9616)	1.729413 (0.9581)	2.008536 (0.9777)
	Group PP-Statistic	-1.959334 (0.0250)	-10.74315 (0.0000)	-1.046052 (0.1478)	-1.877356 (0.0302)	-2.105206 (0.0176)	-8.735720 (0.0000)
	Group ADF-Statistic	-0.953525 (0.1702)	-4.528175 (0.0000)	-1.899179 (0.0288)	-2.695894 (0.0035)	-2.035969 (0.0209)	-5.067853 (0.0000)

Note: P-values are reported in the parentheses. Automatic selection of maximum lags is based on 0-2 SIC: Newey-west bandwidth selection using Bartlett and Kernel.

The Pedroni panel cointegration results are reported in Table 2.3. In the case of low income, high income, South Asian, Southeast Asian region, and a full panel of the 17 countries, the results indicate that four out of seven statistics are accepting the alternative hypotheses of cointegration. It simply illustrates the long run relationship of CO_2 emissions with GDP, forest per thousand persons, and urbanization. The results of cointegration between the variables linked with Wang et al. (2016). But there is no cointegration in the case of middle-income countries. Table 2.4 reported the second-generation test of cointegration has been employed to overcome this issue of cross-sectional dependence crossways the SSEA regions. Overall, results concluded a long run relationship between economic growth, deforestation, urbanization, and carbon emissions in the SSEA regions with both methods.

Table 2.4: Westerlund (2007) Panel Cointegration Analysis

Economies		G_t	G_a	P_t	P_a	Economies	G_t	G_a	P_t	P_a
Low income	Without trend	-3.136 (0.00)	-0.78 (1.00)	8.537 (0.00)	-0.986 (0.99)	**Middle income**	-2.703 (0.11)	-1.122 (1.00)	-3.724 (0.82)	-1.390 (0.98)
	With trend	-3.452 (0.01)	-0.45 (1.0)	-8.717 (0.00)	-0.765 (1.00)		-2.432 (0.77)	-0.872 (1.00)	-3.570 (0.99)	-0.941 (1.00)
High income	Without trend	-3.467 (0.00)	-5.42 (0.9)	-4.388 (0.46)	-2.385 (0.95)	**All countries**	-3.080 (0.00)	-2.267 (1.00)	-7.354 (0.05)	-1.454 (1.00)
	With trend	-3.096 (0.15)	-2.83 (1.0)	-4.195 (0.91)	-1.633 (0.99)		-2.987 (0.09)	-1.302 (1.00)	-7.583 (1.00)	-0.988 (1.00)
South Asia	Without trend	-3.184 (0.002)	-1.89 (1.00)	-6.186 (0.238)	-1.304 (0.996)	**Southeast Asia**	-2.988 (0.008)	-2.601 (1.000)	-5.030 (0.756)	-1.541 (0.997)
	With trend	-3.321 (0.023)	-0.90 (1.00)	-7.997 (0.07))	-1.212 (1.000)		-2.691 (0.518)	-1.657 (1.000)	-4.605 (0.999)	-0.889 (1.000)

Note: No cointegration taken as the null hypothesis. The test regression is fitted with constant, constant and trend, with one lag and a 0-1 lead. The width of the Bartlett Kernel, the window has been used in the semi parametric estimation of long-run variances. The p-values are reported in the parentheses

The pooled mean regression group results reported in Table 2.5.In the case of full countries panel, a long-run association between GDP square and urbanization with CO_2 emissions is observed. The result shows that a 1% increase in urban population causes 0.76% rise in carbon emissions. A positive and significant coefficient of GDP square is found which confirmed a U-shaped relationship, and these results align with (Chandran and Tang, 2013; Lean and Smyth, 2010; Liu et al., 2017; Narayan and Narayan, 2010) in case of ASEAN countries, (Sarkodie and Strezov, 2019) for India. However, forest and GDP are found to affect CO_2 emissions in the long run negatively.

The result concludes a 0.73% increase in CO_2 emissions is due to a 1% decrease in a forest area while economic growth has 1.73% impact on CO_2 emissions in the opposite direction in the SSEA regions. There is no worthy association founded between the short-run variables presented in full panel. The short-run results of GDP per capita and urbanization are linked with Behera and Dash (2017). The negative and statically significant error correction term confirms the long-run relationship between variables. The error correction term -0.42 shows that the speed of adjustment back towards the equilibrium is corrected by 0.42% each year.

Table 2.5: Pooled Mean Group Regression (PMG) Analysis

Equations	Variables	High	Middle	Low	All	South (Asia)	Southeast (Asia)
Long run	**Urban**	1.43***	-3.32**	1.570***	0.760*	1.191**	0.981**
		(4.84)	(2.89)	(3.82)	(2.00)	(2.85)	(3.49)
	For	-0.09*	-3.51**	-0.30**	-0.737**	-0.650**	-0.593***
		(1.66)	(2.98)	(-2.79)	(3.19)	(2.70)	(-4.88)
	Gdp	-0.58*	-9.45**	-0.207	-1.723**	-1.64**	-0.149
		(-2.03)	(2.89)	(-0.49)	(3.54)	(2.97)	(-0.84)
	gdp^2	0.09**	0.720**	0.037	0.154 ***	0.140 **	0.057 **
		(3.22)	(3.17)	(0.71)	(4.28)	(3.51)	(3.18)
Error correction coefficients		-0.43*	-0.26**	-0.39**	-0.42***	-0.519**	-0.409
		(-1.68)	(2.93)	(-2.69)	(5.25)	(3.36)	(4.60) ***
Short run	**D. urban**	2.433373	19.749	5.31*	15.854	5.843	14.880
		(1.00)	(0.90)	(1.88)	(1.01)	(0.98)	(-1.53)
	D. for	3.988690	-2.387	-4.11	-2.220	-1.082	1.428
		(1.29)	(0.43)	(-1.29)	(1.03)	(0.51)	(0.49)
	D. gdp	75.93329	-18.212	-31.76	25.180	1.479	35.56
		(1.26)	(1.54)	-1.28)	(0.97)	(0.12)	(1.25)
	D. gdp^2	-3.740775	1.247	2.671	-1.168	-0.192	-1.79
		(-1.31)	(1.55)	(1.30)	(0.90)	(0.21)	(-1.14)
constants	**_cons**	-2.16***	-7.91**	9.68**	-2.158**	-2.49**	-9.91 **
		(6.22)	(2.82)	(3.56)	(6.18)	(4.04)	(2.82)
N		120	144	144	408	192	216

Note: *, **, and *** indicates 10%, 5% and 1% level of significance, respectively. T-values reported in parentheses.

Furthermore, in the case of subpanels' lower-income, high-income countries, South Asia, and Southeast Asian region results indicate that urbanization has a positive relationship with CO_2 emissions although; the coefficients of urbanization vary between 0.98 and 1.57 in all subpanels except middle-income group. However, in the case of middle-income countries, urbanization negatively affects CO_2 emission in the long run.

Moreover, forests and GDP are negatively related to CO_2 emissions in the entire income groups countries with other two subpanels name as South and Southeast Asian regions in the long run. The forest coefficients vary between -0.09 and -3.5 in all panels.

Nevertheless, the GDP and GDP square sign, as well as significance level, are providing evidence of U-shaped relationship in the middle, high, South, and Southeast Asian region panels. The signs of the GDP and GDP square are consistent with (Begum et al., 2015; Mert and Bölük, 2016; Wang et al., 2017). Country specific conditions and policies, and various econometric approaches produced divergent results on the validity of the EKC hypothesis in the Asian economies (Ota, 2017). However, our study found insignificant results in the low-income group.

The EKC hypothesis is not fulfil in the low income countries because they are in the stage of early development (income inequality is higher than the income equality) (Al-mulali et al., 2015).

Moreover, the error correction term is significant and confirmed long-run relationship among the variables. There is no association has been reported between the short-run variables presented in all subpanels.

Table 2.6: FMOLS and DOLS Analysis

Economies	Variables	FMOLS	DOLS	Economies	FMOLS	DOLS
High (income)	**For**	6.93***	10.29**	**South (Asia)**	0.030*	0.055
		(0.006)	(0.04)		(0.10)	(0.59)
	Gdp	-2.56***	-3.00		-0.074	-0.627*
		(0.00)	(0.34)		(0.36)	(0.08)
	urban	26.83***	38.01*		1.58***	1.45***
		(0.00)	(0.10)		(0.00)	(0.00)
	gdp^2	0.204***	0.166		0.042***	0.104***
		(0.00)	(0.52)		(0.00)	(0.00)
Middle (Income)	**For**	-0.10***	-1.65	**Southeast (Asia)**	-0.29	-0.22
		(0.00)	(0.75)		(0.00)	(0.09)
	Gdp	0.032	49.39**		-0.55***	-0.87***
		(0.79)	(0.04)		(0.00)	(0.00)
	urban	0.88***	0.68**		0.63***	-0.41*
		(0.00)	(0.02)		(0.00)	(0.08)
	gdp^2	0.013	-3.35**		0.090***	0.11***
		(0.39)	(0.04)		(0.00)	(0.00)
Low (Income)	**For**	-0.09***	-0.137	**All panels**	-0.076***	-0.15*
		(0.00)	(0.37)		(0.00)	(0.09)
	Gdp	-0.72***	0.295		-0.192***	-0.53***
		(0.00)	(0.52)		(0.00)	(0.00)
	urban	0.96***	2.24***		1.37***	0.76***
		(0.00)	(0.00)		(0.00)	(0.00)
	gdp^2	0.11***	-0.002		0.052***	0.08***
		(0.00)	(0.96)		(0.00)	(0.00)

Note: *, **, *** represents 1%, 5% and 10% level of significance, respectively. P- Values reported in the parentheses. DOLS regression includes fixed leads and lags specifications. (Lead=1, lag=1) coefficient covariance computing with default method, long-run variance (Bartlett Kernel, Newey-west fixed bandwidth) used for coefficient covariance.

Table 2.6 reported FMOLS and DOLS results to examine the long-run coefficients to check the robustness of the PMG estimates. The empirical results indicate that that coefficient of forest per thousand people has a negative and significant impact on CO_2 emissions in the case of the full panel as well as low-income, middle-income, and Southeast Asian regions while there is insignificant relationship exist in South Asian region. The results indicate that these areas are facing deforestation. Moreover, we found a positive impact of forest on CO_2 emissions in the high-income countries. It means that the forest area is also increasing with economic growth in high-income countries. Conversely, we found the same results as well with the DOLS method.

GDP per capita has an inverse and significant effect on CO_2 emissions in the case of the full panel of countries along with low-income, high-income, South Asia, and Southeast Asian regions. Our empirical evidence is similar to (M. M. Alam et al., 2016; Apergis, 2016; Ben Jebli et al., 2016; Le and Quah, 2018; Li et al., 2016; Ouyang and Lin, 2017; Shahbaz et al., 2015; Zaman and Moemen, 2017).

The relationship between urbanization and CO_2 emissions is positive and significant in the full panel as well as in all other sub-panels and result similar to (Sheng and Guo, 2016). Moreover, the same results as FMOLS could be found by applying alternative DOLS estimator. The mentioned statement illustrates that, in SSEA regions, deforestation and urbanization are the primary cause to increase the CO_2 emissions.

Table 2.7 reports Dumitrescu and Hurlin (2012) causality results, and we note the presence of feedback effect, i.e. forest, urbanization, and economic growth, are found to have bidirectional causality with CO_2 emissions in case of the full countries, South Asian, and Southeast Asian regions panels. However, the unidirectional causality is seen running from economic growth to CO_2 emissions is confirmed for the case of entire countries and South Asia panels. Moreover, no causal relationship exists between economic growth and CO_2 emissions in the case of the Southeast Asian region.

Furthermore, in the lower income countries, CO_2 emissions have a bidirectional causal link with forest and urbanization. The results also illustrated that economic growth and urbanization bidirectional causes forest while; unidirectional causality exists towards CO_2 emissions and urbanization to economic growth. Furthermore, high-income countries have a little different pattern than lower income countries — for instance, bidirectional relationships found between the urbanization and forest, economic growth and forest, urbanization with forest and economic growth. The unidirectional causality is detected running from forest and economic growth to CO_2 emissions. However, in the case of middle-income countries, a neutral effect is observed between forests, economic growth with CO_2 emissions. A unidirectional casual association running from forest to economic growth is also found. The empirical findings support the implementation of proper management of forest area, control urbanization policy for the long run in the SSEA regions. Dumitrescu-Hurlin causality results indicate that all the variables are interdependent in all cases and our results a line with (Gokmenoglu et al., 2019).

Table 2.7: Pair wise Dumitrescu-Hurlin Panel Causality Analysis

Economies	Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Economies	W-Stat.	Z bar-Stat.	Prob.
Low income	LFOR does not homogeneously cause LCO2	7.23717	4.78823	0.0000	**High income**	3.14450	0.78399	**0.4330**
	LCO2 does not homogeneously cause LFOR	10.9435	8.34670	0.0000		5.71107	3.03348	0.0024
	LGDP does not homogeneously cause LCO2	4.76222	2.41200	0.0159		3.12970	0.77102	**0.4407**
	LCO2 does not homogeneously cause LGDP	2.49473	0.23497	**0.8142**		4.36016	1.84947	0.0644
	LURBAN does not homogeneously cause LCO2	10.3563	7.78295	0.0000		4.94210	2.35951	0.0183
	LCO2 does not homogeneously cause LURBAN	5.58497	3.20193	0.0014		6.53636	3.75681	0.0002
	LGDP does not homogeneously cause LFOR	7.62682	5.16233	2.E-07		5.67328	3.00036	0.0027
	LFOR does not homogeneously cause LGDP	4.24912	1.91938	0.0549		7.33536	4.45710	0.0000
	LURBAN does not homogeneously cause LFOR	11.4952	8.87643	0.0000		7.59784	4.68714	0.0000
	LFOR does not homogeneously cause LURBAN	10.5900	8.00736	0.0000		5.33372	2.70275	0.0069
	LURBAN does not homogeneously cause LGDP	3.86248	1.54816	**0.1216**		6.16823	3.43416	0.0006
	LGDP does not homogeneously cause LURBAN	4.49713	2.15749	0.0310		7.58490	4.67581	0.0000
Middle income	LFOR does not homogeneously cause LCO2	2.66007	0.39371	**0.6938**	**South Asia**	3.04477	0.88111	0.3783
	LCO2 does not homogeneously cause LFOR	3.83679	1.52349	**0.1276**		7.74611	6.09320	0.0000
	LGDP does not homogeneously cause LCO2	3.85426	1.54026	**0.1235**		4.43957	2.42744	0.0152
	LCO2 does not homogeneously cause LGDP	2.81804	0.54538	**0.5855**		3.45837	1.33965	**0.1804**
	LURBAN does not homogeneously cause LCO2	4.93484	2.57774	0.0099		5.59312	3.70632	0.0002
	LCO2 does not homogeneously cause LURBAN	4.43082	2.09383	0.0363		4.66720	2.67980	0.0074
	LGDP does not homogeneously cause LFOR	23.6029	20.5011	0.0000		20.5428	20.2801	0.0000
	LFOR does not homogeneously cause LGDP	2.60593	0.34173	**0.7326**		4.42401	2.41020	0.0159
	LURBAN does not homogeneously cause LFOR	55.9597	51.5672	0.0000		46.9872	49.5974	0.0000
	LFOR does not homogeneously cause LURBAN	6.25354	3.84384	0.0001		9.01147	7.49603	0.0000
	LURBAN does not homogeneously cause LGDP	9.79717	7.24612	0.0000		8.25107	6.65302	0.0000
	LGDP does not homogeneously cause LURBAN	7.40685	4.95114	0.0000		5.35963	3.44745	0.0006
Southeast Asia	LFOR does not homogeneously cause LCO2	5.63864	3.98466	0.0000	**All countries**	4.41799	3.50371	0.0005
	LCO2 does not homogeneously cause LFOR	6.14091	4.57528	0.0000		6.89630	7.50890	0.0000
	LGDP does not homogeneously cause LCO2	3.53675	1.51308	**0.1303**		3.96161	2.76614	0.0057
	LCO2 does not homogeneously cause LGDP	2.89005	0.75263	**0.4517**		3.15750	1.46661	**0.1425**
	LURBAN does not homogeneously cause LCO2	7.96805	6.72379	0.0000		6.85043	7.43479	0.0000
	LCO2 does not homogeneously cause LURBAN	6.15988	4.59759	0.0000		5.45744	5.18357	0.0000
	LGDP does not homogeneously cause LFOR	5.71136	4.07017	0.0000		12.6909	16.8735	0.0000
	LFOR does not homogeneously cause LGDP	4.71278	2.89595	0.0038		4.57689	3.76050	0.0002
	LURBAN does not homogeneously cause LFOR	7.42456	6.08471	0.0000		26.0423	38.4508	0.0000
	LFOR does not homogeneously cause LURBAN	6.18204	4.62365	0.0000		7.51354	8.50643	0.0000
	LURBAN does not homogeneously cause LGDP	5.19895	3.46764	0.0005		6.63524	7.08701	0.0000
	LGDP does not homogeneously cause LURBAN	7.38571	6.03903	0.0000		6.43226	6.75897	0.0000

Note: 5% level of significance has been used. Insignificant values are highlighted

2.5 Conclusions and Policy Implications

This study designed to determine the effects of deforestation, economic growth, and urbanization on carbon emissions in the South and Southeast Asian (SSEA) regions for period of 1990-2014. This essay has examined the long-run relationship between CO_2 emissions, economic growth, urbanization, and forests by using Pedroni and Westerlund cointegration tests of 17 countries. The data was divided into five sub-panels, three of them are income-based groups (namely, lower, middle, and high-income panels) and the other two are South and Southeast Asian regions.

As noted in the introduction and literature review, urbanization and deforestation process in the World and Asian countries in recent decades has been worrying economic growth and sustainable economic growth. In this sense, the present study sought to assess the relationship between these variables. The conclusions reached allowed us to better understand what the mutual impact between those variables is and how policies can be formulated to promote the sustainable growth, with urbanization and forest as presented in this process.

The Pedroni cointegration test yields the confirmation of long-run relationship between forests, economic growth, urbanization, and CO_2 emissions in the SSEA regions. Nonetheless, the results produce by Westerlund cointegration are somehow different as compared to Pedroni test. Furthermore, in case of a full panel of 17 countries, low income and South Asian region panel, the Westerlund cointegration test yield the evidence of a long-run relationship between CO_2 emissions, economic growth, urbanization, and forests, thus supporting the Pedroni results. However, in the case of high, middle income and Southeast Asian region panels, we do not find any indication of long-run relationships among the variables throughout 1990-2014. The second major findings were that the existence of U-shaped relationship in the in case of a full panel of the 17 countries, Middle, high income, and South, Southeast Asian regions panels. However, in the case of lower income countries, results did not confirm this relationship. The research has also shown that the bidirectional causality exists among the variables in the SSEA region.

Taken together, these results suggest that deforestation and urbanization are substantially raising the CO_2 emissions in the SSEA region. Also, the result shows that the significance of the relationship between forests, economic growth, urbanization and CO_2 emissions in all income groups and region wise studies. This study concludes that deforestation is significantly increasing the level of CO_2 emissions in all income level countries and region wise panels resulted in an exaggeration of the greenhouse gas problem along with the destruction of environmental quality. However, it has been observed that industrialized and emerging economies are in the phase of restoration while, developing world in the stage of deforestation. Furthermore, urbanization is also significant in raising CO_2 emissions, but in the case of middle-income countries, we do not find any substantial effect.

Our results do not confirm EKC but evidence a U-shape relationship between CO_2 emissions and economic growth. Some studies found this kind of relationship, as Yandle et al. (2002), Wang et al. (2017), Begum et al.(2015) and Mert and Bölük (2016). The explanation for this result is based on the fact that most pollutants create localized problems like lead and sulfur, and there is a need to cleaning up such pollutants in a fast way. Therefore, as the regions verify economic growth, the marginal value of cleaning up such pollutants improves the quality of citizens' lives largely. On the contrary, reducing emissions has not so visible impact at the local level, but improves the environment at the global level.

This lead to the well-known “tragedy of the commons” (Hardin, 1968), where no one has the incentive to reduce pollution, and in the end, everyone is worse. So, Yandle et al. (2002) state that even in countries with a high level of income, carbon emissions could not be decreasing following the EKC. Accordingly, as CO_2 is a global pollutant, there is no consensus about its validity within Kuznets Curve (Uchiyama, 2016). Yandle et al. (2002) referred that policies that stimulate growth (as for instance trade liberalization) are good for the environmental quality.

The existence of a U-shape curve may suggest that for the studied countries the re-linking hypothesis is being verified (CO_2 and yield simultaneously growing) (R, 1996). On the other hand, population pressure in Asian countries may also be contributing to the verification of this assumption, as environmental quality may deteriorate as population pressure increases further. Furthermore, as stated by Ekins (1997), even if there is an EKC, growth in global population income will increase environmental damage. This damage is considered the main obstacle for achieving sustainable development (O’Neill et al., 1996). Thus, if the growth does not automatically lead to higher environment quality, environmental policies should help in this regard. It should also be noted that when analyzing different countries together, the maximum level of pollution depends on the costs and benefits of reducing pollution, which differ between countries. Different countries will have different absorptive capacity, social preferences, and discount rates, which implies different optimal levels of pollution between countries. This warns of the limitation of collective policies compared to local policies (de Bruyn et al., 1998). Our results also suggest that deforestation and urbanization could aggravate the environmental pollution and climate change of these regions and it could affect the further sustainable development in the long-run.

The findings of our study have several important implications for future practices. We found that deforestation is significantly increasing carbon emissions in the SSEA regions. The conclusion of the study leads to several different questions regarding the forest policy as well as the scientific research also indicate the climate change which can increase the forest fire.

The findings suggest effective forest management to help to reduce CO_2 emissions from deforestation and degradation, so required proper development on forest management would be a policy recommendation in this regard. Although forest managers are aware that their margin of action is limited, the profession and utilization of woodland are by their very nature essentially "residuals" and most depending on what occurs within the different sectors of human activity. As forest development is essential in all aspect for the well-being of local and national communities, the management must indulge them in defending the forests and their sustainable management.

In this regard, countries should be introduced an amendment in laws to protect the forests, and individual actions should be done against timber mafia. Colonization or new housing societies should be ban in the wooded areas, apartments or high buildings should be encouraged, and people would be required special permission before cutting trees. Another important practical implication is to aware people about the importance of trees on traditional media along with social media; especially motivate teenagers at the school level for the long-run sustainability. Moreover, the most appropriate and cost-effective method to minimize anthropogenic CO_2 emissions is the improvement of forest activities.

The second significant finding of the discussion above suggests that urbanization is significantly raising the carbon emissions in the South and Southeast Asian regions. It concludes that sustainable urbanization models should be applied instead of unreliable sustainable urbanization models in SSEA countries. Furthermore, to maintain a certain threshold level of pollution and environmental degradation, SSEA countries must take the initiative of a cross-country settlement. Moreover, an active interference for trans-border movement should be implemented to regulate the air pollutants.

The confirmation of a U-shape relationship between CO_2 emissions and economic growth means that these countries can grow in a sustainable path, but they must be aware of long term risks of this economic growth, as this sustainable path could be compromised when reaching the turning point of the "U". Due to lenient environmental policies of the developing countries or ease of doing, business and cheap labor together motivates the investor to invest in some Asian countries. This process is called carbon leakage. Conversely, developing countries are also more concern about employment opportunities rather than harmful environmental effects. In this situation, policymaker should revise the environmental policies and encourage environmentally friendly projects and compensate them in the taxes. Besides, promote investor to invest in remote areas, especially in the green zone. Every new project must declare some green space nearby to offsetting the carbon emissions.

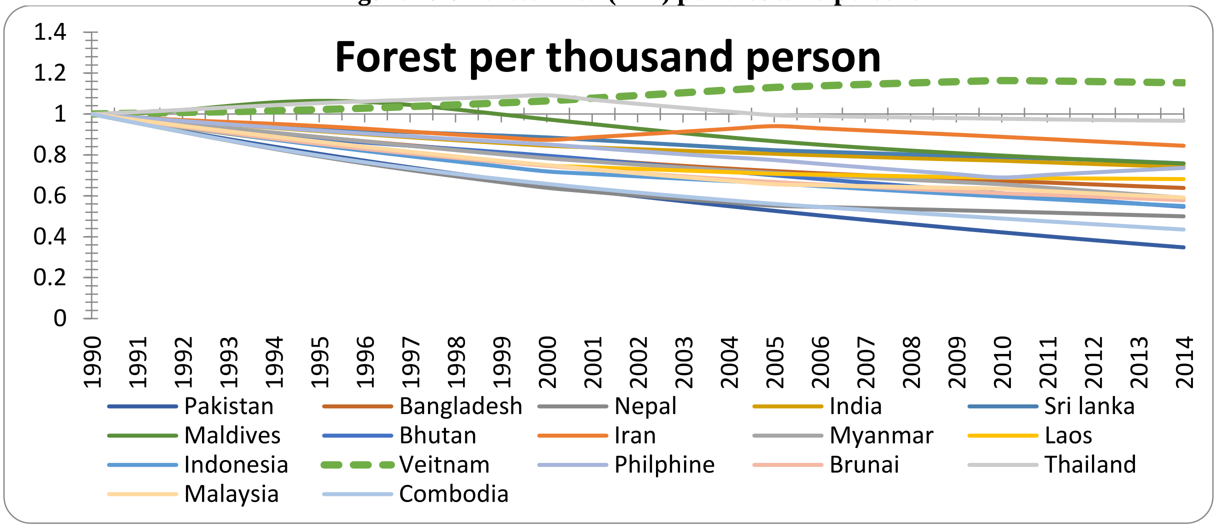
The generalisability of these results is subject to the following limitations. First, forest per thousand-person data is used instead of per capita because the population is varying in different countries. Second, the data used for this study is bounded only to the country level with annual observations. Third, the study did not evaluate the use of other relevant variables that caused carbon dioxide emissions like energy demand, Information and communication technology (ICT), foreign direct investment, trade openness.

2.6 Future Research Direction

Finally, and most importantly, the future recommendation is the nonlinear modelling procedures. This study could be possible with other econometric techniques like GMM two-step, or three steps approach, panel smooth transition regression model (PSTR). The present study could be tried with STRIPAT model, cubic model approach for EKC hypothesis, etc. Further investigation could focus the implications at cities or district level. Moreover, this work should be exploited with quarterly data to check the proper short-run effects, or even more including more related variables with forest and urbanization with extended sample period to capture the impact of deforestation policies by the countries in the SSEA regions.

2.7 Appendix A

Figure 2.1: Forest Area (km^2) per thousand persons



Source: Own elaboration with World Bank data

Table 2. 8: Descriptive Statistics and Correlation Matrix

Economies	Variables	Max	Min	Mean	S.D	CO_2	Forest	GDP	Urbanization
High income	**CO_2**	24.60	0.67	6.98	6.06	1	0.72	0.90	0.73
	Forest	15.96	0.03	5.02	4.79		1	0.74	0.62
	GDP	37838.3	2502.71	11808	12418.07			1	0.57
	Urbanization	0.77	0.25	0.53	0.17				1
Middle income	**CO_2**	2.56	0.22	0.92	0.44	1	-0.25	0.46	0.61
	Forest	49.65	0.55	8.63	15.59		1	-0.08	-0.17
	GDP	3692.94	431.89	1614.1	758.9			1	0.45
	Urbanization	0.53	0.16	0.31	0.35				1
Lower Income	**CO_2**	0.99	0.033	0.30	0.24	1	-0.38	0.61	0.75
	Forest	41.43	0.08	8.46	11.30		1	0.09	-0.13
	GDP	1470.50	193.24	655.73	268.89			1	0.65
	Urbanization	0.36	0.08	0.23	0.07				1
South Asian	**CO_2**	8.28	0.03	1.40	1.90	1	-0.14	0.73	0.92
	Forest	49.64	0.02	6.02	14.11		1	-0.14	-0.09
	GDP	8124.70	357.20	2213.15	2127.83			1	0.63
	Urbanization	0.72	0.08	0.30	0.15				1
Southeast Asian	**CO_2**	24.60	0.67	6.98	6.06	1	0.72	0.90	0.73
	Forest	15.95	0.02	5.02	4.79		1	0.74	0.62
	GDP	37838.32	2502.71	11808.35	12418.07			1	0.57
	Urbanization	0.76	0.25	0.53	0.17				1
Overall	**CO_2**	24.60	0.03	2.48	4.39	1	0.01	0.93	0.78
	Forest	49.64	0.02	7.51	11.81		1	0.04	-0.08
	GDP	37838.32	193.24	4274.18	8318.43			1	0.67
	Urbanization	0.76	0.08	0.35	0.17				1

Note: Authors own calculation based on the data over the period 1990-2014. Mean = simple average, Max= maximum; Min = Minimum; S.D = standard deviation and right columns presented pair-wise correlations and results reported till second decimal.

Table 2.9: Unit Root Analysis

Economies	Variables	Without trend		With trend		Economies	Without trend		With trend	
		ADF Fisher	PP-Fisher	ADF Fisher	PP-Fisher		ADF Fisher	PP-Fisher	ADF Fisher	PP-Fisher
Low	**co2**	5.694	5.040	10.294	9.622	**High**	8.5416	12.706	11.3814	19.914
		(0.930)	(0.956)	(0.590)	(0.649)		(0.576)	(0.240)	(0.3286)	(0.042)
	Δco2	45.432	84.278	33.612	71.369		53.016	111.086	42.229	322.67
		(0.000)	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
	For	12.389	116.319	26.402	9.517		11.494	27.899	23.415	3.0097
		(0.415)	(0.000)	(0.009)	(0.658)		(0.3203)	(0.001)	(0.009)	(0.983)
	Δfor	6.701	3.919	27.586	2.564		21.102	7.3107	14.7406	5.4682
		(0.876)	(0.984)	(0.006)	(0.997)		(0.010)	(0.695)	(0.141)	(0.857)
	Gdp	0.5072	0.2898	4.595	5.052		3.8101	4.3174	20.98	15.217
		(1.000)	(1.00)	(0.970)	(0.956)		(0.95)	(0.93)	(0.02)	(0.13)
	Δgdp	26.158	50.024	27.779	50.670		54.26	87.61	39.38	203.99
		(0.010)	(0.000)	(0.006)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
	Urban	36.661	53.760	23.3927	5.381		157.49	57.594	29.154	2.797
		(0.000)	(0.000)	(0.024)	(0.944)		(0.000)	(0.000)	(0.001)	(0.985)
	Δurban	7.885	5.179	14.913	40.479		7.189	10.591	6.117	71.557
		(0.794)	(0.951)	(0.246)	(0.001)		(0.707)	(0.390)	(0.805)	(0.000)
Middle	**co2**	7.718	8.573	10.650	8.2532	**All**	21.954	26.32	32.32	37.79
		(0.806)	(0.738)	(0.559)	(0.765)		(0.94)	(0.82)	(0.54)	(0.30)
	Δco2	55.790	90.429	41.169	73.000		154.24	285.79	117.0	467.04
		(0.00)	(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	(0.00)	(0.00)
	For	12.577	39.664	249.28	6.846		36.461	183.88	299.09	19.373
		(0.400)	(0.0001)	(0.000)	(0.867)		(0.354)	(0.000)	(0.000)	(0.979)
	Δfor	44.536	6.954	25.044	2.836		72.34	18.185	67.37	10.86
		(0.000)	(0.860)	(0.014)	(0.996)		(0.000)	(0.987)	(0.000)	(0.999)
	Gdp	4.286	1.869	6.167	7.493		8.6038	6.476	31.745	27.763
		(0.977)	(0.999)	(0.907)	(0.823)		(1.00)	(1.000)	(0.578)	(0.766)
	Δgdp	37.077	61.734	29.705	53.182		117.50	199.36	96.865	307.85
		(0.000)	(0.000)	(0.003)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
	Urban	12.467	57.914	8.945	1.796		206.625	169.270	61.492	9.975
		(0.408)	(0.000)	(0.707)	(0.999)		(0.000)	(0.000)	(0.85)	(1.000)
	Δurban	3.698	2.350	4.772	4.542		18.773	18.121	25.802	116.580
		(0.988)	(0.998)	(0.965)	(0.971)		(0.9840)	(0.988)	(0.05)	(0.000)
South Asia	**co2**	9.192	9.4688	9.040	20.493	**Southeast Asia**	12.761	16.851	23.286	17.297
		(0.905)	(0.892)	(0.911)	(0.198)		(0.805)	(0.533)	(0.179)	(0.502)
	Δco2	75.150	162.527	56.324	356.35		79.089	123.26	60.686	110.692
		(0.000)	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
	For	11.044	79.638	269.203	6.945		25.417	104.24	29.89	12.428
		(0.806)	(0.000)	(0.000)	(0.974)		(0.113)	(0.000)	(0.630)	(0.824)
	Δfor	61.276	9.934	63.598	5.987		11.0635	8.25	48.17	59.11
		(0.000)	(0.870)	(0.000)	(0.988)		(0.891)	(0.97)	(0.00)	(0.00)
	Gdp	1.195	1.570	13.240	15.930		7.981	5.996	23.794	14.747
		(1.000)	(1.000)	(0.6551)	(0.457)		(0.992)	(0.998)	(0.2515)	(0.790)
	Δgdp	63.245	127.345	51.948	243.87		67.098	94.1594	54.725	81.345
		(0.000)	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
	Urban	75.761	81.609	9.119	5.630		130.86	87.660	28.574	4.345
		(0.000)	(0.000)	(0.908)	(0.991)		(0.000)	(0.000)	(0.063)	(0.999)
	Δurban	9.826	5.066	28.94	31.312		8.946	13.055	58.661	51.424
		(0.875)	(0.995)	(0.00)	(0.012)		(0.9610)	(0.788)	(0.00)	(0.000)

Note: P-values are reported in the parentheses. Automatic selection of maximum lags is based on 0-2 SIC: Newey-west bandwidth selection using Bartlett and Kernel.

References

Abdallh, A.A., Abugamos, H., 2017. A semi-parametric panel data analysis on the urbanisation-carbon emissions nexus for the MENA countries. Renewable and Sustainable Energy Reviews 78, 1350–1356. https://doi.org/10.1016/j.rser.2017.05.006

Adu, D.T., Denkyirah, E.K., 2018. Economic growth and environmental pollution in West Africa: Testing the Environmental Kuznets Curve hypothesis. Kasetsart Journal of Social Sciences. https://doi.org/10.1016/j.kjss.2017.12.008

Ahmed, K., Rehman, M.U., Ozturk, I., 2017. What drives carbon dioxide emissions in the long-run? Evidence from selected South Asian Countries. Renewable and Sustainable Energy Reviews 70, 1142–1153. https://doi.org/10.1016/j.rser.2016.12.018

Ahmed, K., Shahbaz, M., Qasim, A., Long, W., 2015. The linkages between deforestation, energy and growth for environmental degradation in Pakistan. Ecological Indicators 49, 95–103.

Alam, Md.M., Murad, Md.W., Noman, A.H.Md., Ozturk, I., 2016. Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. Ecological Indicators, Navigating Urban Complexity: Advancing Understanding of Urban Social – Ecological Systems for Transformation and Resilience 70, 466–479. https://doi.org/10.1016/j.ecolind.2016.06.043

Ali, H.S., Abdul-Rahim, A.S., Ribadu, M.B., 2017. Urbanization and carbon dioxide emissions in Singapore: evidence from the ARDL approach. Environmental Science and Pollution Research 24, 1967–1974.

Al-mulali, U., Binti Che Sab, C.N., Fereidouni, H.G., 2012. Exploring the bi-directional long run relationship between urbanization, energy consumption, and carbon dioxide emission. Energy 46, 156–167. https://doi.org/10.1016/j.energy.2012.08.043

Al-mulali, U., Fereidouni, H.G., Lee, J.Y.M., Sab, C.N.B.C., 2013. Exploring the relationship between urbanization, energy consumption, and CO2 emission in MENA countries. Renewable and Sustainable Energy Reviews 23, 107–112. https://doi.org/10.1016/j.rser.2013.02.041

Al-Mulali, U., Solarin, S.A., Ozturk, I., 2016. Investigating the presence of the environmental Kuznets curve (EKC) hypothesis in Kenya: an autoregressive distributed lag (ARDL) approach. Nat Hazards 80, 1729–1747. https://doi.org/10.1007/s11069-015-2050-x

Al-mulali, U., Weng-Wai, C., Sheau-Ting, L., Mohammed, A.H., 2015. Investigating the environmental Kuznets curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation. Ecological Indicators 48, 315–323. https://doi.org/10.1016/j.ecolind.2014.08.029

Alvarez-Herranz, A., Balsalobre-Lorente, D., Shahbaz, M., Cantos, J.M., 2017. Energy innovation and renewable energy consumption in the correction of air pollution levels. Energy Policy 105, 386–397. https://doi.org/10.1016/j.enpol.2017.03.009

Amri, F., 2018. Carbon dioxide emissions, total factor productivity, ICT, trade, financial development, and energy consumption: testing environmental Kuznets curve hypothesis for Tunisia. Environ Sci Pollut Res 25, 33691–33701. https://doi.org/10.1007/s11356-018-3331-1

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

Antonakakis, N., Chatziantoniou, I., Filis, G., 2017. Energy consumption, CO2 emissions, and economic growth: An ethical dilemma. Renewable and Sustainable Energy Reviews 68, 808–824. https://doi.org/10.1016/j.rser.2016.09.105

Apergis, N., 2016. Environmental Kuznets curves: New evidence on both panel and country-level CO2 emissions. Energy Economics 54, 263–271. https://doi.org/10.1016/j.eneco.2015.12.007

Awan, U., Abbasi, A.S., Humayon, A.A., 2014. The Concept of Civic Sustainability is Need of Hour. Research Journal of Environmental and Earth Sciences 6, 347–352.

Awan, U., Kraslawski, A., Huiskonen, J., 2018. Governing Interfirm Relationships for Social Sustainability: The Relationship between Governance Mechanisms, Sustainable Collaboration, and Cultural Intelligence. Sustainability 10, 4473. https://doi.org/10.3390/su10124473

Begum, R.A., Sohag, K., Abdullah, S.M.S., Jaafar, M., 2015. CO 2 emissions, energy consumption, economic and population growth in Malaysia. Renewable and Sustainable Energy Reviews 41, 594–601. https://doi.org/10.1016/j.rser.2014.07.205

Behera, S.R., Dash, D.P., 2017. The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. Renewable and Sustainable Energy Reviews 70, 96–106. https://doi.org/10.1016/j.rser.2016.11.201

Ben Jebli, M., Ben Youssef, S., Ozturk, I., 2016. Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries. Ecological Indicators 60, 824–831. https://doi.org/10.1016/j.ecolind.2015.08.031

Berry, Lobley, B.J., 1973. Comparative urbanization: divergent paths in the twentieth century. Macmillan Publishers Limited.

Chandran, V.G.R., Tang, C.F., 2013. The impacts of transport energy consumption, foreign direct investment and income on CO2 emissions in ASEAN-5 economies. Renewable and Sustainable Energy Reviews 24, 445–453. https://doi.org/10.1016/j.rser.2013.03.054

Chaolin, G., Liya, W., Cook, I., 2012. Progress in research on Chinese urbanization. Frontiers of Architectural Research 1, 101–149. https://doi.org/10.1016/j.foar.2012.02.013

Chikaraishi, M., Fujiwara, A., Kaneko, S., Poumanyvong, P., Komatsu, S., Kalugin, A., 2015. The moderating effects of urbanization on carbon dioxide emissions: A latent class modeling approach. Technological Forecasting and Social Change 90, 302–317.

Christopoulou, O., Polyzos, S., Minetos, D., 2007. Peri-urban and urban forests in Greece: obstacle or advantage to urban development? Management of Environmental Quality: An International Journal 18, 382–395.

Ciesielski, M., Stereńczak, K., 2018. What do we expect from forests? The European view of public demands. Journal of environmental management 209, 139–151.

Coletta, V., Lombardi, F., Altieri, V., Bombino, G., Marcianò, C., Menguzzato, G., Marziliano, P.A., 2016. Environmental resources conservation through sustainable forest management. Procedia-Social and Behavioral Sciences 223, 758–763.

de Bruyn, S.M., van den Bergh, J.C.J.M., Opschoor, J.B., 1998. Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves. Ecological Economics 25, 161–175. https://doi.org/10.1016/S0921-8009(97)00178-X

De Chant, T., Gallego, A.H., Saornil, J.V., Kelly, M., 2010. Urban influence on changes in linear forest edge structure. Landscape and Urban Planning 96, 12–18.

De Sy, V., Herold, M., Achard, F., Beuchle, R., Clevers, J., Lindquist, E., Verchot, L., 2015. Land use patterns and related carbon losses following deforestation in South America. Environmental Research Letters 10, 124004.

DeFries, R.S., Rudel, T., Uriarte, M., Hansen, M., 2010. Deforestation driven by urban population growth and agricultural trade in the twenty-first century. Nature Geoscience 3, 178–181. https://doi.org/10.1038/ngeo756

Delphin, S., Escobedo, F.J., Abd-Elrahman, A., Cropper, W.P., 2016. Urbanization as a land use change driver of forest ecosystem services. Land Use Policy 54, 188–199.

Dinda, S., 2004. Environmental Kuznets Curve Hypothesis: A Survey. Ecological Economics 49, 431–455. https://doi.org/10.1016/j.ecolecon.2004.02.011

Dumitrescu, E.-I., Hurlin, C., 2012. Testing for Granger non-causality in heterogeneous panels. Economic Modelling 29, 1450–1460.

Ekins, P., 1997. The Kuznets Curve for the Environment and Economic Growth: Examining the Evidence. Environ Plan A 29, 805–830. https://doi.org/10.1068/a290805

Nations, F. and A.O. of the U., 2018. Global Forest Resources Assessment 2015: How are the world's forests changing? Second edition. Food & Agriculture Org.

Glaeser, E.L., Kahn, M.E., 2010. The greenness of cities: Carbon dioxide emissions and urban development. Journal of Urban Economics 67, 404–418. https://doi.org/10.1016/j.jue.2009.11.006

Gokmenoglu, K.K., Olasehinde-Williams, G.O., Taspinar, N., 2019. Testing the Environmental Kuznets Curve Hypothesis: The Role of Deforestation, in: Energy and Environmental Strategies in the Era of Globalization. Springer, pp. 61–83.

Gołos, P., 2013. Selected aspects of the forest recreational function in view of its users. Forest Research Papers 74, 257–272. https://doi.org/10.2478/frp-2013-0025

Granger, C.W., 1969. Investigating causal relations by econometric models and cross-spectral methods. Econometrica: Journal of the Econometric Society 424–438.

Grossman, G.M., Krueger, A.B., 1995. Economic growth and the environment. The quarterly journal of economics 110, 353–377.

Grossman, G.M., Krueger, A.B., 1991. Environmental impacts of a North American free trade agreement. National Bureau of Economic Research.

Hardin, G., 1968. The Tragedy of the Commons. Science 162, 1243–1248. https://doi.org/10.1126/science.162.3859.1243

He, Z., Xu, S., Shen, W., Long, R., Chen, H., 2017. Impact of urbanization on energy related CO 2 emission at different development levels: Regional difference in China based on panel estimation. Journal of Cleaner Production 140, 1719–1730. https://doi.org/10.1016/j.jclepro.2016.08.155

Heidari, H., Turan Katircioğlu, S., Saeidpour, L., 2015. Economic growth, CO2 emissions, and energy consumption in the five ASEAN countries. International Journal of Electrical Power & Energy Systems 64, 785–791. https://doi.org/10.1016/j.ijepes.2014.07.081

Heil, M.T., Selden, T.M., 2001. Carbon emissions and economic development: future trajectories based on historical experience. Environment and Development Economics 6, 63–83.

Hewson, J., Razafimanahaka, J.H., Wright, T.M., Mandimbiniaina, R., Mulligan, M., Jones, J.P., Van Soesbergen, A., Andriamananjara, A., Tabor, K., Rasolohery, A., 2019. Land Change Modelling to Inform Strategic Decisions on Forest Cover and CO 2 Emissions in Eastern Madagascar. Environmental Conservation 46, 25–33.

Hui, C., Wong, A., Tjosvold, D., 2007. Turnover intention and performance in China: The role of positive affectivity, Chinese values, perceived organizational support and constructive controversy. Journal of Occupational and Organizational Psychology 80, 735–751.

Intergovernmental Panel on Climate Change 2018, reportWorking Group 1 Report, 2018. . IPCC.

Kishor, N., Belle, A., 2004. Does improved governance contribute to sustainable forest management? Journal of Sustainable Forestry 19, 55–79.

Koirala, B.S., Li, H., Berrens, R.P., 2011. Further investigation of environmental Kuznets curve studies using meta-analysis. International Journal of Ecological Economics and Statistics 22, 13–32.

Koirala, B.S., Mysami, R.C., 2015. Investigating the effect of forest per capita on explaining the EKC hypothesis for CO2 in the US. Journal of Environmental Economics and Policy 4, 304–314.

Le, T.-H., Quah, E., 2018. Income level and the emissions, energy, and growth nexus: Evidence from Asia and the Pacific. International economics 156, 193–205.

Lean, H.H., Smyth, R., 2010. CO2 emissions, electricity consumption and output in ASEAN. Applied Energy 87, 1858–1864.

Li, H., Mu, H., Zhang, M., Gui, S., 2012. Analysis of regional difference on impact factors of China’s energy – Related CO2 emissions. Energy 39, 319–326. https://doi.org/10.1016/j.energy.2012.01.008

Li, K., Lin, B., 2015. Impacts of urbanization and industrialization on energy consumption/CO 2 emissions: Does the level of development matter? Renewable and Sustainable Energy Reviews 52, 1107–1122. https://doi.org/10.1016/j.rser.2015.07.185

Li, T., Wang, Y., Zhao, D., 2016. Environmental Kuznets curve in China: new evidence from dynamic panel analysis. Energy Policy 91, 138–147.

Liu, X., Bae, J., 2018. Urbanization and industrialization impact of CO2 emissions in China. Journal of Cleaner Production 172, 178–186. https://doi.org/10.1016/j.jclepro.2017.10.156

Liu, X., Zhang, S., Bae, J., 2017. The impact of renewable energy and agriculture on carbon dioxide emissions: Investigating the environmental Kuznets curve in four selected ASEAN countries. Journal of Cleaner Production 164, 1239–1247. https://doi.org/10.1016/j.jclepro.2017.07.086

Martínez-Zarzoso, I., Maruotti, A., 2011. The impact of urbanization on CO2 emissions: Evidence from developing countries. Ecological Economics 70, 1344–1353. https://doi.org/10.1016/j.ecolecon.2011.02.009

Marziliano, P.A., Lafortezza, R., Colangelo, G., Davies, C., Sanesi, G., 2013. Structural diversity and height growth models in urban forest plantations: A case-study in northern Italy. Urban forestry & urban greening 12, 246–254.

Meng, L., Crijns-Graus, W.H., Worrell, E., Huang, B., 2018. Impacts of booming economic growth and urbanization on carbon dioxide emissions in Chinese megalopolises over 1985–2010: an index decomposition analysis. Energy Efficiency 11, 203–223.

Mert, M., Bölük, G., 2016. Do foreign direct investment and renewable energy consumption affect the CO2 emissions? New evidence from a panel ARDL approach to Kyoto Annex countries. Environ Sci Pollut Res 23, 21669–21681. https://doi.org/10.1007/s11356-016-7413-7

Miao, L., 2017. Examining the impact factors of urban residential energy consumption and CO2 emissions in China–Evidence from city-level data. Ecological indicators 73, 29–37.

Mishra, V., Smyth, R., Sharma, S., 2009. The energy-GDP nexus: evidence from a panel of Pacific Island countries. Resource and Energy Economics 31, 210–220.

Moomaw, W.R., Unruh, G.C., 1997. Are environmental Kuznets curves misleading us? The case of CO 2 emissions. Environment and Development Economics 2, 451–463.

Narayan, P.K., Narayan, S., 2010. Carbon dioxide emissions and economic growth: Panel data evidence from developing countries. Energy policy 38, 661–666.

O'Neill, R.V., Kahn, J.R., Duncan, J.R., Elliott, S., Efroymson, R., Cardwell, H., Jones, D.W., 1996. Economic Growth and Sustainability: A New Challenge. Ecological Applications 6, 23–24. https://doi.org/10.2307/2269544

Ota, T., 2017. Economic growth, income inequality and environment: assessing the applicability of the Kuznets hypotheses to Asia. Palgrave Commun 3, 1–23. https://doi.org/10.1057/palcomms.2017.69

Ouyang, X., Lin, B., 2017. Carbon dioxide (CO2) emissions during urbanization: A comparative study between China and Japan. Journal of cleaner production 143, 356–368.

Pacione, M., 2003. Quality-Of-Life Research in Urban Geography. Urban Geography 24, 314–339. https://doi.org/10.2747/0272-3638.24.4.314

Parajuli, R., Joshi, O., Maraseni, T., 2019. Incorporating Forests, Agriculture, and Energy Consumption in the Framework of the Environmental Kuznets Curve: A Dynamic Panel Data Approach. Sustainability 11, 2688. https://doi.org/10.3390/su11092688

Pedroni, P., 2004. Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econometric theory 20, 597–625.

Pedroni, P., 2001a. Purchasing power parity tests in cointegrated panels. Review of Economics and Statistics 83, 727–731.

Pedroni, P., 2001b. Fully modified OLS for heterogeneous cointegrated panels, in: Nonstationary Panels, Panel Cointegration, and Dynamic Panels. Emerald Group Publishing Limited, pp. 93–130.

Pesaran, M.H., 2007. A simple panel unit root test in the presence of cross-section dependence. Journal of applied econometrics 22, 265–312.

Pesaran, M.H., 1997. The role of economic theory in modelling the long run. The Economic Journal 107, 178–191.

Pesaran, M.H., Shin, Y., Smith, R.P., 1999. Pooled mean group estimation of dynamic heterogeneous panels. Journal of the American Statistical Association 94, 621–634.

Piussi, P., Farrell, E.P., 2000. Interactions between society and forest ecosystems: challenges for the near future. Forest Ecology and Management 132, 21–28.

Poumanyvong, P., Kaneko, S., 2010. Does urbanization lead to less energy use and lower CO2 emissions? A cross-country analysis. Ecological Economics 70, 434–444. https://doi.org/10.1016/j.ecolecon.2010.09.029

R, S., 1996. CO2 EMISSION-INCOME RELATIONSHIP: POLICY APPROACH FOR CLIMATE CONTROL 7, 207–229.

Rafiq, S., Salim, R., Nielsen, I., 2016. Urbanization, openness, emissions, and energy intensity: A study of increasingly urbanized emerging economies. Energy Economics 56, 20–28. https://doi.org/10.1016/j.eneco.2016.02.007

Richmond, A.K., Kaufmann, R.K., 2006. Is there a turning point in the relationship between income and energy use and/or carbon emissions? Ecological economics 56, 176–189.

Saidi, K., Hammami, S., 2015. The impact of energy consumption and CO2 emissions on economic growth: Fresh evidence from dynamic simultaneous-equations models. Sustainable Cities and Society 14, 178–186. https://doi.org/10.1016/j.scs.2014.05.004

Sarkodie, S.A., Strezov, V., 2019. Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. Science of The Total Environment 646, 862–871. https://doi.org/10.1016/j.scitotenv.2018.07.365

Shahbaz, M., Dube, S., Ozturk, I., Jalil, A., 2015. Testing the environmental Kuznets curve hypothesis in Portugal. International Journal of Energy Economics and Policy 5, 475–481.

Shahbaz, M., Loganathan, N., Muzaffar, A.T., Ahmed, K., Jabran, M.A., 2016. How urbanization affects CO2 emissions in Malaysia? The application of STIRPAT model. Renewable and Sustainable Energy Reviews 57, 83–93.

Shahbaz, M., Tiwari, A.K., Nasir, M., 2013. The effects of financial development, economic growth, coal consumption and trade openness on CO2 emissions in South Africa. Energy Policy 61, 1452–1459.

Sharma, S.S., 2011. Determinants of carbon dioxide emissions: empirical evidence from 69 countries. Applied Energy 88, 376–382.

Sheng, P., Guo, X., 2016. The Long-run and Short-run Impacts of Urbanization on Carbon Dioxide Emissions. Economic Modelling 53, 208–215. https://doi.org/10.1016/j.econmod.2015.12.006

Stock, J.H., Watson, M.W., 1993. A simple estimator of cointegrating vectors in higher order integrated systems. Econometrica: Journal of the Econometric Society 783–820.

Uchiyama, K., 2016. Environmental Kuznets Curve Hypothesis, in: Environmental Kuznets Curve Hypothesis and Carbon Dioxide Emissions. Springer Japan, Tokyo, pp. 11–29. https://doi.org/10.1007/978-4-431-55921-4_2

Ünal, H.E., Birben, Ü., Bolat, F., 2019. Rural population mobility, deforestation, and urbanization: case of Turkey. Environmental Monitoring and Assessment 191. https://doi.org/10.1007/s10661-018-7149-6

Urbanet, 2018. News and Debates on Municipal and Local Government, Sustainable Urabn Development Decentralisation.

Wang, P., Wu, W., Zhu, B., Wei, Y., 2013. Examining the impact factors of energy-related CO2 emissions using the STIRPAT model in Guangdong Province, China. Applied Energy 106, 65–71. https://doi.org/10.1016/j.apenergy.2013.01.036

Wang, S., Li, G., Fang, C., 2018a. Urbanization, economic growth, energy consumption, and CO2 emissions: Empirical evidence from countries with different income levels. Renewable and Sustainable Energy Reviews 81, 2144–2159. https://doi.org/10.1016/j.rser.2017.06.025

Wang, S., Yang, F., Wang, X., Song, J., 2017. A Microeconomics Explanation of the Environmental Kuznets Curve (EKC) and an Empirical Investigation. Pol. J. Environ. Stud. 26, 1757–1764. https://doi.org/10.15244/pjoes/68567

Wang, S., Zeng, J., Huang, Y., Shi, C., Zhan, P., 2018b. The effects of urbanization on CO2 emissions in the Pearl River Delta: a comprehensive assessment and panel data analysis. Applied energy 228, 1693–1706.

Wang, Y., Chen, L., Kubota, J., 2016. The relationship between urbanization, energy use and carbon emissions: evidence from a panel of Association of Southeast Asian Nations (ASEAN) countries. Journal of Cleaner Production 112, 1368–1374. https://doi.org/10.1016/j.jclepro.2015.06.041

Wang, Y., Zhao, T., 2015. Impacts of energy-related CO2 emissions: evidence from under developed, developing and highly developed regions in China. Ecological Indicators 50, 186–195.

Westerlund, J., 2007. Testing for error correction in panel data. Oxford Bulletin of Economics and statistics 69, 709–748.

World development indicators, 2019. . World Bank.

World Energy Outlook, 2017. International Energy Agency.

Worldometer, 2018. Worldometers.

Xie, Q., Liu, J., 2019. Combined nonlinear effects of economic growth and urbanization on CO2 emissions in China: Evidence from a panel data partially linear additive model. Energy 186, 115868. https://doi.org/10.1016/j.energy.2019.115868

Yandle, B., Vijayaraghavan, M., Bhattarai, M., 2002. The environmental Kuznets curve. A Primer, PERC Research Study 02–01.

Zaman, K., Moemen, M.A., 2017. Energy consumption, carbon dioxide emissions and economic development: Evaluating alternative and plausible environmental hypothesis for sustainable growth. Renewable and Sustainable Energy Reviews 74, 1119–1130. https://doi.org/10.1016/j.rser.2017.02.072

Zhang, N., Yu, K., Chen, Z., 2017. How does urbanization affect carbon dioxide emissions? A cross-country panel data analysis. Energy Policy 107, 678–687. https://doi.org/10.1016/j.enpol.2017.03.072

Zhang, Y.-J., Liu, Z., Zhang, H., Tan, T.-D., 2014. The impact of economic growth, industrial structure and urbanization on carbon emission intensity in China. Natural hazards 73, 579–595.

Zhu, H.-M., You, W.-H., Zeng, Z., 2012. Urbanization and CO2 emissions: A semi-parametric panel data analysis. Economics Letters 117, 848–850. https://doi.org/10.1016/j.econlet.2012.09.001

Chapter III

The role of ICT in energy consumption and environment: an empirical investigation of Asian economies with cluster analysis

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3 The role of ICT in energy consumption and environment: an empirical investigation of Asian economies with cluster analysis

3.1 Introduction

Information and Communication Technology (ICT) refers to “technologies that provide access to information through telecommunications” (Christensson, 2010), including Internet, wireless networks, cell phones, and other communication mediums. In the past few decades, ICT have provided society with a massive selection of new communication skills. For example, people can communicate in real-time with others in different countries using technologies such as instant messaging and video-conferencing. Social networking websites allow users from all over the world to remain in contact and communicate on a regular basis. Modern information and communication technologies have created a "global village". Recent studies have provided a perception of the effects of ICT on economic growth, productivity, employment, competitiveness, and firm performance (Bloom et al., 2010; Cardona et al., 2013; Kossaï and Piget, 2014; Majeed and Khan, 2019). These multi-dimensional changes have been observed in almost all aspects of life: economics, education, communication, and travel.

There are no doubts that ICT plays a significant role in economic growth and social development in the modern era; nonetheless, it also harms the quality of the environment (Park et al., 2018) and has a substantial impact on climate change. Carbon dioxide (CO_2) emissions are one of the primary sources of climate change. According to the existing literature, several drivers of CO_2 emissions have been discussed on different platforms like economic growth, industrialization, urbanization, deforestation, waste management, air pollution, energy consumption. Since the late 1990s, ICT is also discussed as one of the factors which influenced the global climate (Salahuddin et al.,2016). Cohen et al. (1998) and Jokinen et al. (1998) are the pioneer researchers who tested ICT and environmental relationships from a theoretical and conceptual perspective.

In the recent decade, several studies discussed the effect of ICT on CO_2 emissions (Park et al., 2018). A direct effect is expected, due to energy consumption in the ICT production process, distribution, and use. This effect is estimated by 1.4% of global CO_2 emissions (Malmodin and Lundén, 2018). Moreover, there are indirect effects, as ICT has an impact in other economic sectors and in this sense can help with the reduction of CO_2 emissions, through energy efficiency and smart applications. These indirect effects were estimated in 6 to 15% of reduction until 2030 (Malmodin and Bergmark, 2015). However, a “rebound-effect” can occur, as ICT changes behaviors. More available and affordable technologies increase consumption, and the previously described reduction of emissions can be cancelled with this raise in ICT consumption, with the consequent rise in energy consumption and emissions. Therefore, there seems to be a time lag between ICT technological and structural changes and the effect on emissions (Hernnäs, 2018), and this could make different countries, with different socio-economic stages, have different impacts of ICT on emissions.

Empirical studies found twofold results (positive and negative) regarding the impacts of ICT on the environment quality around the globe. For example, Al-Mulali et al. (2015), conducted a research on 77 developed and under developed countries, and concluded that the use of ICT enhances environmental quality in the developed countries. Ozcan and Apergis (2018), Higon et al.(2017), C. Zhang and Liu (2015), Ishida (2015) and Salahuddin and Gow (2016) also found similar results.

Conversely, the usage of ICT raises energy demand, which ultimately increases CO_2 emissions as explained by another group of researchers (see; Salahuddin et al. (2016) for OECD countries, Belkhir and Elmeligi (2018) and Lee and Brahmasrene (2014) for ASEAN countries, Park et al. (2018) for the European Union and Asongu (2018) in Sub-Saharan Africa).

Furthermore, in a survey of data centers, Zakarya (2018) discussed the energy consumption of ICT equipment and presented classification of energy and performance efficient techniques. Their findings show significant improvement in energy efficiency, in the performance of ICT equipment, and large-scale computing systems such as data centers and identify a few open challenges. On the other hand, Amri (2018) reported the non-significant effect of ICT on CO_2 emissions in the case of Tunisia for the period of 1975-2014.

A country’s financial development may also influence CO_2 emissions through the financial support of energy projects and technological progress in the energy sector to reduce emissions. However, it can raise emissions as they also stimulate industry and polluting activities (Jensen, 1996). Environmental quality can also be affected by financial development as it can improve research and development (R&D) activities and general economic growth (Frankel and Romer, 1999; Shahbaz et al., 2013a).

Moreover, there is a connection between ICT and financial development as the first can enhance the second. For example, the use of the internet helps to increase investment activities, trading activities, and effective allocation; monitor resources; and reduce the cost of bank loans (Raheem et al., 2019). The literature illustrated a relationship between financial development, CO_2 emissions, trade openness, and ICT. For instance, Lu (2018)employed 12 Asian countries to investigate the impact of economic growth, ICT, financial development, and energy consumption on CO_2 emissions throughout 1993-2013 and found that the financial development caused CO_2 emissions. The discussion about the relationship between CO_2 emissions with financial development and ICT disclosed mixed results for different economies. ICT and financial development are present realities in developing and developed countries, and their impact on CO_2 emissions requires more research, as existing results are not consensual.

The present study examines the linkages between ICT, energy consumption, economic growth, financial development, CO_2 emissions and trade openness, and validation of Environmental Kuznets Curve (EKC) hypothesis taken as a case study the South and Southeast Asian regions (SSEA) from 1990 to 2014, due to the rapid growth in population, economic conditions, and technology in this region. EKC relationship states that pollution initially rises and then falls as an economy develops (Dinda, 2004). The variables relationship is analysed in several aspects: firstly, we investigate the impact of ICT, energy consumption, trade, economic growth, and financial development on CO_2 emissions, explicitly addressing the issue of cross-sectional dependence for South and Southeast Asian countries. Secondly, first and second-generation unit root test are applied such as ADF-Fisher, PP-Fisher and CIPS unit tests to check the stationarity. Thirdly, for the confirmation of cointegration, Pedroni (2001a) and Westerlund (2007) cointegration tests are employed. Fourthly, we apply the Pooled Mean Group (PMG) regression method, followed by the estimation of the error correction approach. Moreover, the robustness of the long-run coefficients is determined by Group Mean Fully Modified Ordinary Least Squares (GM-FMOLS) and Dynamic Ordinary Least Square (DOLS) methods. Finally, the Dumitrescu-Hurlin causality test is applied for examining causal relationship.

The current study adds to the existing body of knowledge in several ways:

(a) This study used Factor analysis to calculate the social development score based on the social development indicators such as Urbanization, Technology, Economic level, Industrial structure, and Energy to identify the country rank. Furthermore, we applied

Cluster Analysis (Hierarchical and K-means methods) to divide the countries into two areas named as Potential and Advanced based on the social development score.

(b) Especially in SSEA regions, the empirical investigation for the impact of ICT on CO_2 emissions and the comparison of two areas is rare in literature.

(c) It is one of the few studies which elaborate the ICT-environment nexus with reference to EKC in the SSEA region.

(d) The present study used advanced econometric techniques to handle the cross-sectional dependence.

The remainder of the essay is structured as follows, after this Introduction: the “Literature Review” section, the “Data and Model” section, the “Econometric approaches,” the “Result and discussions,” and in the end “Conclusions and policy implication” section.

3.2 Literature Review

3.2.1 ICT role in CO_2 emissions

Several researchers study the role of ICT in CO_2 emissions and found mixed results, both positive and negative around the globe, leading to two different schools of thoughts.

According to the first school, ICT helps to enhance environmental quality. For instance, Ozcan and Apergis (2018) explored the link between internet use and CO_2 emissions. In the case of 20 emerging economies, the authors concluded that the usage of internet lessens air pollution. They also suggested that the flourishing the ICT sector is a productive way to reduce emissions. Al-Mulali et al. (2015) applied generalized method of moments (GMM) and two-stage least square (TSLS) techniques to study the relationship between internet retailing and CO_2 emissions across the 77 developed and underdeveloped countries over a time frame of 2000-2013. The authors concluded that internet retailing has an adverse significant and insignificant impact on CO_2 emissions in the developed and underdeveloped economies, respectively.

In the case of the provincial level study, C. Zhang and Liu (2015) found that the impact of the ICT industry contributes to decreasing CO_2 emissions in China. Lu (2018) also demonstrated the significant negative impact of ICT on CO_2 emissions in 12 Asian economies over the period of 2000-2013. Moreover, Higon et al. (2017) have researched 142 countries around the globe from 1995 to 2010, to prove the inverted U-shaped relationship between ICT and CO_2 emissions and confirmed this relationship for 26 developed countries.

The second group of researchers argued that increasing ICT resulted in increasing CO_2 emissions and hence, decreasing the environmental quality (Belkhir and Elmeligi, 2018; Lee and Brahmasrene, 2014; Salahuddin and Gow, 2016). In the case of OECD economies, Salahuddin et al. (2016) found that use of the internet raises CO_2 emissions both in short and long-run analysis. Park et al. (2018) have applied the Pooled Mean Group (PMG) method over to investigate the impact of ICT on CO_2 emissions. The results demonstrated that there is a long-run positive relationship between the variables in the European Union from 2001 to 2014.

According to Asongu et al. (2018) increasing ICT has a positive net effect on CO_2 emissions in the 44 sub-Saharan Africa economies for period 2000-2012. Concerning the environmental impact of ICT, the elasticity of CO_2 emissions regarding ICT is positive and significant, indicating that ICT increases the level of carbon dioxide in the 20 emerging economies (Danish et al., 2018).

3.2.2 ICT impact on Energy Consumption

Information and Communication Technology devices and services are becoming more and more widespread in all aspects of human life (Van Heddeghem et al., 2014). Room (2002) supported the view that the recent drop in energy intensity noticed was due to the astonishing expansion in information technology from 1996 to 2000 in the USA.

Collard et al. (2005) evaluated the electricity use and the development of ICT in the service sector of France. Their findings show that once controlled for technical progress, the electricity intensity of production increases with computer and software, while it decreases with the diffusion of the communication device.

Conversely, Cho et al. (2007), declared that ICT investment in the service and manufacturing industries increased electricity consumption in Korea. Another study by Sadorasky (2012) also confirms that the use of ICT raised the energy consumption in the emerging economies. Besides, the use of the internet and economic growth both stimulate energy consumption in Australia (Salahuddin and Alam, 2015).Van Heddeghem et al. (2014) demonstrated how electricity consumption progressed in three categories of ICT, namely, communication networks, personal computers, and data centers. Their estimated results show that the annual growth of all three individual ICT categories is higher than the growth of global electricity consumption from 2007 to 2012.

On the contrary, Ishida (2015) proved that ICT improved environmental quality through energy efficiency in Japan. Recently, Dehghan Shahbani and Shahnazi (2019) investigated the relationship among ICT, energy consumption, and CO_2 emissions for 2002-2013 in Iran. Their findings illustrated that the usage of ICT increased the CO_2 in the industrial sector while improved the environmental quality in the transportation and service sectors. Moreover, the results suggested that bidirectional causality exists between ICT and CO_2 in the sectors of industrial and transportation, whereas unidirectional causal linkages were confirmed in the service sector.

3.2.3 Economic Growth, Financial Development, Trade openness and CO_2 emissions

This subsection is divided into two strands: (i) the relationship between economic growth and CO_2 emissions and (ii) the linkages between CO_2 emissions, trade, and financial development.

The links between per capita income and environmental degradation were introduced by Grossman and Krueger (1991)that noted the inverted-U shaped relationship between the variables, which is known as the Environmental Kuznets Curve (EKC). The EKC hypothesis suggests that, during the initial stage of income growth, ecological degradation and per capita income increased parallel, and then after achieving the threshold level, environmental degradation decreased with further per capita income(Dinda, 2004). Numerous contradicting results have been found in such a relationship, particularly among developed and developing countries. Several studies confirmed the validation of EKC hypothesis (see for instance Moomaw and Unruh,1997, Koirala et al.,2011, Alam et al., 2016; Apergis, 2016; Ben Jebli et al., 2016; Le and Quah, 2018; Li et al., 2016; Ouyang and Lin, 2017; Shahbaz et al., 2015; Zaman and Moemen, 2017).

Nevertheless, Richmond and Kaufmann (2006) illustrated the invalidation of EKC in Non-Organization for Economic Co-operation and Development countries. Some other studies rejected the EKC hypothesis. For example, Al-Mulali et al. (2016) failed to confirm the EKC in Kenya, and Antonnakakis et al. (2017) for 106 countries of different income groups. Adu and Denkyirah (2018) also found the non-existence of EKC in the West African countries with the same income groups. A low level of turning point is an inconvenience in this case. Besides, Amri (2018) was unable to find the inverted U-shaped because of not attaining the expected level of total factor productivity in the Tunisian economy.

Secondly, the linkage between CO2 emission, trade, and financial development has been greatly discussed in the literature. For example, Lu (2018) explored the relationship between CO_2 emissions, energy consumption, economic growth, financial development, and ICT in 12 Asian economies. The result demonstrated that financial development causes CO_2 emissions for 1993-2013. Park et al. (2018) also reported that trade openness and financial development have a diminishing negative effect on carbon emissions in the European economies. Conversely, financial development stimulates the level of CO_2 emissions in emerging economies (Danish et al., 2018). For Turkey, over the period of 1960-2007, Ozturk and Acaravci (2013) examined a relationship between economic growth, CO_2 emission, trade, financial development, and energy consumption. The bounds F-test for cointegration confirmed long-run relationships between the studied variables. Their findings suggested that the trade increases the carbon emission, whereas there is an insignificant effect of financial development on CO_2 emissions in the long run.

To sum up, the existing literature about financial development, ICT, and CO_2 emissions nexus disclosed the mixed results for different countries and economies. Moreover, ICT impact on energy consumption is also questionable, so further investigation is justified. Nonetheless, such association has significant implication for environmental sustainability around the globe.

3.3 Data, Model, and Econometric approaches

3.3.1 Data

In this study, we use the annual data for 14 countries of South Asian and Southeast Asian (SSEA) regions covering the period of 1990-2014. Countries considered are as follows: Pakistan, India, Bangladesh, Iran, Vietnam, Sri Lanka, Nepal, Cambodia, Indonesia, the Philippines, Malaysia, Brunei, Singapore, and Thailand. Both the time period and countries were selected based on the availability of data retrieved from World Development Indicators(2019).

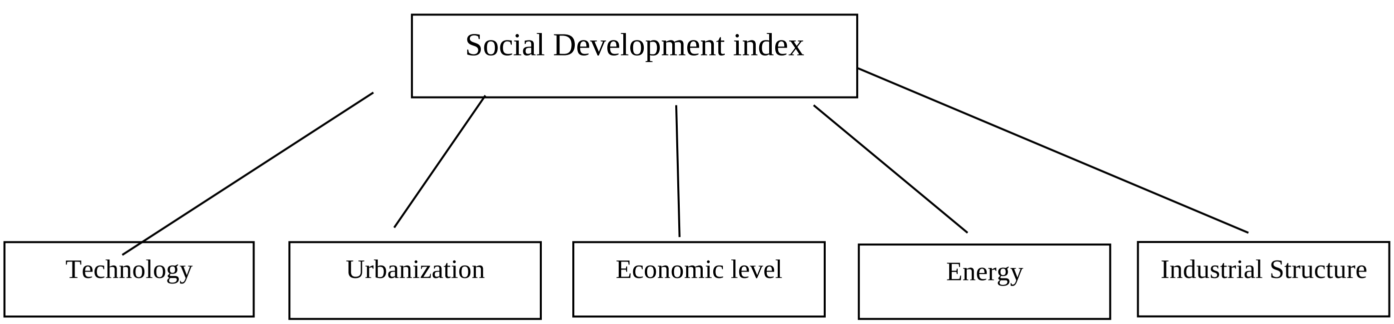
The data for our dependent variable CO_2 emissions is expressed in metric tons per capita. Independent variables definition, units, initials used are as follows: (i) real gross domestic product stated in per capita constant 2010 U.S. dollar (GDP); (ii) the sum of the fixed telephone and mobile subscription data per 100 people used as a proxy of information and communication technology (ICT) (Amri, 2018); (iii) the sum of imports and exports in percentage of GDP used as a measurement of trade variable (TRD) (Park et al., 2018); (iv) the energy consumption variable is measured by the electrical power consumption kWh per capita (EPH); (v) the domestic credit to the private sector in terms of GDP is treated as financial development indicator (FIN); and (vi) urban population per capita (used only for cluster analysis) (urban).

Moreover, we divide the data into three panels: (1) cluster 1, potential countries (2) cluster 2, advanced countries and (3) full panel of 14 countries. Firstly, we rank the economies based on social development index and calculate the score with the help of factor analysis. Secondly, we use hierarchical cluster analysis, and thirdly, K-means cluster method helps us to classify the countries into clusters.

3.3.2 Index system of social development

There are numerous indicators of social development. According to Yuan et al. (2012), these indicators are economic level, urbanization, technology, industrial structure, and energy effective use. Limited studies have gone through the process of dividing the countries based on social development with cluster analysis. For instance, Lau (1990) divided the 31 countries of different income groups such as low income and high income, and regions like Southern European, East European non-market, Market-oriented, and high income oil exporter with cluster analysis.

Figure 3. 1: Social development evaluation system



In this study, there are five factors selected for the regional discrepancy:(i) energy consumption used to reflect the effective energy use; (ii) GDP per capita, to play the role of the economic level;(iii) urban population per capita acts as urbanization indicator; and (iv) ICT to represent technology; and (v) financial development and trade to calculate the industrial role in development.

3.3.2.1 Factor Analysis

Based on the previous research by Zhang and Zhao (2019), we calculated the social development score with factor analysis models, which are presented below:

$$
\begin{aligned}
y_1 &= b_{11}q_1 + b_{12}q_2 + b_{13}q_3 + \cdots + b_{1l}q_l + \mu_1 \\
y_2 &= b_{21}q_1 + b_{22}q_2 + b_{23}q_3 + \cdots + b_{2l}q_l + \mu_2 \\
y_3 &= b_{31}q_1 + b_{32}q_2 + b_{33}q_3 + \cdots + b_{3l}q_l + \mu_3 \\
&\ldots\ldots\ldots\ldots\ldots\ldots \qquad (1) \\
y_m &= b_{m1}q_1 + b_{m2}q_2 + b_{m3}q_3 + \cdots + b_{ml}q_l + \mu_m
\end{aligned}
$$

Where $y_1, y_2, y_3, \ldots\ldots. y_m$ represent the variables; b_{ij} are factor loadings (i=1,2,3,…….l; j=1,2,3,…, m);q_i are the main factors and μ_i are special factors (i=1,2,3,…….l). First, we applied the method of dimensionless on raw data and then calculated the scores of each factor according to the model (Zhang and Zhao, 2019). Table 3. ***1*** reported the results of overall scores of social developments of each country.

Table 3. 1: Factor Analysis Score Results

Countries	GDP	EPH	TRD	ICT	FIN	Urban	Total-Score	Rank
Bangladesh	-0.68719	-0.03535	-1.15023	-0.72857	-0.55639	-2.27768	-5.43	14
Pakistan	0.11087	-0.53444	-1.14845	-0.60898	1.00383	0.75231	-0.42	10
Nepal	-1.60749	0.32483	-0.29173	0.98552	-1.32944	-0.19348	-2.11	11
Cambodia	-1.03001	-2.399	1.40098	-0.54974	-0.1185	0.12348	-2.57	12
India	-0.20607	0.24189	-1.26012	0.02549	1.33563	-0.26471	-0.12	9
Sri Lanka	-0.4542	-0.51378	0.12889	0.17296	-0.19914	1.32365	0.45	8
Indonesia	0.20501	-0.17976	-0.48342	-0.77527	-1.75858	0.07652	-2.91	13
Vietnam	-0.95079	0.18129	0.85257	-0.33913	2.15409	-0.38362	0.51	7
Philippine	0.01052	0.64701	0.13683	-0.89651	-0.22443	0.94558	0.61	6
Thailand	-0.3247	1.82104	0.17849	0.8131	0.12112	0.0516	2.66	1
Malaysia	0.28303	1.34708	0.84891	-0.71897	-0.24049	0.72452	2.24	3
Brunei	1.97093	-0.6261	0.06126	1.68447	0.29243	-1.34766	2.03	4
Singapore	1.25601	0.3554	1.89704	-0.51338	-0.34347	-0.73229	1.91	5
Iran	1.42408	-0.63011	1.17104	-0.55101	-0.13664	1.20177	2.47	2

3.3.2.2 Cluster Analysis

Like prior studies by Yuan et al. (2012), Zhang and Zhao (2019), we also applied the cluster analysis which is known as the multivariate statistical method for classifying the indicators or sample. We used two techniques of cluster analysis named as K-means cluster and hierarchical cluster analysis. The hierarchical cluster method helps in finding condensation points, which can be the initial K-value in K-means cluster method. There are commonly eight methods to deal hierarchical cluster analysis such as between-groups linkage, within-groups linkage, Nearest clustering, median clustering, Wald's minimum variance. Based on factor analysis score, we choose Ward's minimum variance method with squared Euclidean Distance to study. The results of Ward's Dendrogram (see Figure 3. 2) show that our sample divided into two clusters. The second method K-means cluster result reported in Table 3.2. which helped us to classify the countries.

Figure 3. 2: Hierarchical cluster analysis

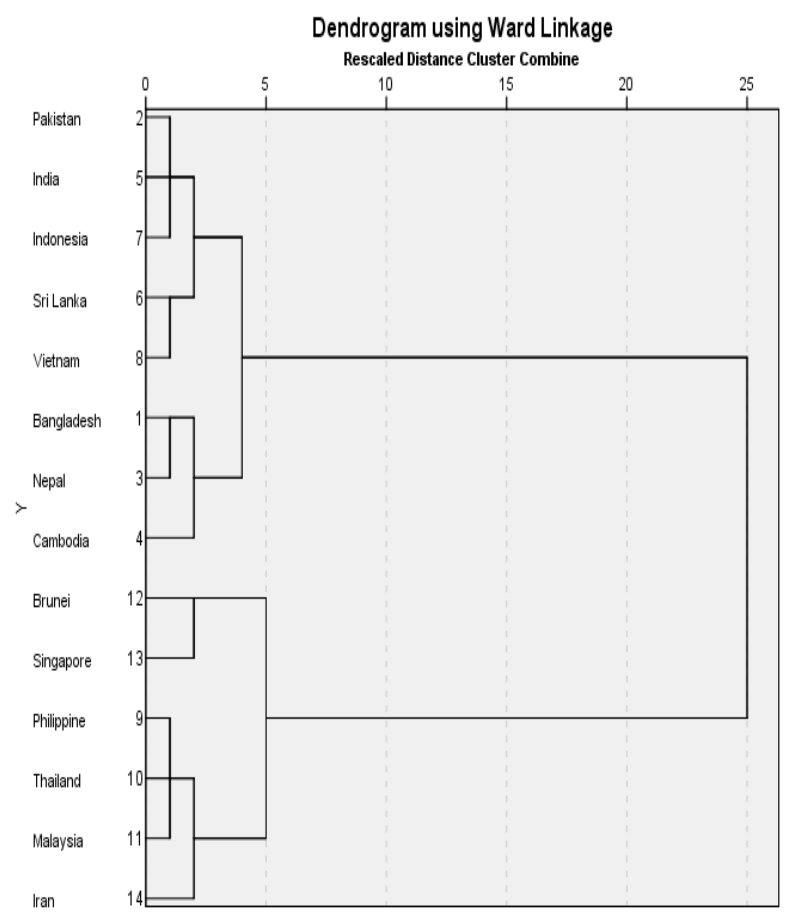


Table 3. 2: K- Means Cluster method

Cluster Membership

Case Number	countries	Cluster	Distance
1	Bangladesh	1	1.906
2	Pakistan	1	2.833
3	Nepal	1	1.510
4	Cambodia	1	.000
5	India	1	3.039
6	Sri Lanka	1	2.847
7	Indonesia	1	3.376
8	Vietnam	1	2.821
9	Philippine	2	4.037
10	Thailand	2	3.383
11	Malaysia	2	2.175
12	Brunei	2	1.594
13	Singapore	2	.000
14	Iran	2	3.687

In summary, we found the same classification of the clusters with factor analysis and cluster analysis. Our results are also comparable with World Bank's different income groups' classifications (World Bank, 2019).

For instance, cluster 1 (potential countries) represents lower-middle-income economies such as Pakistan, Bangladesh, India, Nepal, Cambodia, Indonesia, Vietnam, and Sri Lanka. Cluster 2 (advanced countries) is the combination of upper-, middle-, and high-income countries such as the Philippines, Malaysia, Thailand, Iran, Brunei, and Singapore.

3.3.3 Model

The current study analyse the relationship among financial development, CO_2 emissions, ICT, GDP, trade, and energy consumption in SSEA regions. The general form of our model is designed as follows:

$$CO_2 = f(EPH, ICT, TRD, FIN, GDP,\ GDP^2) \quad (2)$$

Where CO_2, EPH, ICT, TRD, FIN, GDP and GDP square represent CO_2 emissions per capita, energy consumption, information and communication technology, trade, financial development, economic growth, and square of economic growth, respectively.

The primary objective of this study is to find the long-run relationships between the mentioned variables. Based on prior relevant studies, for instance, Park et al. (2018) for European Union, Ozcan and Apergis (2018) for emerging economies, Salahuddin et al. (2016) for OECD countries and Amri (2018), our empirical model is as follows:

$$LCO_{2it} = \alpha_{1it} + \alpha_{yit} LGDP_{it} + \alpha_{y^2it} LGDP_{it}^2 + \alpha_{Eit}\, LEPH_{it} + \alpha_{netit}\, LICT_{it} + \alpha_{Tit}\, LTRD_{it} + \alpha_{Fit}\, LFIN_{it} + \epsilon_{it} \quad (3)$$

Where: L stands for log-linear specification for empirical analysis; ϵ_{it} is an idiosyncratic error term, independent and identically distributed, which represents the standard normal distribution with unit variance and zero mean; i represent the country (i=1,2,…….14); t stands for a time period (t= 1,2,3,……..25); α_{1it} is intercept, while $\alpha_{yit}, \alpha_{y^2it}, \alpha_{Eit}, \alpha_{netit}, \alpha_{Tit}$ and α_{Fit} are the long-run elasticity's estimates of CO_2 emissions per capita (LCO_2) with respect to the explanatory variables such as real GDP per capita (LGDP), the square of real GDP per capita

(LGDP^2) for the validation of EKC hypothesis, energy consumption kWh per capita (LEPH), ICT (LICT), Trade (LTRD), and financial development (LFIN), respectively.

Before progressing to further empirical analysis, we provide some statistical measures of variables (see Table 3. 3). The average CO_2 fluctuates from 0.12 in Nepal to 17.82 in Brunei, while the overall 14 countries mean is (3.60) in SSEA regions. Regarding GDP per capita, Nepal (486.79 U. S. dollar) is a low-income country, and Brunei (36338.96 U. S. dollar) is has a high-income country, whereas the average GDP per capita is 7146.15 in this region of Asia. In respect to energy consumption, Nepalian people consume 72.67 kWh per capita, which is less than other considered nations while Brunei and Singapore consume 7584.79, 7418.34 kWh per capita, respectively, and stand as leading users on the list.

Concerning trade as sum of the exports and imports (% GDP), Bangladesh has low trade (32.19), compared with other countries in the sample, and Singapore has high trade (359.40).

With regard to ICT, again Nepal (15.85) has the minimum fixed and mobile users per 100 people, while Singapore has (116.85) the highest number of users. However, average users in SSEA regions is 45.00. Lastly, in the case of financial development, Cambodia is the least financially developed (14.77) economy, while Thailand and Malaysia are the more financially developed (116 approximately) economies.

Furthermore, the most considerable variation in CO_2 emissions was verified in Philippine (65%), whereas Pakistan has the lowest variation (13%). Moreover, the highest variation in GDP is 45% also in Philippine while lowest in Brunei. Besides, the Indonesian nation has the maximum variation in the case of energy consumption, whereas Pakistan has the lowest variation. In the case of ICT and financial development, the Cambodian economy has notable volatility than others. Moreover, India has the highest fluctuation in trade over the years (45%). Nevertheless, the lowest variation in trade and financial development belongs to Brunei and Singapore, respectively.

Table 3. 3: Descriptive Statistics

Countries	Variables	Mean	SD	CV	Countries	Mean	SD	CV	Countries	Mean	SD	CV
Bangladesh	CO_2	0.26	0.10	38%	**Pakistan**	0.80	0.11	13%	**Nepal**	0.12	.05	41%
	GDP	585.15	159.16	27%		912.49	118.36	12%		486.79	92.27	18%
	EPH	147.31	82.57	56%		387.45	54.18	13%		72.67	32.37	44%
	TRD	32.19	9.12	28%		34.02	2.88	8%		48.15	7.44	15%
	ICT	17.56	26.15	148%		23.17	29.15	125%		15.85	26.13	164%
	FIN	27.20	9.76	35%		23.39	3.69	15%		33.19	16.04	48%
Cambodia	CO_2	0.22	0.09	40%	**Philippine**	2.05	1.35	65%	**Brunei**	17.82	4.15	23%
	GDP	578.88	198.16	34%		2905.42	1317.99	45%		36338.9	194.18	0.05%
	EPH	76.00	74.74	98%		1091.45	701.27	64%		7584.79	1645.30	21%
	TRD	105.93	29.62	27%		97.10	24.92	25%		104.94	6.48	6%
	ICT	28.07	46.74	166%		47.27	47.20	99%		74.50	44.28	59%
	FIN	14.77	16.28	110%		74.47	45.34	60%		44.07	9.39	21%
Indonesia	CO_2	1.47	0.42	28%	**Malaysia**	6.04	1.39	23%	**Iran**	5.99	1.52	25%
	GDP	2508.98	560.00	22%		7435.98	1633.42	21%		5311.16	788.28	14%
	EPH	442.11	491.27	111%		2855.63	1013.24	35%		1850.39	661.18	35%
	TRD	57.01	10.47	18%		179.55	25.68	14%		43.48	6.71	15%
	ICT	38.32	49.60	129%		71.35	53.58	75%		45.78	45.02	98%
	FIN	36.10	13.75	38%		116.26	21.58	18%		33.18	13.79	41%
Thailand	CO_2	3.25	0.86	26%	**Sri Lanka**	0.52	0.18	34%	**India**	1.08	0.25	23%
	GDP	4023.42	918.09	22%		2072.51	703.04	33%		929.63	348.16	37%
	EPH	1666.60	549.62	32%		328.28	125.95	38%		471.56	154.89	32%
	TRD	111.75	23.12	20%		69.68	12.39	17%		36.94	16.78	45%
	ICT	53.87	52.27	97%		36.51	45.22	123%		21.16	27.82	131%
	FIN	115.84	23.60	20%		27.35	8.65	31%		35.25	11.74	33%
Singapore	CO_2	11.10	3.43	30%	**Vietnam**	0.93	0.51	54%	**Overall (14 countries)**	3.60	5.22	145%
	GDP	36163.6	9127.27	25%		911.5	353.72	38%		7145.15	12313.32	172%
	EPH	7418.34	1322.83	17%		526.05	419.28	79%		1738.82	2568.31	147%
	TRD	359.4	35.89	9%		117.73	33.78	28%		98.80	85.20	86%
	ICT	116.85	57.08	48%		46.39	62.28	134%		45.00	51.40	114%
	FIN	96.93	13.54	13%		52.28	35.44	67%		49.21	36.79	74%

Note: Authors own calculation based on the data over the period 1990-2014 after applying natural logarithm. Mean = simple average, S.D = standard deviation.

3.3.4 Econometric approaches

There are seven acquainted steps in a comprehensive analysis concerning an econometric point of view: (i) Cross-sectional dependence, (ii) Stationarity testing, (iii) Cointegration analysis, (iv) Pooled mean regression group (PMG) for long-run elasticities, (v) Mean group Regression (MG) for individual country coefficients, (vi) DOLS and FMOLS to check the robustness of PMG findings, and (vii) Dumitrescu- Hurlin (DH) causality test.

3.3.4.1 Cross-Sectional Dependence

The current study used balanced panel data of 14 South and Southeast Asian countries. It is may possible that a cross-sectional dependence (CD) occurs among the variables with Panel data, which may produce unreliable and biased results. For further empirical analysis, we need to confirm the cross-sectional dependence, using the well-known Pesaran (2004) CD test. Table 3.11reported results of CD test in the appendix B, which confirms the cross-sectional dependence among the variables.

3.3.4.2 Unit Root tests

In the prior relevant literature, most of the macroeconomic variables were found to be non-stationary at the level. Non-stationary data can produce spurious results. After the confirmation of cross-sectional dependence, the next step consists in investigating the unit root problem in the panel of variables, to determine the presence of stochastic trends, which is broadly designed to elaborate on the postulation of cross-sectional dependence (Arshad et al., 2020). Numerous panel unit root tests have been introduced to check the integrated order of the variables such as Breitung, Hadri, Levin Lin Chu, IPS (IM Pesaran shin), ADF-Fisher, PP-Fisher, CIPS, and CADF. Researchers divide these tests into two groups: 1) Breitung, Hadri and Levin Lin Chu tests, that depend on cross-sectional properties and that are known as first-generation tests and 2) ADF-Fisher, PP-Fisher, CIPS, CADF and IPS (IM Pesaran shin), that handled the problem of homogeneity and that are known as second-generation tests.

However, in the current study ADF Fisher, PP Fisher and CIPS tests have been employed to determine the issues of stationarity. The aim of applying several unit root tests in the panel is to analyze the reliability of empirical results (Arshad et al., 2020). Moreover, South and Southeast Asian regions are suffering from cross-country heterogeneity, cross-sectional dependence, and transborder pollutants' effect (Behera and Dash, 2017) . Thus, Pesaran (2007) panel unit root tests are more suitable to manage the trouble of cross-sectional dependence.

3.3.4.3 Co-integration

We applied two cointegration methods, Pedroni (2004) and Westerlund (2007), to develop the long-run relationship among the variables of consideration. The cointegration tests provided long-run information in the pool and short-run dynamics of the cross-sectional unit.

3.3.4.3.1 Pedroni Test

Pedroni (2001a, 2001b) presents seven-panel cointegration statistics, out of which four considered within dimension statistics and three between-dimension statistics.

3.3.4.3.2 Westerlund Cointegration Approach

The Westerlund (2007) test of cointegration has also applied to robust the Pedroni findings as well as this test strengthens the cross-sectional dependence through bootstrapping. Westerlund (2007)technique enables researchers to estimate the diverse forms of heterogeneity, along with probability values (p-values). Westerlund (2007) introduced four tests to evaluate the cointegration process. First, two tests named as group statistics are designed to consider the cointegration as a whole and denoted by (G_τ and G_α). Second, the remaining two tests are described as panel statistics which are indicated by (P_τ and P_α) and intended to examine the cointegration panel with at least one cross-sectional unit. The Westerlund (2007) test is based on the following error correction model:

$$\Delta y_{it} = \delta' w_t + \alpha_i \left(y_{it-1} - \beta_i' x_{it-1} \right) + \sum_{j=1}^{r_i} \alpha_{ij} \Delta y_{it-j} + \sum_{j=-m_i}^{r_i} \gamma_{ij} \Delta x_{it-j} + e_{it} \qquad (4)$$

equation-4 implies that i=1,……., N and t=1,… , T stand as cross-sectional and time-series units, respectively, whereas w_t comprises the deterministic components.

3.3.5 Pooled Mean Group Regression (PMG)

After the confirmation of cointegration process, the third step is pooled mean group (PMG) estimation, which is introduced by Pesaran (1997) and Pesaran et al. (1999). This estimation provides convergence speed and short-run adjustment to measure the heterogeneity of each country. The model of the PMG estimation is as follows:

$$\Delta(\mathrm{CO}_{2i})_t = \sum_{j=1}^{p-1} \rho_j^i \, \Delta(\mathrm{CO}_{2i})_{t-j} + \sum_{j=0}^{q-1} \delta_j^i \, \Delta(x_i)_{t-j} + \theta^i\left[(\mathrm{CO}_{2i})_{t-1} - \alpha_1^i (X_i)_{t-j}\right] + \epsilon_{it}$$

(5)

Where: $(\mathrm{CO}_{2i})_{t-j}$ and $(\mathrm{CO}_{2i})_{t-1}$ describe short and long-run standards regarding CO_2 emissions; ; ρ_j^i and δ_j^i are the short-run coefficients; $(x_i)_{t-j}$ and $(X_i)_{t-j}$ are the values of short-run and long-run variables, respectively; θ^i is the error correction term; α_1^i are the long-run coefficients; $\epsilon_{it} = \mu_i + e_{it}$, whereas μ_i represents country-specific fixed ande_{it} time-variant effects.

3.3.6 DOLS and GM-FMOLS

The next step, after the evidence of cointegration, leads to estimate the parameters presented in the empirical model (see equation 3). The desired estimation may be found by applying simple ordinary least square (OLS) method, random effect, fixed effect or GMM approaches. Nonetheless, these methods can be a cause of inconsistency and misleading coefficients when applied to cointegrated panel data (Ahmed et al., 2017). However, the Group Mean Fully Modified Ordinary Least Squares (GM-FMOLS) proposed by Pedroni (2001b) and dynamic ordinary least square (DOLS) introduced by Stock and Watson (1993) are appropriate methods to avoid this type of inconsistency and misleading of coefficients. Moreover, FMOLS and DOLS methods also provide robustness of PMG findings. Besides, FMOLS is useful to eliminate the problem of endogeneity in the regressors, and serial correlation, which might also result in consistent estimate parameters in a relatively small sample[8](Behera and Dash, 2017). Likewise, the dilemma of endogeneity, serial correlation, and multicollinearity is solved by using the DOLS estimator by including lags and leads of the differenced I(1) regressors in the regression (Stock and Watson, 1993). Moreover, the DOLS method reveals the cointegrating vector.

[8] For detail discussion see (Ramirez, 2010)

3.3.7 Dumitrescu- Hurlin (DH) Causality Test

Some policy implications can be defined through the analysis of short-run and long-run relationship without prior knowledge (Shahbaz et al., 2013b). Thus, in a last step, the Dumitrescu and Hurlin (2012) causality test was applied, as this is an appropriate method and presents more advantages compared to the traditional Granger (1969) causality test. Moreover, two critical domains of heterogeneity, known as the heterogeneity of the regression model and the heterogeneity of the causal relationship are presented by DH (2012) test.

3.4 Results and Discussion

3.4.1 Cross-sectional dependence and unit root tests

3.4.1.1 Cross-sectional dependence

Due to different characteristics of the countries, Pesaran (2004) cross-sectional dependence (CD) test was performed. The Pesaran CD test results reported in Table 3.11 in the appendix B accept the alternative hypothesis of CD at 1% level of significance; hence, there is significant evidence of cross-sectional dependence among the variables considered, in all cases.

3.4.1.2 Unit root tests

Countries have different characteristics and the panels may contain the presence of CD which may lead to unreliable and biased results (Park et al., 2018). The results of the PP-Fisher and ADF Fisher panel unit root tests are presented in Table 3. 4. In all the three panels, almost all the variables are non-stationary at the level. However, variables are stationary at the first differences, accepting the alternative hypothesis at 5% level of significance. These results show that the variables have a panel unit root.

The literature illustrated that to manage the cross-sectional dependence, the ADF test is not enough (Arshad et al., 2020). Therefore, another panel unit root test such as IPS cross-sectional (CIPS) is preferred, to allow for the cross-sectional dependence (Danish et al., 2018). The cross-sectional IPS (CIPS) test results reported on the right-side columns also show that all the variables are non-stationary at the level and that they are stationary at integrated order 1. Thus, we can declare that PP-Fisher, ADF Fisher, and CIPS unit root tests have similar findings.

Table 3. 4: Unit root analysis

Tests		ADF				CIPS	
		Without trend		With trend			
	Variables	**ADF Fisher**	**PP-Fisher**	**ADF Fisher**	**PP-Fisher**	**Without trend**	**With trend**
Overall Countries	LCO_2	20.33 (0.85)	25.16 (0.61)	27.00 (0.51)	26.37 (0.55)	-0.70	-2.13
	Δ LCO_2	119.75*** (0.00)	220.71*** (0.00)	91.97*** (0.00)	204.23*** (0.00)	-5.81***	-6.23***
	LEPH	25.93 (0.57)	35.28 (0.16)	29.10 (0.40)	27.81 (0.47)	-0.51	-2.30
	Δ LEPH	93.40 *** (0.00)	155.48*** (0.00)	78.19*** (0.00)	142.83*** (0.000)	-5.12***	-5.35***
	LFIN	30.45 (0.34)	16.55 (0.95)	34.72 (0.17)	22.44 (0.76)	-0.67	-2.20
	Δ LFIN	90.40*** (0.00)	156.85*** (0.00)	58.77*** (0.00)	121.83*** (0.00)	-5.22***	-5.44***
	LGDP	8.28 (0.99)	7.09 (1.00)	27.90 (0.46)	15.63 (0.97)	-0.53	-2.04
	Δ LGDP	100.56*** (0.00)	137.61*** (0.00)	83.39*** (0.00)	118.73*** (0.00)	-5.43***	-5.61***
	LICT	25.69 (0.58)	24.37 (0.66)	16.69 (0.95)	5.91 (1.00)	0.18	-1.84
	Δ LICT	49.45*** (0.00)	56.18*** (0.00)	53.93*** (0.000)	58.01*** (0.000)	-3.35***	-3.74***
	LTRADE	29.31 (0.39)	43.18 (0.03)	22.70 (0.74)	116.10 (0.00)	-1.23	-2.99
	ΔLTRADE	128.96*** (0.00)	477.55*** (0.00)	108.70*** (0.00)	717.01*** (0.00)	-5.82***	-5.97***
Potential area	LCO_2	9.13 (0.90)	8.99 (0.91)	14.00 (0.59)	12.92 (0.67)	-1.98	-2.55
	Δ LCO_2	65.38*** (0.00)	128.02*** (0.00)	51.17*** (0.00)	111.43*** (0.00)	-6.12***	-6.42***
	LEPH	8.13 (0.94)	12.66 (0.69)	18.15 (0.31)	20.56 (0.19)	-2.02	-1.99
	Δ LEPH	61.82*** (0.00)	99.30*** (0.00)	50.22*** (0.00)	89.46*** (0.00)	-6.12***	-6.42***
	LFIN	9.49 (0.89)	4.83 (0.99)	16.96 (0.38)	14.18 (0.58)	-1.22	-2.51
	Δ LFIN	53.39*** (0.00)	101.24*** (0.00)	37.52*** (0.00)	79.92*** (0.00)	-5.59***	-6.00***
	LGDP	4.41 (0.99)	2.10 (1.00)	8.55 (0.93)	5.09 (0.99)	-0.86	-2.021
	Δ LGDP	44.22*** (0.00)	70.68*** (0.00)	40.03*** (0.00)	65.19*** (0.00)	-6.12***	-6.26***
	LICT	8.42 (0.93)	3.87 (0.99)	14.89 (0.53)	5.40 (0.99)	-0.14	-2.08
	Δ LICT	28.81*** (0.02)	30.43*** (0.01)	21.49 (0.16)	19.62 (0.23)	-4.23***	-4.20***
	LTRADE	18.45 (0.29)	29.63 (0.02)	14.66 (0.54)	107.97 (0.00)	-1.02	-2.19
	ΔLTRADE	79.02*** (0.00)	378.83*** (0.00)	58.79*** (0.00)	601.36*** (0.00)	-5.90***	-6.20***

Continue Table 3.4							
Advance area	LCO_2	11.20 (0.51)	16.16 (0.18)	13.00 (0.36)	13.44 (0.33)	-1.98	-2.55
	Δ LCO_2	54.37*** (0.00)	92.68*** (0.00)	40.80*** (0.00)	92.80*** (0.00)	-6.10***	-6.40***
	LEPH	17.80 (0.12)	22.61 (0.03)	10.94 (0.53)	7.24 (0.84)	-2.00	-1.99
	Δ LEPH	31.58*** (0.00)	56.17*** (0.00)	27.96*** (0.00)	53.36*** (0.00)	-6.12***	-6.42***
	LFIN	20.96 (0.05)	11.71 (0.46)	17.76 (0.12)	8.25 (0.76)	-1.22	-2.51
	Δ LFIN	37.01*** (0.00)	56.60*** (0.00)	21.25** (0.04)	41.90*** (0.00)	-5.59***	-6.00***
	LGDP	3.87 (0.98)	4.98 (0.95)	19.34 (0.08)	10.53 (0.56)	-0.86	-2.02
	Δ LGDP	56.34*** (0.00)	66.92*** (0.00)	43.36*** (0.00)	53.53*** (0.00)	-6.12***	-6.26***
	LICT	17.27 (0.13)	20.50 (0.05)	1.80 (0.99)	0.50 (1.00)	-0.14	-2.08
	Δ LICT	20.64** (0.05)	25.75*** (0.01)	32.43*** (0.00)	38.39*** (0.00)	-4.23**	-4.20**
	LTRADE	10.85 (0.54)	13.55 (0.33)	8.03 (0.78)	8.13 (0.77)	-1.02	-2.19
	ΔLTRADE	49.94*** (0.00	98.72*** (0.00)	49.91*** (0.00)	115.65*** (0.00)	-5.90***	-6.20***

Note: p-values are reported in the parentheses, and *, ** and *** represents the significance level at 10%, 5% and 1% respectively.

3.4.2 Cointegration

After the first order of integration of the variables, the next step was to examine the cointegration process. To do so, two cointegration tests, namely Pedroni (2004) and Westerlund (2007)were used. The results of the Pedroni cointegration test are presented in Table 3. 5.

In the case of potential countries, advanced countries, and of the full panel of the 14 countries, the results indicate that four statistics accept the alternative hypotheses of cointegration. To robust the Pedroni cointegration test results, the Westerlund cointegration test was also used, which even overcomes the issue of cross-sectional dependence. The Westerlund (2007) test takes no cointegration as null. The test regression is fitted with constant and no trend, one lag, and one lead. The width of the Bartlett Kernel windows is used in the semi-parametric estimation of long-run variances, and the p-values are for a one-sided test based on the normal distribution. The p-values result (see Table 3. 6) suggested that in all three panels, four of reported two are pointing towards cointegration among the considered variables. Our results are a line with (Behera and

Dash, 2017; Danish et al., 2018; Newton et al., n.d., p. 240). Moreover, we also used the boot strap approach of Westerlund (2007) to account for the cross-sectional dependence and the number of replication is 400.

Table 3. 5: Pedroni- Cointegration

Cointegration		**Potential area**		**Advance area**		**Overall (14 Countries)**	
		Without trend	With trend	Without trend	With trend	Without trend	With trend
Within - dimension	Panel v-Statistic	-0.2342	-0.6630	-1.6082	-2.6994	-1.6355	-3.0371
		(0.59)	(0.74)	(0.94)	(0.99)	(0.94)	(0.99)
	Panel rho-Statistic	0.9987	1.8182	0.5678	1.2695	1.0410	2.0951
		(0.84)	(0.96)	(0.71)	(0.89)	(0.85)	(0.98)
	Panel PP-Statistic	-1.706**	-2.79***	-5.39***	-6.40***	-5.450***	-7.376***
		(0.04)	(0.00)	(0.00)	(0.00)	(0.00)	(0.000)
	Panel ADF-Statistic	-1.355*	-2.50***	-2.79***	-3.36***	-3.256***	-4.490***
		(0.08)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Between-dimension	Group rho-Statistic	2.033	2.866	1.3207	1.9608	2.4021	3.4507
		(0.97)	(0.99)	(0.90)	(0.97)	(0.99)	(0.99)
	Group PP-Statistic	-2.102***	-4.73***	-5.97***	-12.10***	-5.500***	-11.504***
		(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	Group ADF-Statistic	-1.985**	-2.022**	-1.33*	-3.01***	-2.371***	-3.500***
		(0.02)	(0.02)	(0.09)	(0.00)	(0.00)	(0.00)

Note: P-values are reported in the parentheses.

Table 3. 6: Westerlund Cointegration

Statistics	**Potential area**				**Advance area**				**Full Countries**			
	Value	**Z-value**	**P-value**	**Robust P-value**	**Value**	**Z-value**	**P-value**	**Robust P-value**	**Value**	**Z-value**	**P-value**	**Robust P-value**
Gt	-3.344	-2.070	0.019	0.001***	-3.682	-1.777	0.038	0.001***	-3.874	-1.896	0.018	0.000***
Ga	-10.782	1.439	0.925	0.100*	-1.678	4.675	1.000	0.110*	-9.295	2.578	0.995	0.080***
Pt	-8.358	-1.523	0.064	0.000***	-7.240	-0.891	0.004	0.000***	-6.891	-0.936	0.075	0.008***
Pa	-9.725	0.540	0.705	0.090*	-2.476	3.585	1.000	0.110*	-9.044	1.020	0.846	0.100*

Note: No cointegration taken as the null hypothesis. The p-values are reported in the parentheses and *, ** and *** represents the significance level at 10%, 5% and 1% respectively.

From Table 3. 6, using the robust p-values and disclosing that the null hypothesis of no cointegration is rejected; we can conclude that there is cointegration among the variables. It merely illustrates that the long-run relationship occurs between CO_2 emissions, ICT, financial development, GDP, trade, and energy consumption in advanced, potential, and full countries panels of SSEA region.

The results of cointegration among the variables confirm the ones of Ozcan and Apergis (2018), Park et al. (2018), Danish et al. (2018), Salahuddin et al. (2016) and Lee and Brahmasrene (2014) for case of Southeast Asian region.

3.4.3 PMG, FMOLS and DOLS

The current study applies PMG, FMOLS, and DOLS regression methods to estimate the long-run coefficients. The results drawn from the PMG method are reliable because this approach allows cross-sectional dependence and is robust to the heterogeneity. The result of PMG, and FMOLS, DOLS are reported in Table 3.7and Table 3. 8, respectively.

3.4.3.1 Long-Run Elasticities

Firstly, concerning the environmental-economic growth nexus, PMG results (see Table 3.7) indicates that long-run elasticities of CO_2 emission with respect to GDP are approximately 8.33-0.46y, 9.51-0.56y, and 2.90-0.20y in the potential, advance, and full countries panels, respectively. The coefficients of GDP are positive significant while the coefficients of the square term of GDP are negative which validate the inverted U-shaped EKC hypothesis in all three considered panels of SSEA region. It implies that during the economic growth process, CO_2 emissions increase and then these will decrease the carbon emissions after reaching the certain threshold level, although the effect of economic growth is different in all the panels. Mostly, carbon emissions in the early stage will rise due to the scale effect and energy consumption. Nevertheless, it will decrease the carbon emissions due to composition and or technique effect (Destek et al., 2018). Our results are consistent with (Md. M. Alam et al., 2016; Apergis, 2016; Ben Jebli et al., 2016; Dogan and Inglesi-Lotz, 2020; Dogan and Seker, 2016a; Le and Quah, 2018; Li et al., 2016; Ouyang and Lin, 2017; Shahbaz et al., 2015; Zaman and Moemen, 2017).

Secondly, energy consumption raises the CO_2 emissions in all three panels. The rapid wave of urbanization is one of the causes of energy demand, which ultimately raises CO_2 emissions in the SSEA regions. Besides, the rapid changes in population in the South and Southeast Asian region, especially in Pakistan, India, and Bangladesh, lead the companies to accelerate their shifting towards this region due to cheap labor and intense market. Furthermore, the significant portion of electricity is derived from fossil fuels, which ultimately increases the CO_2 emissions. Similar findings were presented by Salahuddin et al. (2016), Ozcan and Apergis (2018) for the emerging economies, Heidari et al. (2015) for ASEAN countries and Shahbaz et al. (2016) for Malaysia.

Thirdly, the results show that there is a significant direct link between CO_2 emissions and financial development in potential economies and full countries panel in the long-run. A 1%

increase in financial development raises CO_2 emissions by 0.01% and 0.02% in potential countries and full countries panel, respectively. It implies that the domestic credit to the private sector in terms of GDP diminishes the environmental quality and means that most of the invested financial resources are made in non-friendly environmental projects. Besides, those projects increased the energy demand which ultimately raises the CO_2 emissions. Our results are in line with (Amri, 2018; Chen and Lei, 2018).

However, in the case of advanced countries[9], we found an inverse relationship between financial development and CO_2 emissions. A 1% increase in financial development reduces CO_2 emissions by 0.11%. It means that financial development improves environmental quality. In fact, the financial sector of developed countries is better established than the one of developing countries. Our findings are similar to the ones of Park et al. (2018) and Salahuddin et al. (2016).

Fourthly, in the case of ICT impacts on CO_2 emissions in the long-run, our findings suggest that there is a positively significant relationship between ICT and CO_2 emissions in all the panels. A 1% increase in ICT resulted in 0.12%, 0.15%, and 0.04% rise in CO_2 emissions in potential, advanced, and full countries panel, respectively. It means that ICT positively contributed to CO_2 emissions in SSEA region. However, advanced countries have a higher positive impact of ICT on CO_2 emissions compared with potential countries' impact.

The outcomes are defensible because ICT products consume more energy, which ultimately put pressure on CO_2 emissions. It is suggested that information and communication technology is not energy efficient in the SSEA regions.

Nevertheless, our results are similar to (Lee and Brahmasrene, 2014; Park et al., 2018; Salahuddin et al., 2016). On the other hand, Asongu (2018) explored a negative relationship between ICT and CO_2 emissions in 44 African economies which is in contradiction with our study.

Lastly, the role of trade in CO_2 emissions has been observed, and the result suggested that trade mitigates the CO_2 emissions in potential countries and full countries panel in SSEA regions. A 1% increase in trade resulted in 0.27% and 0.20% decrease the CO_2 emissions, in the advanced countries and full countries panel, respectively. This finding is in line with Salahuddin et al. (2016) and Park et al. (2018).

[9] Relatively high income, technological advance, higher number of ICT users, financially develop and with high per capita energy consumption countries in the sample list.

However, in the case of potential countries, we found a significant positive relationship between trade and CO_2 emissions. Ozcan and Apergis (2018) and Amri (2018) found similar results.

Furthermore, the statically significant negative signs of error correction terms of all panels also confirmed the long-run relationships among variables. The error correction term of full countries panel (-0.53) shows that the speed of adjustment back towards the equilibrium is corrected by 0.53% each year. Yet, the rate of change back towards the equilibrium is fixed by 0.53% and 0.57% in the cases of potential and advanced countries, respectively.

Moreover, the results for error correction terms are negative and significant for individual countries such as Pakistan, Bangladesh, India, Nepal, Cambodia, Indonesia, Vietnam, Sri Lanka, the Philippines, Malaysia, Thailand, Iran, Brunei, and Singapore. It means that long-run relationships exist among the variables. The negative and significant error correction terms for each economy are reported in **Table 3. 12**(see in Appendix B). According to the findings, the fastest speed of adjustment back towards the equilibrium in the long-run is in Vietnam, whereas it is the slowest in Thailand.

The summary of the above discussion is that ICT, energy consumption, and financial development raises CO_2 emissions, while trade decrease CO_2 emissions in the SSEA regions.

Furthermore, in short-run analysis, energy consumption has significant positive impact on CO_2 emissions in advance countries, whereas trade in potential countries panels has inverse effect on CO_2 emissions. Conversely, there is no worthy association found between the short-run variables presented in potential, advanced, and full countries panels.

3.4.3.2 FMOLS and DOLS

Table 3. 8 reported FMOLS and DOLS results to examine the long-run coefficients to check the robustness of the PMG estimates. Similar signs of the coefficients (see Table 3.7 for comparison) which robust the PMG findings were observed. Our outcome is in line with Salahuddin et al. (2016), Ozcan and Apergis (2018) for the emerging economies, and with Park et al. (2018).

Table 3.7: Pooled Mean Group Regression

Dependent variable: CO_2 Emission	Potential area		Advanced area		Overall Countries	
Variables	**Coefficient**	**Prob***	**Coefficient**	**Prob***	**Coefficient**	**Prob***
Long-run coefficients						
LEPH	0.7538***	0.0010	1.5178***	0.0000	0.4460***	0.0000
LFIN	0.0163***	0.0000	-0.1137**	0.0045	0.0195***	0.0000
LGDP	8.3373***	0.0013	9.5108***	0.0088	2.9005***	0.0003
LGDP^2	-0.4668**	0.0035	-0.5696***	0.0070	-0.2076***	0.0002
LICT	0.1227***	0.0000	0.1523*	0.0845	0.0481*	0.0500
LTRADE	0.9294***	0.0000	-0.2974***	0.0000	-0.2008*	0.0700
Error correction coefficients	-0.5395**	0.0095	-0.5743***	0.0053	-0.5377***	0.0000
Short-run coefficients						
D(LEPH)	0.2841	0.3063	0.5377*	0.0523	0.4920	0.1247
D(LFIN)	0.1181	0.9793	0.5442	0.2573	-0.0181	0.7983
D(LGDP)	-41.140	0.2485	-90.943	0.4860	17.4751	0.5707
D(LGDP)^2	-1.9316	0.0851	4.3137	0.4860	-0.2918	0.8661
D(LICT)	-0.1547	0.5481	0.1464	0.3183	0.0457	0.4865
D(LTRADE)	-0.27***	0.0001	-0.4482	0.2987	-0.1106	0.1961
C	-19.2**	0.0110	-27.73**	0.0490	-7.0698***	0.0000

Note: *, ** and *** represents the significance level at 10%, 5% and 1% respectively.

Table 3. 8: FMOLS and DOLS Analysis

	Potential area		Advance area		Overall countries	
Variables	**FMOLS**	**DOLS**	**FMOLS**	**DOLS**	**FMOLS**	**DOLS**
LEPH	0.16**(0.02)	0.63**(0.02)	0.74***(0.00)	0.63***(0.00)	0.27***(0.00)	-1.07***(0.0)
LFIN	0.09**(0.03)	0.31 (0.21)	-0.02*(0.08)	0.02 (0.76)	0.01(0.82)	0.197*(0.10)
LGDP	0.38(0.62)	7.95*(0.05)	6.83***(0.00)	7.19***(0.00)	2.62***(0.0)	4.54**(0.02)
LGDP^2	0.009(0.85)	-0.54(0.11)	-0.37***(0.0)	-0.39***(0.0)	-0.15(0.00)	-0.16(0.12
LICT	0.06*(0.06)	0.15***(0.00)	0.11 (0.06)	0.12**(0.03)	0.03*(0.10)	0.14*(0.04)
LTRD	-0.02*(0.09)	-0.08* (0.10)	0.14(0.34)	0.10(0.49)	-0.08 (0.33)	-0.38 (0.11)

Note: Dependent variable: CO_2 Emission, P values are reported in the parentheses, *, ** and *** represents the significance level at 10%, 5% and 1% respectively.

3.4.4 Mean Group Regression (MG)

The mean group country-wise analysis of 14 sample countries is reported in Table 3. 9 . In the current section, we inspected the time series analysis of each country for the variable used. The analysis demonstrated that energy consumption raises the CO_2 emissions in some countries, for instance, Bangladesh, Vietnam, the Philippines, Malaysia, and Iran. It implies that energy consumption worsens environmental quality in these countries. Contrarily, we found reverse findings in Pakistan and Cambodia.

In fact, Pakistan in betting in an energy policy focused on renewable, as installed capacity of alternative and renewable energy sources in the power sector has risen from 0.2% in 2013 to 5.2% of total installed capacity in 2018 (IRENA, 2018). Also, Cambodia had in 2018 62% of installed electricity capacity based on renewable energy with by far the largest part of that coming from hydropower dams (ADB, 2019).

Table 3. 9: Mean Group Country Wise Analysis

Countries	Variables	LEPH	LFIN	LGDP	LICT	LTRD
Bangladesh	Coefficients	0.1451***	0.3620***	0.7600*	-0.0398***	-0.0102
	Prob.	0.019	0.000	0.0956	0.000	0.365
Pakistan	Coefficients	-0.2079***	0.0538***	0.1601	0.0379***	0.0808**
	Prob.	0.005	0.003	0.500	0.00	0.023
Nepal	Coefficients	-0.2139	-0.0878	2.2639	-0.2515***	0.4075*
	Prob.	0.604	0.333	0.595	0.000	0.048
Cambodia	Coefficients	-0.0607***	-0.1840***	-0.2319***	-0.1200***	-0.3812***
	Prob.	0.006	0.000	0.000	0.000	0.000
India	Coefficients	0.1527	-0.0244	0.3246*	0.0437***	0.0234***
	Prob.	0.182	0.307	0.09	0.003	0.000
Sri Lanka	Coefficients	-0.2595	-0.0151***	-0.0386	0.1335***	0.4550***
	Prob.	0.126	0.004	0.925	0.000	0.000
Indonesia	Coefficients	0.7987	-0.0385	0.6857	0.2253***	-0.0940
	Prob.	0.281	0.277	0.614	0.006	0.180
Vietnam	Coefficients	0.8847***	-0.0541**	-0.0093	-0.0188**	0.1271***
	Prob.	0.010	0.024	0.990	0.029	0.005
Philippine	Coefficients	1.2028***	0.2498***	-0.8305	-0.2724***	-0.0524*
	Prob.	0.003	0.000	0.331	0.000	0.075
Thailand	Coefficients	0.7572	-0.0404**	0.4560	0.0135	-0.1308***
	Prob.	0.292	0.048	0.309	0.179	0.003
Malaysia	Coefficients	0.3172***	-0.0701**	1.0611***	0.0173	-0.1875***
	Prob.	0.004	0.033	0.000	0.685	0.008
Brunei	Coefficients	0.6111	0.0529	-1.8738	0.5226*	-1.3916*
	Prob.	0.352	0.644	0.491	0.081	0.07
Singapore	Coefficients	2.9208	2.9471*	5.2255	-0.9839*	0.3018
	Prob.	0.683	0.093	0.413	0.106	0.689
Iran	Coefficients	-1.2493**	0.1661***	1.4790***	-0.5181***	-0.1044***
	Prob.	0.035	0.000	0.001	0.000	0.000

Note: *, ** and *** represents the significance level at 10%, 5% and 1% respectively.

We did not find significant outcomes in the case of India, Sri Lanka, Indonesia, Thailand, Brunei, and Singapore. Similarly, economic growth also contributed positively to CO_2 emissions in countries such as Bangladesh, India, Malaysia, and Iran.

However, in the case of Cambodia, economic growth reduces CO_2 emissions. In addition, we explored insignificant results in the rest of the sample countries. The result regarding financial development shows that this variable increases CO_2 emissions in countries such as Bangladesh, Pakistan, Brunei, Singapore, the Philippines, and Iran. In contrast, financial development reduces CO_2 emissions in Cambodia, Sri Lanka, Vietnam, Thailand, and Malaysia.

Table 3. 10: Pairwise Dumitrescu Hurlin panel causality test

Null Hypothesis:	W-Stat.	Z bar-Stat.	Prob.	Causality
LEPH does not homogeneously cause LCO2	7.43413	7.60300	3.E-14	EPH↔ CO_2
LCO2 does not homogeneously cause LEPH	3.76823	2.22663	0.0260	
LFIN does not homogeneously cause LCO2	4.55233	3.37658	0.0007	FIN→ CO_2
LCO2 does not homogeneously cause LFIN	3.25438	1.47301	**0.1407**	CO_2— FIN
LGDP does not homogeneously cause LCO2	4.16798	2.81290	0.0049	GDP→ CO_2
LCO2 does not homogeneously cause LGDP	2.64153	0.57421	**0.5658**	CO_2— GDP
LICT does not homogeneously cause LCO2	5.21905	4.35438	1.E-05	ICT→ CO_2
LCO2 does not homogeneously cause LICT	2.02267	-0.33340	**0.7388**	CO_2 — ICT
LTRADE does not homogeneously cause LCO2	3.55569	1.91492	0.0555	TRADE↔ CO_2
LCO2 does not homogeneously cause LTRADE	3.36291	1.63218	0.1026	
LFIN does not homogeneously cause LEPH	4.15635	2.79584	0.0052	FIN ↔EPH
LEPH does not homogeneously cause LFIN	5.41504	4.64182	3.E-06	
LGDP does not homogeneously cause LEPH	5.84287	5.26927	1.E-07	GDP→ EPH
LEPH does not homogeneously cause LGDP	3.15011	1.32010	**0.1868**	EPH — GDP
LICT does not homogeneously cause LEPH	4.09259	2.70233	0.0069	ICT↔ EPH
LEPH does not homogeneously cause LICT	5.14802	4.25021	2.E-05	
LTRADE does not homogeneously cause LEPH	2.96455	1.04795	**0.2947**	TRADE— EPH
LEPH does not homogeneously cause LTRADE	5.23796	4.38212	1.E-05	EPH→ TRADE
LGDP does not homogeneously cause LFIN	21.3310	27.9840	0.0000	GDP→ FIN
LFIN does not homogeneously cause LGDP	2.92505	0.99003	**0.3222**	FIN — GDP
LICT does not homogeneously cause LFIN	3.86610	2.37016	0.0178	ICT↔ FIN
LFIN does not homogeneously cause LICT	3.48224	1.80719	0.0707	
LTRADE does not homogeneously cause LFIN	6.44213	6.14814	8.E-10	TRADE → FIN
LFIN does not homogeneously cause LTRADE	2.62221	0.54588	**0.5851**	FIN — TRADE
LICT does not homogeneously cause LGDP	7.12845	7.15470	8.E-13	ICT↔ GDP
LGDP does not homogeneously cause LICT	3.33962	1.59803	0.1100	
LTRADE does not homogeneously cause LGDP	3.19555	1.38674	**0.1655**	TRADE — GDP
LGDP does not homogeneously cause LTRADE	4.96495	3.98172	7.E-05	GDP→ TRADE
LTRADE does not homogeneously cause LICT	5.11817	4.20643	3.E-05	TRADE↔ ICT
LICT does not homogeneously cause LTRADE	3.95147	2.49537	0.0126	

Note: insignificant values reported bold and ↔, →, — shows bidirectional, unidirectional, no causality, respectively.

Results suggested that ICT increases the CO_2 emissions in countries such as Pakistan, India, Sri Lanka, Indonesia, and Brunei. However, we found an inverse relation between ICT and CO_2 emissions in countries such as Bangladesh, Nepal, Cambodia, Vietnam, the Philippines, Singapore, and Iran. It simply means that these countries are using environmentally friendly ICT products and services. For two further countries, Malaysia, and Thailand, we found insignificant results.

The result concerning trade contribution to CO_2 emissions, demonstrated that trade is contributing to the increase of CO_2 emissions in countries such as Pakistan, Nepal, India, Sri Lanka, and Vietnam. Further, results show that trade is mitigating the CO_2 emissions in countries such as Cambodia, the Philippines, Thailand, Malaysia, Brunei, and Iran. Trade may be improving the environmental quality in these countries. However, our results did not confirm the significant findings in Bangladesh, Indonesia, and Singapore.

3.4.5 Causality

PMG, FMOLS, and DOLS results did not provide the information about causality analysis between the variables. The Dumitrescu and Hurlin (2012) causality test might be helpful for policymakers to make the appropriate policies, as this test gives information about the direction of the causal relationship among the variables.

Table 3. 10 reports Dumitrescu and Hurlin (2012) pairwise panel causality test, and we noticed the presence of feedback effect, i.e., energy consumption is found to have bidirectional causality with CO_2 emissions. Notwithstanding, the unidirectional causality is seen running from economic growth, trade, ICT, and financial development to CO_2 emissions. The DH causality results are in line with (Park et al., 2018; Salahuddin et al., 2016).

3.5 Conclusion and Policy Implications

The current study aimed to determine the effects of ICT, economic growth, energy consumption, trade, and financial development on carbon emissions in the South and Southeast Asian regions for the period of 1990-2014.

The study observed that there is cointegration among the variables in all three panels. The long-run panel estimator indicates that ICT and energy consumption have a positive impact on CO_2 emissions in all panels. This could mean that ICT goods and services are not energy efficient in both potential and advanced countries. Furthermore, our study also confirmed the EKC inverted U-shaped curve between GDP per capita and CO_2 emission per capita for potential, advance, and full countries panels. It means that in the beginning economic growth deteriorated the environment quality; however, later, it will mitigate the CO_2 emissions after reaching the certain threshold level in the SSEA region.

A positive impact on the financial development of CO_2 emissions in potential countries was found. However, in the case of advanced countries, this effect is negative. This result suggests that most of the investment in potential countries is made on financial resources that are non-friendly environmental projects. Besides, those projects increased the energy demand which ultimately increases CO_2 emissions in potential countries while in advanced countries financial development decreases CO_2 emissions. Moreover, in the case of advanced countries, we found a significant positive relationship between trade and CO_2 emissions while negative in the case of potential countries. This means that trade improved the environmental quality in the potential countries and increased CO_2 emissions in advanced countries. We also observed that energy consumption has bidirectional causality with CO_2 emissions. Nevertheless, the unidirectional causality is seen running from trade, ICT, financial development, and economic growth to CO_2 emissions for the full countries panel.

In the modern era, more people are using powerful ICT installed hardware-based devices which ultimately increase energy demand. There is a need for developing green mobile communications, which can ensure reduced energy consumption and increased battery life, besides increased capacity to enable massive deployment of small cell base stations. The wireless communication network with these features is stated to as an energy-efficient green mobile communication and referred as fifth generation technology (5G) (Chapa et al., 2020) .The telecommunications industry has taken a bold position in reducing its CO_2 emissions, primarily by reducing the energy consumption and replacing old with new green cellular infrastructure. The main objective of 5G networks are to motivate and create a common platform for both mobile network operators and mobile handset manufacturers to work together to minimize the environmental footprint of their products (Wang and Rangapillai, 2012). Although the energy efficiency of ICT hardware is improving, the total demand for ICT services is growing even faster than the energy efficiency of ICT devices. ICT sectors can perform better if other sectors such as non-ICT household appliances (heaters, Microwave ovens, stove, and refrigerator), industrial machines, and transport use energy systematically. Moreover, to increase energy efficiency, especially those sectors that partly based on ICT such as residential, transport, and industrial sectors required innovative technologies. As a result, the ICT sector can make a significant contribution to a low carbon economy due to the reduction of energy demand.

However, policymakers should be aware that ICT energy demand is increasing rapidly than the overall energy demand. The two research areas are of increasing importance, such as energy used by ICT and the energy efficiency induced by ICT. Nonetheless, the second question will compromise policies to focus on the first one. It is necessary to differentiate "good" from "bad" ICT energy consumption, as policies that limit energy consumption can weaken policies that support ICT for energy efficiency.

In the studied countries, the opportunities offered by ICT are not being seized automatically. ICT also provides workers with more free time, lower prices for consumers, higher profits for companies by improving efficiency, and productivity, which leads to higher overall consumption and increased CO_2 emissions, offsetting the positive effect on the initially generated environment, which is called the rebound effect. ICT technologies can offer a variety of ICT applications that can add the value to the global effort to reduce emissions. There are opportunities in developed countries, which can be replicated by developing countries, for innovative ICT technologies that decrease GHG emissions 'from the beginning (WWF, 2008).

Results suggest the importance of measures that make users aware and be well informed about this problem, that raise awareness of what they can do to waste less energy during and after the use of these technologies, and that strengthen the regulation of their manufacture to facilitate integration of energy efficiency into user routines. Also, Energy Efficiency labelling for all of these technologies, including auxiliary devices (routers, for example), should be an essential measure in Asian countries as well as the programming of these technologies to display messages to alert users of the implications of the various power consumption options as well as offering more intuitive power saving options and features. Due to the increasing use of standby mode and Wi-Fi assistive devices, the rapid implementation of legislation regulating these technologies to make them more efficient is recommended. Our result showed that financial development can increase emissions in potential countries but can improve the environment in advanced countries. Once again, developing countries should follow developed countries' practices concerning this topic. For instance, the banking system can give priority or give incentives to finance economic activities with lower emission levels or add the environmental cost of emissions to the cost of the financial product (Shahbaz et al., 2013a).

Finally, the generalizability of these results is subject to the following limitation with future directions. For instance, the data used for this study is bounded only to the country level with annual observations. Furthermore, this study could be tested with other econometric techniques like 2SLS, 3SLS, GMM approach, and panel smooth transition regression model (PSTR) amongst others. Besides, future studies can introduce new variables such as particulate matters ($PM_{2.5}$, PM_{10}), carbon footprint, ecological footprint, sulfur dioxide (SO_2), and sulfur hexafluoride (SF_6) as environmental degradation. Furthermore, call for future research in ICT in the context of industry 4.0. However, a potential future research direction is to examine how does the internet of things (IoT), and block chain technologies affect emissions reduction (Awan, 2019). Moreover, studies could investigate the social development with Human development index (HDI) such as education, life expectancy and GDP. This research could be applied in the city level as well as other economies around the globe with different data such as quarterly, monthly, etc.

3.6 Appendix B

Table 3.11: Pesaran CD (Cross sectional dependence)

Variables	LCO_2	LGDP	LEPH	LTRD	LICT	LFIN
Potential area	23.707*	24.985*	25.604*	4.5053*	25.949*	6.892*
	(0.00)	(0.00)	(0.00)	(0.05)	(0.00)	(0.00)
Advance area	3.610*	8.272*	18.61*	2.943*	19.062*	4.484*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Overall	27.295*	34.224*	45.644*	5.208*	46.368*	9.347*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Note: P-values reported in parenthesis and * represents 1% level of significance.

Table 3. 12: Error Correction Term for each Country

Countries	Error correction coefficient	Std. Error	t-Statistic	Prob. *
Bangladesh	-0.6012	0.0374	-16.05	0.0005*
Pakistan	-0.6434	0.0404	-15.92	0.0005*
Nepal	-0.4595	0.0086	-53.03	0.0000*
Cambodia	-0.3360	0.0129	-25.97	0.0001*
India	-0.4844	0.0367	-13.18	0.0009*
Sri Lanka	-0.5486	0.0332	-16.51	0.0005*
Indonesia	-0.8352	0.0586	-14.24	0.0007*
Vietnam	-0.9078	0.0333	-27.19	0.0001*
Philippine	-0.5433	0.0427	-12.70	0.0011*
Thailand	-0.0749	0.0144	-5.18	0.0139*
Brunei	-0.1484	0.0132	-11.19	0.0015*
Malaysia	-0.2163	0.0203	-10.61	0.0018*
Singapore	-0.5423	0.0453	-11.95	0.0013*
Iran	-0.6387	0.0431	-14.80	0.0007*

Note: *, ** shows significant level at 1% and 10% respectively.

References

Adu, D.T., Denkyirah, E.K., 2018. Economic growth and environmental pollution in West Africa: Testing the Environmental Kuznets Curve hypothesis. Kasetsart Journal of Social Sciences. https://doi.org/10.1016/j.kjss.2017.12.008

Ahmed, K., Rehman, M.U., Ozturk, I., 2017. What drives carbon dioxide emissions in the long-run? Evidence from selected South Asian Countries. Renewable and Sustainable Energy Reviews 70, 1142–1153. https://doi.org/10.1016/j.rser.2016.12.018

Alam, Md.M., Murad, Md.W., Noman, A.H.Md., Ozturk, I., 2016. Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. Ecological Indicators, Navigating Urban Complexity: Advancing Understanding of Urban Social – Ecological Systems for Transformation and Resilience 70, 466–479. https://doi.org/10.1016/j.ecolind.2016.06.043

Al-Mulali, U., Sheau-Ting, L., Ozturk, I., 2015. The global move toward Internet shopping and its influence on pollution: an empirical analysis. Environ Sci Pollut Res 22, 9717–9727. https://doi.org/10.1007/s11356-015-4142-2

Al-Mulali, U., Solarin, S.A., Ozturk, I., 2016. Investigating the presence of the environmental Kuznets curve (EKC) hypothesis in Kenya: an autoregressive distributed lag (ARDL) approach. Nat Hazards 80, 1729–1747. https://doi.org/10.1007/s11069-015-2050-x

Amri, F., 2018. Carbon dioxide emissions, total factor productivity, ICT, trade, financial development, and energy consumption: testing environmental Kuznets curve hypothesis for Tunisia. Environ Sci Pollut Res 25, 33691–33701. https://doi.org/10.1007/s11356-018-3331-1

Antonakakis, N., Chatziantoniou, I., Filis, G., 2017. Energy consumption, CO2 emissions, and economic growth: An ethical dilemma. Renewable and Sustainable Energy Reviews 68, 808–824. https://doi.org/10.1016/j.rser.2016.09.105

Apergis, N., 2016. Environmental Kuznets curves: New evidence on both panel and country-level CO2 emissions. Energy Economics 54, 263–271. https://doi.org/10.1016/j.eneco.2015.12.007

Asongu, S.A., 2018. ICT, openness and CO2 emissions in Africa. Environ Sci Pollut Res 25, 9351–9359. https://doi.org/10.1007/s11356-018-1239-4

Asongu, S.A., Le Roux, S., Biekpe, N., 2018. Enhancing ICT for environmental sustainability in sub-Saharan Africa. Technological Forecasting and Social Change 127, 209–216.

Baloch, M.A., 2018. Dynamic linkages between road transport energy consumption, economic growth, and environmental quality: evidence from Pakistan. Environmental Science and Pollution Research 25, 7541–7552.

Behera, S.R., Dash, D.P., 2017. The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. Renewable and Sustainable Energy Reviews 70, 96–106. https://doi.org/10.1016/j.rser.2016.11.201

Belkhir, L., Elmeligi, A., 2018. Assessing ICT global emissions footprint: Trends to 2040 & recommendations. Journal of cleaner production 177, 448–463.

Ben Jebli, M., Ben Youssef, S., Ozturk, I., 2016. Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries. Ecological Indicators 60, 824–831. https://doi.org/10.1016/j.ecolind.2015.08.031

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

Cho, Y., Lee, J., Kim, T.-Y., 2007. The impact of ICT investment and energy price on industrial electricity demand: Dynamic growth model approach. Energy Policy 35, 4730–4738.

Cohen, S., Demeritt, D., Robinson, J., Rothman, D., 1998. Climate change and sustainable development: towards dialogue. Global Environmental Change 8, 341–371.

Collard, F., Fève, P., Portier, F., 2005. Electricity consumption and ICT in the French service sector. Energy Economics 27, 541–550.

Danish, Khan, N., Baloch, M.A., Saud, S., Fatima, T., 2018. The effect of ICT on CO2 emissions in emerging economies: does the level of income matters? Environ Sci Pollut Res 25, 22850–22860. https://doi.org/10.1007/s11356-018-2379-2

Dehghan Shabani, Z., Shahnazi, R., 2019. Energy consumption, carbon dioxide emissions, information and communications technology, and gross domestic product in Iranian economic sectors: A panel causality analysis. Energy 169, 1064–1078. https://doi.org/10.1016/j.energy.2018.11.062

Dumitrescu, E.-I., Hurlin, C., 2012. Testing for Granger non-causality in heterogeneous panels. Economic Modelling 29, 1450–1460.

Frankel, J.A., Romer, D.H., 1999. Does Trade Cause Growth? American Economic Review 89, 379–399. https://doi.org/10.1257/aer.89.3.379

Granger, C.W., 1969. Investigating causal relations by econometric models and cross-spectral methods. Econometrica: Journal of the Econometric Society 424–438.

Grossman, G.M., Krueger, A.B., 1991. Environmental impacts of a North American free trade agreement. National Bureau of Economic Research.

Heidari, H., Turan Katircioğlu, S., Saeidpour, L., 2015. Economic growth, CO2 emissions, and energy consumption in the five ASEAN countries. International Journal of Electrical Power & Energy Systems 64, 785–791. https://doi.org/10.1016/j.ijepes.2014.07.081

Hernnäs, H., 2018. What is the impact of ICT on CO2emissions?A macro perspective. Université Paris 1 Panthéon-Sorbonne, Paris.

Higón, D.A., Gholami, R., Shirazi, F., 2017. ICT and environmental sustainability: A global perspective. Telematics and Informatics 34, 85–95.

Ishida, H., 2015. The effect of ICT development on economic growth and energy consumption in Japan. Telematics and Informatics 32, 79–88.

Jensen, A.L., 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Canadian Journal of Fisheries and Aquatic Sciences 53, 820–822. https://doi.org/10.1139/f95-233

Jokinen, P., Malaska, P., Kaivo-oja, J., 1998. The environment in aninformation society': A transition stage towards more sustainable development? Futures 30, 485–498.

Koirala, B.S., Li, H., Berrens, R.P., 2011. Further investigation of environmental Kuznets curve studies using meta-analysis. International Journal of Ecological Economics and Statistics 22, 13–32.

Lau, J., 1990. Cluster analysis of international information and social development. Information processing & management 26, 317–328.

Le, T.-H., Quah, E., 2018. Income level and the emissions, energy, and growth nexus: Evidence from Asia and the Pacific. International economics 156, 193–205.

Lee, J.W., Brahmasrene, T., 2014. ICT, CO2 emissions and economic growth: evidence from a panel of ASEAN. Global Economic Review 43, 93–109.

Li, T., Wang, Y., Zhao, D., 2016. Environmental Kuznets curve in China: new evidence from dynamic panel analysis. Energy Policy 91, 138–147.

Lu, W.-C., 2018. The impacts of information and communication technology, energy consumption, financial development, and economic growth on carbon dioxide emissions in 12 Asian countries. Mitig Adapt Strateg Glob Change 23, 1351–1365. https://doi.org/10.1007/s11027-018-9787-y

Malmodin, J., Bergmark, P., 2015. Exploring the effect of ICT solutions on GHG emissions in 2030. Presented at the EnviroInfo and ICT for Sustainability 2015, Atlantis Press. https://doi.org/10.2991/ict4s-env-15.2015.5

Malmodin, J., Lundén, D., 2018. The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010–2015. Sustainability 10, 3027. https://doi.org/10.3390/su10093027

Moomaw, W.R., Unruh, G.C., 1997. Are environmental Kuznets curves misleading us? The case of CO 2 emissions. Environment and Development Economics 2, 451–463.

Ouyang, X., Lin, B., 2017. Carbon dioxide (CO2) emissions during urbanization: A comparative study between China and Japan. Journal of cleaner production 143, 356–368.

Ozcan, B., Apergis, N., 2018. The impact of internet use on air pollution: Evidence from emerging countries. Environmental Science and Pollution Research 25, 4174–4189.

Ozturk, I., Acaravci, A., 2013. The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Economics 36, 262–267. https://doi.org/10.1016/j.eneco.2012.08.025

Park, Y., Meng, F., Baloch, M.A., 2018. The effect of ICT, financial development, growth, and trade openness on CO 2 emissions: an empirical analysis. Environmental Science and Pollution Research 25, 30708–30719.

Pedroni, P., 2004. Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econometric theory 20, 597–625.

Pedroni, P., 2001a. Purchasing power parity tests in cointegrated panels. Review of Economics and Statistics 83, 727–731.

Pedroni, P., 2001b. Fully modified OLS for heterogeneous cointegrated panels, in: Nonstationary Panels, Panel Cointegration, and Dynamic Panels. Emerald Group Publishing Limited, pp. 93–130.

Pesaran, M.H., 2007. A simple panel unit root test in the presence of cross-section dependence. Journal of applied econometrics 22, 265–312.

Pesaran, M.H., 2004. General diagnostic tests for cross section dependence in panels.

Pesaran, M.H., 1997. The role of economic theory in modelling the long run. The Economic Journal 107, 178–191.

Pesaran, M.H., Shin, Y., Smith, R.P., 1999. Pooled mean group estimation of dynamic heterogeneous panels. Journal of the American Statistical Association 94, 621–634.

Raheem, I., Tiwari, A., Balsalobre-lorente, D., 2019. The Role of ICT and Financial Development on CO2 Emissions and Economic Growth (Working Paper No. 19/058). European Xtramile Centre of African Studies (EXCAS).

Richmond, A.K., Kaufmann, R.K., 2006. Is there a turning point in the relationship between income and energy use and/or carbon emissions? Ecological economics 56, 176–189.

Romm, J., 2002. The internet and the new energy economy. Resources, conservation and recycling 36, 197–210.

Sadorsky, P., 2012. Information communication technology and electricity consumption in emerging economies. Energy Policy 48, 130–136.

Salahuddin, M., Alam, K., 2015. Internet usage, electricity consumption and economic growth in Australia: A time series evidence. Telematics and Informatics 32, 862–878.

Salahuddin, M., Alam, K., Ozturk, I., 2016. The effects of Internet usage and economic growth on CO2 emissions in OECD countries: A panel investigation. Renewable and Sustainable Energy Reviews 62, 1226–1235. https://doi.org/10.1016/j.rser.2016.04.018

Salahuddin, M., Gow, J., 2016. The effects of internet usage, financial development and trade openness on economic growth in South Africa: A time series analysis. Telematics and Informatics 33, 1141–1154.

Shahbaz, M., Dube, S., Ozturk, I., Jalil, A., 2015. Testing the environmental Kuznets curve hypothesis in Portugal. International Journal of Energy Economics and Policy 5, 475–481.

Shahbaz, M., Loganathan, N., Muzaffar, A.T., Ahmed, K., Jabran, M.A., 2016. How urbanization affects CO2 emissions in Malaysia? The application of STIRPAT model. Renewable and Sustainable Energy Reviews 57, 83–93.

Shahbaz, M., Solarin, S.A., Mahmood, H., Arouri, M., 2013a. Does financial development reduce CO2 emissions in Malaysian economy? A time series analysis. Economic Modelling 35, 145–152. https://doi.org/10.1016/j.econmod.2013.06.037

Shahbaz, M., Tiwari, A.K., Nasir, M., 2013b. The effects of financial development, economic growth, coal consumption and trade openness on CO2 emissions in South Africa. Energy Policy 61, 1452–1459.

Stock, J.H., Watson, M.W., 1993. A simple estimator of cointegrating vectors in higher order integrated systems. Econometrica: Journal of the Econometric Society 783–820.

WWF, 2008. The potential global CO2 reductions from ICT use. WWF Sweden, Sweden.

Van Heddeghem, W., Lambert, S., Lannoo, B., Colle, D., Pickavet, M., Demeester, P., 2014. Trends in worldwide ICT electricity consumption from 2007 to 2012. Computer Communications 50, 64–76.

Westerlund, J., 2007. Testing for error correction in panel data. Oxford Bulletin of Economics and statistics 69, 709–748.

World Bank, 2019. World development indicators. Retrieved from.http://data.worldbank.org/country.

Yuan, Y., Wen-Jia, C., Can, W., Si-Qiang, W., 2012. Regional allocation of CO2 intensity reduction targets based on cluster analysis. Advances in climate change research 3, 220–228.

Zakarya, M., 2018. Energy, performance and cost efficient datacenters: A survey. Renewable and Sustainable Energy Reviews 94, 363–385.

Zaman, K., Moemen, M.A., 2017. Energy consumption, carbon dioxide emissions and economic development: Evaluating alternative and plausible environmental hypothesis for sustainable growth. Renewable and Sustainable Energy Reviews 74, 1119–1130. https://doi.org/10.1016/j.rser.2017.02.072

Zhang, C., Liu, C., 2015. The impact of ICT industry on CO2 emissions: a regional analysis in China. Renewable and Sustainable Energy Reviews 44, 12–19.

Zhang, S., Zhao, T., 2019. Identifying major influencing factors of CO2 emissions in China: Regional disparities analysis based on STIRPAT model from 1996 to 2015. Atmospheric Environment 207, 136–147.

Chapter IV

Renewable and Non-renewable energy, Economic growth, and Natural resources impact on environmental quality: Empirical evidence from South and Southeast Asian countries with CS-ARDL Modeling

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[The sequence of the names of the authors reflect their relative contribution, with the first author making the biggest contribution in every section of this article. The remaining authors are all tenured Professors.]

4 Renewable and Non-renewable energy, Economic growth, and Natural resources impact on environmental quality: Empirical evidence from South and Southeast Asian countries with CS-ARDL Modeling

4.1 Introduction

From the last few decades climate change has been a very wide spoken phenomenon and exhalation of carbon dioxide (CO_2 emissions) is considered its chief source. The intensity of the CO_2 emissions has been risen by 45% from the last 130 years which is constantly deteriorated the environmental quality (Carbon Footprint, 2018).

According to the existing literature, several drivers of CO_2 emissions (CO_2) have been discussed such as economic growth (GDP), industrialization, urbanization (URB), deforestation, waste management, air pollution, renewable energy (RE) sources, non-renewable energy (NRE) sources (Arshad et al., 2020) and natural resources (NR) etc. To meet the demand for the ever increasing population of this planet, labor, capital and other inputs of production (especially energy sources), uplift of human efforts are considered liable for the world's astonishing economic progress (Owusu and Asumadu-Sarkodie, 2016), which ultimately raised the level of carbon emissions. Briefly speaking the release of carbon dioxide has proved itself for the threat to environment system and human development (Bekun et al., 2019). The gaseous emission alarming increased from the figure of 9434.4 million tons in 1961 to a gigantic figure of 34649.4 million tons in year 2011 (IPCC, 2014). British Petroleum (BP) agency (2018) report reveals that a uplift of carbon dioxide from 29714.2 million tons in 2009 to 33444 million tons in 2017 was observed on the globe.

The dynamic that has affected the energy-related carbon emissions have been widely discussed in the existing literature: Farhani and Shahbaz (2014) for Middle East and North African (MENA) countries, Shafiei and Salim (2014) for OECD countries, Ben Jebli and Ben Youssef (2015)for Tunisia, Bhattacharya et al. (2017) for 85 developed and developing economies, Bento and Moutinho (2016) for the Italian case, Rasoulinezhad and Saboori (2018) for the commonwealth of independent states (CIS), Dong et al. (2019) for 128 countries and Adam and Nsiah (2019) for 28 Sub-Saharan African economies, are some examples.

Besides, the economic growth and NR nexus is also discussed in the existing literature, that provides the mixed (positive and negative) substantiation of a NR on economic growth (Satti et al., 2014). The economies with abundant NR perform lesser than the NR-scarce nations (Sachs and Warner, 1995). For instance, Korea, Singapore, Japan, Hong Kong, and Switzerland performed very well and made enormous progress with no or very limited access to natural resources (Krueger, 1998) and contrary to NR abundant countries made three times more progress (Auty, 2001; Sachs and Warner, 1995). Shaw (2013) also proved that NR abundance is the only reason for low economic growth in Azerbaijan.

Conversely, some South American countries took advantage of the NR boom to enhance their economic growth. Notably, Ecuador increased its GDP per capita during the boom period of NR(Sachs and Warner, 1999). Besides, the resources of ore and coal in England and Germany were the significant ingredients behind the industrial revolution in Europe (Sachs and Warner, 1995). The exploitation of NR abundance was also behind the success story of Norway to achieve a high level of income prosperity with proper economic planning (Gylfason, 2001).

Furthermore, natural resources (NR) are also included in different studies to investigate the impact on environmental quality. Recently, Bekun et al. (2019) analyzed the causal interaction between economic growth, NR rent, RE and NRE consumption in CO_2 emissions for EU 16 countries covering the period of 1996-2014 by PMG-ARDL models. The Kao cointegration techniques confirmed the long-run relationship between the variables, and the study suggested that NR rent have a significant positive impact on CO_2 emissions. It indicates that overdependence on the NR rent has effects on environmental sustainability if a proper management is ignored. The study also noted that NRE and economic growth increase, whereas RE consumption decrease the CO_2 emissions. The causality results display a feedback result effect amidst NRE, RE, and economic development. Further, the study also found feedback causality between NR rent and economic growth.

The above discussion about energy (RE and NRE) consumption-CO_2 emissions nexus disclosed mixed results for different countries and economies with different time spam. Moreover, NR abundance or scarce role in the economic growth has been a challenge in developing and developed countries, and their impact on CO_2 emissions requires more research, as existing results are not consensual. For this purpose, the current study investigates the linkages between economic growth, NR rent, CO_2 emissions, RE and NRE consumption over the period of 1990-

2014 for the South and Southeast Asian countries (SSEA). We developed two models to full fill the aim of the study: model 1, to access the impact of RE, NRE and NR effects on economic growth, model 2, to access the impact of all the discussed variables on CO_2 emissions.

Although several studies have considered the factors influencing CO_2 emissions at single-country, regional and global perspective, there is a limited number of studies examining the impacts of economic growth, NR rent, RE and NRE consumption on carbon emissions within the same framework for SSEA countries.

Further, this piece of writing dissent from the current composition in several modes. Firstly, it is a humble effort to meet the literature gap, by studying South and Southeast Asian (SSEA) economies, using the referred variables, as the estimations were made for 3 panels: (i) full countries panel, (ii) South Asian countries, and (iii) Southeast Asian countries. Secondly, this essay considers advance panel data techniques that allow the heterogeneous unobserved parameters and cross-sectional dependence (CD) of the sample countries. Thirdly, the study uses the advance Pooled Mean Group (PMG) technique to estimate the short and long-run dynamics. Fourthly, to robust the PMG estimation we have applied a new technique named as Dynamic Common Correlated Effects (DCCE) CS-ARDL introduced by Chudik et al. (2016).Finally, this essay controls for the result of diagnostic and specification tests, which have been rarely considered in prior studies.

Different cointegration techniques such as Pedroni, Kao, Fisher, and Westerlund allowed us to conclude a long-run relationship exist among the considered variables. Findings from the PMG and DCCE CS-ARDL estimations reveal that RE and NRE rise the economic development in the selected three panels. Besides, natural resources impede the economic growth in South Asian and full countries panels while increase the economic activities in Southeast Asian countries. In the case of model 2, results demonstrated that NRE and economic growth increased the CO_2 emissions, whereas, RE consumption lessens the carbon emissions in all three selected panels. However, natural resources also contributed to raise CO_2 emissions in the case of South Asian and full countries panels while improved the environmental quality in the Southeast Asian region.

The policy implication in this regard, is that RE sources should be preferred to decrease CO_2 emissions in the SSEA countries. Moreover, for the better use of natural resources, the government should concentrate on education and corruption to improve the economic growth in the selected studied areas.

The remaining portion of essay has arranged in following way: the Literature Review chapter, the Models construction, Data overview and Methodology chapter, the Result and discussion chapter and in the end, the Conclusions, policy implications, limitations and future recommendation chapter.

4.2 Literature Review

The anterior literature has discussed the linkages among energy consumption (EC), renewable energy (RE), non-renewable energy (NRE), energy prices, industrialization, economic growth, and other macro-economic variables such as foreign investment (FDI), financial development (FD), trade openness (TRD), and natural resource (NR) abundance, with CO_2 emissions as a proxy of greenhouse gases (GHGs).

We divided our literature into two strands: (i) the effect of (RE), (NRE), economic development and other macro-economic variables with environmental degradation in the form of carbon emissions and (ii)the influence of NR on economic growth and on CO_2 emissions (CO_2).

4.2.1 Economic growth, CO_2 emissions, Renewable and Non-renewable energy

Numerous studies that investigated the environmental pollution-macroeconomic variables nexus are quite insignificant to justify such extensive phenomenon at single-country level, territorial scale, and worldwide. For instance, in the case of the MENA countries, Farhani and Shahbaz (2014) examined the relationship among RE, NRE, GDP, and CO_2 emissions for 1980-2009. The study used the fully modified ordinary least square (FMOLS) and dynamic ordinary least square (DOLS) method to investigate the long-run elasticities. The results show that RE and NRE consumption increase carbon emissions. The study also found an inverted U-shaped environment Kuznets curve (EKC) with economic growth and CO_2 emissions. Unidirectional causality running from RE, NRE, and output to CO_2 emissions were found in the short run, while in the long run, bidirectional causality running from RE and NRE to CO_2 emissions was observed.

In addition to the concern mentioned above, Shafiei and Salim (2014) focused on the OECD countries during 1980-2011 and investigated with STIRPAT model the relationship between urbanization, CO_2emissions,RE and NRE consumption. The results show that NRE has a direct impact on CO_2 emissions, while RE decreases carbon emissions. The study also confirmed the

EKC hypothesis with urbanization and CO_2 emissions. Besides, in Tunisia, Ben Jebli and Ben Youssef (2015) derived similar results with data covering years 1980-2009. Further, Bhattacharya et al.(2017) demonstrated the role of RE consumption and institutions on economic growth and in combating CO_2 emissions for 85 developing and developed economies of different income groups around the globe. The results from the generalized moment method (GMM) and FMOLS show that RE has a significant favorable impact on economic growth and improved environmental quality. The production of RE is the key to mitigate carbon emissions in Italy, as concluded by Bento and Moutinho (Bento and Moutinho, 2016).

For the case of Turkey, Pata (2018)analyzed the short and long-run dynamic relationship between GDP per capita, CO_2 emissions, urbanization, RE consumption, FD, hydropower energy consumption and alternative EC, during 1974-2014 with ARDL bound testing and FMOLS method. The work reveals the ultimate relationships among mutable with Gregory-Hansen and Hatemi-J cointegration approaches. In addition, the study noted that economic growth, urbanization, and FD increase CO_2 emissions, whereas RE consumption, hydropower consumption and alternative energy consumption sources had insignificant effects on environmental quality.

Inglesi-Lotz and Dogan (2018) confirmed the long-run relationships between income, TRD, NRE, RE consumption, and CO_2 emissions for the ten biggest electricity generators in Sub-Saharan Africa over the period of 1980 to 2011.Moreover, the authors concluded that the use of RE improved while NRE worsened the environment quality, and that there is unidirectional causality running from income, CO_2 emissions, TRD, and NRE towards RE. Top RE users countries need to increase RE production, FD and TRD to lessen the carbon emissions (Dogan and Seker, 2016b). Conversely, Rasoulinezhad and Saboori (2018) noted the long-run connections between RE, NRE, TRD,GDP, financial openness, and carbon emissions for the commonwealth of independent states (CIS) for 1992-2015. The results from panel cointegration methods such as FMOLS and DOLS declared that RE has no impact on CO_2 emissions and that fossil fuel proxy of NRE consumption declined whereas financial openness improved the environmental quality in the long run.

In more recent studies, authors illustrated different linkages between variables. For instance, Sharif et al.(2019) concentrated on the ultimate liaison connecting NRE, RE consumption, and carbon emissions. The long-run elasticities show an inverse impact of RE and direct effects of

NRE consumption on the environment for the panel of 74 nations during 1990-2015. Also, Belaïd and Zrelli (2019) and Chen et al. (2019)explored similar findings for 9 Mediterranean countries and regional study in China, respectively.

However, Adam and Nsiah (2019) noticed that both RE and NRE consumption increased the CO_2 emissions in 28 economies of Sub Saharan Africa. In another scenario, Dong et al. (2019)estimated the linkages between RE intensity, NRE, and economic growth with STIRPAT modelling the global and regional context of an unbalanced panel dataset of 128 countries covering 1990-2014. The results indicated that at a global level, RE intensity, NRE, economic growth, and population deteriorated the environment. Nonetheless, the regional perspective findings suggested that RE declined the CO_2 emissions in the two regions such as South and Central America and Europe and Eurasia.

4.2.2 Natural resources-economic growth-environmental pollution nexus

The natural resources-economic growth nexus has been discussed into two scenarios: resource abundance and resource dependence in the prior literature. Resource abundance can be explained by "annual per capita rent of resource production" (Apergis and Payne, 2014; Brunnschweiler, 2008) whereas resource dependence can be measured by "rents from natural resources over GDP"(Auty, 2007; Bhattacharyya and Hodler, 2014), "the share of total natural resource in total export" (Dietz et al., 2007), or "the share of total natural resource export in GDP" (Boschini et al., 2013; Sachs and Warner, 1995).

Several studies have been discussed the linkages between natural resources abundance and economic indicators around the globe. For instance, Sarmindi et al. (2014) proved that resource abundance affects growth positively after the threshold level of institutional quality. After 2003, the oil abundance affects positively economic growth in MENA countries (Apergis and Payne, 2014). Conversely, Satti et al. (2014) inspected the connection among NR abundance, economic growth, FD, capital, and trade by ARDL bounds testing approach and VECM for 1971-2011. The findings confirmed the existence of long-run relationship between the considered variables and suggested that NR abundance impedes the economic growth whereas FD, trade openness and capital stock improve the economic development in Venezuela. Ahmed et al. (2016) also proved the association between NR, economic growth, capital, labour, and exports by Cobb-Douglas production function. The results show that a 1% increase in NR results in 0.47% decline in GDP in the long-run. It means that NR abundance slowed the economic development in Iran during 1965-2011. The causality results proved the feedback effect between economic growth and NR abundance. Besides, Kim and Lin(2017)noticed similar linkages between NR abundance and economic growth by heterogeneous panel cointegration technique for 40 developing countries covering the period from 1990 to 2012. Ben-Salha et al. (2018) determined the causal connections between NR rent and economic growth by PMG estimator to identify the short and long-run dynamics for top NR abundance economies covering the period of 1970-2013. The result shows that NR rent increased the economic development (FD) in the long run. Further, the result of the causality analysis shows that bidirectional relationship exists between the selected variables. Shahbaz et al. (2018) also investigated the stimulating role of NR abundance in financial development for the USA for 1960-2016. The study also included additional variables such as education, economic growth, and capitalization as FD in the financial demand function. The existence of cointegration confirmed between FD and its determinants. The empirical results also show that NR abundance, economic growth, and education have a positive impact on FD while capitalization is inversely linked with FD.

Furthermore, in the meta-analysis of last two decades studies about natural resources and economic growth, Havranek et al. (2016) observed that 40% of studies reported insignificant result,40% studies supports the natural resource curse whereas the last 20% studies find blessing of natural resources. The authors noticed that institutional quality, investment activities, different nature of natural resources, and natural resources scarce or abundance could be possible in explaining the differences across the studies.

However, in recent years some studies found that NR-abundant countries have positive and rapid economic growth, especially with cross-sectional data. Researchers believe that to have a clear picture of the connection between economic growth and NR needs to be studied more in time series and panels frameworks (Badeeb et al., 2017).

Moreover, the role of NR is also included in different studies to investigate the impact on environmental quality. Among of them, Balsalobre-Lorente et al. (2018)employed the carbon function to investigate the EKC hypothesis for European countries such as Germany, Spain, England, France, and Italy for the 1985-2016 period. The study also included other additional variables such as TRD, NR abundance, RE consumption, and energy innovation to augment the carbon emission function. Results confirmed the existence of the N-shaped EKC phenomenon.

Findings also suggested that NR, RE consumption, and energy innovation mitigate CO_2 emissions whereas, TRD and the interaction between economic growth and RE consumption deteriorated the environmental quality.

In this regard, the review of limited literature represents quite distinct results, that has influenced in extending the vagueness regarding the specific association between the variables, thus requiring new investigation to clarify and validate the inconclusive findings of existing studies (Balcilar et al., 2018).

4.3 Models, Data and Methodology

This section consists of three parts: (i) we will develop the empirical models, (ii) we will discuss the definition of the variables with data sources, and also demonstrate the individual country variables role over the year and descriptive statistics, and (iii) we will discuss the different econometrics techniques which are going to be the part of the analysis.

4.3.1 Models construction

The study aims to determine the linkages between economic growth, renewable energy, non-renewable energy, natural resources rent, and carbon emissions. For this purpose, we use two models.

Model 1: we observe the impact of RE, NRE, NR rent on economic development. One of the aims is to examine the relationship between GDP, RE, NRE consumption, and NR rent in SSEA region. The general form of the economic growth function model is designed as follows:

$$\text{GDP} = f(\,RE, NRE, RENT\,) \qquad (1)$$

Where RE, NRE, RENT, and GDP represents renewable energy consumption, non-renewable, energy consumption, natural resources rent, and economic growth, respectively. A large number of studies have jointly examined the nexus between natural resources and economic growth along with other macro-economic indicators (Sarmindi et al. (2014), Satti et al. (2014), Ahmed et al. (2016), Kim and Lin (2017), Shahbaz et al.(2018), Ben-Salha et al.(2018), etc). Based on the prior relevant studies, our empirical model is as follows:

$$LGDP_{2it} = \alpha_{1it} + \alpha_{rit}\, LRE_{it} + \alpha_{nrit}\, LNRE_{it} + \alpha_{renit}\, RENT_{it} + \epsilon_{it} \qquad (2)$$

Model 2: the role of economic growth, RE, NRE, and NR rent in CO_2 emissions is accessed. Further to probe the connection among dependent variable CO_2 emissions and independent variables such as RE consumption, NRE consumption, economic growth, and NR rent the basic framework of carbon emission is established based on the model of Balsalobre-Lorente et al. (2018) and Bekun et al.(2019):

$$CO_2 = f(RE, NRE, RENT, GDP) \quad (3)$$

Where CO_2symbolizes CO_2 emissions per capita and the rest of the variables we have already discussed in equation 1. The estimated equation for this model:

$$LCO_{2it} = \beta_{1it} + \beta_{yit} LGDP_{it} + \beta_{rit} LRE_{it} + \beta_{nrit} LNRE_{it} + \beta_{renit} LRENT_{it} + \mu_{it} \quad (4)$$

For equation (2) and (3) L stands for log-linear specification;ϵ_{it} and μ_{it} arethe idiosyncratic error terms, independent, and identically distributed, that represents the standard normal distribution with unit variance and zero mean; i represent the country (i=1,2,…….14); t stands for a time period (t= 1,2,3,……..25);α_{1it} is intercept; $\alpha_{rit}, \alpha_{nrit}, \alpha_{renit}$are the long-run elasticity's estimates of economic growth (LGDP) with respect to the explanatory variables such as renewable energy consumption (LRE), non -renewable energy (LNRE) and rent (LRENT) in model 1.

Furthermore, equation 4 implies that β_{1it} is the intercept whereas $\beta_{yit}, \beta_{rit}, \beta_{nrit}$, and β_{renit} are the long-run elasticity's estimates of CO_2 emissions per capita (LCO_2) concerning the independent variables such as real GDP per capita (LGDP), renewable energy consumption (LRE), non-renewable energy consumption (LNRE), and natural resources rent (LRENT), respectively.

4.3.2 Data

Our empirical analysis is established on the yearly time series data covering the time span from 1990 to 2014 for 5 South[10] and 6 Southeast [11] Asian countries. The data was retrieved both for the

[10]Pakistan, India, Bangladesh, Sri Lanka, and Nepal

period and selected countries from World Development Indicator (2019). CO_2 emissions are measured in metric tons per capita; renewable energy consumption consists in energy consumption from of hydro, solar, wind, biogas, and biofuels, in percentage of total final energy consumption; non-renewable energy (NRE) consumption refers to "use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport, measured in kg of oil equivalent per capita" (World Bank, 2019); real GDP was stated in per capita constant 2010 U.S. dollar and the total natural resources are "the sum of oil, natural gas, coal, minerals, and forest rents in percentage of GDP" (World Bank, 2019). In Table 4. 1 we present variables definition as well as supporting references for each one.

Table 4. 1: Description of the Variables and sources

Variables	Definition	Supporting Reference	Source
CO_2	CO_2 emissions metric tons per capita	(Adams and Nsiah, 2019; Amri, 2019; Belaïd and Zrelli, 2019)	WDI
RE	Renewable energy consumption (% of total final energy consumption)	(Ben Jebli and Ben Youssef, 2015; Dogan and Seker, 2016b; Sharif et al., 2019)	WDI
NRE	Non-renewable energy consumption (kg of oil equivalent per capita)	(Dogan, 2016; Shafiei and Salim, 2014; Sharif et al., 2019)	WDI
RENT	Total natural resources rent (% of GDP)	(Balsalobre-Lorente et al., 2018; Bekun et al., 2019; Shahbaz et al., 2018)	WDI
GDP	GDP per capita constant (2010 US$)	(Belaïd and Zrelli, 2019; Dong et al., 2019; Mert et al., 2019)	WDI

Note: World development indicator (WDI)

Evolution of the selected variables with respect to countries is presented in Figure 4. 1. Figure shows that Singapore has the highest income, while the lowest GDP per capita is verified in Nepal. Construct to these graphs, the highest CO_2 emissions per capita was in Singapore although with a negative trend whereas the lowest level was in Nepal. In the case of RE and NRE consumption picture clearly shows that sample countries relay more on NRE rather than in RE sources. Besides, total natural resources have a decreasing rate over the years in all the sample countries.

Furthermore, Table 4. 2 reflects the statistics summary of selected variables for the three panels, between 1990 and 2014. The Southeast Asian countries have the highest mean value of CO_2 emissions per capita (3.99) compared to South Asian (0.56) whereas on the overall panel,

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[11]Indonesia,Philippines, Malaysia, Vietnam, Singapore, and Thailand

countries are facing carbon emissions of 2.40. Besides, Southeast Asian countries have high volatility than South Asian countries. When, analyzing the GDP per capita, we observe that Southeast Asian are richer than South Asian economies. Concerning renewable energy, the highest consumption is registered by South Asian countries (61.72) compared to the Southeast Asian (27.37).

Table 4. 2: Descriptive Statistics and Correlation Matrix

Economies	Variables	Min	Max	Mean	S.D	CO_2	GDP	NRE	RE	RENT
South Asian	**CO_2**	0.03	1.73	0.56	0.39	1	0.38	0.75	-0.75	0.66
	GDP	357.20	3506.73	997.31	671.29		1	0.54	-0.25	-0.19
	NRE	118.89	636.57	366.57	122.44			1	-0.25	0.41
	RE	36.65	95.11	61.72	16.68				1	-0.40
	RENT	0.10	7.35	1.45	1.21					1
Southeast Asian	**CO_2**	0.30	18.04	3.94	3.99	1	0.77	0.90	-0.80	-0.22
	GDP	431.8	52244.4	8805.10	13006.8		1	0.92	-0.67	-0.40
	NRE	260.79	7370.65	1719.68	1698.1			1	-0.79	-0.31
	RE	0.19	76.08	27.37	20.53				1	0.15
	RENT	0.00	25.80	5.40	5.04					1
Overall	**CO_2**	0.03	18.04	2.40	3.40	1	0.804	0.92	-0.77	0.06
	GDP	357.20	52244.4	5256.1	10362.0		1	0.92	-0.62	-0.15
	NRE	118.65	7370.65	1104.63	1424.98			1	-0.74	-0.01
	RE	0.19	95.11	42.99	25.47				1	-0.26
	RENT	0.00	25.80	3.60	4.28					1

Note: Authors own calculation based on the data over the period 1990-2014. Mean = simple average, Max= maximum; Min = Minimum; S.D = standard deviation and right columns presented pair-wise correlations and results reported till second decimal.

However, in the case of non-renewable energy Southeast Asian countries consumed more than South Asian economies. In terms of volatility, South Asian economies are more consistent users of renewable and non-renewable energy sources as they have the lowest standard deviation. Furthermore, the average natural resources rent in South Asian countries is 5.40 while in South Asia is 1.40. Concerning the volatility of natural resources rent, Southeast Asian countries are more volatile than South Asian economies.

4.3.3 Methodology

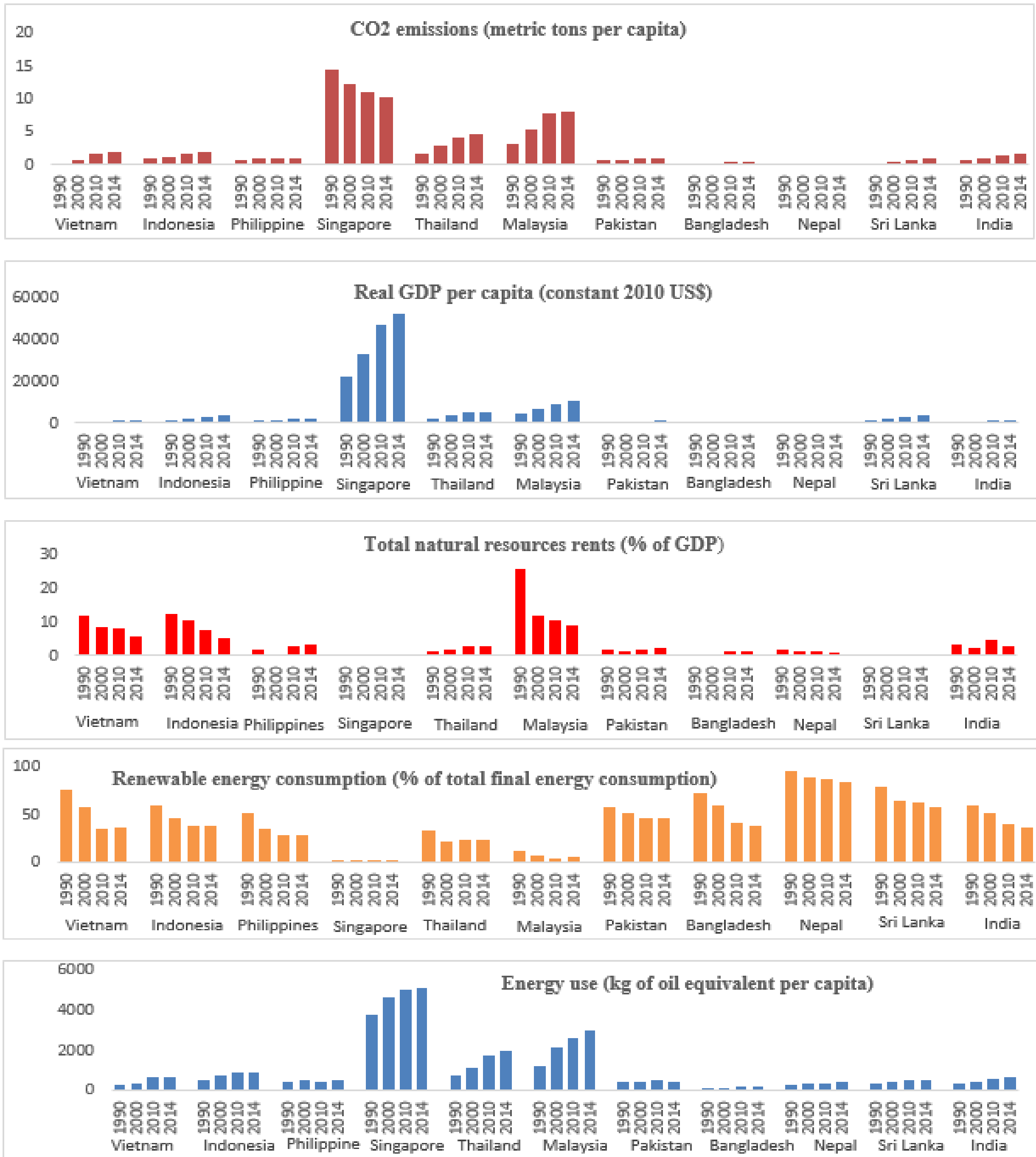
4.3.3.1 Cross-Sectional Dependence and panel heterogeneity

We used balanced panel data of 11 SSEA countries in the current study. One of the assumptions of panel data is that there may occur a cross-sectional dependence (CD) among the variables, which may produce unreliable and biased results (Pesaran, 2007). From the existing literature, it is concluded, that panel data models are expected to exhibit significant cross-sectional dependence in the errors (De Hoyos and Sarafidis, 2006). The reason for the cross-correlation of errors might be due to omitted common effects, unobserved components, and spatial effects or the presence of common shocks (Pesaran, 2004). From Figure 4. 1 it can be noted that the countries investigated in the present study illustrate a different pattern in their economic growth performance, RE, NRE, RENT, and therefore, provides an indication of inherent heterogeneity of individual cross-sectional units.

Moreover, the CD across the Asian economies will be an essential issue to account because of the substantial economic and financial integration of the economies (Bhat, 2018). This indicates that there is a strong interdependence between cross-sectional units (Belaïd and Zrelli, 2019). Furthermore, these steps also allow us to choose suitable unit root tests for further analysis.

Several tests has been performed to check the CD among the countries, as Friedman (1937), Breusch-Pagan LM (1980), Frees (1995), and Pesaran (2004) CD tests. However, for further empirical analysis we used well-known Breusch-Pagan LM (1980) test, since it works better in the case of panels featured with $N < T$, where N stand for cross-sectional dimensions while, T represents the time dimensions of the panel. It means that no desirable statically properties are required (Pesaran, 2004). Besides, it is applicable in balance or unbalance panel data. For the robustness of the LM results Pesaran (2004) CD test is also applied.

Figure 4. 1: CO_2 emissions per capita, Renewable energy consumption, Non-renewable energy consumption, total natural resources rent by country from 1990-2014.



Source: Own elaboration with World Bank data

4.3.3.2 Stationarity

The second step is to confirm the stationarity after investigated the CD in the panel data modelling. After the confirmation of cross-sectional dependence, the next step consists in examining the stationary problem in the panel of variables, in determining the presence of stochastic trends, which is broadly designed to elaborate on the postulation of cross-sectional dependence (Arshad et al., 2020). Numerous tests of the unit root have been discussed in the prior literature for instance,(Breitung, 2001; Choi, 2001; Hadri, 2000; Harris and Tzavalis, 1999; Im et al., 2003; Levin et al., 2002; Maddala and Wu, 1999; Pesaran, 2007; Quah, 1994). The researchers divided them into two groups such as first-generation (Breitung, Hadri and Levin Lin Chu tests) who deal with cross-sectional independence and second-generation (ADF-Fisher, PP-Fisher, CIPS, CADF and IPS (IM Pesaran shin)) that considered cross-sectional dependence. However, it is evident that the cross-sectional dependence exists, so we used two second-generation test names as Augmented Dickey-Fuller (CADF) and cross-sectional IPS (CIPS) who deals with heterogeneous panels and CD, as proposed by (Pesaran, 2007).

4.3.3.3 Cointegration

The next step is the cointegration process after the confirmation of the stationarity of the variables at the same level. This process helps us to identify whether long-run relationships exist between considered variables, that means that the variables move together in the long-run. This panel cointegration method can also be used to study the long-run equilibrium process. Therefore, we applied four cointegration methods. Three belongs to the first generation method such as Pedroni (2004), Kao (1999) and Fisher proposed by (Maddala and Wu, 1999) to identify the long-run relationships between variables. Besides, to robust the first generation cointegration tests, we applied Westerlund (2007) cointegration technique which is known as a second-generation method and not only deals with the cross-sectional dependence but it also not relays on integrated order of the variables, what makes this method applicable in very general conditions.

4.3.3.4 Pooled Mean Group Regression

The PMG regression suggested by Pesaran (1997) and Pesaran et al. (1999) is applied, which permits convergence speed and short-run adjustment to estimate the heterogeneity of each country. The PMG estimation is the revised version of Mean Group regression (MG) (Pesaran and Smith, 1995). According to the Pesaran et al. (1999), MG is a kind of pooled estimation because this model use average values of the coefficients of each group and assume that the slope coefficients and error variance are indistinguishable. However, PMG model takes the cointegration form of the simple ARDL model and adapts it to a panel set by allowing the intercepts, short-run coefficients and cointegrating terms to differ across cross-sections. It further executes the restrictions of the cross-country homogeneity on the long-run coefficients (Pesaran et al., 1999).To achieve the Pesaran et al. (1999) PMG estimation, the ARDL (p, q) models are as follows:

$$\Delta(GDP_i)_t = \sum_{j=1}^{p-1} \rho_j^i \, \Delta(GDP_i)_{t-j} + \sum_{j=0}^{q-1} \delta_j^i \, \Delta(y_i)_{t-j} + \theta^i\left[(GDP_i)_{t-1} - \alpha_1^i (Y_i)_{t-j}\right] + e_{it} \quad (5)$$

$$\Delta\left(CO_{2_i}\right)_t = \sum_{j=1}^{p-1} \rho_j^i \, \Delta\left(CO_{2_i}\right)_{t-j} + \sum_{j=0}^{q-1} \delta_j^i \, \Delta(y_i)_{t-j} + \theta^i \left[\left(CO_{2_i}\right)_{t-1} - \alpha_1^i (Y_i)_{t-j}\right] + e_{it}$$
(6)

Where$(GDP_i)_{t-j}$ and $(GDP_i)_{t-1}$ refer to short and long-run coefficients, respectively; $\left(CO_{2_i}\right)_{t-j}$ and $\left(CO_{2_i}\right)_{t-1}$ describe short and long-run standards regardingCO_2 emissions respectively;ρ_j^i and δ_j^i are the short-run coefficients; θ^i is the error correction term; $(y_i)_{t-j}$ and $(Y_i)_{t-j}$ are the values of short-run and long-run variables; α_1^i are the long-run coefficients; $e_{it} = \mu_i + v_{it}$; μ_i and v_{it} represents country-specific fixed and time-variant effects in both equations respectively.

4.3.3.5 Dynamic Common Correlated Effects (DCCE) CS-ARDL

Chudik and Pesaran (2015) introduced a new panel technique named as "dynamic common correlated effects" (DCCE) which is helpful to handle the problem of cross-sectional dependence. Besides, this approach is the extension of common correlated effect (CCE) by Pesaran (2006). DCCE approach considers CD by assuming that the variables can be represented by common factor. DCCE technique is developed on the principle of Mean group (MG), PMG, and CCE estimations presented by Pesaran and Smith (1995), Pesaran (1997) and Pesaran (2006), respectively. According to the approach of DCCE we can make the estimator more consistent by including more lags of CD in regression. Moreover, DCCE have four advantages over the existing techniques in the relevant literature (Chudik and Pesaran, 2015) (1) Deals the problem of CD by taking logs and average values of all the cross-sectional units. (2) It computes the dynamic common correlated effects by considering heterogeneous slopes and assuming the variables represented by common factor. (3) It can handle the small sample size. (4) This technique can also apply in the presence of structural breaks and un-balance panel data(Ditzen, 2016). Besides, for the long-run estimation of coefficients two methods can be applied, first, Cross-sectional Augmented Distributed lag (CS-DL) which directly estimates the long-run coefficients (Chudik et al., 2016). Second, cross-sectional Augmented ARDL (CS-ARDL) method (Chudik et al., 2016). However, we have employed Dynamic Common Correlated Effects CS-ARDL method to estimate the long-run coefficients.

4.3.3.6 Dumitrescu- Hurlin Causality Test

The last step of the empirical analysis is the causality test to identify the direction causality of the variables. The direction could be the unidirectional bidirectional or no causality. For this purpose, we used Dumitrescu and Hurlin (DH) (2012) causality test as it is an befitting approach for the directional causality and presents more advantages compared to the traditional Granger (1969) causality test and presents the two critical spheres of heterogeneity, known as the heterogeneity of the regression model, and the heterogeneity of the causal relationship.

4.4 Results and Discussion

4.4.1 Cross-sectional dependence

South and Southeast Asian economies such as Pakistan, India, Bangladesh, Thailand, Malaysia, Indonesia are being affected from cross-sectional dependence (CD), transborder pollutants' effect, and cross-country heterogeneity (Behera and Dash, 2017). Due to different characteristics of the countries, and to robust the LM test results Breusch-Pagan LM (1980) CD and Pesaran (2004) CD tests were performed. Table 4. 3which describe the results of both tests denies the null hypothesis of no CD at 1% level of significance. There is significant evidence of the presence of CD among the variables considered, such as CO_2 emissions, GDP, RE, NRE, and NR rent in all cases.

Table 4. 3: Cross sectional dependence

Tests	Variables	LCO_2	LGDP	LNRE	LRE	LRENT
	South Asia	14.05[a]	15.60 [a]	13.66 [a]	13.29 [a]	3.947 [a]
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Pesaran CD	Southeast Asia	6.86 [a]	18.68 [a]	6.13 [a]	7.90 [a]	3.84 [a]
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	Overall	22.10[a]	36.06 [a]	20.15 [a]	22.33 [a]	7.26 [a]
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Breusch-	South Asia	198.50 [a]	243.41 [a]	189.07 [a]	178.03 [a]	107.19 [a]
Pagan LM		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	Southeast Asia	214.91 [a]	349.11 [a]	163.51 [a]	200.48 [a]	70.98 [a]
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	Overall	936.30 [a]	1300.87 [a]	804.30 [a]	841.82 [a]	414.22 [a]
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Note: [a] represents the significance level 1% and P-values reported in the parenthesis.

4.4.2 Unit Root tests

Countries have different characteristics and the panels may contain the presence of CD which may lead to unreliable and biased results (Park et al., 2018). Pesaran (2007) presented two unit root tests named IPS cross-sectional (CIPS) and Augmented Dickey-Fuller (CADF) that are used to handle the ambiguity of CD. The results of the CADF and CIPS panel unit root tests have been described in Table 4. 4.

In all the three panels, almost all the variables represent non-stationary results at the level. Nevertheless, the null hypothesis is rejected at 5% as variables represent the stationary results at first difference. Thus, we can declare the similar findings both for CADF and CIPS.

4.4.3 Cointegration

Following the first order integration of variables, further was to examine the cointegration process among variables. To do so, three traditional test, namely Pedroni (2004), Kao (1999), Fisher proposed by (Maddala and Wu, 1999), were used. Moreover, to handle the cross-sectional dependence and robust the traditional cointegration tests, Westerlund (2007) was applied. The results of the Pedroni, Kao and Fisher panel cointegration test are presented in Table 4. 5.

In the case of South Asian, Southeast Asian and of the full panel of the 11 countries, the results illustrated that a set of four out of seven (statistics) reject the null hypothesis of no cointegration. Furthermore, Kao results ensured the existing of cointegration among the variables and Fisher results also support this conclusion. To robust the traditional cointegration test results, the Westerlund cointegration test was also used, which even overcomes the issue of cross-sectional dependence. From, Table 4. 6 it is disclosed that the alternative hypothesis of cointegration is accepted which means that considered variables move together in the long-run. The above mentioned four cointegration methods have the same results. This merely illustrates that the long-run relationship occurs between CO_2 emissions, GDP, RE consumption, NRE consumption, and NR rent in SSAE region over the period considered. The results of cointegration among the variables confirm the ones of Bekun et al., (2019) and Shahbaz et al. (2018).

Table 4. 4: Second Generation Unit root analysis

Tests		CIPS		CADF					
				Without trend			With trend		
Economies	**Variables**	**Without trend**	**With trend**	**T-bar**	**Z-t-tilde-bar**	**P-value**	**T-bar**	**Z-t-tilde-bar**	**P-value**
Overall	LCO_2	-1.25	-1.88	-1.47	0.99	0.84	-1.93	1.39	0.91
	ΔLCO_2	-6.04[a]	-6.15[a]	-3.81[a]	-6.98[a]	0.00	-3.49[a]	-5.81[a]	0.00
	LGDP	-0.49	-2.32	-1.84	-0.25	0.40	-1.96	1.26	0.89
	Δ LGDP	-5.71[a]	-5.90[a]	-2.93[a]	-3.98[a]	0.00	-3.37[a]	-3.77[a]	0.00
	LNRE	-1.04	-2.25	-1.70	0.22	0.59	-2.06	0.92	0.82
	Δ NRE	-5.88[a]	6.09[a]	-4.02[a]	-8.33[a]	0.00	-4.27[a]	-6.96[a]	0.00
	LRE	-1.08	-2.04	-1.67	0.32	0.62	-1.85	1.64	0.95
	Δ RE	-5.62[a]	-5.99[a]	-3.80[a]	-6.65[a]	0.00	-3.95[a]	-5.81[a]	0.00
	LRENT	-0.51	-2.97	-1.50	0.92	0.82	-2.93	-2.19	0.01
	Δ LRENT	-6.02[a]	-6.22[a]	-4.51[a]	-9.37[a]	0.00	-4.63[a]	-8.24[a]	0.00
South Asia	LCO_2	-0.39	-1.81	-0.91	1.95	0.97	-1.26	2.52	0.99
	ΔLCO_2	-6.08[a]	-6.40[a]	2.96[a]	-2.76[a]	0.00	-3.14[b]	-2.01[b]	0.02
	LGDP	-0.037	-3.24	-2.50	-1.72	0.04	-2.36	-0.12	0.45
	Δ LGDP	-6.11[a]	-6.27[a]	-3.73[a]	-4.54[a]	0.00	-4.05[a]	-4.20[a]	0.00
	LNRE	-0.16	-1.04	-1.03	1.67	0.95	-0.81	3.59	1.00
	Δ NRE	-5.50[a]	-5.96[a]	-2.74[a]	-2.26[a]	0.01	-3.07[b]	-1.84[b]	0.03
	LRE	0.10	-1.80	-1.35	0.93	0.82	-1.68	1.51	0.93
	Δ RE	-5.14[a]	-5.37[a]	-2.63[b]	1.99[b]	0.02	-2.82[c]	-1.24[c]	0.10
	LRENT	-0.30	-3.13	-0.97	1.81	0.96	-2.79	-1.71	0.12
	Δ LRENT	-5.83[a]	-6.03[a]	-4.39[a]	-6.07[a]	0.00	-4.39[a]	-5.01[a]	0.00
Southeast Asia	LCO_2	-1.36	-1.84	-1.96	-0.50	0.30	-2.27	0.09	0.53
	ΔLCO_2	-5.82[a]	6.04[a]	-3.79[a]	-5.12[a]	0.00	-3.81[a]	-3.97[a]	0.00
	LGDP	-1.92	-1.91	-1.82	-0.17	0.43	-1.45	2.24	0.98
	Δ LGDP	-6.12[a]	-6.42[a]	-2.67[a]	-2.30[a]	0.01	-3.03[b]	-2.03[b]	0.02
	LNRE	-1.63	-2.55	-2.31	-1.39	0.08	-2.47	-0.44	0.32
	Δ NRE	-5.83[a]	-6.30[a]	-3.97[a]	-5.58[a]	0.00	-3.91[a]	-4.22[a]	0.00
	LRE	-0.77	-2.34	-1.88	-0.30	0.38	-2.20	0.26	0.60
	Δ RE	-6.12[a]	-6.42[a]	-3.75[a]	-5.02[a]	0.00	-3.91[a]	-4.22[a]	0.00
	LRENT	-0.58	-2.31	-1.52	0.60	0.72	-2.50	-0.50	0.30
	Δ LRENT	-6.11[a]	-6.36[a]	-3.90[a]	-5.41[a]	0.00	-4.06[a]	-4.61[a]	0.00

Note: [a, b, c] represents the significance level 1%, 5% and 10% respectively. we also reported (T-bar) and Z (t-tilde-bar) statistics in the table.

Table 4. 5: Pedroni, Kao and Fisher Cointegration Analysis

Pedroni Test	**Null Hypothesis: No cointegration**			**Newey-West automatic bandwidth selection and Bartlett kernel**			
Economies		**South Asia**		**Southeast Asia**		**Overall**	
		Statistic	**Weighted Stat**	**Statistic**	**Weighted Stat**	**Statistic**	**Weighted Stat**
Within – dimension	Panel v	0.7515	-0.3322	0.1929	0.2472	0.4586	-0.0797
		(0.22)	(0.63)	(0.42)	(0.40)	(0.32)	(0.53)
	Panel rho	-0.5826	-0.1686	1.028	0.7933	0.8706	0.4107
		(0.28)	(0.43)	(0.84)	(0.78)	(0.80)	(0.65)
	Panel PP	-4.2189 [a]	-4.2234 [a]	-4.0364 [a]	-1.548[c]	-1.4410 [c]	-4.1479 [a]
		(0.00)	(0.00)	(0.01)	(0.06)	(0.07)	(0.00)
	Panel ADF	-2.2965 [a]	-3.7051 [a]	-0.5058 [a]	-1.1653[c]	-1.7504 [b]	-3.0163 [a]
		(0.01)	(0.00)	(0.00)	(0.09)	(0.05)	(0.00)
Between-dimension	Group rho	0.2820		1.6985		1.4446	
		(0.61)		(0.95)		(0.92)	
	Group PP	-4.8840 [a]		-5.083 [a]		-7.0474 [a]	
		(0.00)		(0.00)		(0.00)	
	Group ADF	-3.1626 [a]		-2.7371 [a]		-2.8798 [a]	
		(0.01)		(0.00)		(0.00)	
Kao Residual Cointegration Test							
ADF		**T-Stat**	**Prob**	**T-Stat**	**Prob**	**T-Stat**	**Prob**
		-3.1591 [a]	0.0008	-2.9940 [a]	0.0014	-4.2508 [a]	0.0000
Automatic lag length selection based on SIC				**Newey-West automatic bandwidth selection and Bartlett kernel**			
Johansen Fisher Panel Cointegration Test							
No of Cointegration		**Trace**	**Max eigen test**	**Trace**	**Max eigen test**	**Trace**	**Max eigen test**
None		94.47 [a]	56.95 [a]	280.1 [a]	232.1 [a]	490.2 [a]	374.8 [a]
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
At most 1		46.53 [a]	27.68 [a]	188.8 [a]	140.4 [a]	286.6 [a]	189.9 [a]
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
At most 2		26.61 [a]	11.82	86.57 [a]	69.13 [a]	144.8 [a]	110.9 [a]
		(0.00)	(0.29)	(0.00)	(0.00)	(0.00)	(0.00) [a]
At most 3		24.16 [a]	19.29 [b]	33.29 [a]	27.27 [a]	60.75 [a]	45.82 [a]
		(0.00)	(0.03)	(0.00)	(0.00)	(0.00)	(0.00)
At most 4		20.42 [b]	20.42 [b]	24.98 [a]	24.98 [a]	53.65 [a]	53.65 [a]
		(0.02)	(0.02)	(0.01)	(0.01)	(0.00)	(0.00)

Note: [a, b, c] represents the significance level 1%, 5% and 10% respectively. The p -values for Pedroni and Fisher tests reported in parenthesis.

Table 4. 6: Westerlund Cointegration

Statistics	**South Asia**			**Southeast Asia**			**Full Countries**		
	Value	Z-value	P-value	Value	Z-value	P-value	Value	Z-value	P-value
Gt	-6.058	-7.873	0.00[a]	-3.226	-2.002	0.02 [b]	-2.879	-1.505	0.06 [c]
Ga	-3.552	3.573	1.00	-8.035	1.573	0.94	-8.497	1.930	0.97
Pt	-9.489	-3.617	0.00 [a]	-6.360	-1.213	0.10 [c]	-5.889	-1.705	0.04 [b]
Pa	-5.679	2.132	0.98	-4.954	1.406	0.92	-4.487	2.108	0.98

Note: [a, b, c] represents the significance level 1%, 5% and 10% respectively

4.4.4 Pooled Mean Group Regression vs Mean Group Regression (MG)

The current study aim is to examine the effect of considerable explanatory variables on economic growth and CO_2 emissions. First, we determined the impact of RE consumption, NRE consumption, and NR rent on economic growth, which is known as model 1.

In the second model, we investigated the impact of RE consumption, NRE consumption, NR rent, and economic growth on CO_2 emissions.

To achieve the statements mentioned above for two proposed models, we applied PMG estimator to investigate the short and long-run dynamics in the South and Southeast Asian regions as PMG estimator constrains long-run coefficients to be equal across all group. In the case of the homogenous model, PMG estimator will be consistent whereas Mean Group (MG) estimator will be inconsistent. However, MG estimators and PMG estimators will be consistent and inconsistent respectively in case of heterogeneous model (Mert and Bölük, 2016). To do so first, we applied Mean group regression along with PMG estimator. Hereafter, we used a Hausman test to confirm the long-run homogeneity (Blackburne and Frank, 2007). The findings of the Hausman test indicated the rejection of the null hypothesis in both models for all the cases such as South Asian, Southeast Asian, and full countries panels. Hence, the findings of the Hausman test confirmed the homogeneity of the models. It implies that the PMG estimator is more appropriate than MG estimator for different panels and models of SSEA region (see Table 4. 7).

4.4.5 PMG regression

4.4.5.1 Long-run Elasticity's (Model-1)

The PMG results reported in Table 4. 8 to explain the short and long-run dynamics in the two proposed models. According to the PMG long-run results of model 1, the results show that NRE and RE are a significant positive contribution to economic development in all three considered panels. It is also observed that NRE has a stronger impact on economic growth than RE. Our results for RE and NRE impact on economic growth are in line with (Paramati et al., 2018).

Concerning, NR nexus economic growth results show that NR impedes the economic development for the cases of South Asia and full country for 1990-2014. It means that NR slows down the economic activities in the case of South Asian and overall countries. There are four main channel of transmissions to NR to slow down economic growth such as Dutch disease, overconfidence, neglect of education, and rent-seeking (Gylfason, 2001). However, we found the inverse role of NR in economic development in the Southeast Asian panel. Our results are consistent with (Ahmed et al., 2016; Ben-Salha et al., 2018; Sarmidi et al., 2014; Satti et al., 2014).

Moreover, the significant negative error terms -0.47, -0.26 and -0.23 in Southeast Asia, South Asia and full countries panels respectively confirm the long-run relationships between variables. The error correction terms show that the speed of adjustment back towards the equilibrium is corrected by 47%, 26%, and 23% in Southeast, South and overall country's panels respectively in each year.

4.4.5.2 Short-run analysis (Model-1)

For the short-run analysis, we found that only NRE has a significant and positive impact on economic growth, in the case of South Asia and full countries panels. However, we did not find any significant results in the case of the Southeast Asian region.

4.4.5.3 Long-run Elasticity's (Model-2)

Table 4. 8also reported the model 2 estimation, where PMG long-run results revealed that economic growth increased the CO_2 emissions in all the selected panels. It means that the economic activities deteriorated the environmental quality in SSEA region. According to our first model, results suggested that NRE increases economic growth. Notably, NRE is mostly produced by fossil fuels to fulfil the requirement of different economic activities, which ultimately increases the CO_2 emissions. Our results are consistent with Al-Mulali et al. (2015) in the case of 77 developed and developing countries.

Long-run elasticities of CO_2 emissions concerning NRE consumption are 1.34%, 0.70%, and 1.27% in the South, Southeast and full countries panels, respectively. It means that NRE deteriorated the environmental quality in the SSEA region, with a higher impact on South countries. The rapid wave of urbanization is one of the causes of energy demand, which ultimately raises CO_2 emissions in the SSEA regions. Besides, the rapid changes in population in the South and Southeast Asian region, especially in Pakistan, India, and Bangladesh, lead the companies to accelerate their shifting towards this region because of cheap labor and intense market. Moreover, upcoming projects increase the energy demand, the significant portion of non-renewable electricity is derived by fossil fuels, which ultimately increases the CO_2 emissions.

Table 4. 7: Hausman results

Model 1	**Dependent variable: Economic Growth**				
Economies	**Variables**	**Coefficients**			
		(b) MG	(B) PMG	(b-B) Difference	Sqrt (diag (V_b-V_B)) S. E
Overall	**LNRE**	0.16	1.16	-1	1.26
	LRE	-0.62	0.02	-0.64	0.70
	LRENT	-0.09	-0.11	0.02	0.06
	chi2(3) = (b-B)'[(V_b-V_B) ^ (-1)] (b-B) = 1.79, Prob>chi2 = 0.61				
South Asia	**LNRE**	0.27	0.99	-0.72	0.80
	LRE	-1.06	0.13	-0.93	0.96
	LRENT	-0.08	-0.25	0.17	0.26
	chi2(3) = (b-B)'[(V_b-V_B) ^ (-1)] (b-B) = 1.89, Prob>chi2 = 0.82				
Southeast Asia	**LNRE**	0.07	0.47	-0.40	0.70
	LRE	-0.25	0.21	-0.46	0.89
	LRENT	-0.09	0.07	-0.16	0.20
	chi2(3) = (b-B)'[(V_b-V_B) ^ (-1)] (b-B) = 1.96, Prob>chi2 = 0.58				
Model 2	**Dependent variable: CO_2 emissions**				
Economies	**Variables**	**Coefficients**			
		(b) MG	(B) PMG	(b-B) Difference	Sqrt (diag (V_b-V_B)) S. E
Overall	**LNRE**	-0.39	1.27	-1.66	2.04
	LGDP	0.76	0.35	-0.41	0.70
	LRE	-3.94	-0.25	-3.69	5.49
	LRENT	-0.12	0.02	-0.14	0.23
	chi2(4) = (b-B)'[(V_b-V_B) ^ (-1)] (b-B) = 5.01, Prob>chi2 = 0.28				
South Asia	**LNRE**	-2.48	1.34	-2.88	4.48
	LGDP	1.06	0.40	0.66	0.99
	LRE	-9.29	-0.04	-9.25	12.11
	LRENT	-0.33	0.04	-0.37	0.45
	chi2(4) = (b-B)'[(V_b-V_B) ^ (-1)] (b-B) = 4.32, Prob>chi2 = 0.36				
Southeast Asia	**LNRE**	1.34	0.70	0.64	0.94
	LGDP	0.50	0.26	0.24	0.31
	LRE	0.51	-0.42	0.93	1.03
	LRENT	-0.04	-0.01	-0.03	0.10
	chi2(4) = (b-B)'[(V_b-V_B) ^ (-1)] (b-B) = 2.89, Prob>chi2 =0.57				

Note: b = consistent under Ho and Ha; obtained from xtpmg, B = inconsistent under Ha, efficient under Ho; obtained from xtpmg and Ho: difference in coefficients not systematic

Moreover, the impact of RE on CO_2 emissions in long run implies that 1% increase in the RE consumption improved the environmental quality 0.04%, 0.42%, and 0.25% in the South, Southeast Asian and 11 countries panels, respectively.

It means that the use of RE sources mitigates the carbon emissions in the selected countries, with a remarked impact on the Southeast countries. Our results about NRE and RE impacts on CO_2 emissions are in line with (Belaïd and Zrelli, 2019; Ben Jebli et al., 2016; Bölük and Mert, 2015; Inglesi-Lotz and Dogan, 2018; Sharif et al., 2019).

Finally, results suggest that natural resources have significant positive impact on CO_2 emissions in the South Asian and full countries panel. Our results are consistent with Bekun et al. (2019). However, in the case of Southeast Asian countries natural resources decrease the CO_2 emissions in the long-run. Our findings are in line with Balsalobre-Lorente et al. (2018). Moreover, the significant negative error terms also confirm the long-run relationships between variables in all three selected panels.

4.4.5.4 Short-run analysis (Model-2)

Moreover, in the short run analysis we did not find any significant effect of RE, NRE, NR rent and GDP on CO_2 emission for all three selected panels.

4.4.5.5 Coefficient diagnostics

Furthermore, coefficient diagnostics test has been performed, the red mark in the center confirms that the estimation of the proposed models presents a significant confidence level (see Figure 4. 3in appendix C).

4.4.6 Dynamic Common Correlated effects (DCCE) CS-ARDL

The traditional methods such as MG, PMG, FMOLS, DOLS, and AMG may be provided weak outcomes due to CD (Chudik and Pesaran, 2015; Dogan et al., 2017). Therefore, we also applied the DCCE CS-ARDL technique to calculate the coefficients of the considered variables and to robust the PMG estimation. However, we find similar signs of the coefficients, although coefficients of the variables are different than PMG estimation (see Table 4. 8 and Table 4. 9 for comparison).

Table 4. 8: Pooled Mean Group Regression

Model 1	Dependent Variable: GDP					
Variables	South Asia		Southeast Asia		Overall	
Long-run coefficients	Coefficients	Prob	Coefficients	Prob	Coefficients	Prob
LNRE	0.9919 [a]	0.0000	0.4765 [a]	0.0002	1.1696 [a]	0.0000
LRE	0.1393 [c]	0.0769	0.2127 [a]	0.0022	0.0252 [b]	0.0428
LRENT	-0.2597 [a]	0.0000	0.0713 [a]	0.0000	-0.1077 [a]	0.0000
Error Correction coefficients	-0.2676 [a]	0.0019	-0.4741 [a]	0.0006	-0.2346[a]	0.0001
Short-run coefficients						
D(LNRE)	0.5880 [b]	0.0126	0.0327	0.7881	0.4302 [a]	0.0009
D(LRE)	0.1173	0.6216	-0.2790	0.1816	-0.0608	0.4894
D(LRENT)	-0.0016	0.7873	-0.0492	0.1680	0.0043	0.7197
Constant	1.6127 [a]	0.0078	2.0124 [a]	0.0005	1.4519 [a]	0.0002
Model 2	**Dependent Variable: CO_2 Emissions**					
Long-run coefficients	Coefficients	Prob	Coefficients	Prob	Coefficients	Prob
LGDP	0.4070 [a]	0.0000	0.2627 [a]	0.0000	0.3537 [a]	0.0000
LNRE	1.3489 [a]	0.0000	0.7064 [a]	0.0000	1.2721 [a]	0.0000
LRE	-0.0453	0.8582	-0.4294 [a]	0.0000	-0.2522 [a]	0.0005
LRENT	0.0430 [b]	0.0403	-0.0184 [c]	0.0910	0.0266 [a]	0.0286
Error Correction coefficients	-0.4067 [a]	0.0064	-0.4894 [b]	0.0144	-0.3566 [a]	0.0002
Short-run coefficients						
D(GDP)	-0.8004 [a]	0.0052	0.1562	0.8393	-0.0130	0.8856
D(LNRE)	0.8997 [c]	0.0926	0.1679	0.5448	-0.3970	0.3377
D(LRE)	-1.8111	0.2470	0.0239	0.9312	0.4186	0.1902
D(LRENT)	-0.0142	0.5751	-0.0812	0.1605	-1.0956	0.1307
Constants	-4.5572 [a]	0.0056	-2.4130 [a]	0.0093	-0.0511	0.1729

Note: [a, b, c] represents the significance level 1%, 5% and 10% respectively.

Table 4. 9: Dynamic common correlated effect

Model 1	Dependent Variable: GDP					
Variables	South Asia		Southeast Asia		Overall	
Long-run coefficients	Coefficients	Prob	Coefficients	Prob	Coefficients	Prob
LNRE	0.7762[a]	0.000	0.8682[b]	0.000	0.7780 [a]	0.000
LRE	0.4292[a]	0.003	0.1902[b]	0.003	3.6441[b]	0.042
LRENT	-0.0003 [a]	0.000	0.0236 [a]	0.000	-0.1477 [b]	0.050
Short-run coefficients						
D(LNRE)	0.2237 [a]	0.006	0.1317[b]	0.072	0.2219 [a]	0.011
D(LRE)	0.2063	0.322	-0.1253	0.524	0.0764	0.585
D(LRENT)	0.0030	0.868	0.0213	0.544	-0.0162	0.322
Model 2	**Dependent Variable: CO_2 Emissions**					
Long-run coefficients	Coefficients	Prob	Coefficients	Prob	Coefficients	Prob
LGDP	0.4236 [a]	0.041	8.1753[b]	0.051	2.9541 [a]	0.014
LNRE	1.3701 [b]	0.071	0.6797 [b]	0.087	0.0552	0.919
LRE	-0.3190[b]	0.086	-1.7937	0.298	-0.6606 [b]	0.058
LRENT	-0.0024 [c]	0.091	-0.3761 [c]	0.101	0.2493 [c]	0.084
Short-run coefficients						
D(GDP)	-1.1889	0.579	-1.7695	0.418	-1.2825	0.233
D(LNRE)	2.3701	0.041	0.3202	0.420	0.9447	0.082
D(LRE)	0.4002	0.862	-0.5632	0.263	-0.1040	0.842
D(LRENT)	-0.0460	0.649	-0.1729	0.332	-0.1543	0.247

Note: [a, b, c] represents the significance level 1%, 5% and 10% respectively.

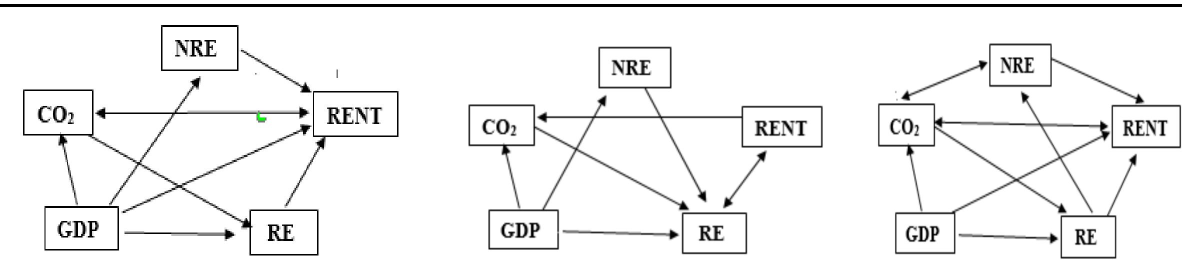
Table 4. 10: Pairwise Dumitrescu Hurlin panel causality test

Economies	Overall			South Asia			Southeast Asia		
Null Hypothesis	W-Stat.	Z bar-Stat.	Prob.	W-Stat.	Z bar-Stat.	Prob.	W-Stat.	Z bar-Stat.	Prob.
LGDP does not homogeneously cause LCO2	3.29	4.28	0.00[a]	6.10	3.38	0.00[a]	3.96	1.64	0.09[c]
LCO2 does not homogeneously cause LGDP	0.40	-1.37	0.16	1.17	-0.93	0.34	2.22	-0.02	0.98
LNRE does not homogeneously cause LCO2	1.91	1.58	0.10[c]	3.79	1.35	0.17	2.47	0.21	0.83
LCO2 does not homogeneously cause LNRE	2.35	2.43	0.01[b]	3.12	0.76	0.44	2.21	-0.03	0.97
LRE does not homogeneously cause LCO2	1.33	0.45	0.65	2.18	-0.05	0.95	1.98	-0.25	0.79
LCO2 does not homogeneously cause LRE	2.25	2.24	0.02[b]	4.37	1.85	0.06[c]	4.32	2.07	0.06[c]
LRENT does not homogeneously cause LCO2	1.94	1.63	0.10[c]	4.04	1.57	0.10[c]	3.54	1.68	0.09[c]
LCO2 does not homogeneously cause LRENT	3.75	5.18	0.00[a]	5.30	2.67	0.00[a]	2.41	0.15	0.87
LNRE does not homogeneously cause LGDP	0.53	-1.11	0.26	1.98	-0.22	0.81	2.84	0.57	0.56
LGDP does not homogeneously cause LNRE	3.93	5.53	0.00[a]	6.69	3.89	0.00[a]	3.73	1.66	0.09[a]
LRE does not homogeneously cause LGDP	0.78	-0.63	0.52	2.43	0.16	0.86	1.23	-0.97	0.33
LGDP does not homogeneously cause LRE	1.92	1.61	0.09[c]	4.34	1.83	0.06[b]	2.22	1.62	0.09[c]
LRENT does not homogeneously cause LGDP	1.32	0.42	0.66	2.60	0.30	0.75	2.37	0.12	0.90
LGDP does not homogeneously cause LRENT	2.38	2.50	0.01[a]	7.34	4.46	0.00[a]	1.87	-0.35	0.72
LRE does not homogeneously cause LNRE	2.60	2.93	0.00[a]	2.88	0.55	0.57	2.43	0.18	0.85
LNRE does not homogeneously cause LRE	1.20	0.19	0.84	2.79	0.47	0.63	3.10	1.64	0.08[c]
LRENT does not homogeneously cause LNRE	0.89	-0.41	0.67	3.24	0.87	0.38	0.93	-1.26	0.20
LNRE does not homogeneously cause LRENT	4.04	5.74	0.00[a]	6.22	3.48	0.00[a]	3.12	0.84	0.39
LRENT does not homogeneously cause LRE	1.77	1.30	0.19	2.70	0.39	0.69	4.53	2.19	0.02[b]
LRE does not homogeneously cause LRENT	4.49	6.62	0.00[a]	7.02	4.18	0.00[a]	4.10	1.78	0.07[c]

Note: [a, b, c] represents the significance level 1%, 5% and 10% respectively.

Figure 4. 2: Causality Directions

South Asia	Southeast Asia	Overall



Note: ↔, → shows bidirectional, unidirectional causality between variables.

4.4.7 Pair-wise Dumitrescu Hurlin panel causality

Table 4. 10 report the causality results and Figure 4. 2 illustrate the causality direction of the selected variables in the South, Southeast Asian and full countries panels. For the case of South Asian economies causality, results show that six significant unidirectional causalities are running from GDP to CO_2 emissions, GDP to RE, GDP to NRE, GDP to rent, NRE to rent, and RE to rent. Furthermore, we found a bidirectional causality running from CO_2 emissions to rent.

Concerning the Southeast Asian region, results show that significant unidirectional causality running from GDP to CO_2, GDP to NRE, GDP to rent, CO_2 to RE, NRE to RE and rent to CO_2 while bidirectional causality found between RE and rent.

Lastly, full countries panel results illustrate unidirectional causality running from GDP to RE, GDP to rent, GDP to CO_2, CO_2 to RE, RE to rent, RE to NRE and NRE to rent, while bidirectional causality was found between CO_2 and NRE, CO_2 and rent.

4.5 Conclusion and Policy implications

The current study tried to develop the linkages between renewable (RE) and non-renewable energy (NRE) consumption, economic growth (GDP), natural resources (NR) and CO_2 emissions in the South and Southeast Asian (SSEA) countries for the period of 1990-2014. Our empirical findings confirmed the long-run relationship by using Pedroni, Kao, Fisher, and Westerlund cointegration tests in the selected panels. Moreover, we examined the long-run elasticities with two proposed models by using PMG method. Firstly, we explored the long-run elasticities of RE consumption, (NRE) consumption, and NR concerning economic growth. Our results suggested that RE consumption and NRE consumption increased the economic growth in all panels. Furthermore, in South Asian and full countries panels, NR decreased the economic development in the long run. However, we found a significant and positive impact of NR on economic growth in the Southeast Asian region.

Secondly, we identified the long-run impact of RE consumption, NRE consumption, economic growth, and NR on CO_2 emissions. The findings demonstrated that NRE and economic growth worsened the environment quality in all three selected panels. Conversely, in the case of RE consumption, results suggested that RE consumption mitigates the carbon emission for all three panels.

However, NR also contributed to CO_2 emissions in the case of South Asian and full countries panels while NR improved the environmental quality in the Southeast Asian region. The DH causality test was applied to examining the causal relationship. The causality results illustrated that unidirectional causality running from GDP to CO_2 emissions, GDP to RE and GDP to NRE consumption in South, Southeast, and overall countries panels. However, we found bidirectional causality exists between CO_2 emissions and natural resources.

The current results lead to some policy implications. For instance, the countries should be concentrating on RE sources such as wind, solar, geothermal and biomass, rather than NRE sources to improve the environmental quality. Besides, policymakers need to encourage environment-friendly projects to sustain economic growth.

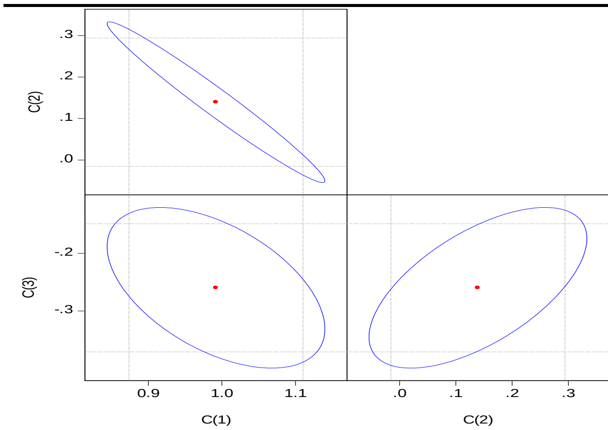
On the other hand, policymakers should be aware of the natural resource's management. The best way to improve the contribution of NR in economic growth could be by decreasing corruption and improving education level. Particularly, in South Asian countries, natural resources can be a curse on the economic growth, while in Southeast Asian region; NR can be managed as an important source of economic development. As stated by Sovacool (2010) ASEAN region promoted entrepreneurial activities and private actors in the resource production process. They encourage industrialization, and each country has co-operated as an active partner to the exploration, production, and distribution process, especially with international oil and gas firms.

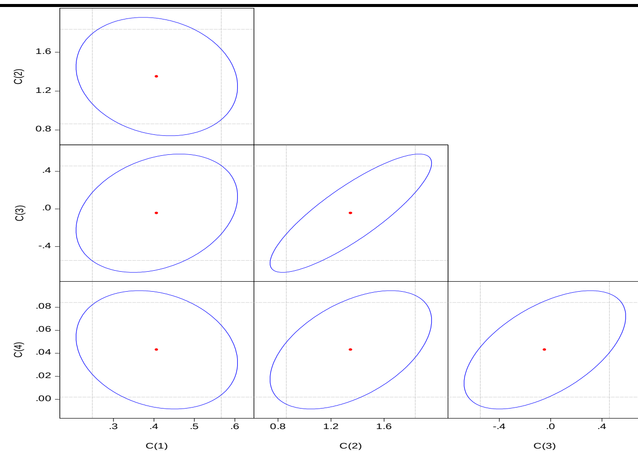
Finally, we have a few limitations for this research, which will give us direction for future research. For instance, we have ignored some GHG emissions such as sulfur dioxide (SO_2), sulfur hexafluoride (SF_6), perfluoro carbons (PFCs), hydro fluoro carbons (HFCs) and particulate matter $PM_{2.5}$, PM_{10} as an air pollutant due to unavailability of data. Moreover, we use CO_2 emissions per capita instead of ecological footprints and its sub-components such as bio-capacity, cropland, fishing grounds, carbon footprint, grazing lands, and forest products. Future studies can use these proxies of environment quality to see how the results vary across these indicators. Furthermore, we have taken 11 countries out of a total of 19 SSEA countries by dropping 8 countries due to non-availability of data between 1990 and 2014. The future study will consider the dropping countries on the availability of the data. Besides, the future study can estimate the EKC hypothesis with the quadratic or cubic function.

4.6 Appendix C

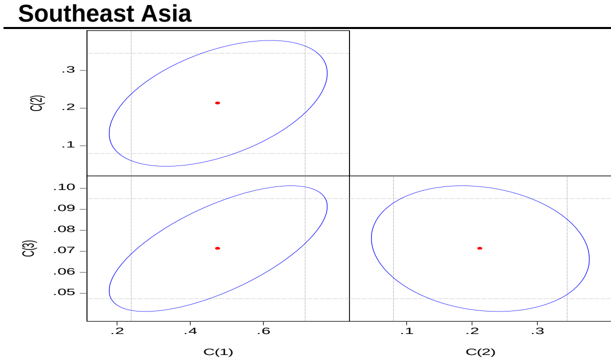
Figure 4. 3: coefficient diagnostics confidence interval (ellipse test)

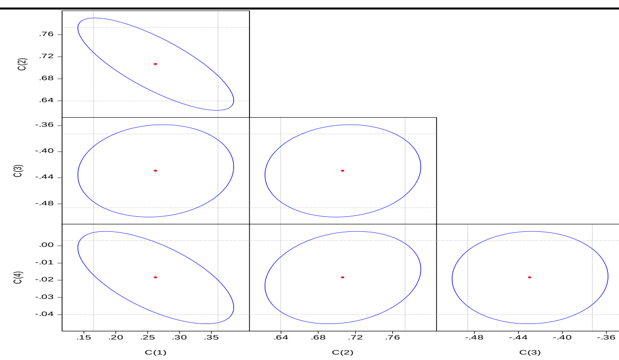
South Asia | **Model 1** | **Model 2**



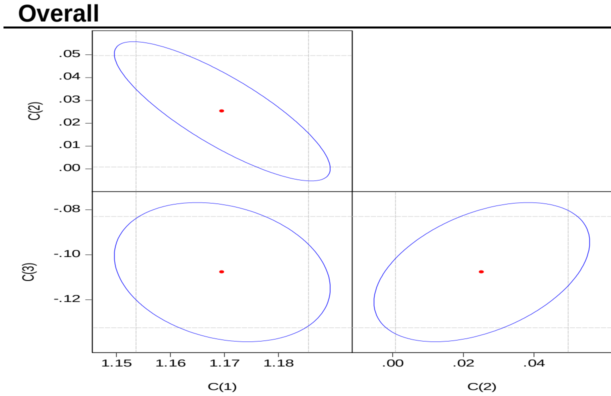


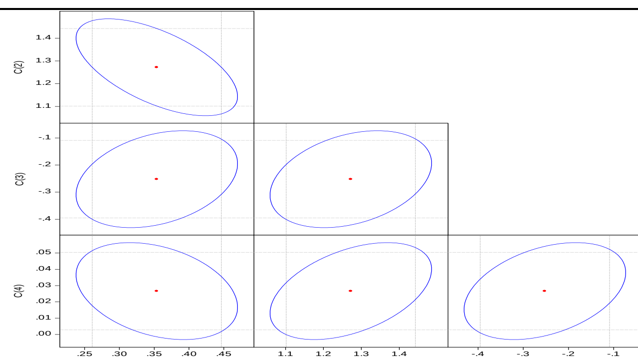
Southeast Asia





Overall





References

Adams, S., Nsiah, C., 2019. Reducing carbon dioxide emissions; Does renewable energy matter? Science of The Total Environment 693, 133288. https://doi.org/10.1016/j.scitotenv.2019.07.094

Ahmed, K., Mahalik, M.K., Shahbaz, M., 2016. Dynamics between economic growth, labor, capital and natural resource abundance in Iran: An application of the combined cointegration approach. Resources Policy 49, 213–221. https://doi.org/10.1016/j.resourpol.2016.06.005

Al-Mulali, U., Sheau-Ting, L., Ozturk, I., 2015. The global move toward Internet shopping and its influence on pollution: an empirical analysis. Environ Sci Pollut Res 22, 9717–9727. https://doi.org/10.1007/s11356-015-4142-2

Amri, F., 2019. Renewable and non-renewable categories of energy consumption and trade: Do the development degree and the industrialization degree matter? Energy 173, 374–383. https://doi.org/10.1016/j.energy.2019.02.114

Apergis, N., Payne, J.E., 2014. The oil curse, institutional quality, and growth in MENA countries: Evidence from time-varying cointegration. Energy Economics 46, 1–9. https://doi.org/10.1016/j.eneco.2014.08.026

Auty, R.M., 2007. Natural resources, capital accumulation and the resource curse. Ecological Economics, Special Issue on Environmental Accounting: Introducing the System of Integrated Environmental and Economic Accounting 2003 61, 627–634. https://doi.org/10.1016/j.ecolecon.2006.09.006

Auty, R.M., 2001. The political state and the management of mineral rents in capital-surplus economies: Botswana and Saudi Arabia. Resources Policy 27, 77–86. https://doi.org/10.1016/S0301-4207(01)00008-3

Badeeb, R.A., Lean, H.H., Clark, J., 2017. The evolution of the natural resource curse thesis: A critical literature survey. Resources Policy 51, 123–134. https://doi.org/10.1016/j.resourpol.2016.10.015

Balcilar, M., Ozdemir, Z.A., Ozdemir, H., Shahbaz, M., 2018. The renewable energy consumption and growth in the G-7 countries: Evidence from historical decomposition method. Renewable Energy 126, 594–604. https://doi.org/10.1016/j.renene.2018.03.066

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., Farhani, S., 2018. How economic growth, renewable electricity and natural resources contribute to CO2 emissions? Energy Policy 113, 356–367. https://doi.org/10.1016/j.enpol.2017.10.050

Behera, S.R., Dash, D.P., 2017. The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. Renewable and Sustainable Energy Reviews 70, 96–106. https://doi.org/10.1016/j.rser.2016.11.201

Bekun, F.V., Alola, A.A., Sarkodie, S.A., 2019. Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. Science of The Total Environment 657, 1023–1029. https://doi.org/10.1016/j.scitotenv.2018.12.104

Belaïd, F., Zrelli, M.H., 2019. Renewable and non-renewable electricity consumption, environmental degradation and economic development: Evidence from Mediterranean countries. Energy Policy 133, 110929. https://doi.org/10.1016/j.enpol.2019.110929

Ben Jebli, M., Ben Youssef, S., 2015. The environmental Kuznets curve, economic growth, renewable and non-renewable energy, and trade in Tunisia. Renewable and Sustainable Energy Reviews 47, 173–185. https://doi.org/10.1016/j.rser.2015.02.049

Ben Jebli, M., Ben Youssef, S., Ozturk, I., 2016. Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries. Ecological Indicators 60, 824–831. https://doi.org/10.1016/j.ecolind.2015.08.031

Ben-Salha, O., Dachraoui, H., Sebri, M., 2018. Natural resource rents and economic growth in the top resource-abundant countries: A PMG estimation. Resources Policy. https://doi.org/10.1016/j.resourpol.2018.07.005

Bento, J.P.C., Moutinho, V., 2016. CO2 emissions, non-renewable and renewable electricity production, economic growth, and international trade in Italy. Renewable and Sustainable Energy Reviews 55, 142–155.

Bhat, J.A., 2018. Renewable and non-renewable energy consumption—impact on economic growth and CO2 emissions in five emerging market economies. Environ Sci Pollut Res 25, 35515–35530. https://doi.org/10.1007/s11356-018-3523-8

Bhattacharya, M., Awaworyi Churchill, S., Paramati, S.R., 2017. The dynamic impact of renewable energy and institutions on economic output and CO2 emissions across regions. Renewable Energy 111, 157–167. https://doi.org/10.1016/j.renene.2017.03.102

Bhattacharyya, S., Hodler, R., 2014. Do Natural Resource Revenues Hinder Financial Development? The Role of Political Institutions. World Development 57, 101–113. https://doi.org/10.1016/j.worlddev.2013.12.003

Blackburne, E.F., Frank, M.W., 2007. Estimation of Nonstationary Heterogeneous Panels. The Stata Journal 7, 197–208. https://doi.org/10.1177/1536867X0700700204

Bölük, G., Mert, M., 2015. The renewable energy, growth and environmental Kuznets curve in Turkey: An ARDL approach. Renewable and Sustainable Energy Reviews 52, 587–595. https://doi.org/10.1016/j.rser.2015.07.138

Boschini, A., Pettersson, J., Roine, J., 2013. The Resource Curse and its Potential Reversal. World Development 43, 19–41. https://doi.org/10.1016/j.worlddev.2012.10.007

Breitung, J., 2001. The local power of some unit root tests for panel data. Emerald Group Publishing Limited.

Breusch, T.S., Pagan, A.R., 1980. The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics. The Review of Economic Studies 47, 239–253. https://doi.org/10.2307/2297111

British Petroleum, 2018. BP statistical review of world energy.

Brunnschweiler, C.N., 2008. Cursing the Blessings? Natural Resource Abundance, Institutions, and Economic Growth. World Development 36, 399–419. https://doi.org/10.1016/j.worlddev.2007.03.004

Carbon Footprint, 2018. Climate change.

Chen, Y., Zhao, J., Lai, Z., Wang, Z., Xia, H., 2019. Exploring the effects of economic growth, and renewable and non-renewable energy consumption on China’s CO2 emissions: Evidence from a regional panel analysis. Renewable Energy 140, 341–353. https://doi.org/10.1016/j.renene.2019.03.058

Choi, I., 2001. Unit root tests for panel data. Journal of International Money and Finance 20, 249–272. https://doi.org/10.1016/S0261-5606(00)00048-6

De Hoyos, R.E., Sarafidis, V., 2006. Testing for Cross-Sectional Dependence in Panel-Data Models. The Stata Journal 6, 482–496. https://doi.org/10.1177/1536867X0600600403

Dietz, S., Neumayer, E., Soysa, I.D., 2007. Corruption, the resource curse and genuine saving. Environment and Development Economics 12, 33–53. https://doi.org/10.1017/S1355770X06003378

Dogan, E., 2016. Analyzing the linkage between renewable and non-renewable energy consumption and economic growth by considering structural break in time-series data. Renewable Energy 99, 1126–1136. https://doi.org/10.1016/j.renene.2016.07.078

Dogan, E., Seker, F., 2016. The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. Renewable and Sustainable Energy Reviews 60, 1074–1085. https://doi.org/10.1016/j.rser.2016.02.006

Dong, K., Dong, X., Dong, C., 2019. Determinants of the global and regional CO2 emissions: What causes what and where? Applied Economics 51, 5031–5044. https://doi.org/10.1080/00036846.2019.1606410

Dumitrescu, E.-I., Hurlin, C., 2012. Testing for Granger non-causality in heterogeneous panels. Economic Modelling 29, 1450–1460.

Farhani, S., Shahbaz, M., 2014. What role of renewable and non-renewable electricity consumption and output is needed to initially mitigate CO2 emissions in MENA region? Renewable and Sustainable Energy Reviews 40, 80–90. https://doi.org/10.1016/j.rser.2014.07.170

Frees, E.W., 1995. Assessing cross-sectional correlation in panel data. Journal of Econometrics 69, 393–414. https://doi.org/10.1016/0304-4076(94)01658-M

Friedman, M., 1937. The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance. Journal of the American Statistical Association 32, 675–701. https://doi.org/10.1080/01621459.1937.10503522

Granger, C.W., 1969. Investigating causal relations by econometric models and cross-spectral methods. Econometrica: Journal of the Econometric Society 424–438.

Gylfason, T., 2001. Natural resources, education, and economic development. European Economic Review, 15th Annual Congress of the European Economic Association 45, 847–859. https://doi.org/10.1016/S0014-2921(01)00127-1

Hadri, K., 2000. Testing for stationarity in heterogeneous panel data. The Econometrics Journal 3, 148–161. https://doi.org/10.1111/1368-423X.00043

Harris, R.D.F., Tzavalis, E., 1999. Inference for unit roots in dynamic panels where the time dimension is fixed. Journal of Econometrics 91, 201–226. https://doi.org/10.1016/S0304-4076(98)00076-1

Havranek, T., Horvath, R., Zeynalov, A., 2016. Natural Resources and Economic Growth: A Meta-Analysis. World Development 88, 134–151. https://doi.org/10.1016/j.worlddev.2016.07.016

Im, K.S., Pesaran, M.H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. Journal of Econometrics 115, 53–74. https://doi.org/10.1016/S0304-4076(03)00092-7

Inglesi-Lotz, R., Dogan, E., 2018. The role of renewable versus non-renewable energy to the level of CO2 emissions a panel analysis of sub- Saharan Africa's Big 10 electricity generators. Renewable Energy 123, 36–43. https://doi.org/10.1016/j.renene.2018.02.041

IPCC, 2014. AR5 Synthesis report : retrieved from. https://www.ipcc. ch/report/ar5/syr/.

Kao, C., 1999. Spurious regression and residual-based tests for cointegration in panel data. Journal of Econometrics 90, 1–44. https://doi.org/10.1016/S0304-4076(98)00023-2

Kim, D.-H., Lin, S.-C., 2017. Natural Resources and Economic Development: New Panel Evidence. Environ Resource Econ 66, 363–391. https://doi.org/10.1007/s10640-015-9954-5

Krueger, A., 1998. Why Trade Liberalisation is Good for Growth. The Economic Journal 108, 1513–1522. https://doi.org/10.1111/1468-0297.00358

Levin, A., Lin, C.-F., James Chu, C.-S., 2002. Unit root tests in panel data: asymptotic and finite-sample properties. Journal of Econometrics 108, 1–24. https://doi.org/10.1016/S0304-4076(01)00098-7

Maddala, G.S., Wu, S., 1999. A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test. Oxford Bulletin of Economics and Statistics 61, 631–652. https://doi.org/10.1111/1468-0084.0610s1631

Mert, M., Bölük, G., 2016. Do foreign direct investment and renewable energy consumption affect the CO2 emissions? New evidence from a panel ARDL approach to Kyoto Annex countries. Environ Sci Pollut Res 23, 21669–21681. https://doi.org/10.1007/s11356-016-7413-7

Mert, M., Bölük, G., Çağlar, A.E., 2019. Interrelationships among foreign direct investments, renewable energy, and CO2 emissions for different European country groups: a panel

ARDL approach. Environ Sci Pollut Res 26, 21495–21510. https://doi.org/10.1007/s11356-019-05415-4

Owusu, P.A., Asumadu-Sarkodie, S., 2016. A review of renewable energy sources, sustainability issues and climate change mitigation. Cogent Engineering 3, 1167990. https://doi.org/10.1080/23311916.2016.1167990

Paramati, S.R., Apergis, N., Ummalla, M., 2018. Dynamics of renewable energy consumption and economic activities across the agriculture, industry, and service sectors: evidence in the perspective of sustainable development. Environ Sci Pollut Res 25, 1375–1387. https://doi.org/10.1007/s11356-017-0552-7

Park, Y., Meng, F., Baloch, M.A., 2018. The effect of ICT, financial development, growth, and trade openness on CO 2 emissions: an empirical analysis. Environmental Science and Pollution Research 25, 30708–30719.

Pata, U.K., 2018. Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: Testing EKC hypothesis with structural breaks. Journal of Cleaner Production 187, 770–779. https://doi.org/10.1016/j.jclepro.2018.03.236

Pedroni, P., 2004. Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econometric theory 20, 597–625.

Pesaran, M.H., 2007. A simple panel unit root test in the presence of cross-section dependence. Journal of applied econometrics 22, 265–312.

Pesaran, M.H., 2004. General diagnostic tests for cross section dependence in panels.

Pesaran, M.H., 1997. The role of economic theory in modelling the long run. The Economic Journal 107, 178–191.

Pesaran, M.H., Shin, Y., Smith, R.P., 1999. Pooled mean group estimation of dynamic heterogeneous panels. Journal of the American Statistical Association 94, 621–634.

Pesaran, M.H., Smith, R., 1995. Estimating long-run relationships from dynamic heterogeneous panels. Journal of Econometrics 68, 79–113. https://doi.org/10.1016/0304-4076(94)01644-F

Quah, D., 1994. Exploiting cross-section variation for unit root inference in dynamic data. Economics Letters 44, 9–19. https://doi.org/10.1016/0165-1765(93)00302-5

Rasoulinezhad, E., Saboori, B., 2018. Panel estimation for renewable and non-renewable energy consumption, economic growth, CO2 emissions, the composite trade intensity, and financial openness of the commonwealth of independent states. Environ Sci Pollut Res 25, 17354–17370. https://doi.org/10.1007/s11356-018-1827-3

Sachs, J.D., Warner, A.M., 1999. The big push, natural resource booms and growth. Journal of Development Economics 59, 43–76. https://doi.org/10.1016/S0304-3878(99)00005-X

Sachs, J.D., Warner, A.M., 1995. Natural Resource Abundance and Economic Growth (Working Paper No. 5398). National Bureau of Economic Research. https://doi.org/10.3386/w5398

Sarmidi, T., Law, S.H., Jafari, Y., 2014. Resource Curse: New Evidence on the Role of Institutions. International Economic Journal 28, 191–206. https://doi.org/10.1080/10168737.2013.787110

Satti, S.L., Farooq, A., Loganathan, N., Shahbaz, M., 2014. Empirical evidence on the resource curse hypothesis in oil abundant economy. Economic Modelling 42, 421–429. https://doi.org/10.1016/j.econmod.2014.07.020

Shafiei, S., Salim, R.A., 2014. Non-renewable and renewable energy consumption and CO2 emissions in OECD countries: A comparative analysis. Energy Policy 66, 547–556. https://doi.org/10.1016/j.enpol.2013.10.064

Shahbaz, M., Naeem, M., Ahad, M., Tahir, I., 2018. Is natural resource abundance a stimulus for financial development in the USA? Resources Policy 55, 223–232. https://doi.org/10.1016/j.resourpol.2017.12.006

Sharif, A., Raza, S.A., Ozturk, I., Afshan, S., 2019. The dynamic relationship of renewable and nonrenewable energy consumption with carbon emission: A global study with the application of heterogeneous panel estimations. Renewable Energy 133, 685–691. https://doi.org/10.1016/j.renene.2018.10.052

Shaw, D.L., 2013. Good governance in the post-Soviet south: testing theories of the resource curse in Azerbaijan. Journal of Politics & International Studies 9, 520–561.

Sovacool, B.K., 2010. The political economy of oil and gas in Southeast Asia: heading towards the natural resource curse? The Pacific Review 23, 225–259. https://doi.org/10.1080/09512741003624484

Westerlund, J., 2007. Testing for error correction in panel data. Oxford Bulletin of Economics and statistics 69, 709–748.

World Bank, 2019. World development indicators. Retrieved from.http://data.worldbank.org/country.

Chapter V

General Conclusion and Global Policy Implications

5 General Conclusion and Global Policy Implications

The current thesis consists of three self-contained empirical essays. The study investigated the impact of macroeconomic variables on CO_2 emissions in the South and Southeast Asian (SSEA) regions. Each essay examined the role of macroeconomic variables such as urbanization, economic growth, energy consumption, ICT, financial development, trade openness, renewable and non-renewable energy, and availability of natural resources on the environmental quality of the SSEA region over the period of 1990-2014. The time spans and countries' selection have been made based on the availability of the data from World Bank data sources. All the essays included institutional and policy aspects, examining their impact on sustainable development, since the contextual features of institutions and policies help to understand the mechanism through which they matter for sustainable economic growth. We applied several econometric techniques and different combination of macro variables on different income groups and regional panels to check their effects on the environmental conditions in the selected areas. For example, the first essay analyzed the effects of deforestation, economic growth, and urbanization on carbon dioxide (CO_2) emissions levels based on different income levels such as lower, middle, and high income as suggested by the World Bank, and we found mixed results among income groups. Additionally, this essay used two regions, the South Asia and Southeast Asian region, for the detailed empirical evidence.

The findings in the first essay (chapter 2) confirmed a long-run relationship between deforestation, economic growth, urbanization, and CO_2 emissions using the Pedroni cointegration and Westerlund cointegration tests in the SSEA regions. Furthermore, the empirical results reveal the existence of a U-shaped relationship between CO_2 emissions and economic growth for all panels (excepting low-income countries) by the PMG method. We also found similar results using the FMOLS and DOLS methods to robust the PMG findings. In addition, our results suggested that deforestation and urbanization can aggravate environmental pollution in these regions and can further affect sustainable development in the long run. While these results are in line with previous findings(Begum et al., 2015; Mert and Bölük, 2016; Wang et al., 2017), those concerning deforestation are novel in the existing literature.

For the causality results, we used the Dumitrescu and Hurlin test, and found the presence of a feedback effect: forest, urbanization, and economic growth are found to have a bidirectional causality with CO_2 emissions in the cases of the full countries, South Asian, and Southeast Asian regions' panels. However, the unidirectional causality is seen running from economic growth to CO_2 emissions for the case of entire countries and South Asia panels. Moreover, no causal relationship exists between economic growth and CO_2 emissions in the case of the Southeast Asian region. Furthermore, in the lower income countries, CO_2 emissions have a bidirectional causal link with forest and urbanization. The Dumitrescu-Hurlin causality results indicate that all the variables are interdependent in all cases, and our results are in line with those reported by Gokmenoglu et al., 2019.

In the second essay (chapter 3), we divided the countries into three panels, classified as potential, advanced and full countries, based on their social development performance with the help of cluster analysis. The study tested the relationships between the variables under consideration such as ICT, trade, economic growth, financial development, and energy consumption, and carbon emissions in South and Southeast Asian (SSEA) region for the period of 1990–2014. Moreover, the essay also examined the environmental Kuznets curve (EKC) hypothesis between GDP per capita and CO_2 emissions, and the long-run connection between the variables was examined using the Pedroni and Westerlund cointegration methods. Additionally, the long-run elasticities of ICT, financial development, energy consumption, trade, and economic growth with respect to CO_2 emissions were estimated by PMG, FMOLS and DOLS methods.

Importantly, individual country-wise long-run coefficients were also found. The results show that financial development and ICT deteriorated the environment quality in the SSEA region, suggesting ICT goods and services are not energy-efficient in both potential and advanced countries, and that most of the financial investment was made in non-friendly environmental projects in potential countries. On the contrary, in advanced countries, financial development mitigates CO_2 emissions. In addition, the results also confirmed an inverted U-shaped relationship for all the considered three panels (potential, advanced, and full-countries panels), supporting the EKC hypothesis. These results are, therefore, consistent with those reported byMd. M. Alam et al., 2016; Apergis, 2016; Ben Jebli et al., 2016; Dogan and Inglesi-Lotz, 2020; Dogan and Seker, 2016a; Le and Quah, 2018; Li et al., 2016; Ouyang and Lin, 2017; Shahbaz et al., 2015; Zaman and Moemen, 2017. Finally, the causality findings showed bidirectional causality between CO_2 emissions and energy consumption, as well as unidirectional causality from trade, economic growth, financial development, and ICT to CO_2 emissions.

The third essay (chapter 4) aimed at estimating the effects of economic growth, renewable energy consumption, non-renewable energy, and natural resources on carbon emissions in the South and Southeast Asian regions for the period of 1990-2014. The long-run relationship between the variables was examined using Pedroni, Kao, Fisher and Westerlund cointegration tests in 11 countries, and 3 panels: (i) full countries' panel, (ii) South Asian countries, and (iii) Southeast Asian countries. For all panels, the long-run elasticises were estimated with PMG, and for the robustness of PMG estimation the Dynamic common correlated effects CS-ARDL technique was applied through two models: model 1, to determine the long-run coefficients of renewable energy consumption, non-renewable energy consumption and natural resources' rents concerning economic growth; and model2, to estimate renewable energy consumption, non-renewable energy consumption, natural resources' rents and economic growth concerning CO_2emissions. The results of model 1 suggest that non-renewable and renewable energy consumption increase economic development in the three panels. Moreover, natural resources impede the economic growth in South Asian and full countries panels, while increasing the economic activities in Southeast Asian countries. In the case of model 2, the results indicate that non-renewable and economic growth increase CO_2 emissions, whereas renewable energy consumption lessens the carbon emissions. However, natural resources also contributed to CO_2 emissions in the case of South Asian and full countries panels, while improving the environmental quality in the Southeast Asian region.

Our results regarding the NRE and RE impacts on CO_2 emissions are in line with those previously reported by Belaïd and Zrelli, 2019; Ben Jebli et al., 2016; Bölük and Mert, 2015; Inglesi-Lotz and Dogan, 2018; Sharif et al., 2019. In addition, our results on the positive impact of natural resources are consistent with those found by Bekun et al. (2019) using the PMG method, but add to the existing literature through our novel application of the Dynamic common correlated effects CS-ARDL technique in this context. Moreover, the Dumitrescu-Hurlin causality test was also applied to examine the causal relationship between the variables, and it was observed that there is cointegration among the variables in all three panels.

In summary, in all the essays we have made one panel, which represents the full countries list, but the selected countries are different as they were 17 in essay one, 14 in essay two and 11 in essay three. Moreover, we addressed the problem of cross-sectional dependence by applying CD and LM tests in the selected countries for all essays. Results demonstrated similar finding of unit root analysis in all the selected studies by applying various unit root first- and second-generation tests such as IPS (IM Pesaran shin), ADF-Fisher, PP-Fisher, CIPS and CADF. The study also found long-run relationship between all the macroeconomic variables under consideration by applying Pedroni, Kao, Fisher and Westerlund cointegration methods. The cross-section dependence, unit root and cointegration support the robustness of the results in all the essays. However, the estimated short and long-run coefficients by applying PMG, DOLS, FMOLS, and DCCE CS-ARDL methods vary in the different essays. Notwithstanding, we found similar signs of all the selected macroeconomic variables on carbon emissions, except for economic growth. However, the sign of the economic growth's impact on CO_2 emissions only differed in essay one, which may be due to the use of the quadratic specification in this essay. Likewise, we note that the direction of the causality also fluctuates in the selected studies, and that we also observed that different combinations of macroeconomic variables and models produced dissimilar impacts of the considered variables on the environmental quality of SSEA countries.

The overall results from these three essays allowed us to derive relevant policy implications both from a global and SSEA' countries perspective.

In summary, the empirical findings in the first essay support the need to implement proper management of the forest areas and adopt controlled urbanization policies for the long run in the SSEA regions. Despite focusing on these regions, the findings also indicate that other regions of the world should also tackle these issues as they might face the same problems in a near future.

Policy recommendations can also be derived from the second essay concerning the ICT-energy nexus in general and the ICT-emissions nexus in particular. Not only those in the SSEA region, but policymakers worldwide should be aware of the increasing population growth and energy demand levels mainly supplied by non-renewable sources especially by fossil fuel, and that the economies can use innovative ICT devices to improve the environmental quality. For example, countries should promote the use of energy efficient devices such as smart phones, smart TV, smart home appliances and other post-industrial innovative products to minimize global carbon emissions. Moreover, the application of ICT-enabled technologies is also helpful in controlling the increasing global emissions, especially in the building, logistics and manufacturing sectors. This suggests that funding from developed countries could be channeled to help developing and poor countries in the promotion of internet infrastructure which will be helpful to decrease their energy consumption. In fact, better internet accessibility in these countries will facilitate more online shopping, attending teleconferences and working remotely rather than travelling, thereby lessen their energy use and decrease global emissions levels. Thus, although the mitigating process of carbon emissions has adverse effect on economic growth efficient ICT can play a vital role to increase the development level of these economies.

The findings in the third essay also have policy implications, as the results show that renewable energy sources should be preferred to decrease CO_2 emissions in order to control the climatic changes in the South and Southeast Asian countries. Moreover, for the better use of natural resources, governments in these regions should concentrate on education, and combat corruption, in order to improve the economic growth in the selected studied areas. Although these findings pertain to these particular regions, it is important to note that the rest of the countries, especially developed countries, need to observe closely the growing economic activities, increasing population, and deteriorated environmental quality of the South and Southeast Asian countries since any lenient environmental policies indirectly affect the other continents of the world as well.

References

Alam, Md.M., Murad, Md.W., Noman, A.H.Md., Ozturk, I., 2016. Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. Ecological Indicators, Navigating Urban Complexity: Advancing Understanding of Urban Social – Ecological Systems for Transformation and Resilience 70, 466–479. https://doi.org/10.1016/j.ecolind.2016.06.043

Apergis, N., 2016. Environmental Kuznets curves: New evidence on both panel and country-level CO2 emissions. Energy Economics 54, 263–271. https://doi.org/10.1016/j.eneco.2015.12.007

Begum, R.A., Sohag, K., Abdullah, S.M.S., Jaafar, M., 2015. CO 2 emissions, energy consumption, economic and population growth in Malaysia. Renewable and Sustainable Energy Reviews 41, 594–601. https://doi.org/10.1016/j.rser.2014.07.205

Bekun, F.V., Alola, A.A., Sarkodie, S.A., 2019. Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. Science of The Total Environment 657, 1023–1029. https://doi.org/10.1016/j.scitotenv.2018.12.104

Belaïd, F., Zrelli, M.H., 2019. Renewable and non-renewable electricity consumption, environmental degradation and economic development: Evidence from Mediterranean countries. Energy Policy 133, 110929. https://doi.org/10.1016/j.enpol.2019.110929

Ben Jebli, M., Ben Youssef, S., Ozturk, I., 2016. Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries. Ecological Indicators 60, 824–831. https://doi.org/10.1016/j.ecolind.2015.08.031

Bölük, G., Mert, M., 2015. The renewable energy, growth and environmental Kuznets curve in Turkey: An ARDL approach. Renewable and Sustainable Energy Reviews 52, 587–595. https://doi.org/10.1016/j.rser.2015.07.138

Dogan, E., Inglesi-Lotz, R., 2020. The impact of economic structure to the environmental Kuznets curve (EKC) hypothesis: evidence from European countries. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-020-07878-2

Dogan, E., Seker, F., 2016. An investigation on the determinants of carbon emissions for OECD countries: empirical evidence from panel models robust to heterogeneity and cross-sectional dependence. Environ Sci Pollut Res 23, 14646–14655. https://doi.org/10.1007/s11356-016-6632-2

Gokmenoglu, K.K., Olasehinde-Williams, G.O., Taspinar, N., 2019. Testing the Environmental Kuznets Curve Hypothesis: The Role of Deforestation, in: Energy and Environmental Strategies in the Era of Globalization. Springer, pp. 61–83.

Inglesi-Lotz, R., Dogan, E., 2018. The role of renewable versus non-renewable energy to the level of CO2 emissions a panel analysis of sub- Saharan Africa's Big 10 electricity generators. Renewable Energy 123, 36–43. https://doi.org/10.1016/j.renene.2018.02.041

Le, T.-H., Quah, E., 2018. Income level and the emissions, energy, and growth nexus: Evidence from Asia and the Pacific. International economics 156, 193–205.

Li, T., Wang, Y., Zhao, D., 2016. Environmental Kuznets curve in China: new evidence from dynamic panel analysis. Energy Policy 91, 138–147.

Mert, M., Bölük, G., 2016. Do foreign direct investment and renewable energy consumption affect the CO2 emissions? New evidence from a panel ARDL approach to Kyoto Annex countries. Environ Sci Pollut Res 23, 21669–21681. https://doi.org/10.1007/s11356-016-7413-7

Ouyang, X., Lin, B., 2017. Carbon dioxide (CO2) emissions during urbanization: A comparative study between China and Japan. Journal of cleaner production 143, 356–368.

Shahbaz, M., Dube, S., Ozturk, I., Jalil, A., 2015. Testing the environmental Kuznets curve hypothesis in Portugal. International Journal of Energy Economics and Policy 5, 475–481.

Sharif, A., Raza, S.A., Ozturk, I., Afshan, S., 2019. The dynamic relationship of renewable and nonrenewable energy consumption with carbon emission: A global study with the application of heterogeneous panel estimations. Renewable Energy 133, 685–691. https://doi.org/10.1016/j.renene.2018.10.052

Wang, S., Yang, F., Wang, X., Song, J., 2017. A Microeconomics Explanation of the Environmental Kuznets Curve (EKC) and an Empirical Investigation. Pol. J. Environ. Stud. 26, 1757–1764. https://doi.org/10.15244/pjoes/68567

Zaman, K., Moemen, M.A., 2017. Energy consumption, carbon dioxide emissions and economic development: Evaluating alternative and plausible environmental hypothesis for sustainable growth. Renewable and Sustainable Energy Reviews 74, 1119–1130. https://doi.org/10.1016/j.rser.2017.02.072